WHEAT IN INDIA

ITS PRODUCTION, VARIETIES AND IMPROVEMENT

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PREFACE.

In January 1906, the subject of the improvement of Indian wheat was considered by the Board of Agriculture in India. It was found that the information on the crop was somewhat scanty and was moreover widely scattered among the various farm reports and in other papers not usually accessible. Mr. F. G. Sly, I.C.S., Officiating Inspector-General of Agriculture in India, considered it desirable that all the useful information on the subject including the results of the experiments hitherto conducted on the experimental farms in the country should be brought together and further that a botanical survey of the wheats of India should be made. We were entrusted with this work in 1906 and the large mass of material that had to be consulted occupied us for upwards of a year during which period the botanical survey of the crop was commenced. The work was delayed by an unavoidable absence from duty in 1907 and 1908 and could not be completed till the end of the present year.

In order to be useful to all interested in the various aspects of wheat production in India, the scope of the book has been made as wide as possible. The botanical survey of the wheats of India and of each Province separately is new. As much useful information as possible on the agriculture of the crop has been included. In the third section dealing with the improvement of the crop we have endeavoured to bring out the more important aspects of the investigations which have been carried out in Germany, Austria, Sweden and in England, Canada, the United States and Australia, in the hope that this will be of use both to advanced students and to all interested in the improvement of wheat who have not ready access to the mass of foreign literature which has now accumulated on the subject. As regards the trade aspects of the subject we have merely touched on some points on which difference of opinion exists and in which improvement may be possible in the future.

The records in the Imperial Secretariat at Calcutta as well as those in the office of the Reporter on Economic Products to the Government of India and in the various Provincial Departments of Agriculture have been consulted and extensive collections of wheat have been placed at our disposal by the officers of the Agricultural Department. In addition, a large number of wheats have been grown by us at Lyallpur and Púsa during the last three years.

We are under a deep obligation to Mr. F. G. Sly, I.C.S., formerly Officiating Inspector-General of Agriculture in India, at whose suggestion this work was undertaken and who at all times did his utmost to further it in every way. In the Punjab, Mr. W. Renouf, I.C.S., placed the resources of his Department at our disposal and has been the means of considerably advancing the work, while Mr. A. C. Dobbs, formerly Principal of the Lyallpur College, was kind enough to undertake the sowing and care of our cultures at Lyallpur during our absence from India in 1907 and to read the proof sheets. We are indebted to him for many valuable suggestions. In the United Provinces, Messrs. W. H. Moreland, C.I.E., I.C.S., and H. M. Leake have placed a very large collection of wheats at our disposal. In Bengal, we desire to thank the Hon. Mr. C. E. A. W. Oldham, I.C.S., formerly Director of Agriculture, for assistance with regard to the wheats of that Province. Captain A. T. Gage, I.M.S., Superintendent of the Calcutta Botanical Gardens, was good enough to lend us the herbarium material available at Sibpur, while Mr. I. H. Burkill, Officiating Reporter on Economic Products to the Government of India, placed at our disposal a large amount of Indian literature and dried specimens of wheat. Our thanks are due to Mr. E. J. Butler, Imperial Mycologist, for bringing to our notice some recent work on the fungus diseases of wheat, and to Mr. H. M. Lefroy, Imperial Entomologist, for kindly reading the section on insect pests. In the Central Provinces, we are specially indebted to Messrs. Gaskin and Evans of the Agricultural Department for a very large collection of wheats of the Province. In Bombay, Professor Gammie and Mr. F. Fletcher supplied us with a large amount of material, while in Mysore, Dr. Lehmann obtained some interesting specimens of wheats at considerable trouble. In Madras, a very useful collection

of wheats was made for us by Dr. Barber, Government Botanist in 1905, while recently Messrs. Wood and Shepperton have kindly sent us further material.

The geological map of India and the map showing the distribution of wheat in India have been taken from the *Statistical Atlas of India*, 1895, the map of Bombay from the *Proceedings of the Board of Agriculture in India*, 1906. Mr. Evans has kindly placed at our disposal his map showing the distribution of wheat in the Central Provinces.

With regard to the milling and baking aspect of the subject, we have been fortunate in obtaining the invaluable assistance of Mr. A. E. Humphries, Past President of the Incorporated National Association of British and Irish Millers.

Albert Howard,
Gabrielle L. C. Howard.

Pusa,
December 2nd, 1909.

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SECTION I.

THE PRODUCTION OF WHEAT IN INDIA.

A. General.

B. Experimental.

THE PRODUCTION OF WHEAT IN INDIA.

A. General.

CHAPTER I.

DISTRIBUTION AND AREA.

THE wheat-growing area of the Indian Empire embraces the whole of northern India down to the Gangetic delta and the greater part of the central plateau above the Ghāts. The crop is not cultivated at all in the Bombay Konkan or in the coastal districts on both sides of the Bay of Bengal, while in Assam and in Burma wheat is of very little importance. Although the distribution of wheat in India is very wide, it will be seen from the following table that the North-West is the great wheat-growing tract and that nearly seventy-five per cent. of the crop is produced in the Punjab and the United Provinces :—

THE AREA AND YIELD OF THE 1909 WHEAT CROP.[1]

PROVINCE OR STATE.	Average total area (in acres) under the crop in five years ending 1906-07.	Per centage of India.	Area reported (acres).	Comparison of current year (1908-09) with average of five years ending 1906-07 as reported in forecasts.			
				Increase.		Decrease.	
			1908-09.	Actual.	Per cent.	Actual.	Per cent.
1	2	3	4	5	6	7	8
			(*a*)				
Punjab ...	8,029,000	29·5	8,884,000	...	...	100,000	1·3
United Provinces .	7,185,500	26·4	5,674,700	...	...	1,501,200	20·9
C. P. and Berár ...	3,306,200	12·1	2,780,800	...	...	529,400	16·0
Bombay (*a*) ...	1,836,500	6·7	1,600,200	...	...	248,300	13·4
Bengal ..	1,311,200	4·8	1,255,200	...	...	51,400	3·9
N.-W. Frontier ...	974,000	3·6	1,019,500	31,100	3·0	...	...
Sind (*a*) ..	548,300	2·0	532,800	...	...	15,500	2·8
E. B. and Assam ...	178,600	0·6	77,100	...	...	95,800	55·5
Central India ..	1,932,100	7·1	2,024,800	91,700	4·7	...	...
Hyderábád ...	969,900	3·6	1,098,300	128,400	13·2	..	...
Rájputána ...	895,100	3·3	887,800	...	...	7,300	0·8
Mysore ...	4,600	0·02	1,600	...	..	1,800	53·5
Total	27,172,000	99·72	25,836,000	...	...	2,299,500	8·2

1 Reprinted from the *Final General Memorandum on the Wheat Crop, 1908-09*, Commercial Intelligence Department, India.

(*a*) Including Native States within provincial boundaries.

Province or State.	Ratio of Retail Price on 30th April 1909 to average of five years ending 1907 at same date.	Estimated Yield (tons). 1908-09.	Comparison of current year (1908-09) with average of five years ending 1906-07 as reported in forecasts. Increase. Actual.	Increase. Per cent.	Decrease. Actual.	Decrease. Per cent.
	9	10	11	12	13	14
	Per cent.	(a)				
Panjáb ...	153	3,057,300	...	...	282,000	9·1
United Provinces .	143	2,132,100	...	.	406,400	16·0
C. P. and Berár ..	147	693,500	...	...	126,300	15·4
Bombay (a) ..	142	357,800	...	..	54,700	13·2
Bengal ..	139	319,800	.	..	59,100	23·6
N.-W. Frontier ..	209	213,300	.	.	69,700	24·6
Sind (a) ...	155	129,900	...	...	27,500	17·5
E. B. and Assam ..	148	14,300	.	..	33,700	157·5
Central India ...	145	392,600		.	95,600	19·6
Hyderábád ...	107	71,600	...	..	7,300	9·3
Rájputána ...	127	198,400	18,400	10·2	...	...
Mysore ...	174	200		.	300	60·0
Total ...	147	7,580,800	...		1,184,200	13·5

(a) Including Native States within provincial boundaries.

The annual variations in the area under wheat are considerable in some of the Provinces. These are due to various causes. The dominant factor, in most parts, is the favourable or unfavourable rainfall just prior to, and at sowing time. The character of the preceding autumn crop also affects the area put down to wheat, whilst the cultivator is further influenced by the success or failure of the preceding wheat harvests. Again, famines affect the wheat area, not only because of the necessity for immediately renewing food stocks by the growth of early ripening autumn food-grains, but because the crippling of the resources of the cultivators prevents them from selecting a crop like wheat, the growth of which involves a substantial outlay of capital. Bad autumn crops with a good rainfall in September will result in extended sowings and *vice versâ*. Even in the Panjáb, where canal irrigation is available for much of the wheat area, the effect of good monsoon or autumn rains is most marked. For example, in the case of the crop of 1901 in that Province, the excellent rainfall before sowing time led to a great extension of the area sown

and also materially reduced the proportion of irrigated wheat, as will be evident from the following table :—

AREA IN ACRES.

	Irrigated.	Unirrigated.	Total.	Per cent. irrigated.
Spring 1900 ..	4,024,000	2,342,500	6,366,500	63
,, 1901 ..	3,715,700	5,050,700	8,766,400	42

Thus in 1901 the unirrigated wheat was more than double that of the previous year. In a similar manner the sowings in Sind expand and contract in proportion to the extension or restriction of the area reached by the inundation canals. In Bombay and the Central Provinces, the wheat area diminishes to a great extent during and after famine years, while severe attacks of rust in the latter Province lead to a contraction in the wheat area sown in the following autumn.

Apart from the annual variations in area and yield it will be evident that the total value of the Indian wheat crop is very great. Most of the wheat grown is consumed in the country itself and in certain tracts forms an important source of food of the people. The remainder is exported to Europe. In good years the amount of surplus wheat shipped from India is very large and in 1905 amounted to 2,150,025 tons (p. 259). It is obvious that any improvement in the production of wheat in India either in the direction of increased value of the grain or of greater ease and safety in cultivation would mean an enormous monetary gain to India.

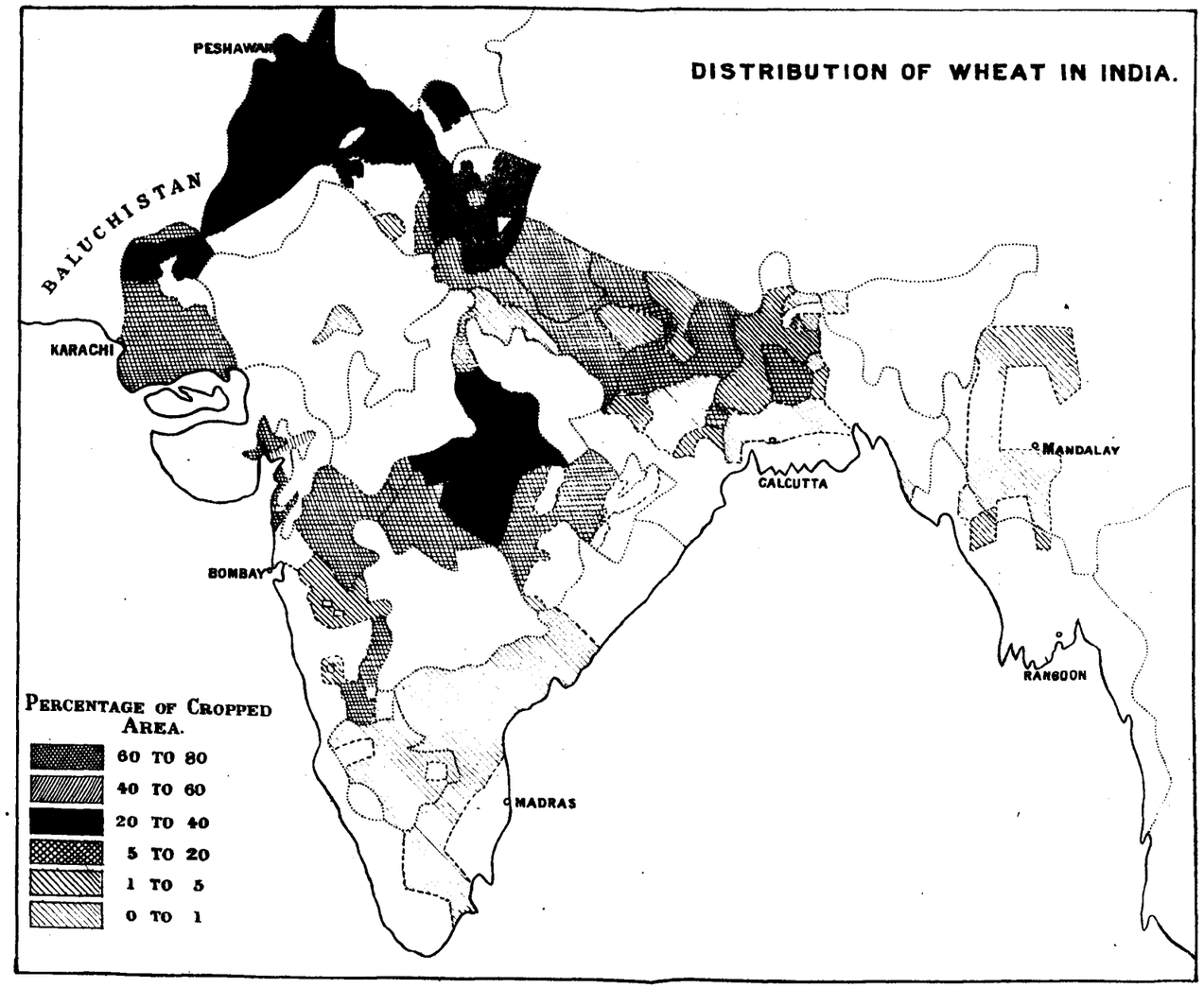
There is no doubt that the wheat now grown in India can be very greatly improved in many respects, notably in rust-resistance, in the strength of the straw and in the quality of the grain. Most of the wheats at present in cultivation are markedly liable to rust attacks and the damage done every year is very great. Watt estimated the annual loss caused by wheat rusts at 10 per cent. of the value of the crop, an estimate which is certainly not an excessive one (p. 90). Translated into money, 10 per cent. of the value of the Indian wheat crop represents an enormous sum, over 400 lakhs of rupees in the case of the crop of 1889. The production of more rust-resistant wheats by hybridization suitable for the various tracts would save a large portion of this enormous annual loss. Such rust-resistant wheats can be produced and indeed are being produced in India at the present time.

Another respect in which many of the Indian wheats are defective is in the strength and standing qualities of the straw. This is notably the case in many of the wheats grown in the United Provinces and in Bihár. Wheats

with weak straw are very liable to damage by laying through wind and rain during the ripening period which results in a greatly diminished yield. This defect can be remedied without much difficulty by crossing weak with strong strawed types.

It is perhaps in the quality of the grain that the greatest improvement in Indian wheat is both possible and desirable. Fortunately, the needs of India itself and of the European market are identical as regards the quality of the wheat in greatest demand. Both require wheats high in nitrogen, with good flour strength and with good milling characters. The wheats preferred by the cultivator for his own consumption are those in greatest demand by the English miller. Such a circumstance is especially fortunate for the improver of Indian wheats. There is thus only one objective, namely, the production of wheats most suitable for internal consumption. The export of the surplus produce to Europe will give the Home miller exactly what he desires most. The stronger wheats with good milling qualities required are most likely to be found among the hard wheats, and the colour of the grain, whether white or red, is now of small consequence. The wheat exported, however, at the present time is soft, notably deficient in nitrogen content and in strength. Indian wheats have a poor reputation in the English market as regards strength, although their great dryness is a quality of considerable value to the English miller. Any improvement in the strength of Indian wheats would mean improved prices and an increase in value of the export trade. Strong wheats are in greatest demand in England and command the highest prices in the market, and as long as the world produces much more weak than strong wheats, this difference in price will remain. It has recently been shown (p. 242) that the wheats grown in India vary considerably in milling qualities and in the strength of the flour they produce, and that wheats have been produced at Púsa notably superior in milling qualities and in strength to the average Indian samples. The work already done at Púsa shows that there is every prospect that the quality of the wheat grown in India can be very materially improved. If the quality of Indian wheat could be improved by so little as two shillings a quarter (approximately four annas a maund), this would mean an annual gain to India of 500 lakhs of rupees. The production therefore of stronger and most rust-resistant wheats for India might mean a yearly increase of 900 lakhs of rupees, or six million sterling, to the wealth of the country.

It is not likely, however, that an improved wheat will ever be found equally suitable for all the wheat tracts of India. The agricultural conditions on the black soils of Central India and Bombay differ from those of the



alluvium of the Indo-Gangetic plain, while in the alluvium itself the moisture conditions vary considerably. Further, some tracts will no doubt be found more suitable than others for the growth of strong wheats, but as strength appears to depend more on the variety than on the environment, it is exceedingly probable that a general improvement in the strength of all Indian wheats will result from well-planned hybridization work.

The preliminary work that must be done before the improvement of the Indian wheat crop can be effectively undertaken is very considerable. A wide outlook is essential at the outset. The general agricultural conditions of the various wheat tracts have to be studied in detail and experience of the actual growing of the crop has to be obtained at first hand. The soils most suitable for wheat, the methods of irrigation and the agricultural practices in regard to cultivation, rotation of crops, harvesting and storage of the grain must be mastered. The needs of the local and export markets as well as the general trade conditions are matters of great moment as well as the diseases to which wheat is subject in India. These details are much more important than appear at first sight. The present condition of Indian agriculture is the heritage of experience handed down from time immemorial by a people little affected by the many changes in the government of the country. The present agricultural practices of India are worthy of respect, however strange and primitive they may appear to Western ideas. The attempt to improve Indian agriculture on Western lines appears to be a fundamental mistake. What is wanted is rather the application of Western Scientific methods to the local conditions so as to improve Indian agriculture on its own lines. Once the general position as regards Indian wheat production has been understood, the investigator is in a position to study what has already been done in the country to improve the wheat crop at the various experimental farms, and how far the investigations now being conducted in other parts of the world can be usefully applied to the conditions of India. We have in the following pages attempted to place in concrete form the gist of our reading and experience on these matters and to sum up the factors concerned in the cultvation of wheat in India. A critical summary of previous work in India has been made, while we have also attempted to show the bearing of the work done in other countries on the improvement of the wheat crop in India.

While considering the various agricultural practices concerned in the production of wheat in India, it is necessary to bear in mind the fact that there is a great range in climatic conditions in the various tracts in which this crop is grown. Wheat is cultivated from Quetta to Mandalay and from

Peshawar to Coimbatore, and is moreover one of the most important crops in the Indo-Gangetic plain. In Baluchistán, sowings take place in October and the crop is reaped in July, the young wheat being covered with snow in the winter as in Northern Europe. In the Panjáb, the growth period is shorter and the crop is reaped in April and May. Passing eastwards down the Gangetic plain, the harvest becomes earlier, till in Bihár, the crop is ripe early in March. On the black cotton soils in Peninsular India, wheat ripens in February. While the harvest time, which depends on the onset of the hot weather, is earlier towards the east and south, there is very little range in the sowing period and the second half of October roughly represents the sowing time of most of the Indian wheat crop.

The length of the growth period and the moisture conditions are the chief factors in the production of Indian wheat, and these materially influence the varieties grown and the practices of the various agricultural tracts. A comparison of the practices in vogue in the various wheat-growing regions reveals how often the smallest differences in procedure are closely bound up with differences in local conditions; for instance, the close connection between the normal depth of sufficient moisture for germination and the use of a seed drill. The connection which exists between these modifications in practice and their causes provides an interesting study and affords much food for thought.

CHAPTER II.

SOILS.

The soils of India fall into three main geological types, namely (1) those of the alluvial tracts, (2) those derived from the Deccan trap formation, and (3) those of the crystalline tract. The best general account we have been able to find of the soils of these great areas is that given in the chapter on Agriculture in the third volume of the new *Imperial Gazetteer of India* from which the following and other extracts are taken :—

"The alluvial tracts are the most extensive, and agriculturally the most important. They occupy the greater portions of Sind, Gujarát, Rájpūtāna, the Panjáb, the United Provinces, Bengal and the Godávari, Kistna, and Tanjore Districts of Madras besides extensive tracts in Assam and Burma. An alluvial strip of varying width extends along the eastern and western coasts of the Peninsula, widening at the deltas of the great rivers and reaching irregularly into the valleys of the Eastern and Western Ghâts. Rich alluvial soils fringe the courses of the great rivers of Peninsular India in many places."

The Indo-Gangetic plain, in which the great wheat-growing areas occur, has been described by Watt[1] as follows :—

"From the numerous mouths of the Ganges, and sweeping round the whole length of the Himálayas, at the same time isolating the great southern tableland, there extends a vast alluvial plain, which is only lost in the North-West Provinces and the Panjáb by blending into the drainage area of the Indus. From this point a similar alluvial region is continued to the mouths of the Indus, and may be said to widen until it embraces the northern division of Bombay. In the Bengal section of this vast expanse, the clay soil of the rice swamps can only be viewed as land, figuratively speaking, recently recovered from the sea; and immense portions of it are even now within tidal influence.

The bulk of Bengal is rain-inundated. Passing higher up the alluvial basin, evidences of a more ancient soil, indeed of a more ancient agriculture, are to be seen in the rich loam of Behar. This soil continues with

[1] Watt, *Journal of the Royal Agricultural Society of England*, Vol. 24, 2nd series, p. 26, 1888.

varying degrees of fertility through the North-West Provinces to the Panjáb, and down the tributaries of the Indus to the basin of the combined stream, until it reaches the swamps of the western coast. Throughout this loam expanse there are two modifications. First, on the inundated tracts of the rivers and on depressed portions of the country (in most cases these are but the old beds of former streams, or the silted-up lakes which were thrown off as contortions of the river isolated by the main stream taking the more direct course through a narrow isthmus), rich clayey loam occurs which merges in its character into the heavy mud soil of Bengal. Secondly, within the regions of climatic extremes, natural growth and cultivation alike have been checked, and loam is there found to be more and more intermixed with sand, until absolute sandy deserts are attained.

Thus there exist four types of soil in the alluvial plains of India : a heavy loam, in which clay predominates (the muddy swamps of Bengal) ; a heavy loam, with a certain amount of sand, in which the clods remain firm (the low-lying and inundated tracts of Upper India) ; a light loam, in which the clods are pulverised on being let fall from the hand (the principal soil of Behar, the North-West Provinces, the Panjáb, and a certain portion of Bombay and Sind) ; and lastly, a poor loam with a large admixture of sand, passing into pure sand in which clods do not form at all (the soil of some parts of the North-West Provinces, of a large proportion of Central India and of Sind, with also certain parts of the Panjáb)."

The following general description of the soils of the Deccan trap and of the crystalline tract are taken from the *Imperial Gazetteer of India* :—

"The Deccan trap formation, which extends over about 200,000 square miles, covers the greater portion of the Bombay Presidency, the whole of Berār, the western third of the Central Provinces, and the western half of Hyderābād. The soils throughout these areas vary to an extraordinary extent in character and productiveness. Scattered throughout the tracts in question are numerous low trap hills and ridges connected with the Western Ghāts and Sátpurá ranges, while the cultivated lands are to a large extent broken and rolling. On the slopes and uplands of the lower trap hills the soils are thin and poor. The disintegrated trap furnishes a light-coloured sandy or gravelly soil, which is moderately productive only in years of favourable rainfall. The lowlands in the broken country have deeper and darker-coloured soils, which are constantly improved by washings from the higher levels. True black cotton soil[1] occurs within

[1] The origin of the black cotton soil is discussed in the *Geology of India* by Oldham (2nd Edition, Calcutta, 1893).

the area of the Deccan trap in undulating or sloping situations, below the general level of the foot-hills. It varies in depth according to position and, where very deep, has been accumulated by alluvial deposit. In places in the valleys of the Tāpti, the Narbadā, the Godāvari and the Kistna the heavy black soil is often 20 feet in depth. Owing to its dense consistence it becomes unworkable during heavy rain, and, in these places, is better adapted for *rabi* crops of wheat, linseed, gram, etc., than for cultivation in the *kharīf* season. The black cotton soil of the Deccan trap area which grows cotton and *jowār* as staple crops in the *kharīf* season, is, as a rule, only three or four feet deep, and is mixed with nodular pieces of limestone and small fragments of disintegrated trap. The subsoil contains a good deal of lime and, being shaly, allows free drainage to the trap rock below. Black soils vary in colour, consistence, and fertility, but all are highly retentive of moisture. In the hot weather shrinkage due to evaporation causes the formation of nu erous cracks, which are often several feet deep. This feature has given origin to the common saying, "Black soil ploughs itself." The deeper descriptions of black cotton soil are entirely unsuitable for irrigation; but the mixed black soil found in the smaller valleys, when it is of moderate depth and the substratum affords good natural drainage, admits of well irrigation and produces under liberal cultivation all kinds of garden crops. The depth of the subsoil water in these situations is usually 25 to 30 feet.

Black cotton soil is also found in the valleys of streams and rivers outside the area of the Deccan trap. The chief Districts[1] in which it predominates are Surat and Broach in Bombay, and Bellary, Kurnool and Cuddapah in Madras. The soils here are alluvial in formation and are practically identical with the deeper black cotton soils of the trap area."

" The gneiss schists, etc., of what is known as the crystalline tract, occupy the whole of Peninsular India outside the areas of Deccan trap and alluvium already referred to. This tract comprises almost the whole of Madras; Mysore; the south-east portion of Bombay; the eastern half of Hyderābād and two-thirds of the Central Provinces; the Orissa and Chotā Nāgpur Divisions, and the Santāl Parganas and Bīrbhūm Districts of Bengal; parts of the Mirzāpur, Jhānsi and Hamīrpur Districts of the United

[1] The Provinces of British India are divided into Divisions, each under a Commissioner, and each Division is further subdivided into Districts, each under a Magistrate-Collector who is sometimes called a Deputy-Commissioner. The District is the administrative unit. Detailed information about the Districts is to be found in the Gazetteers and revenue matters are summed up in the Settlement Reports.

Provinces; the Baghelkhand States of Central India; and a part of Eastern Rājputāna. There is also a long strip of similar formation along the east of Lower Burma.

The soils derived from the rocks of the crystalline tract vary so much that it is difficult to describe them even in a general way. In Mysore and Madras the soils are chiefly light-coloured, thin, and stony on the arid uplands, where they produce the poorest of crops; but the red or red-brown loams and clay loams of the lower levels are very fertile. Soils intermediate in character between these two extremes are found in great variety, and those which are of fair or good depth are irrigated with great advantage. Rice is the chief crop grown where canal irrigation is available; but tank and well irrigation is extensively practised, and a great variety of valuable crops are grown, especially under wells. The soils from this formation in Bombay, in the west of the Belgaum, Dhārwār and North Kanara Districts appear to be derived to a considerable extent from laterite, and are ordinarily clay-like in consistence and yellow-red or reddish-brown in colour. The poorest soils are those which are lightest-coloured. The darker-coloured soils are very fertile, and in well-drained situations grow a great variety of crops. Rice is the chief crop on the lower lying terraced and embanked fields. Throughout the whole of the red-soil area in Belgaum and Dhārwār, fruit trees, especially mangoes, grow vigorously, as they do also in Mysore on somewhat similar soil.

The soils found on the crystalline tracts in other parts of India are generally lighter in colour than in Madras, Mysore, and Bombay, the red tinge being much less noticeable. In other respects there are the same differences in consistence, depth, and fertility, according to position. The crops grown vary with the rainfall and the facilities for irrigation. The best descriptions of soil are suited to a great variety of crops, and repay the cost of irrigation quite as well as the alluvial soils in the north of India. Like other Indian soils, those of the crystalline tract are deficient in phosphoric acid, nitrogen, and organic matter.''

The soils of the various wheat-growing tracts of India are commonly regarded from two points of view--firstly, according to the mode in which they are irrigated, and, secondly, according to their physical character. No systematic soil survey, on modern lines, of these areas has yet been attempted and no physical analyses of the soils on which the best varieties of wheat are grown have been published. In many Provinces, however, a classification of the soils of each district has been made for the purpose of revenue settlement. This is so detailed that it is difficult to construct

from it a broad general classification of the soils. For general information on the composition of the soils met with in the plains and in the central plateau the reader is referred to a paper by Leather in the *Agricultural Ledger*.[1] The geology of these regions is described in the *Geology of India*.

Panjab and North-West Frontier Province.

There are a large number of vernacular terms applied to the soils of the Panjáb which are frequently referred to by the District officers in the Settlement Reports, Gazetteers, and other official documents. The occurrence of these terms in the vernacular shows that the cultivators fully realise the existence of many types of soil of varying suitability for the growth of crops. Possibly a modern soil survey would do little more than express in a scientific way what is already understood and applied by the people.

Many terms are used to describe the physical character of the soils: thus *nyái* is rich land round the homestead. Heavy clay soils are termed *dákar*, *chhamb*, and the heaviest clays on which rice only can be grown are termed *rákar*. The best soils of the Punjab are well drained loams known as *rohi*. The lighter loams are called *rausli* and the sandy soils which only grow millets are known as *bhúr* or *maira*. *Tibba* is almost pure sand and *reti* is a soil with wind-blown hillocks of sand.

Terms of general application referring to the manner in which water is supplied to the crops are as follows: land dependent on rain is known as *baráni*, if watered by canals is called *nahri*, if by wells *chahi*, and if from tanks *abi*. The region between two rivers is *doáb* land, and the tributaries of the Indus break up the Province into numerous and vast *doábs*. Those tracts either inundated or moistened by the rise of the rivers are known as *sailába*, *bhet*, or *khádar*. In these *bhet* tracts, alkali land is commonly met with. The efflorescence on the surface of the barren spots is called *reh* or *kallar*[2] and may be either impure sulphate or carbonate of soda. Land beyond the *bhet* influence is generally known as *desya* or *báng*ar. The interior and higher parts of the *doábs* are called *máhjah*.

The productive power and consequently the land assessment of the Punjab soils depends primarily on the water-supply, whether the land is *baráni*, *nahri*, *chahi* or *abi*. There is a second subdivision according to the physical character. The somewhat low-lying fields which receive the surface drainage water and silt carried from the higher land are, as a rule,

[1] Leather, *Agricultural Ledger*, No. 2, 1898.
[2] Leather, *Agricultural Ledger*, Nos. 7 & 13, 1897.

preferred as such fields retain moisture to the greatest extent. These matters are investigated in great detail when the Districts are resettled, and much local information on this important subject is to be found in the District Settlement Reports, Gazetteers and in a volume on wheat published by the Punjab Government in 1884.[1]

As a rule, the best wheat is sown on *rausli* and *rohi* soils, but there are exceptions—for example, in the well-irrigated District of Jullunder and also in Bannu where the best wheat soils are somewhat sandy in character.

United Provinces of Agra and Oudh.

The soils of the Provinces fall into two main divisions, the Gangetic alluvium and the Bundelkhand Districts.

The alluvial soils stretch from the Jumna to the Himálayas and this tract forms by far the most productive part of these Provinces. The alluvium has been sorted by river action so that there is a uniform gradation from the coarser soils of Saharánpur on the north-west to the silt-like soils of Balliá on the south-east.

Four classes of land have been distinguished in the alluvium between the Jumna and the hills[2]:—

1. *Bhábar* is the slope of gravel along the foot of the mountains. This is mostly forest and extremely unhealthy. Occasionally, however, crops of wheat are raised as in the Naini Tál District.

2. *Tarai* is the unhealthy forest tract next below the *bhábar*, mostly clay land in which the *sál* tree (*Shorea robusta*) prevails and in which there are marshes and land under high grass.

3. *Bángar* is the name applied to the uplands of the alluvial plains of the United Provinces. Three classes of soils are met with in the *bángar* usually arranged in belts across the country and parallel to the rivers.

These soils are:—

(*a*) *Matiyár* (*dhankar*) or heavy clay land in which the *úsar* tracts occur. Rice is the prevailing crop on these soils, which are also characterised by the absence of trees and the occurrence of *jhíls*. Wheat is not usually grown on these soils.

[1] *Punjab Wheat: Its Varieties, Distribution and Husbandry*, Lahore, 1884.

[2] Fisher, *Statistical, Descriptive, and Historical Account of the North-West Provinces of India*, Vol. IX, Allahábád, 1883.

(*b*) *Dumat* (lit. two earths), *doras*, *siwái* or *rausli* (Muzaffarnagar) is the fertile loam of the uplands which is well wooded and grows a very large number of crops. Wheat is the most abundant of the *rabi* crops and is especially important in the upper portions of the Doáb (the tract between the Ganges and the Jumna) in the Districts of Saharánpur, Muzaffarnagar, Meerut, Bulandshahr and Aligarh.

(*c*) *Bhúr* or *baluá* is the sandy land which only grows millets in the *kharíf* and is not usually cultivated in the *rabi* on account of its want of moisture-retaining capacity.

4. *Khádir*, *khádar*, *kachhár* or *tarai* is the name given to the river lowlands which are submerged in the rains and yield *rabi* crops including wheat. *Khádir* lands which correspond to the *saildba* of the Punjab are sometimes renovated and enriched by deposits of fine silt, while at other times their fertility may be destroyed by layers of sand left by the river.

In the region between the Jumna and the Himálayas two special classes of soils occur besides the alluvium proper. In Gorakhpur and Bastí there is a calcareous loam (*bhet*) in the river basins, on which good crops of wheat are grown, and which is characterised by its great power of retaining moisture. Again in the lower *doáb* on the north bank of the Jumna from Etáwah to Allahábád a group of distinct soils (known as *már*, *kábar*, *rákar*, *etc.*) occurs which resemble the similarly named soils of Bundelkhand. They are found north of the Jumna at the point where that river begins to receive the drainage of Central India, and it is probable that the sources of these soils are the same as those of the Bundelkhand Districts which they so closely resemble.

In addition to the wider classes of soils referred to above, there is a second classification depending on the amount of organic matter in the soil. Thus the highly manured land round the villages which is especially characteristic of the eastern part of the Province, is known as *goind* or *gauhán*. This corresponds to the *nyái* of the Punjab and on account of its moisture-retaining capacity bears good crops in dry seasons. The market garden soils near the large cities are of the *goind* class. The outlying village lands which are little manured are termed *pálo* or *uparhar*, while the intermediate fields which are occasionally manured are called *manjhár*. In the western and more prosperous parts of the Province the Játs manure all their fields and this distinction of *goind*, *manjhár* and *pálo* lands is not clearly marked.

Bundelkhand differs widely in its agriculture from that of the alluvium of the United Provinces which has been described above.[1] The difference consists partly in the soil, partly in the uncertainty of the rainfall, and also to some extent in the want of industry of the people. Some portions of this tract contain reddish soils which do not retain sufficient moisture for wheat and other *rabi* crops. Such soils are either uncultivated or only bear inferior millets in the *kharif*. The rest of this region forms the black soil tract in which four types of soil are met with :—

Már (or *moti*), a rich black soil, loose and friable, with similar characters to those of the black cotton soils of the Central Provinces. It retains moisture to an extraordinary extent, becomes impassable in the rains and contracts considerably with wide cracks in time of drought. With favourable conditions for the preparation of the seed-bed and for sowing, *már* yields good mixed crops of wheat and gram (called *birrá*) without irrigation. The red wheat called *kathia* (a macaroni wheat) is said to thrive best on this soil.[2]

Kábar is lighter in colour than *már* and is much stiffer and more difficult to work. Gram is the favourite *rabi* crop on this soil, but wheat is sometimes grown.

Parwá is a lighter soil, reddish or yellowish in colour, which yields good crops of wheat, usually white wheat (*pissi*) if irrigated.

Rákar is a more gravelly soil derived from *már* which does not, as a rule, retain sufficient moisture for *rabi* crops.

In both Bundelkhand and in the region between the Jumna and the Himálayas it may be said that wheat is grown on the best soils which are available each year. The rich lands near the homestead are the most prized for wheat-growing.

Bengal.

This Province may be divided agriculturally into three areas—firstly, the gneissic region comprising the hilly tracts of Chotá Nágpur and Orissa on the south, secondly, the low-lying rain-inundated rice lands of Lower Bengal often referred to as the newer alluvium, and, thirdly, the uplands of Bihár, the older alluvium. A line drawn from the foot of the hills in the north-west corner of the Jalpaiguri District to the

[1] Further details of the soils and general agriculture of the United Provinces are to be found in Moreland's *Agriculture of the United Provinces*, Allahábád, 1904.

[2] Atkinson, *Statistical, Descriptive and Historical Account of the North-West Provinces of India*, Vol. I, Allahábád, 1874.

head of the Gangetic delta between Rájmahál and Murshidábád and continued along the course of the Hooghly roughly divides the older alluvium on the west from the newer alluvium on the east. With the exception of the loams of Bihár the soils of Bengal are generally too heavy for wheat-growing. It is only in the riverain tracts where a certain amount of sand has been mixed with the clay that wheat can be cultivated.

Wheat is only sown to a small extent in Lower Bengal and in Orissa. In these tracts the crop is only cultivated in the basins of the rivers on flat land which is periodically inundated and enriched by silt. In Chotá Nágpur, wheat is either grown on embanked lands where water is stored for rice irrigation or on a black clayey soil very retentive of moisture called *kewal*.

The wheat-growing tracts of Bengal are in Bihár, and are situated principally to the south of the Ganges in the Districts of Sháhábád, Patna, Monghyr and Bhágalpur. The wheat tracts in the Buxar sub-division of Sháhábád, which may be accepted as typical of the best Bihár soils for this crop, have been described as follows :—"There are two principal wheat tracts in which wheat is largely grown in this district : the first is the alluvial soil called *deára* extending from Buxar to the Son. This is the tract in which the beautiful soft white wheat is grown : the land is a rich alluvium annually enriched by the overflow of the Ganges ; it is needless to say that no manure is required in this soil for the finest wheats, and that it is in this tract possible to grow as fine wheat as anywhere in India. The next in importance is the black clay soil extending from the Grand Trunk Road on the one side and on the other to within 15 miles of the Ganges."[1] In all of the Districts of the wheat-growing Divisions of Patna and Bhágalpur, soils similar to those described above in the Buxar sub-division are mentioned as the best for wheat—*deára* lands near the Ganges which are enriched annually by silt or else strong black loams known as *kewal* or *karail*.

Central Provinces and Berar.

Most of the wheat in these Provinces is grown on the black or cotton soil which has been described by Fuller[2] as follows :—

"This black or 'cotton' soil is known by various names indicating the proportion in which it is mixed with lighter soil. It is of very variable depth, lying in much thicker deposits in flat valleys than on sloping

[1] Finucane, *Report on the Cultivation and Trade of Wheat in India*, Calcutta, 1886.

[2] *The Wheat Production and Trade of India*, Calcutta, 1883.

ground. Thus, in the Narsinghpur and Hoshangábád Districts of the Narbadá valley, its average thickness is at least 10 feet, whilst among the hills and slopes of the Nimár District it frequently occurs as a scanty coating of a few inches. It is most suitable for wheat when at its greatest thickness, since, from the great capacity which it then enjoys of absorbing rain water, it can, in a monsoon of average intensity, lay up a store of moisture sufficient to carry a wheat crop through a cold season in which the winter rains hold off entirely. When it is merely a shallow veneer of earth covering rocks, it dries, of course, with far greater rapidity, and is in this case devoted to the production of rain (*kharíf*) crops. This difference is brought into strong relief by a comparison of the agricultural returns for the contiguous Districts of Hoshangábád and Nimár. In Hoshangábád deep black soil predominates, and, in consequence, 63 per cent. of its cultivated area is returned as under wheat. The greater portion of the Nimár District is hilly or undulating ground, consisting of trap rock, overlaid with a shallow bed of black soil. Wheat only occupies 4 per cent. of its cultivated area."

The Narbadá valley is the most important wheat-growing tract of these Provinces, and here about a third of the crop grown in the Central Provinces is produced. It is here that the black cotton soil is seen to perfection. The valley consists of deep black soil flanked at the base of the hills on either side with bands of shallow black or sandy soil on which the *mahuá* tree (*Bassia latifolia*) flourishes. This tree serves to mark the boundary of the black cotton soil area. The standard outturn of wheat in 1893-1894 on the black soil in the Narbadá valley was 660 lbs. on 100 lbs. of seed or 6½ fold ; and the land appears to be more fertile than in 1864 at the time when the Settlement Report by Grant was written. In the recent Gazetteer of the Narsinghpur District it is stated that "the people still neither manure nor irrigate the land and they still grow wheat year after year without rotation ; but they now almost invariably mix a proportion of gram (*Cicer arietinum*) with the wheat, and this has the effect of increasing the fertility of the land, in consequence of the well-known property possessed by plants of the pea tribe of attracting nitrogen from the atmosphere. Grant in the Settlement Report of 1864 does not mention this system of mixing the crops, though he remarks, that, when the soil showed signs of complete exhaustion, gram or another pulse was usually substituted for wheat for two or three years. Whether the admixture of gram is the sole or main cause by which a decrease in the outturn has been prevented cannot be determined here."

On account of its variable depth and the degree of admixture with sand and pebbles the black cotton soil receives various names in these Provinces. Thus :

Kábar, kachár, káli, már or *mariár* are terms applied in the various districts to the best black soil for wheat. On account of its extremely sticky character when wet, *kharíf* crops are not usually grown on *kábar*, and this type of soil is reserved for wheat or for a mixed crop of wheat and gram or for pulses year after year without any rotation at all. As this black soil retains moisture so well, the soft wheats which mature late and thus require more moisture are grown on *kábar*.

Morand, murand, mund, dorsa are names applied to a more loamy and lighter-coloured soil containing a higher percentage of sandy or limestone particles. This is second class black soil and does not retain moisture so well as *kábar*. Consequently the hard wheats which mature early and do not require so much water are generally grown on this second class soil. Further, on account of its loamy character and greater ease of working, both *kharíf* and *rabi* crops may be grown on *morand*.

Patarua and *ránkar* are the names given to poor *morand*, much lighter in colour. Wheat is sometimes sown on soils of this type.

In detailed settlement work the soil classification is based on three principles : (1) the physical character of the soil which determines the *soil class* ; (2) the crop grown—fields which will grow wheat are considered valuable and form a separate class (*gohání*) ; and (3) the lie of the surface which determines the *position class*. Wheat lands are classed according to position as follows :—

Dhongar if high lying on a slope and damaged by surface wash and too much drainage.

Bharkíla if cut up by water channels.

Bandhia if embanked.

Abpáshi if irrigated.

Ujarhá if the crop is damaged by wild beasts.

Mamúli (ordinary) if not falling into any other position.

Bombay Presidency (including Sind).

This Presidency may be divided agriculturally into four regions : (1) Sind in which the climate and conditions resemble those of the Punjab ; (2) Gujarát, the northern part of the Presidency proper in which the largest amount of wheat is grown ; (3) the table land about the Ghats including the Deccan and the Carnatic ; and (4) the Konkan strip of low

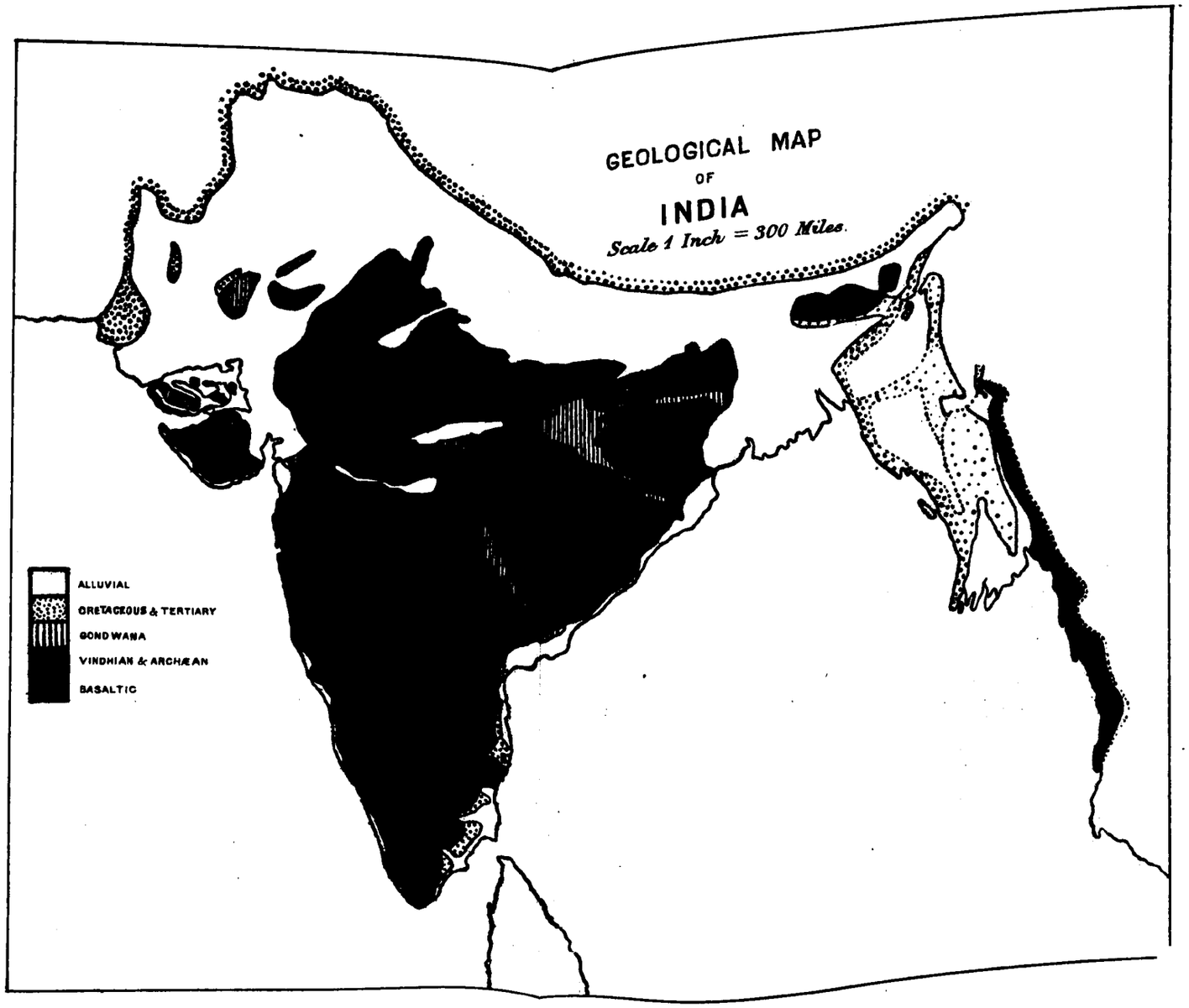
country between the Ghâts and the Indian Ocean in which rice is the important *kharíf* crop and in which wheat is not cultivated.

The soils of the Presidency proper are very diversified and range from black soils, which retain moisture and which are not unlike the cotton soils of the Central Provinces, to reddish sands with little or no moisture retaining power on which *kharíf* crops only can be raised.

The whole of Gujarát is a level plain with small trap hills cropping up here and there. There are various types of soil in this tract, which includes the Districts of Ahmadábád, Kaira, Pánch Maháls, Broach and Surat. *Káli* or *mál* is the name applied to the black moisture-retaining soil on which cotton and dry wheat are largely grown. Extensive tracts of treeless black soil are found in Broach and Surat and in parts of Ahmadábád and Kaira. Medium soils are called *besár* and on these wheat is also grown with irrigation. *Goráti* or *goráddu* is a light sandy soil of great depth which grows fine timber trees. New alluvial soils found on the banks of rivers are known as *bhatha* and marshy salt lands are called *khar*. In Ahmadábád wheat is also grown on low-lying soils (*bara*) which are too moist for cotton.

Throughout the Deccan tract, which includes the Districts of Khándesh, Násik, Ahmadnagar, Poona, Sholápur and Sátára the soils are almost wholly black and formed from trap rock, but they vary to an extraordinary extent in character and productiveness. On the slopes and uplands of the low trap ranges the soils are thin and poor, while on the lowlands especially near the rivers and large streams, strips of deep black soil (*káli*) of great fertility are found. On these low lying soils *rabi* crops including wheat are cultivated. Some of the best unirrigated wheat crops (often called dry wheat) of the Presidency are grown in the deep black alluvial clay (*bari káli*) of the Tápti Valley in Khándesh and along the Godávari in Ahmadnagar. Irrigated wheat is sown on lighter soil and for this purpose the medium black soil, which is abundant in the Deccan, is very suitable. This soil has a substratum of decayed trap rock (*murum*) two or three feet below the surface which prevents water-logging after irrigation, while there is sufficient of the black clay present to retain a fair amount of moisture.

In the eastern portions of the Carnatic Districts, Belgaum, Bijápur, and Dhárwár, there are considerable stretches of black soil country (*yeri bhumi*) on which good crops of wheat are raised, especially if the late rains are sufficient. The red soils of this tract are too dry for wheat and only yield monsoon crops such as millets while the hills are covered with forest growth.


GEOLOGICAL MAP
OF
INDIA
Scale 1 Inch = 300 Miles.
ALLUVIAL
CRETACEOUS & TERTIARY
GONDWANA
VINDHIAN & ARCHÆAN
BASALTIC

The agricultural conditions of Sind are somewhat peculiar. In place of the monsoon of the Presidency proper, the cultivated soils of this tract are watered from June to October by the inundation canals of the Indus, while there is in addition a perennial canal (the Jámrao) which commands about $7\frac{1}{2}$ lakhs of acres. Just as the crops of Bombay vary with the monsoon, so those of Sind rise and fall according to the amount of inundation. The soil is alluvial and is described as somewhat clayey in character, while it is annually enriched by the silt brought down by the Indus and deposited on the *sailába* land.[1] Doubtless with the extension of perennial irrigation in Sind, the wheat production of this tract, like that of the Punjab, will largely increase.

Madras.

There are three great divisions of the Madras Presidency; the land between the Western Ghâts and the sea, the strip of country between the Eastern Ghâts and the Bay of Bengal and the central plateau between the Western and Eastern Ghâts. Three chief groups of soils occur, *regar* or black cotton soil occurs in isolated patches or far-reaching plains all over the Presidency and yields cotton and *cholam* (*Sorghum vulgare*). The red soil is also widely spread and exhibits every degree of fertility and barrenness; cereals and cotton are the chief crops. On the grey soil millets are grown. In Madras, however, the facilities for irrigation are regarded as of more importance than the soil.

Wheat is only grown to a very small extent in the central plateau in the Kistna, Cuddapah, Bellary, Kurnool and Coimbatore Districts and in the Nílgiri hills. The soils best suited to this crop are black cotton soil or *regar*, dark loams and alluvial soils. In Kurnool, land enriched by accumulations of silt is said to be the best, while in Coimbatore wheat is grown only on garden soils.

Mysore.

Wheat is grown only to a very small extent in Mysore on black clayey soils or on rice lands whenever there is a deficiency of water.

Burma.

In this Province wheat is either grown on alluvial land as in Minbu or on the level rich black clayey soil (*sane*) of Sagaing. This black soil is very similar to the *kanhar* of the Central Provinces and retains moisture to a very considerable extent. During the rains it is too wet for successful cultivation, but in October and November it is sown with wheat or gram.

[1] *The Wheat Production and Trade of India*, Simla, 1879.

CHAPTER III.

IRRIGATION[1]

A large proportion of the wheat grown in India depends partly or almost entirely on irrigation for its moisture. In the great wheat-growing tracts of the Punjab, United Provinces and Sind about half the wheat produced is returned in the crop reports as irrigated, while in Bengal, the Central Provinces and Bombay the area artificially watered is small.

PUNJAB, NORTH-WEST FRONTIER PROVINCE AND SIND.

The Punjab is of all the Indian Provinces the best adapted for extensive irrigation from perennial canals. The unfailing supplies of its snow-fed rivers and the even surface of its arid plains have rendered it possible to construct at small cost a vast network of canals by which the greater part of the Province is protected from drought. In addition, considerable areas are watered by means of wells and inundation canals and also by the flooding of low-lying land near the rivers by the rise of the water during the summer months. The perfection of the irrigation systems to a large extent secures the present area under wheat, while the large extensions of the perennial canals projected will no doubt lead to a great increase in the wheat production of this Province. Of the 9,037,800 acres sown with wheat in the Punjab in 1906-07, 4,399,600 acres are returned as irrigated.

The perennial canals of the Province take off from the snow-fed rivers in the submontane region and are found chiefly in the north-eastern tracts. They comprise the Western Jumna, Sirhind, Bári Doáb, Chenáb and Jhelum canals as well as a few minor works. These extensive systems command large areas of the Province including much of the vast *doábs* between the rivers Jhelum, Chenáb, Rávi and Sutlej. The wheat lands are watered before sowing time, ploughed up as soon as the land is dry enough and sown immediately. In this way one watering suffices

[1] It is not proposed to give a detailed account of Indian irrigation in this chapter, but only to indicate generally the manner in which the wheat crop is artificially watered. There is a considerable volume of easily accessible literature on the subject from which further details can be obtained. A full account of irrigation in India and of the present irrigation works and also of the scope for future extensions is given in the *Report of the Indian Irrigation Commission*, 1901-03, while an admirable summary of the subject is to be found in the third volume of the new edition of the *Imperial Gazetteer of India*.

for the production of a proper seed-bed and also supplies sufficient moisture for germination and for the growth of the young seedlings. Two or three subsequent waterings are given, the last or sometimes the last but one about the time the wheat is in flower towards the end of February and the beginning of March. The fields are divided into rather large beds (*kiáris*) and in consequence there is a tendency to apply too much water.

The inundation canals are much smaller works and are found chiefly in the south-west corner of the Province, and derive their water from the Sutlej, Chenáb and Indus. The simple system of irrigation by inundation canals appears to have been practised from time immemorial in the Punjab and in Sind and many of the existing canals of this class in the Multan, Muzaffargarh and Dera Gházi Khán Districts were in operation at the time of annexation, but have since been considerably developed and are now maintained by Government. These canals only flow when the rivers are in flood during the summer and by their means the areas commanded are flooded for some weeks. After the subsidence of the waters the land is cultivated and sown. Sufficient moisture is retained by the soil to ripen the wheat crop with the assistance of a supplementary watering from wells.

Irrigation by wells is largely practised in the Punjab, especially in the south-west corner and in the eastern Districts of Amritsar and Jullunder where wells supplement the rainfall. The wells are, as a rule, permanent and the water is raised by bullock power usually by means of the Persian wheel. This consists of an endless chain of water pots passing over a vertical wheel erected over the top of the well and rotated by means of rough wooden gearing which is worked by a pair of bullocks walking round a circular track. Ordinarily the lift seldom exceeds 40 feet and the average area irrigated per well is 12 acres. In the Delhi Division (see p. 26), well water is generally raised by means of the *charsa* or *mot*.

A considerable area of wheat is grown on the low-lying land near the rivers which is flooded by the rise of the water during the summer. This *sailába* land on which wheat is the chief *rabi* crop often retains sufficient moisture, when supplemented by the winter rains, to mature the crop.

In the Jhelum District, fields are sometimes embanked so as to hold the rainwater during the monsoon in the manner adopted in some parts of the Central Provinces and described below. In the neighbouring District of Sháhpur the system of embankments has been carried much further and is of great interest. In the lower lands, only the lowest portions which receive the drainage and silt from the surrounding higher lands are cultiv-

ated and many of these fields have embankments, so as to hold up the water. In the Salt range, the soil of the valleys is watered by means of the hill torrents and also fertilised by the silt brought down by these streams. The method of applying the water to the land has been described by Wilson as follows[1]:—"Where a torrent debouches from the hills on to comparatively level ground, a strong embankment is thrown across it, not to hold up the water permanently, but to turn it out of its deep natural channel on to the higher-lying culturable land. Should one embankment not be sufficient, another is made lower down to control the surplus water, and so on, until the whole of the water brought down by the torrent, laden with its limestone mud, is poured over the fields on the slopes of the valley. If the torrent is a large one, the embankments are so arranged as to divide the body of the water into several more manageable streams. The fields which receive the first flow have strong and high embankments built round their lower edges so as to retain the water until the field is thoroughly saturated; it is then passed on through an opening made in the embankment to the field below, and so on, in turn, until the whole of the water has percolated into the soil. Thus the slopes of the valleys have been gradually worked into a succession of terraces, one below the other, and in some cases the dams are so strong and so well designed that the natural channel of a large torrent remains perfectly dry and, even after heavy rainfall on its catchment area in the hills, the whole stream is turned on to the ridges on either side, and passing down gradually from terrace to terrace irrigates a large area of comparatively high land, which would naturally remain dry and almost unculturable."

In the North-West Frontier Province about a quarter of the area under wheat (1,146,000 acres in 1906-07) is irrigated, while the rest depends on rainfall alone. There is only one major work, the Swát river canal, but extensive use is made of the numerous hill streams for flooding the surface, while wells are also employed.

The agricultural conditions of Sind correspond closely with those of the rainless tracts of the Punjab. Artificial irrigation is a necessity for agriculture and water is provided almost entirely by inundation canals from the Indus. One of these, the Eastern Nára, is a branch from the left bank of the Indus near Sukkur and discharges into the Rann of Cutch. This branch has been deepened and provides a perennial supply to the canals, *e.g.*, the Jámrao, which take off from it. In place of the monsoon of other parts of India the rise of the Indus in June is used to flood the

[1] Wilson, *Gazetteer of the Sháhpur District*, Revised Edition, Lahore, 1897.

country by means of the inundation canals during the monsoon months, and when the waters subside, the land is cultivated for *rabi* crops including wheat. The area commanded by the canals varies greatly according to the state of the river, the difference between that of a very favourable and unfavourable season being as much as 800,000 acres.

United Provinces.

About half of the area under wheat in these Provinces (7,039,000 acres in 1906-07) is returned as irrigated. There are several large perennial canals of which the Ganges canal was the pioneer irrigation work of any magnitude constructed in Northern India. The Ganges, Lower Ganges, and Eastern Jumna canals irrigate the Doáb country which is the tract of these provinces specially characterised by this form of artificial watering. South of the Jumna there are two major works, the Agra and Betwá canals, the latter of which is a protective work which commands portions of the Bundelkhand Districts.

Although the best wheat grown in the United Provinces in the upper Doáb is watered to some extent by canals, wells[1] are used to a very considerable extent in the alluvium and are the most important source of water. Besides *kachchá* wells, which are simply holes made in the ground for temporary watering, there are two kinds of permanent wells—spring wells and percolation wells. In the alluvium, a permanent well usually consists of a brick-work cylinder sunk through the upper strata of alternate clay or loam and sand down to an impervious stratum of stiff clay, known as the *mota*, through which a tube (3 or 4 inches in diameter) passes into the sandy stratum below. Through this pipe a plentiful supply of water rises into the cylinder. Such wells are known as spring wells. In the submontane tract, in the river valleys and in many parts of the Districts south of the Jumna, percolation wells of larger diameter are met with. These are easy to construct, but they do not irrigate such a large area as spring wells.

In percolation wells where the lift does not usually exceed 15 feet, the water is raised by the *dhenkli*, which consists of a bucket suspended by a rope to the end of a long pole which is pivoted to a post near the other end so as to revolve through a vertical plane. The shorter arm is weighted,

[1] The theory and practice of well-sinking in the United Provinces is admirably dealt with by Molony in Bulletin No. 22 of the Department of Land Records and Agriculture, United Provinces, entitled *A Manual of Irrigation Wells*, Government Press, Allahábád, 1907. There is an earlier paper by the same author—*Irrigation wells in the western portion of the North-West Provinces of India*—Government Press, Allahábád, 1901.

so as to nearly counterbalance the weight of the full bucket and the longer arm. When the lift exceeds 15 feet, the water is generally raised by bullock power by means of the contrivance known as the *mot* which consists of a large leather bag, holding from 30 to 40 gallons of water, fastened to one end of a rope which passes over a pulley overhanging the well. The other end of the rope is attached to a pair of oxen, and when the bag has been lowered and filled, these then walk down a slope (equal in length to the depth of the well). By this means the bag is drawn to the top of the well when it is emptied and the process repeated. The Persian wheel is used in the north of these Provinces where they border on the Punjab, but it is not employed generally in the United Provinces.

Streams, *jhíls* and tanks are also used for the first watering of the wheat and other *rabi* crops, but the supply of water is often insufficient and the spread of well irrigation has led to a decline of these forms of watering. Water is usually raised from these supplies by means of a closely woven basket (*beri*) held by ropes and worked by two labourers who swing the basket into the water and then empty it at the higher level into a channel from which it flows to the field to be irrigated.

Unless the monsoon rains have finished early and there is a dry September, the land is not irrigated before sowing. The first watering is given in November or December to the young crop, a second watering follows in January and a third when the wheat is in ear. After a rainless September the soil is usually too dry for sowing and a preliminary watering is necessary to carry the crop through the seedling stage. Where this is given, the area sown with wheat is much less than in normal years on account of the labour necessary for this preliminary watering in the well-irrigated tracts. The fields are divided into compartments (*kiáris*) by low ridges of earth and the surface is flooded. In canal irrigation these compartments are larger than where the supply is drawn from wells or *jhíls*.

Bengal.

Only about two and-a-half per cent. of the million and-a-quarter acres of wheat sown in Bengal is returned as irrigated. There is only one important canal in Bihár—the Son river canal—and this is chiefly employed to irrigate the rice crop during the *hathia*—the period from September 26th to October 10th. Only about 130,000 acres of the *rabi* crop including some wheat are watered by this canal. One result of this canal has been the substitution of autumn rice for wheat. With this exception and a little irrigation from wells, the wheat crop in Bengal is grown on the

natural rainfall which is sufficient to mature the crop. Often, indeed, there is too much rain in Bengal, especially during the period when the wheat is ripening. In South Bihár and Chotá Nágpur, the monsoon rainfall is embanked to saturate the soil. The water is let off in September and the land prepared for sowing.

It will be evident that, starting from Bihár and passing up the Indo-Gangetic plain through the United Provinces, the Punjab and Sind, the character of the irrigation gradually changes. In Bihár, the wheat crop is practically unirrigated, in the United Provinces north of the Ganges the rainfall is supplemented by wells, *jhíls* and tanks, while in the Doáb and the Eastern Punjab canals and wells supplement the uncertain rainfall. In the vast *doábs* of the Punjab, wheat is grown by means of water from perennial canals while in the south-west of the Province and Sind inundation canals take the place of the monsoon.

Central Provinces.

Only about 1·5 per cent. of the wheat area in the Central Provinces and Berár (3,689,000 acres in 1906-07) is returned as irrigated. There are at present no state irrigation works in the Central Provinces and singularly few wells. In the rice areas there are some 50,000 small private tanks, but these are of little or no importance as far as the wheat crop is concerned. A complete failure of the rains was hardly known till 1896 and in many parts of the Province the cultivation is said to have suffered more frequently and severely from excessive rainfall than from drought. The black, moisture-retaining soils of this tract on which wheat is grown are hardly so adapted to flow irrigation during the growth of the crop as the alluvium of the plains, and as a rule they retain sufficient moisture for the wheat crop until the winter rains. The application of water during the growing period would probably induce rust and might easily do more harm than good.

Although there are practically no wells or canals in the Central Provinces, nevertheless there exists in some of the Districts a very interesting kind of irrigation in the form of embanked fields.[1] These are estimated at about 600,000 acres of which about two-thirds are in the District of Jubbulpore and the remainder chiefly in Narsinghpur, Damoh and Saugor. They are found only where the soil is stiff enough to make water-tight bunds easily and are not met with in the more friable black soils of Hoshangábád

[1] The subject of embanking generally is dealt with by Marsh, in a paper entitled "Protective Works in Central India," *Agr. Jour. of India*, Vol. I, page 290.

and other parts of the Narbadá valley. Wheat is practically the only *rabi* crop grown on these lands. The embankments in the more level lands of Jubbulpore and Narsinghpur are from 3 to 5 feet high, while in the uneven lands of Damoh and Saugor water is often held up to a depth of 10 feet. Besides the conservation of moisture for the wheat crop, embankment serves to enrich the soil by holding up the silt brought down from higher lands and also weeds like *káns* grass (*Saccharum spontaneum*) are eradicated. After the monsoon, the embankments are cut and the water is run off on rice lands or to saturate other fields below, and the land is ploughed up and sown when dry enough. The resulting crop is always much better than that on unembanked land, especially when the winter rains fail, but in some years the wheat is said to suffer considerably from rust. On the whole, however, there is a great advantage from embankment, and when a ryot in these districts wishes to improve his land, his first impulse is to embank for wheat.

Bombay.

Of the total area of wheat in the Presidency Proper (1,637,000 acres in 1906-07), about 12·5 per cent. was returned as assisted by irrigation. Of this, 57 per cent. was in Gujarát, 39 per cent. in the Deccan and 4 per cent. in the Carnatic.

Perhaps, the most important means of irrigation in Gujarát and the Deccan are wells. In the latter tract 60 per cent. of the gross area of all crops irrigated is watered from wells. Next in importance come petty works, such as tanks, while canals are of minor consequence in this Presidency. All the canals are small and command but a limited area and many do not even pay their working expenses.

In Gujarát, wheat is generally watered from wells, ponds and rivers, the water being raised to the surface by means of the *mot* worked by cattle. In the low-lying plains of the Ahmadábad District an interesting system of embankments, on a similar principle to that described above in the Jubbulpore District of the Central Provinces, is adopted. Long lines of embankments (*bunds*) four or five feet high extend across the country by means of which water is held up on the surface of the land above the *bund*. The water is run off and used for rice irrigation on land below the *bund*, while the land above the embankment previously under water is sown with wheat or gram.

In the Deccan, wheat is irrigated from wells, canals and reservoirs. In the Khándesh District, the valleys are open and level and the smaller

rivers flow in shallow beds, blocked here and there by rocky ledges of much service in making masonry weirs (*bandharas*) by which large areas are easily commanded. Field embankments constructed for the purpose of retaining the rainfall on the fields and preventing the soil from being washed away are very numerous throughout the Deccan where their value appears to be appreciated.

In the Carnatic the wheat crop is almost entirely grown on the natural rainfall, unassisted by irrigation.

CHAPTER IV.

MIXED CROPS AND ROTATIONS.

THE principle of the rotation of crops is well understood in India and widely adopted in practice. Instead, however, of growing his crops in a definite order, the Indian cultivator usually grows them mixed, and this practice is well exemplified in the case of wheat. A considerable proportion is grown mixed with gram, barley, linseed and mustard, and fields containing all five of these crops at the same time are commonly to be seen in Bihár.

PUNJAB, NORTH-WEST FRONTIER PROVINCE AND SIND.

On the inundation canals in Sind the rotation is usually *jowár* (*Sorghum vulgare*) or *bájra* (*Pennisetum typhoideum*) one year and wheat another, but in some cases wheat alone is grown. On the Jámrao canal the rotation is cotton one year and wheat the next with catch crops of *jowár* and *bájra*. In all cases long fallows are given periodically.

In the Punjab, wheat is either grown alone or mixed with gram, barley or mustard or with both gram and barley. Although no general practice in this Province as regards sowing wheat mixed with other crops is apparent from the study of published reports of District Officers, it seems that gram is more generally sown with wheat in the dry country south of Ludhiána. In the south-western corner, in the Jhelum and Chenáb Canal colonies, and in the District of Ráwalpindi, the crop is generally grown unmixed as well as in the Districts of the North-West Frontier Province (Pesháwar, Dera Ismail Khán, Bannu, Hazára and Kohát). The principal rotations of wheat land according to Renouf [1] are :—

(1) On *irrigated* land—

(*a*) Wheat follows wheat for a succession of years. Eventually a *kharíf* crop is grown and then the land lies fallow for a year.

(*b*) On rich manured well lands we find wheat followed by maize for a number of years.

(*c*) As a two years' course we have wheat-cotton and a quick maturing crop, such as *chena* (*Panicum miliaceum*) or tobacco or a fallow.

[1] *Proceedings of the Board of Agriculture in India*, Calcutta, 1906, p. 66.

(*d*) Wheat, indigo, wheat, indigo, and so on in the area where indigo is grown.

(2) *Unirrigated* land—

(*a*) Wheat after wheat for a succession of years and then a whole year's fallow.

(*b*) Wheat followed by maize, cotton, *bájra* or *jowár*, and then a year's fallow.

UNITED PROVINCES.

The extent to which mixed wheat is grown in these Provinces is always stated in the Crop reports. In 1906-07 the area under wheat grown alone amounted to 5,537,712 acres and that of wheat grown with gram and barley to 1,501,385 acres. There are two common mixtures in this Province: (1) wheat-barley (*gujai*) frequently met with in the eastern half of the Province where the two grains are harvested and threshed together and ground together into flour, and (2) wheat-gram (*birrá*) which is common in the western districts and is the usual crop in Bundelkhand where water is not often available for irrigation and where it is risky to sow wheat by itself.

The rotations practised in the United Provinces, according to Moreland,[1] are as follows :—

(*a*) "Wheat is rarely grown after a *kharíf* crop in the same year ; in fact, this is done to any extent only in Rohilkhand, where it follows early maize.

(*b*) More commonly it is grown after a *rabi* crop in the preceding year (*i.e.*, with six months' fallow) ; the preceding *rabi* crop in this case is usually either gram alone or a mixture of crops containing gram or peas.

(*c*) A common practice is to grow wheat after sugar-cane (eight to nine months' fallow), in order to make the most profitable use of the manure left over by the sugar-cane, which has usually been treated liberally.

(*d*) Very occasionally wheat follows rice grown in the preceding year ; so far as I know, this is done only where the land is in exceptionally good condition.

(*e*) Wheat used to follow indigo grown in the hot weather, but the disappearance of indigo has made this process rare.

[1] *Proceedings of the Board of Agriculture in India*, Calcutta, 1906, p. 56.

(*f*) The commonest rotation of all is for wheat to follow a *kharíf* crop of the preceding year, *jowár*, *bájra* or cotton, mixed in most cases with *arhar* or a creeping pulse, *e.g.*, *urd* (*Phaseolus radiatus*), or with both of these. If there is no *arhar*, the land gets about 10 months' fallow; if there is *arhar*, the millet or cotton is off the ground in December, the *arhar* stays till April, and there is six months' fallow after its removal.

After wheat it is almost universal to take a mixed *kharíf* crop containing *arhar* or a creeping pulse or both. The exceptions are: (1) if the field is low-lying or for any reason cannot be cultivated in the *kharíf*, it is sown with a *rabi* mixture containing gram or peas with barley; (2) if the wheat has been exceedingly good and the land is clean, a cultivator sometimes takes a second crop of wheat off it. Outside Bundelkhand I have never heard of a third being taken without a pulse-mixture intervening.

The foregoing refers to irrigated wheat, as the practice of irrigation is almost universal. Dry wheat in the *bhat* (calcareous) soil of the north-east is grown on the same rotations as irrigated wheat elsewhere. In Bundelkhand where wheat is grown dry on the heavier soils, it is rare to find it grown without an admixture of gram; the mixture wheat-gram usually follows *jowár* in the *kharíf* of the previous year, or else wheat-gram in the previous *rabi*. There are a few tracts in the black soils of Bundelkhand, where wheat has been grown regularly for many years without any rotation and with continued excellent results, but they have not yet been fully studied."

Bengal.

In Bengal the practice of growing mixed crops is very common. Wheat is found mixed with barley, gram, peas, linseed and rape. Sometimes the land is left fallow during the monsoon.

Central Provinces and Berar.

On the black soils of these Provinces, to which the wheat crop is practically confined, the common practice is to leave the land fallow during the *kharíf* and sow wheat alone or wheat mixed with gram (called *birrá*) for the *rabi*. As far as possible, the black soils are not fallowed in the *rabi* as this practice would allow the *káns* grass to spread to such an extent as to render the land almost useless. On the embanked fields of the northern districts, a catch crop of rice is sometimes grown during the monsoon and removed before the wheat is sown. On such land it is most usual to grow wheat unmixed with gram. The proportion of gram

sown with the wheat is not constant and varies in the different districts from about 5 to 25 per cent. of the crop. The rotations of crops practised on wheat lands in the Central Provinces according to Gaskin[1] are as follows:—

"In *bandhias* which hold water, wheat follows early rice. In *kanhar* and *kábar* soils wheat and gram as a mixture are grown year after year, which serves the purpose of rotation. In *morand* and certain other classes of soils *kharíf* and *rabi* crops are rotated in places where wheat can be grown. Generally where they have a rotation, wheat is grown after gram, *masúr* (*Ervum lens*) or *teora* (*Lathyrus sativus*)."

It will be seen that the importance of leguminous plants in wheat growing is well recognised in practice in these tracts and that there is little danger of any exhaustion of the wheat lands.

Bombay.

The extent to which the wheat crop is grown mixed and the rotation practised on wheat lands in this Province are stated by Mollison[2] to be as follows:—

"Dry crop wheat is either grown alone or with subordinate rows of safflower; sometimes linseed occupies the headlands. Wheat and gram mixed are grown in the Pánch Maháls. Irrigated wheat is usually unmixed.

"Dry crop wheat is grown continuously in some parts of Ahmadnagar, Ahmadábád and Násik. In the cotton Districts of Khándesh, Dhárwár, Broach, etc., it is rotated with cotton and *jowár*. In the deep black soil which borders the Tápti in Khándesh it is rotated with linseed and gram. In the Pánch Maháls, on land brought under tillage during recent years, it follows a *kharíf* crop of maize, the land being double cropped annually. This is an exhaustive system of cropping which can only be practised in virgin land. Irrigated wheat is rotated with ordinary garden crops, but no definite order is followed."

It will be seen that in all the important wheat-growing districts of India, except the irrigated districts of the Punjab, the practice of growing leguminous crops on wheat lands is universal. In this important matter therefore the Indian ryot has nothing to learn from Western practice.

In the canal colonies of the Punjab, however, wheat is grown year after year without manure, apparently without producing any diminution in the fertility of the soil. Judging from the dark green colour of the leaves and

[1] *Proceedings of the Board of Agriculture in India*, Calcutta, 1906, p. 74.
[2] Mollison, *Text-book of Indian Agriculture*, Vol. III, 1901, p. 25.

the general vegetative vigour of the crop, no nitrogenous manures are necessary. The question arises whence do the large wheat crops derive their nitrogenous manure. Apparently the answer is to be found in the leguminous weeds which thrive so luxuriantly as a bottom growth in the wheat fields of the Punjab.[1]

There are three common leguminous weeds among others in the Punjab wheat fields: (1) yellow flowered *senji* (*Melilotus indica*), (2) white flowered *senji* (*Melilotus alba*), and (3) a creeping clover-like plant with curious curved pods (*Medicago denticulata*). These three plants also grow and seed freely on the banks of the water channels, and are very probably distributed by the irrigation water. In the wheat fields they ripen their seeds and dry up by the early part of April before the wheat is cut and thus give no trouble at harvest time. At flowering time in March, their roots are covered with nodules. Their general vigour shows that they are admirably adapted for bottom growth with wheat.

It would appear, therefore, that these weeds confer on the soil of some of the irrigated wheat lands of the Punjab all the benefits of a leguminous rotation, and supply the nitrogenous manure required by the wheat crop. In this respect, the wheat-growers of the Punjab seem to be especially favoured by circumstances as they are able to obtain all the benefits of leguminous crops without any trouble or expense and without the diminution of wheat output entailed in the usual rotations practised on wheat lands in other parts of India. No difficulty would be experienced in obtaining seeds of these leguminous plants. They grow and seed freely among the wheat, in waste places and on the banks of the water channels. Yellow flowered *senji* mixed with the other two weeds is grown as a cold weather fodder crop in the Punjab and is sometimes left to ripen for seed purposes.

Experimental evidence regarding the fertilising value of these plants would be of the greatest interest. The produce of land under wheat alone compared with that of an equal area under wheat mixed with these leguminous weeds could not fail to be of value. The difference in yield may not be great for a few years, but after a time it is likely that the influence of the leguminous crop in increasing the fertility of the soil would be apparent. The experiment would present some difficulty, as it would not be easy to get rid of the *senji* seeds in the ground in the first instance, and the irrigation water for the *senji*-free plot would have to be filtered, so as to remove floating seeds.

[1] Howard, *Agr. Jour. of India*, Vol. I, 1906, p. 403.

CHAPTER V.

CULTIVATION.

THE preliminary preparation of the soil, the extent to which it is manured, the method of sowing, the source of seed and the extent to which the crop is weeded, vary to some extent in the different Provinces.

PUNJAB,[1] NORTH-WEST FRONTIER PROVINCE AND SIND.

The preparation of the soil for the wheat crop differs in these Provinces according to the amount of monsoon rain and to the method of irrigation. In *sailába* land and on lands which are flooded by inundation canals the soil is ploughed up once or twice when dry enough and levelled with the *sohága*—a heavy squared beam drawn by one or two pairs of bullocks, the drivers of which stand on the beam. This is partly to break the clods, partly to pulverise the soil, and partly to consolidate the surface so as to retain the soil moisture. The object of the cultivator on such soils is to prepare a seed-bed and at the same time to lose as little of the moisture as possible.

Well land and *bárani* land in the eastern districts are generally ploughed much more frequently during the monsoon—sometimes as many as 14 times in the case of industrious cultivators. In this way the soil is aerated and all the rainfall is absorbed. On the canal colonies the preliminary preparation is much less as the soil is too hard to plough during the hot season without a preliminary watering. In August and September the land is flooded and ploughed once or twice and left until November when it is watered again and reploughed previous to sowing. In the districts of the North-West Frontier Province the land is not ploughed more than once or twice as it is found that too frequent cultivation renders the crop rank and liable to lodge. In fact, in Dera Ismail Khán and Bannu it is customary for the young crop to be grazed down in December by horses and cattle to check the growth. In Sind, the preparation for the crop is practically the same as that on the inundated lands of the Punjab.

On the whole, a good deal of manure is used in the Punjab. The value of manure is now so far appreciated that cultivators will send in

[1] An excellent account of the cultivation of the various classes of land in the Punjab is to be found in the *Gazetteer of the Lahore District*, 1893-94.

carts to the large cities such as Ludhiána and Multán for the sweepings, etc. As a rule, the wheat crop is not directly manured, but in the Eastern Districts a heavy manuring is given before the maize crop, especially on fields where wheat follows maize in the same year. On well lands the young wheat crop is frequently assisted by a top dressing of pulverised manure—which is usually applied when the crop is about 6 inches high. Indigo refuse, where available, is a very favourite fertiliser. *Sailába* lands and lands commanded by the inundation canals do not require manure as they are annually enriched by deposits of silt. On the canal colonies wheat is grown on the same land for years without any addition of manure.

The best cultivators keep their own seed and in some cases select the ears in the field for sowing the next crop. The poorer class of cultivators obtain seed from the grain dealer or money lender and this is often poor in quality.

Wheat is, as a rule, drilled on *sailába* and *barání* soils where it is essential that the seed should reach the moisture. If, however, the *sailába* lands are moist enough, the seed may be broadcasted on the unploughed surface and worked into the land by two cross ploughings. A common form of drilling is to drop the seed into a bamboo tube attached to the plough. On well lands the seed is, as a rule, broadcasted, while in the canal colonies the wheat is more often dropped by hand into the open furrows, the sowers following the ploughs. This work is generally done by the women and children while the ploughs are driven by the men of the family. In Bannu the seed is said to be drilled 3 or 4 inches deep into the unploughed sandy soil. Except in the case where the seed is drilled the land, after sowing, is smoothed and the surface is consolidated by the *sohága*. By this means a firm seed-bed is obtained and the upper moisture is conserved.

The seed rate is usually about a maund (82 lbs.) an acre, but in the case of late sown wheat the quantity is about 100 lbs.

The last operation of all on irrigated land, which is carried out before germination takes place, is to divide the land into compartments (*kiáris*) for greater convenience of watering. This is done by means of ridges of earth made by two men with the *jandra*—a large wooden rake. One man holds the handle and another pulls a string attached to the handle at its lower end where it joins the rake. The *kiáris* vary in size according to the lie of the surface and are always much smaller in well-irrigated lands than where water is obtained from canals.

As a rule, the wheat crop is not weeded except by the best cultivators on well lands. The most troublesome weed is the onion weed or *piazi* (*Asphodelus fistulosus*) which is exceedingly common everywhere in the Punjab and which seeds freely on the banks of the water channels. In the canal colonies *báthú* (*Chenopodium album*) is also very common in the wheat at harvest time. It is probable that if more care were taken to keep the water channels and waste corners clean, the yearly loss by weeds in the colonies would be much reduced. At present, however, the scarcity and dearness of labour combined with the large holdings are formidable obstacles to a better standard of agriculture in these tracts.

United Provinces.[1]

Except in the Bundelkhand Districts the preparation of the land for the wheat crop in these Provinces varies but little. The best lands are always selected for wheat and, as a rule, they carry no crop during the *kharíf*, but the practice of growing wheat after maize appears to be spreading. The fields are ploughed as frequently as possible during the *kharíf* and the clods are broken down by the *pathár*—a flat beam corresponding to the *sohága* of the Punjab. Often as many as 14 ploughings are given but 8 may be taken as the average in the wheat soils of the alluvium. If an early ploughing can be given in April or May during the hot weather, so much the better, as the exposure of the soil to the dry air and intense solar heat during this season is of great efficacy.

In the black soils of Bundelkhand it is impossible, on account of the tenacious character of the soil, to plough during the monsoon, and if the rains cease early, the soil becomes too hard to plough. Hence the successful cultivation of wheat in these black soil districts depends on the rains being opportune. In Bundelkhand, land infested with *káns* grass is cultivated with the *bakhar* which tends to eradicate the deep rhizomes of this troublesome weed. The *bakhar* is a horizontal iron scythe twenty inches broad and four inches deep, fixed at two ends to a beam of wood. The blade enters the ground about eight inches and the beam pulverises the soil as it is turned up.

The amount of manure rarely exceeds four tons to the acre, and this is generally applied, not directly for wheat, but to the crop of the preceding year.

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[1] The best account of the cultivation of the wheat crop in these Provinces is that of Wright in *The Wheat Production and Trade of India*, Simla, 1879.

The best cultivators keep their own seed and this is the usual practice in the north and west. In the southern and eastern districts, where the people are poorer, the seed is usually obtained from the local merchants.

About a hundred pounds to the acre of seed is sown, the amount being greater in the black soils of Bundelkhand where it is more liable to rot in the ground. Sowing commences after October 15th and is carried on till the middle of November. The seed is usually sown in drills being dropped into a bamboo tube fastened to the plough.

As a rule, and if the land is not too wet, the surface after sowing is levelled and consolidated by the *pathár* so as to bring the moisture up from below and ensure good and even germination. After this the fields are divided into compartments (*kiáris*) to facilitate irrigation. Weeding is not, as a rule, practised, and with the exception of watering, the fields are left till harvest time.

Bengal.

The system of cultivation of wheat in Bengal is less thorough than that of the United Provinces. The wheat lands are sometimes fallow in the *kharíf* and where not inundated by the Ganges are ploughed several times during the monsoon, and again during the *hathia*—the period between September 26th and October 10th. The land is, as a rule, not manured and sowings are made during the last half of October, the seed being broadcasted at the rate of about 50 to 80 lbs. an acre when grown alone. When a mixed crop is to be grown, the various seeds are mixed and sown together. After sowing, the seed bed is consolidated by the *henga*, a flat beam of wood like the *sohága* of the Punjab. The best ryots keep their own seed, but the smaller cultivators obtain their supplies from the village *mahajan* or buy it in the *bazar*. Weeding is not usual and, as a rule, irrigation is not practised.

Central Provinces.[1]

The cultivation of the land for wheat in the Central Provinces is quite different from that in the alluvial soils of the Indo-Gangetic plain. Instead of the plough, the *bakhar* is the implement used in preparing the land for this crop. The land is, as a rule, fallow during the *kharíf* and operations begin in April or May when the ground is scarified with the *bakhar*. During the monsoon this process is repeated once or twice and again towards the end of the rains in September. This last hoeing is of great importance in loosening the surface of the soil and so preventing the loss of moisture. The final hoeing is given early in October and the seed is sown about the middle of that month, at the rate of about 100 lbs. an acre, by means of a bamboo tube attached to a country plough. By this means the seed is planted deeply in a moist seed bed and germination is assured. The surface is left very rough and no implement like the *sohága* is used. In the embanked fields of Jubbulpore and the neighbouring districts, the seed is drilled into the ground, after the water is let off in the beginning of October, without any preliminary ploughing or preparation whatever. In Berár, Nágpur, Wardhá and to some extent in Betul wheat is sown by means of the *tífan*, a native drill by which three furrows are sown at once. Above each of the three drills of the *tífan* is fixed a hollow bamboo tube through which the seed trickles and the three tubes meet in a circular wooden basin at the top into which the seed is fed. Only about 60 lbs. of seed to the acre is used with this drill, but it is unlikely that it could be employed in the stiff wheat soils of the Narbadá valley and the northern districts. The wheat crop is not manured, but in some cases the *kharíf* catch crop of rice, which precedes wheat, is manured to a slight extent. After sowing no weeding is done and the crop is left till harvest time. *Káns* grass is the worst weed of the arable land of the northern districts of the Central Provinces and is most prevalent on the richest soils. As a rule, the cultivator is able to keep this pest in check by careful cultivation with the *bakhar* during the monsoon, but this cultivation is not possible in very dry or in very wet years. When too dry, the black soils are too hard to cultivate, and when too wet, the land will not bear the work cattle. During the last ten years the series of dry seasons in these Provinces has brought about the rapid spread of this pest and made the reclamation of infested land so expensive that very large areas have been abandoned. In ten years or so the weed dies a natural death and in the meantime the land lies useless.[1]

[1] Good accounts of the methods of cultivation employed in the Central Provinces are to be found in the excellent series of District Gazetteers recently issued for the Province. We are indebted to Mr. F. G. Sly for procuring advance copies of some of these for use in connection with this chapter.

Bombay.

The preliminary preparation of the soil for unirrigated wheat in Bombay is on similar lines to that described in the Central Provinces. During the monsoon the land is hoed as often as possible with the *vakhar* (Deccan) or *karab* (Gujarát), an implement which corresponds to the *bakhar* of the Central Provinces. By this means the surface soil is stirred, the cracks are filled up and weeds are destroyed. Manuring is not usual for dry crop wheat, and in October the seed is sown by means of a heavy two-coultered drill which deposits the grains well down in the moisture.

[1] Bachelor, *Agricultural Journal of India*, Vol. I, p. 152, 1906.

The seed rate is low, only about 50 lbs. to the acre, and after sowing, the surface is left rough. The ryots are said to save their own seed in this Presidency.

In the case of irrigated wheat the land is manured with about 12 maunds of old manure to the acre and the seeds are either broadcasted, drilled or sown by hand behind the plough, especially when the seed-bed is in a good condition. Seventy to eighty pounds of seed are sown to the acre and after the seed is put in, the land is divided up into irrigation compartments which are usually about 10 feet square. Little weeding is done in the case of either dry or irrigated wheat and the crop remains till harvest.

CHAPTER VI.

REAPING AND DISPOSAL OF THE CROP.

The methods employed in India in the harvesting and threshing of the wheat crop and in the storage of the produce may appear very primitive at first sight, but they are simple and efficient if the means of the cultivators and the average size of the holdings are borne in mind.

PUNJAB, NORTH-WEST FRONTIER PROVINCE AND SIND.

Harvest begins about the middle of April and extends well into May except in the Frontier Districts where it is not over till the end of June. The grain is cut by hand by means of a sickle, the workers usually squatting on the ground. Large bundles are made so that they may be readily counted and are usually stacked roughly for threshing.[1] The extreme dryness of the straw makes this possible and no loss is suffered by the wheat in the bundles heating. Indeed, so dry and brittle is the straw that the straw bands for tying have to be soaked in water to make them tough enough for the purpose. The labourers are paid usually in kind, but in the Canal colonies where the area to be reaped is enormous and where labour is scarce, as much as 16 annas a day is paid for hired labour. The scarcity of labour and the large holdings in the Canal colonies have had a marked effect on the choice of the variety of wheat grown. Bearded wheat is generally grown in preference to beardless, as this kind is less liable to the depredations of birds and sheds its grain less easily, thus suffering less damage if it remains standing in the field.

The grain is generally trodden out by the feet of cattle assisted by the *phala* or threshing frame. This frame consists of a hurdle covered with brushwood and weighted with bricks or clods of earth. The bullocks are yoked to the *phala* and fastened to a post in the centre of the threshing floor of beaten earth. They are driven round and round the stake about which the wheat is heaped and in a short time the brittle straw is broken up into short pieces and the grain is freed from the chaff. One pair of bullocks with the *phala* will tread out the produce of an acre in four days. In the hills, where stones are available, the threshing floors are carefully paved, but in the plains they are always of earth. The

[1] In Sialkot the District authorities require the stacks to be made close together to prevent the cultivators wilfully setting fire to each other's wheat.

grain is separated from the chaff by being thrown into the air by a pitch-fork when the hot winds which prevail at this time carry the dry chaff to a distance while the grain falls back on the threshing floor. The winnowing basket (*chhaj*) is then used to clean the grain so obtained. Its use is almost universal except in Ráwalpindi where the *phio*—a flat spade-like instrument—is used. Winnowing is done by low caste workmen, rarely by the cultivators themselves who in some cases would prefer to see their grain destroyed by rain rather than winnow it themselves. The chaff (*bhúsa*) is used for fodder and is especially valuable when mixed with gram chaff when it is known as *missa*. When grown with gram, the two plants are threshed together and the resulting grains are often ground and eaten together.

The yield naturally varies according to the season and other conditions, so that an average produce estimate is difficult. On well lands about 10 to 14 maunds[1] per acre is obtained; on canal lands the yield is somewhat less, while on *sailába* lands 8 maunds and on *baráni* soils about 6 maunds to the acre are obtained. In Sind the average yield is stated to be 10 maunds an acre.

Wheat is stored in the houses of the cultivators as a rule, but the old practice of keeping it in pits is still in vogue in some of the districts. The pits are lined with wheat chaff, but after about a year grain so kept is apt to darken and deteriorate. For household use the grain is kept in large earthen jars (*bharolás*). The well-to-do cultivators have granaries of mud or even of brick in some districts. After the monsoon the wheat is sunned and dried as a protection against weevils which, however, in the Punjab are not serious pests.

United Provinces.

The methods of harvesting, threshing and winnowing in these Provinces resemble those in vogue in the Punjab. The corn is trodden out by cattle on the threshing floor, but the use of the frame is not so usual as in the Punjab. The seed is separated from the *bhúsa* (chaff) by the winnowing basket. The grain so obtained is remarkedly pure and free from dirt and chaff and does not contain more than one per cent. of foreign matter. The estimates of the average yield are very various. Wright[2] states that in the districts north of the Jumna 750 lbs., for the districts south of the Jumna 600 lbs., may be accepted as fair estimates of the average outturn per acre of unmixed wheat. Other authorities, on the other hand,

[1] The standard *maund* is 82·28 lbs.

[2] *Wheat Production and Trade of India*, Simla, 1879.

give the outturn on irrigated land as 12 to 15 maunds an acre and on unirrigated land about 8 maunds.

There are several methods of storing wheat in the United Provinces. Grain pits (*khutti*) are dug in the ground, in the shape of a truncated cone with the base downwards, often in one of the rooms of the house. The interior is plastered with mud and cowdung and leaves are burnt inside before storage. The floor is spread with dried leaves—generally those of the mango and *nim* tree (*Melia indica*)—the grain is filled in and covered with *bhúsa* and dried leaves. A corner of the cultivator's house may be separated off by wicker-work and the grain packed in *bhúsa*. Another method is to keep the grain in earthen bins of sun-dried clay packed with chaff and *nim* leaves.

Bengal.

The wheat crop in Bengal is disposed of in a manner very similar to that described above in the case of the United Provinces. We have, however, not been able to arrive at any idea of the average yield of wheat in this Province as the figures to be found in the literature vary from 5 to 30 maunds per acre.

Central Provinces and Berar.

The methods of harvesting, threshing and winnowing in these Provinces follow those described above for the United Provinces. The crop is reaped in March and the average yield is about 600 lbs. per acre or sixfold on the 100 lbs. sown for seed. The standard outturn of wheat lands adopted in Settlement work is based on the general average production of the last few years before the Settlement takes place. These vary from 580 lbs. in Wardhá and Damoh to 660 lbs. in Narsinghpur. The wheat is stored in underground grain pits which are protected from damp and weevils by lining the bottom and sides with chaff and dried leaves. Sometimes the wheat for sowing is stored in bamboo bins (*dholís*), in which case the grain is mixed with chaff and the outside of the bin is carefully cemented with a layer of cowdung and clay.

Bombay.

In Bombay the ripe wheat is often pulled up by hand or cut with a sickle. The treading out of the grain by means of cattle and the separating of the wheat from the chaff follow the methods already described in the United Provinces. In Gujarát winnowing is usually done by an artificial air current from a triangular cloth tied at two corners by ropes

attached to fixed points and swung rapidly at the third corner by a woman. The yield varies much with the season. A very good irrigated crop produces 2,000 lbs. of grain and a ton of straw to the acre, while a very good dry crop does not yield more than half of this amount. A general average of 650 lbs. of grain may be taken as representing the yield of the crop of this Province in an ordinary year.

CHAPTER VII.

SOME ASPECTS OF THE TRADE IN INDIAN WHEAT.

The amount of wheat exported from India every year is small in comparison with the total production (p. 259). Most of the wheat is consumed by the people and it is only the surplus which is shipped to Europe. Often indeed this surplus is held in India, especially in years of famine or when the prospects of the next wheat crop are not assured. The Indian grain dealers and merchants have to handle the produce of an enormous number of small cultivators whose surplus wheat trickles into the towns and cities of India. In good years these smaller sources of grain unite into streams and rivers of wheat which are carried by the railways to Karáchi, Bombay and Calcutta, the three ports of export. Bombay collects much of the wheat grown on the black cotton soils of the Peninsula, Calcutta serves to drain the United Provinces and Bihár, while the enormous surplus production of the Punjab and Sind is taken to Karáchi, the chief port now concerned with the export trade in Indian wheat. The crop moved before the rains is drier and sounder than that which comprises the post-monsoon shipments, as this latter is apt to be damaged by damp and weevils. These circumstances serve to concentrate a large amount of the export trade into a very short period of time. All concerned are anxious to get the wheat on to the railway and into the holds of the steamers with the least possible delay. It is not surprising therefore that the carrying power of the North-Western Railway to Karáchi is taxed to its uttermost just after harvest and that at this time the wharves of Karáchi appear inadequate to cope with the vast volume of wheat daily poured on to the quays.

In the following it is not proposed to deal in detail with all the many-sided aspects of the whole wheat trade in India, but rather to review briefly the more important subjects relating to the export trade which have up to the present received the attention of the Government of India and of the various Indian Chambers of Commerce. Some of these questions such as the adulteration of Indian wheat and the introduction of grain elevators were dealt with in great detail and with great care by the Government of India many years ago and have recently been revived. It does not seem out of place therefore to draw attention to the older records, more especially as they contain much valuable information and ideas which still have considerable force at the present time.

The Adulteration of Indian Wheat.

The subject of the admixture of foreign seeds and dirt in the parcels of Indian wheat sent to England has been referred to very frequently. After considerable enquiry and discussion on the subject in India, the Secretary of State in 1889 called a Conference of representatives of the British Corn Trade and the Home milling interests at the India Office for the purpose of discussing the whole question and if possible of greatly limiting the percentage of adulteration.[1] In the discussion which ensued much diversity of opinion was expressed by the delegates on the practicability and expediency of altering the then existing customs of the trade. The standard of refraction adopted as a result of the Conference allowed of impurities from 4 to 5 per cent. in ante-monsoon shipments and 5 to 6 per cent. in post-monsoon shipments. The result was admittedly a compromise and by no means fulfilled the expectations of the advocates of clean wheat.

The subject was again brought up in 1905, several milling associations in Great Britain having brought to the notice of the Secretary of State the adulterated condition of Indian wheat, especially that shipped from Karáchi. These representations were forwarded to the Commerce and Industry Department of the Government of India who in the same year consulted the various Chambers of Commerce concerned. The papers on the subject are referred to in the reports of the Chambers of Commerce for 1906 and are given in extenso in a Resolution of the Government of India (Department of Commerce and Industry, No. 8758-8765-56) dated the 29th November 1906. As a result the Government of India announced for general information that "if buyers of Indian wheat desire to obtain regular supplies containing not more than 2 per cent. of impurities (that term covering all foreign matter other than food grains) the mass of Indian shipments can be made on that basis."

The Inspection and Grading of Indian Wheats.

As early as 1877 the inspection and grading rules, relating to wheat and other grains, in force at New York, Milwaukee, Chicago, and in the State of Illinois generally were forwarded by the Secretary of State for the consideration of the Government of India. The Local Governments and the Chambers of Commerce were consulted and the replies considered by the Supreme Government. The result is summed up in a Resolution of the Government of India, No. 6-228-224, dated the 30th August

[1] The papers relating to this Conference are to be found in the *Indian Wheat Trade*, Calcutta, 1893.

1879, which is to be found together with the American rules and other papers on this subject in *The Wheat Production and Trade of India*, published in 1879. In the Resolution referred to, it is pointed out that the object of the inspection and grading rules in force in the United States is not to improve the quality of grain, but rather to facilitate transactions in enormous masses of produce. "The Railway Company or the Warehouse man, as the case may be, gives the owner of a consignment a receipt for grain of a known standard, and, confidence in the classification being complete, this receipt is as negotiable as a banknote, and the trouble and inconvenience of dealing with individual lots of grain are prevented, the result being that whoever becomes the holder of the receipt has merely to apply to the Railway Company or the warehouse for the delivery of a parcel of wheat of the quantity and quality stated. Such a system could obviously only arise in large commercial centres at which the grain supplies of vast areas were concentrated, where produce was always bought and sold in bulk, and where trade, both in point of mutual trust amongst merchants and of magnitude, was very highly developed." It was finally pointed out that the great consensus of opinion both on the part of the Chambers of Commerce and of the Local Governments was decidedly adverse to the adoption of the American scheme in India, as it was felt that the rules in force in the United States were not suited to the present conditions of the Indian trade. The Government of India concluded that when the trading public felt the need of any improved system for facilitating the interchange of commodities, the initiative would naturally come from the trade itself.

In 1883, Messrs. Reinhold Brothers[1] of Cawnpore revived the question of the establishment of an agency for cleaning, weighing and classifying wheat under Government supervision before its despatch to Calcutta for exportation. "Briefly the scheme was that warehouses should be established under the management of a committee at the chief centres of trade, like Cawnpore, where wheat could be examined and stored prior to despatch by rail to the ports. All wheat produced at the warehouse was to be first weighed, classed and tested as to impurities, and if these exceeded the proportion admitted by the export trade, the consignment would be refused admittance into the warehouse until it was cleaned down to the proper standard in sheds provided for the purpose. The owners of wheat admitted into the warehouse would receive from the committee a nego-

[1] The papers relating to this subject were printed by the Government of India in Part I of the *Indian Wheat Trade*, Calcutta, 1893.

tiable certificate entitling the holder to the quantity and class of wheat specified therein. To give confidence to dealers in the integrity of the committee, it was considered of vital importance that one of its members should be an official of the Agricultural Department. The principal advantages claimed for the scheme were: freight saved on impurities, re-weighment and re-examination at the port rendered unnecessary, and grain consigned to exporters in a condition to go direct from waggons to the hold." This proposal, which closely follows the American scheme, was in 1885 referred to the Local Governments and Chambers of Commerce. In practically all cases it was considered that the cleaning of wheat could be done more cheaply by the ryots themselves and that the difficulties and expense of the scheme generally greatly outweighed its advantages.

The Introduction of Grain Elevators.

The first definite proposal to erect grain elevators in India on the American principle seems to have been made in 1889 by Mr. J. G. Smith, of Messrs. Ritchie, Stewart & Co., of Bombay, who approached the Secretary of State on the subject in that year. The advantages claimed for the system had best be stated in Mr. Smith's own words. They are:—

(1) "The improvement of the reputation of India as a wheat-growing country.

(2) The extension and the improvement of the cultivation of wheat by the above, and by putting the business on a more satisfactory footing.

(3) The improvement of the position of the producer by depriving others of the opportunities of mixing, carrying and profiting by an adulterated or dirty sample which was subsequently, at considerable expense and trouble, to be brought to a clean state before it can be used.

(4) The reduction of the expense of carrying and handling by sea and by land.

(5) Facilitating the storage, purchase and sale of, or the borrowing and lending of money on, the grain crops.

(6) Opening the trade to all acquainted with the markets as opposed to the present state under grain experts, and to those who can or will pass off an adulterated article." (Letter of Mr. J. G. Smith to the Under-Secretary of State for India, dated 17th September 1889.)

The Local Governments, Railway Companies, Merchants and Port Trusts and several District officers were consulted on the practicability of the scheme. All the papers and the final Resolution of the Government of India on the subject, dated October 20th, 1893, are printed in the third

part of the *Indian Wheat Trade* published by the Government of India at Calcutta in 1893. Similar objections to those put forward when Messrs. Reinhold's scheme was considered are to be found in the papers on this question. It was felt that the conditions of trade in India are so different from those in America that there would be little chance of success, and in matters such as this it was considered that if the scheme was to be worked at all, measures for the grading of wheat must be arranged by a combination of the leading merchants at the seaports.

The subject has recently been brought up by the *Indian Trade Journal*[1] in three articles entitled "The grain elevator system and railway traffic." In the third of these articles are given the produce exchange rules at present in force in New York. These include a list and description of the various grades of wheat and the regulations of inspection of the New York grain market. In the two earlier articles in the *Indian Trade Journal* the advantages of elevators from the railway point of view are chiefly dealt with. As is well known, exporters of Indian wheat are anxious to ship the grain out of India before the monsoon as such shipments are less damaged by weevils and reach England in better condition than those which leave after the rains. Consequently in years of excess production in wheat, there is a great demand for waggons to move the wheat to the ports, especially in the case of the railway to Karáchi. Since Railway Companies have to work at a profit, it is natural that the rolling-stock they provide is based on average demands and at times of enormous wheat production the supply falls short of the demand. If, however, the wheat could be kept in elevators it is argued that it could be safely and cheaply stored against climatic risks and the movement of the wheat to the ports could extend over a longer period to the great advantage of the carrying companies. The cases of America and Canada are quoted as examples in favour of the above proceeding. We cannot refrain from pointing out several great weaknesses in the argument, weaknesses which in our judgment, unless definite evidence can be brought forward to the contrary, would entirely ruin the undertaking except perhaps in the drier tracts of the Punjab. The climatic conditions in America and Canada after harvest are absolutely different from those which obtain in India. Soon after harvest in the wheat-growing tracts of North America cooler weather sets in followed by a winter of almost arctic severity. The

[1] *Indian Trade Journal*, 23rd January and 6th and 20th February, 1908. Since writing the above the arguments in favour of grain elevators in India have been summed up by Noel-Paton in a pamphlet entitled *Wheat Elevators for India*, Calcutta, 1909, and a Commission is now investigating the subject.

climate is therefore admirably adapted for the safe storage of wheat. The conditions in India after the *rabi* harvest are quite different. Threshing has to be hurried through and the grain stored or sold before the rains. During the monsoon the combined high humidity and high temperature of the air rapidly spoil wheat freely exposed to the atmosphere. Weevils and moths increase in abundance and complete the destruction. Without definite proof to the contrary, we do not think large quantities of grain like wheat could be stored with safety in elevators in India during the monsoon on account of the damage by damp and insects. If it were possible, it may well be asked why does the cultivator go to such pains in India to store his seed wheat during the rains and to protect it from insects and from the damp hot air.

B. EXPERIMENTAL.

In the following pages an account is given of the various field experiments on wheat which have been carried out at the experimental farms in India. These experiments include work on manuring, irrigation, cultivation and also the trials of implements and machines. In order to evaluate the results which have been obtained and also the experimental schemes themselves, it appears desirable to consider them in the light of the factors on which the yield of wheat in India depends. The application to field experiments of the conception of limiting factors is a recent one and is due to Blackman.[1] An example will help to show how the idea of limiting factors applies to the growth of a crop.

"In agricultural experience, in manuring the soil with nitrogen and the essential secondary elements, the same phenomenon is observed when there is a shortage of any single element. If a continuous though inadequate supply of some one element is available then the crop development is limited to the amount of growth corresponding to this supply. Agriculturists have formulated the 'law of the minimum,' which states that the crop developed is limited by the element which is minimal, *i.e.*, most in deficit. Development arrested by 'nitrogen-hunger' is perhaps the commonest form of this. All this is of course in accordance with expectation on physical-chemical principles. The quantity of anabolic reaction taking place should be proportional to the amount of actively reacting substances present, and if any one essential substance is quite absent, the whole reaction must cease. It therefore seems clouding a simple issue and misleading to say of a plant which, from the arrested development of nitrogen-hunger, starts growth again when newly supplied with nitrogen that this new growth is a response to a 'nitrogen stimulus.' It would appear rather to be only the removal of a limiting condition."

Apart from the duration of the growth period which limits the choice of varieties, the principal limiting factors on which the yield of wheat in India depends are the available moisture, the amount of nitrogen in the soil and the temperature. Nitrogenous manures are not likely to give results in the absence of sufficient moisture, while irrigation experiments are apt to be misleading in the absence of an effective supply of available nitrogen.

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[1] Blackman, *Annals of Botany*, Vol. 19, 1905, page 281, and Presidential address to the Botanical Section of the British Association for the Advancement of Science, 1908.

The majority of the experiments carried out in the past have been devoted to the effect of manures. Considering the smallness of the holdings, the means of the cultivators and the scarcity of manure, especially of artificial manures, it is likely that any lessons to be learned from long and elaborate manurial experiments must remain, for many years to come mere counsels of perfection. There are however other directions in which much important work may be done, for example, experiments on the conservation of soil moisture, on the most efficient methods of cultivation, and on the water requirements of wheat would probably yield important and interesting results.

Attention in the future should perhaps be paid to the effect of manures, various methods of cultivation and of irrigation on the quality as well as on the yield of wheat. The discovery of the best methods of obtaining a sample of wheat uniform in texture would do much to improve the milling qualities of Indian wheats and would lead to better prices in the long run. It must in justice be pointed out however that all the experimental farms in the past have suffered greatly from frequent changes in the staff and consequently from numerous alterations in the scheme of experiments. Now that a fully equipped Agricultural Service has been established in India it is expected that the essential continuity both in direction and in programme will in the future be possible.

CHAPTER VIII.

MANURIAL EXPERIMENTS.

A considerable amount of attention has been paid to the manurial requirements of the wheat crop in India and numerous field experiments on the subject have been carried out, principally at the Cawnpore and Nágpur experimental farms. At both Cawnpore and Nágpur the experiments have extended over a period of upwards of 20 years, and we have carefully examined the reports of these farms as well as those of all the other farms which have been started in India with a view of ascertaining what results of general interest have been obtained up to the present.

The Cawnpore Experiments.

Both in order of time and in importance the Cawnpore experiments must be first considered.

The soil of the Cawnpore farm is a light reddish coloured loam and is typical of the alluvial soil which occurs over a large portion of the Ganges-Jumna Doáb. The farm is irrigable from a distributary of the Ganges Canal and is thus well-protected against seasons of drought or deficient rainfall.

The Ville Series. During the season 1881-82 a series of experiments was started by Fuller (now Sir Bamfylde Fuller) at Cawnpore known as the Ville series. The object of the experiment was to analyse the soil by means of a wheat crop and to find out in what manurial constituents the soil is deficient. This was attempted by comparing the yield of a plot with a complete artificial manure with that of plots in which each manurial constituent was successively excluded, The experiments were continued for four years and the results are given in the following table :—

The Ville Series at Cawnpore.

	Manurial treatment per acre.	Yields in lbs. per acre.				Average yield per annum for the four years 1882—85.
		1882.	1883.	1884.	1885.	
1.	Calcium superphosphate ... 180 lbs. Ammonium chloride ... 138 lbs. Potassium sulphate ... 90 lbs. Calcium sulphate ... 96 lbs.	2,142	1,726	1,771	1,459	1,774
2.	Do. less Calcium superphosphate	1,896	1,771	1,417	1,452	1,634
3.	Do. less Potassium sulphate.	1,908	2,076	1,497	1,398	1,434
4.	Do. less Calcium sulphate...	1,812	1,641	1,323	1,210	1,496
5.	Do. less Ammonium chloride	840	1,192	1,001	808	960
6.	No manure	858	1,045	762	757	855

An examination of these results indicates that nitrogen is the limiting factor in the manurial requirements of the wheat crop at Cawnpore and that potash, phosphate and lime are of very much less importance.

The wheat standard and duplicate series—Two series of 10 plots, each in duplicate (*i.e.*, four sets in all) known as the standard and duplicate series, each about one-twelfth of an acre in area, were laid out by Fuller in 1879 for permanent experiments to determine the effect of manures on wheat and maize. During the first two years the plots were cropped with cotton and maize without manure so as to remove the effect of any previous treatment of the soil and to ascertain the suitability of the land for experimental work. The experiments were started in 1881 on all the series and plots. The experiment was conducted in four series.

Plots in series no. I are cropped every year with maize (standard *kharīf*).

Plots in series no. III are cropped every year with wheat (standard *rabi*).

Plots in series nos. II & IV are cropped alternately with maize and wheat (duplicate series).

In series I, the plots bear a maize crop after a fallow of 9 months; those in series III, bear a wheat crop after a fallow of 6 months; while in series II and IV maize follows wheat after a fallow of 3 months and wheat follows maize after a fallow of rather more than a year. As far as wheat is concerned only two of these series, Nos. III and IV (the wheat standard and duplicate plots), only concern us. Series I and II refer more particularly to the *kharif* crop maize. For the first two years, 1881-82 and 1882-83, the manurial treatment of the plots was as follows :—

1. Cowdung 132 cwts. per acre.
2. ,, ,, bonedust 360 lbs. per acre.
3. ,, ,, calcium sulphate 240 lbs. per acre.
4. Ashes of 132 cwts. of cowdung per acre.
5. Potassium nitrate 240 lbs. per acre.
6. ,, ,, ,, bone dust 360 lbs. per acre.
7. Bone superphosphate 240 lbs. per acre.
8. Bonedust 360 lbs. per acre.
9. Calcium sulphate 240 lbs. per acre.
10. No manure.

It was soon found that the application of bonedust, superphosphate and calcium sulphate by themselves produced practically no effect on the

yield and accordingly in 1883-84 the manurial treatment of plots 7, 8, and 9 was altered and each was re-inforced by the addition of a nitrogenous manure as follows :—

Plot 7. Bone superphosphate 240 lbs. + potassium nitrate 240 lbs.
Plot 8. Bonedust 360 lbs. + sheepdung 132 cwts.
Plot 9. Calcium sulphate 240 lbs. + sheepdung 132 cwts.

During the year 1884-85 three more plots were added :—

11. Potassium nitrate 240 lbs. + ashes of 132 cwts. cowdung.
12. Sheepdung 132 cwts.
13. Poudrette 132 cwts.

This scheme of manuring was continued till the *rabi* season of 1899-00 when it was changed at the instance of Leather.[1]

Up to and including the season 1898-99 the results of the standard and duplicate series are given in the following tables :—

Statement showing the outturn of the rabi standard series—wheat.

	Manurial treatment per acre.	Outturn of grain per acre in pounds.			
		Average outturn for five years 1883-84 to 1887-88.	Average outturn for five years 1888-89 to 1892-93.	Average outturn for five years 1893-94 to 1897-98.	Outturn in 1898-99.
Each plot-400 square yards.	Cowdung 132 cwts. ...	1,474	1,581	2,092	2,184
	Cowdung 132 cwts., bonedust 360 lbs. ...	1,360	1,706	2,215	2,363
	Cowdung 132 cwts., gypsum 240 lbs.	1,496	1,620	1,993	2,166
	Sheepdung 132 cwts.	1,270	1,610	2,326	2,505
	Sheepdung 132 cwts., bonedust 360 lbs. ...	1,086	1,584	2,189	2,232
	Sheepdung 132 cwts., gypsum 240 lbs. ...	1,192	1,748	2,234	2,682
	Poudrette 132 cwts.	1,258	1,699	2,114	2,245
	Saltpetre 240 lbs.	1,357	1,419	1,697	2,242
	Saltpetre 240 lbs., bonedust 360 lbs. ,,	1,206	1,480	1,776	2,287
	Saltpetre 240 lbs., bone superphosphate 240 lbs.	1,380	1,427	2,031	2,360
	Ashes of 132 cwts. cowdung	889	1,339	1,576	1,851
	Ashes of 132 cwts. cowdung, saltpetre 240 lbs.	1,298	1,442	1,891	1,567
	Unmanured.	918	1,181	1,399	1,386

[1] *Report of the Cawnpore Farm*, 1899-00.

Statement showing the outturn of the rabi duplicate series—wheat.

	Manurial treatment per acre.	Outturn of grain per acre in lbs.			
		Average outturn for 5 years 1883-84 to 1887-88.	Average outturn for five years 1888-89 to 1892-93.	Average outturn for five years 1893-94 to 1897-98.	Outturn in 1898-99.
Each plot=400 square yards.	Cowdung 132 cwts.	1,802	1,819	1,882	2,505
	Cowdung 132 cwts., bonedust 360 lbs. ...	1,739	1,592	1,808	2,384
	Cowdung 132 cwts., gypsum 240 lbs. ...	1,773	1,528	2,055	2,217
	Sheepdung 132 cwts.	1,602	1,602	2,289	2,741
	Sheepdung 132 cwts., bonedust 360 lbs. ...	1,750	1,742	2,244	3,028
	Sheepdung 132 cwts., gypsum 240 lbs. ...	1,589	1,924	2,342	2,898
	Poudrette 132 cwts.	1,640	1,868	2,384	2,357
	Saltpetre 240 lbs.	1,785	1,433	2,189	2,608
	Saltpetre 240 lbs., bonedust 360 lbs. ...	2,137	1,626	1,936	2,689
	Saltpetre 240 lbs., bonesuperphosphate 240 lbs.	1,993	1,565	1,798	2,602
	Ashes of 132 cwts., of cowdung. ...	1,457	1,260	1,716	1,761
	Ashes of 132 cwts. of cowdung, saltpetre 240 lbs.	1,288	1,564	1,912	1,597
	Unmanured	1,318	1,360	1,429	1,658

The feature of the results is undoubtedly the great effect of nitrogenous manures both on the yield of straw and grain. The outturns further show a marked increase since the season of 1895-96 when a deeper tillage and subsoiling than that formerly adopted was undertaken. The produce of the unmanured plot in both series shows a steady increase and in 1898-99 gave 1,386 and 1,658 lbs. per acre and an average of 1,328 lbs. or nearly 22 bushels per acre in both plots after 16 years continual cultivation of wheat or of wheat and maize alternately.

In the season 1899-00 the experimental scheme was changed in accordance with the details given in the following table :—

Table showing the old and new schemes of treatment and quantities of manure.

A	Old treatment.	New treatment.	Remarks.
6	Cattle manure at 132 cwts. per acre	Cattle manure to supply 100 lbs. Nitrogen per acre.	Plots nos. 7, 4, 5, 11, 9, 3, 13 of the alternate series A and of the corresponding plots of the other series receive much about the same amount of nitrogenous manure as formerly. Plots nos. 6 and 2 now receive about 100 lbs. nitrogen instead of 60—70. Plot no. 1 now receives 100 and plots nos. 10 and 12, 50 lbs. nitrogen instead of 140 lbs. Plot no. 8 gets nothing in place of some 60—70 lbs. nitrogen. Thus plots 10 and 12 may be expected to yield for some time more than would be expected from the application of 50 lbs. nitrogen and of course plot 8 will show the effect of the manure residue for a long time.
7	Do. at 132 cwts., bonedust 360 lbs. per acre.	Do. 50 lbs. Do. Do. 25 lbs. Do. Do. 25 lbs.	
8	Do. Do. gypsum 240 lbs. Do.	No manure.	
1	Sheepdung at 132 cwts. per acre.	Sheepdung Do. 100 lbs. Do. Do. 50 lbs.	
10	Do. Do. bonedust 360 lbs. per acre.	Do. Do. 50 lbs. Do. Do. 100 lbs.	
12	Do. Do. gypsum 240 lbs. Do.	Poudrette Do. 50 lbs. Do. Do. 100 lbs.	
2	Poudrette at 132 cwts. per acre	Do. Do. 25 lbs. Do. Do. 25 lbs.	
4	Saltpetre at 240 lbs. Do. ...	Saltpetre Do. 35 lbs. Do. Do. 25 lbs.	
5	Do. at 240 lbs., bonedust 360 lbs. Do.	Do. Do. 35 lbs. Do. Do. 10 lbs.	
11	Do. Do. bonesuperphosphate 240 lbs.	Bonedust Do. 35 lbs. Do. Do. 10 lbs.	
9	Ashes of 132 cwts. of cowdung per acre. ...	Saltpetre Do. 35 lbs. Do. Do. 10 lbs.	
3	Do. Do. Do. saltpetre at 240 lbs.	Bonesuperphosphate Do. 35 lbs. Do. Do. 10 lbs.	
13	Unmanured.	Ashes of 132 cwts. of cowdung per acre.	
		Ashes and saltpetre to supply 25 lbs. nitrogen per acre.	
		Unmanured.	

Up to 1907 the altered scheme of manuring has been continued. Plot 8 which has been unmanured since 1899 has almost maintained its fertility and the unmanured plots of both the standard and alternate series which have not been manured for 20 years still give, comparatively speaking, high yields. The plots which have received the double dressing of nitrogenous manure are no better than those which have received the smaller amount. These experiments distinctly show that with good cultivation only small dressings of nitrogenous manures, preferably farmyard manure, are required for wheat. The continued application of saltpetre to the soil is giving a gradually diminishing yield compared with the animal nitrogenous manures, a result probably due both to the known injurious effects of nitrates on the tilth and also to the good effect of humus on the soil.

As an example of the cultivation given to these plots that of the season 1904-05 may be quoted. "The two series bearing wheat were treated as follows :—Ploughed 4 times, subsoiled once, cultivated with the Planet Jr. cultivator twice ; levellings varied from 5 to 6 according to the needs of the plots. The manures were spread on the 28th to 30th October, 1904, except saltpetre which was supplied in two instalments on the 26th to 27th November and 30th December as a top dressing. The seed (Muzaffarnagar white) was sown with the country plough on October 31st, at the rate of 120 lbs. per acre and the land levelled. The crop was weeded once, watered twice and harvested on 19th to 21st April."

Green manuring. The influence of leguminous crops, both as regards their use as green manure and also in rotation with wheat, has been the subject of experiment at the Cawnpore Farm from the year 1884 up to the present time. The first series extend up to the wheat harvest of 1901 and include the use of old and fresh indigo refuse, green indigo and *san* (*Crotalaria juncea*), the latter ploughed in as green dressings. A second series involving green dressings of *san, khurti* (*Dolichos biflorus*) and *urd* (*Phaseolus mungo*) was started in 1894. A third series including the rotation of wheat with gram, *san,* indigo, *urd, arhar* (*Cajanus indicus*) and lucerne extends from 1884 to 1901.

Although in the earlier years of the experiments the effect of green manuring was considerable, nevertheless the results on the whole have not been quite satisfactory and the plots were accordingly abandoned in 1901. The experiments show :—

(1) that the effect on the succeeding wheat of green dressings ploughed in a month or so before sowing have been generally, except in the case of *san,* not very encouraging.

(2) That sufficient length of time for the preparatory tillage is a very important factor in wheat-growing and the time between the ploughing in of a green dressing given during the rains and the sowing of the wheat in October is not sufficiently long.

(3) Old indigo refuse ploughed in has given higher yields than fresh refuse from the steeping vasts, a result due perhaps to denitrification in the latter case.

In 1903, a new series of two-year rotations of wheat with various leguminous crops (gram, *arhar, urd, san* and *kurthi*) was started and four of the green manuring plots started in 1894 were continued. It is too early to speak of the results of the new experiments. With regard to the green manure series the most remarkable result is the small difference in the yield between the no manure plots and those manured by means of leguminous green dressings.

On the whole, there is no question that nitrogen is the limiting factor in the manurial requirements of wheat at Cawnpore and that provided the supply of moisture and the temperature are suitable, the amount of available nitrogen alone limits the yield. The best way to apply this manure is in the form of farmyard manure, continuous applications of potassium nitrate not being so effective, possibly due to its influence on the tilth. Since 1895, when deeper cultivation has been carried out on the farm, the yields have improved showing that the effects of manure must only be considered after the most has been got out of the soil by proper cultivation. The results of green manuring have been somewhat disappointing due to the shortness of time which ordinarily elapses between the ploughing in of the crop and the sowing of the wheat. The lessons of the manurial experiments with wheat at Cawnpore therefore show the prime importance of frequent cultivation during the hot weather and rains and the need for occasional dressings of good farmyard manure. Where this is not available an occasional green manuring with *san* is of great value in improving the fertility.

The Nagpur Experiments.

The soil of the Nágpur Farm is described as black cotton soil and is said to be fairly typical of the tract in which the farm is situated. The district, however, is not a true *rabi* tract but rather a cotton-jowár country, and, therefore, the results with wheat at this farm cannot be taken as typical of the great wheat-growing tracts of the Narbadá Valley of the Central Provinces.

In 1883-84 the Ville series of field experiments was started at the Nágpur Farm by Fuller. The results for the first two years only can be considered on account of various accidents. Thus in 1885-86 there was a shortage of rain at sowing time and excessive rain and cloudy weather in December which brought on rust especially on this series of plots and particularly on those to which ammonium chloride had been applied. The next year heavy rains after sowing washed the manures from plot to plot with the result that the no manure plot was nearly the best. In 1887-88 no manure was applied and the crop was a good deal injured by rust, while in 1888-89 the series of plots was ruined by a change of manuring—the dressings for some reason, which is not stated, having been applied in the reverse order. The yields and manurial treatment for the first two years are given in the following table :—

Ville series—unirrigated.

Plot No.	Manurial treatment per acre.	Yields in lbs. per acre.		
		1883/84	1884/85.	Average.
1	Calcium superphosphate 180 lbs. Ammonium chloride 140 lbs. Potassium sulphate 90 lbs. Calcium sulphate 100 lbs. ...	2,000	1,380	1,690
2	Do. less Calcium superphosphate ...	1,780	1,465	1,622
3	,, ,, Potassium sulphate ...	1,460	1,270	1,365
4	,, ,, Calcium sulphate ...	1,560	1,320	1,440
5	,, ,, Ammonium chloride ...	1,170	920	1,045
6	Nil	780	735	757

The results indicate that as at Cawnpore nitrogen is the limiting factor as far as manurial requirements are concerned.

It was early noticed at Nágpur that large crops of wheat are only obtained provided the sowing and cold weather rains are sufficient in quantity and accordingly a second series of Ville plots was started in 1890-1891, with irrigation. Although the deficiency in the supply of moisture was made good in this series, other difficulties were encountered which proved to be insuperable. In the first year the plots were attacked by

rust, especially those to which nitrogenous manures had been applied. The season 1891-92 was a very good one and most reliance can be placed on this year's results. In the next three seasons the crops were attacked by rust to such an extent that the results cannot be considered, especially when it is borne in mind that both in 1893 and 1894 the plots of this series had to be resown. The results are given below :—

Ville series—irrigated.

Plot No.	Manurial treatment per acre.	Yields in lbs. per acre.		
		1890/91.	1891/92.	Average for 2 years.
1	Calcium superphosphate 180 lbs. Ammonium chloride 140 lbs. Potassium sulphate 90 lbs. Calcium sulphate 100 lbs. ..	1,435	1,230	1,332
2	Do. less Calcium superphosphate ...	1,270	1,500	1,385
3	Do. ,, Potassium sulphate ...	1,455	1,440	1,447
4	Do. ,, Calcium sulphate ...	1,270	1,240	1,255
5	Do. ,, Ammonium chloride ...	805	710	758
6	Nil	765	710	737

The result shows more definitely than in the unirrigated series the need for nitrogen and also the fact that superphosphate, lime and potash are not required in the Nágpur soil.

A more extended series of experiments on the influence of manures on wheat known as the A and B series is to be found in the Nágpur farm reports. The former deals with the effect on wheat (grown continuously on the same land) of different kinds of manures applied year after year without irrigation. Series B, started six years later, is a corresponding experiment, but in this case the plots are irrigated. The same wheat, the Nágpur *Haura*, was grown in both sets. The results are summarised in the following tables :—

Nágpur series A—unirrigated.

Plot No.	Manurial treatment per acre.	Average of 5 years 1885/89.	Average of 5 years 1890/94.	1896.
1	Saltpetre 240 lbs.	1,133	751	836
2	Bonedust 360 lbs.	891	534	486
3	Saltpetre 240 lbs. and bonedust 360 lbs.	1,094	865	621
4	Dung 160 mds. per acre	913	627	532
5	Dung 160 mds. per acre & bonedust 360 lbs.	953	666	632
6	Ashes of 160 mds. dung per acre ...	949	576	621
7	Unmanured	799	418	209
8	Green manured with *san*	705	584	236

Nágpur series B—irrigated.

Plot No.	Manurial treatment per acre.	Average of 5 years 1891/95.	1896.
1	Saltpetre 240 lbs. per acre	931	1,188
2	Bonedust 360 lbs. per acre ...	626	765
3	Saltpetre 240 lbs. per acre & bonedust 360 lbs.	1,012	1,145
4	Dung 160 mds. per acre	717	1,050
5	Dung 160 mds. per acre & bonedust 360 lbs.	739	1,294
6	Ashes of 160 mds. dung per acre ...	584	754
7	Unmanured	486	517
8	Green manured with *san*	564	730

It will be seen that as in the Ville series nitrogenous manures have given the best result and also that irrigation has had a marked effect. The effect of green manuring with *san* on the succeeding wheat crop has been very variable. In dry years where the plant has not decayed and where there has been a failure of the cold weather rains the ploughing in of this crop led to such a loss of moisture that the yield was less than that of the unmanured plot. With a suitable monsoon and cold weather rains or with irrigation good results however have been obtained.

The value of the series A & B given above after the year 1896 was generally diminished by a radical change in treatment—the unirrigated series now became irrigated while the irrigated plots were grown with dry wheat. In 1903 other plots were added to the series but no further results were obtained except that the plots with saltpetre gradually yielded less and gave place to those with farmyard manure.

The fact that the available soil moisture was found to be a limiting factor in wheat production at the Nágpur Farm suggested the desirability of conserving moisture by the system of embanked fields such as is largely used for wheat on the black cotton soils in Saugor, Damoh, Jubbulpore, and Bálághát. The experiments began in 1886 and lasted till 1894 when they were discontinued. In general, embanking proved a failure with the Nágpur soil.

It will be seen that the manurial experiments with wheat at Nágpur have been attended with only partial success. It was finally decided in 1902 that the Nágpur farm was not suited to *rabi* crops and the future experiments with wheat were transferred to Hoshangábád in the Narbadá valley where an area of typical black soil for wheat was secured.

A perusal of the records of the Nágpur Farm would indicate that the failure of wheat growing is due almost entirely to the small moisture retaining capacity of the soil of this tract. Good crops of wheat could

only be obtained when the monsoon, the sowing and winter rains were all favourable. Irrigation in all cases did not make up for the failure of the rains and embanking was not successful. It would seem that the soil has ilttle power to hold moisture and therefore the first condition of successful wheat growing on black soils in India could not be obtained.

It is interesting to notice the somewhat parallel moisture conditions of the great plains of North America with those of the black soils of the Central Provinces. According to Alway[1], the moisture stored in the subsoil during the previous summer is the cause of the high yields of wheat and oats obtained in Southern Saskatchewan. Similarly in the Central Provinces, good crops of wheat are only obtained on typical deep black cotton soils which have high retentive power for water. Such soils are the celebrated black cotton soils of the Narbadá Valley. On second class black soils such as those of the Nágpur country, sufficient monsoon rainfall is not retained for the wheat crop of the succeeding cold weather.

Other manurial experiments with wheat.

Subsidiary experiments with saltpetre, cowdung and other manures have been carried out at the Dumraon Farm in Bihár. In general it has been found that nitrogenous manures have increased the yield to the greatest extent especially when combined with irrigation. Green manuring with *san* has given somewhat irregular results, favourable only when the sowing rains were abundant.

We consider that far better results with *san* might have been obtained in the alluvium. Our experience on this matter at Púsa is that really good results with this green manure are only obtained provided the crop is sown very early in a well aerated and well cultivated seed bed. Sowings should be made not later than the middle of May, either on natural rainfall or on irrigation. Sown in this manner the seedlings grow very rapidly on the early monsoon showers and the crop can be ploughed in during the first half of July. This gives sufficient time for the crop to decay and to be thoroughly incorporated with the soil and also enables the land to absorb moisture for the coming wheat crop. If too old and woody or if ploughed in late, the *san* does not decay in time, white ants are encouraged, the soil is too open in texture and insufficient rainfall is absorbed. Other limiting factors are thus called into play which mask the effect of the green manure.

The fertilising effect of growing wheat mixed with gram in Northern India and in the Central Provinces has been already referred to (p. 31)

[1] Alway, *Jour. of Agr. Science*, Vol. II, 1908, p. 333.

and also the occurrence of leguminous weeds as a bottom growth in the wheat fields of the Punjab.

There is one consideration of some importance which has been omitted in all the field experiments with wheat in India, namely, the effect of the manurial treatment on the quality of the crop. It has recently been shown at Rothamstead and Woburn and has been suspected for many years by Continental observers that the quality of wheat may be materially altered by manuring. Sometimes the baking quality of the grain is injuriously effected by manure as in the case of the plots continuously manured with farmyard manure at Rothamstead.[1] In view of the above facts it appears desirable that in judging the value of any manurial experiment with wheat the effect of the manure both on the quality and yield should be considered. Mere increase of bulk with loss of quality is a result of more than doubtful value.

Conclusions.

It is clear that up to the present it has been found in India that given suitable soil moisture for germination and the subsequent growth of the crop, the limiting factor in the production of wheat is the supply of nitrogen in an available condition. This is best applied in the form of farmyard manure or cowdung which gives better results than saltpetre in the long run on account of the good influence of dung on the tilth and moisture-retaining power of the soil. Saltpetre, although a good manure, should only be occasionally applied as long continued application seems to do harm. Occasional green manuring with *san* is to be recommended, but there is always a danger that the succeeding wheat crop may suffer through the loss of moisture entailed by the growth of this crop and its incorporation with the soil unless ploughed in at the proper time.

The utility of cowdung as a wheat manure suggests the desirability of further efforts being made to find some substitute as fuel so that the whole of this material can be used as manure. Watson[2] in an interesting paper on this subject states that the manurial value of cowdung is greater than its fuel value. It is suggested that experiments should be made in villages to find out how far pieces of land could be used to grow firewood thereby setting free all the cowdung for manure. Without well-planned and successful examples however it is idle to expect to change practices in India which have been in vogue from time immemorial.

[1] Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 1.
[2] Watson, *Indian Trade Journal*, Calcutta, May 27th, 1908.

CHAPTER IX.

IRRIGATION EXPERIMENTS.

The minimum amount of water required for the wheat crop has been made the subject of experiment both in the United Provinces and in the Punjab. In the latter, where canal irrigation is so important, the experiments were designed to demonstrate that in the ordinary way there is a great waste of water every time water is applied and also that too many waterings give a decreased yield. The irrigation experiments conducted by the Punjab Irrigation Department with wheat are the most important and most carefully conducted work we have so far met with on the subject in India.

United Provinces.

Two sets of irrigation experiments have been conducted in the United Provinces, one at Sítápur in Oudh, and the other at the Cawnpore Farm.

The Sítápur experiment was only conducted for one year with plots one-quarter of a *pacca bigha* in area and similar results were obtained with wheat, barley, gram and peas. The water used was taken from a tank. The results with wheat are given in the following table, and it will be seen that watering every month gave the best results and that too much water diminished the yield.

Plot.	Frequency of waterings.	No. of waterings.	Weight of grain in lbs.
1	Every 7 days	15	64 lbs.
2	,, 14 ,, ...	7	81 ,,
3	,, 28 ,, ...	4	111 ,,
4	Nil	Nil	27 ,,

At the Cawnpore Farm two series of irrigation experiments with wheat were carried out, firstly, to determine the relative merits of canal and well water and, secondly, to ascertain the effect of an increasing number of waterings. The results were summed up in the farm report for 1892 and are given in the following table[1] :—

[1] It must be remembered that the winter rains to some extent masked the effect of these experiments and influenced the yield on the unirrigated plot and on those watered only once or twice.

Experiment.	Plot No.	Special treatment.	Yield per acre in lbs. 1882	1883	1884	1885	1886	1887	Average.
To determine the relative merits of canal and well water.	1	Irrigation from well	1,312	1,381	864	1,028	399	1,041	1,004
	2	,, ,, canal	1,109	1,227	720	641	436	690	804
	1	,, ,, well	...	...	1,824	1,205	1,036	...	1,355
	2	,, ,, canal	..	...	1,579	916	998	...	1,164
To ascertain the effect of irrigation in increasing the yield.	1	Irrigated once	696	412	769	509	762	762	667
	2	,, twice	513	481	815	662	835	968	712
	3	,, three times	921	651	846	951	841	1,065	870
	4	,, four times	1,104	698	908	1,016	865	1,248	988
	5	,, five times	1,209	...	1,252	1,125	968	1,367	1,185
	6	Unirrigated	513	330	360	302	641	750	487

It will be seen from these figures that well water proved better than canal water and that five waterings gave a higher yield than any smaller number. The increase in outturn due to well water is probably due to two causes. In the first place, well waters in India often contain potassium nitrate in solution and thus act as manures. Further, irrigation from wells generally permeates the soil much more slowly than canal water and so destroys the tilth to a much less extent. The rush of canal water acts like a sudden downpour of rain and makes the surface run together and so prevents æration. Of the two causes the latter has no doubt the greater effect.

In conducting irrigation experiments with wheat it must not be forgotten that the yield depends to a great extent on the previous preparation of the soil which should be ploughed up before the rains so as to store up as much moisture as possible. If the fields are left hard till September and only ploughed up late, the wheat crop never does so well. This is well seen in the results of an experiment at Cawnpore in 1881. One portion of a field was ploughed in July, the other half in September. Otherwise the treatment was the same. The results are given in the following table :—

Treatment.	Yield per acre in lbs.
Portion ploughed in July	1,630·7
Do. not ploughed till September...	983·4

It is stated that the crop on the early ploughed land was almost twice as tall and as thick as that on the later ploughed portion.

PUNJAB.

The wheat irrigation experiments carried out by the Punjab Irrigation Department have reference both to the waste of water and also to the best number of waterings.[1]

The experiments on the waste of water by the cultivators in wheat-growing were started in 1904-05. At several stations the yield of two plots, similar in all respects except as regards watering, were compared. Plot A was managed by the Canal officers and was divided up into *kiáris* 70′ × 70′. The water used was measured as was that used in plot B which was managed by a cultivator who took as much water as he thought proper. It was found that plot A in all cases gave the best yield while the cultivator always used too much water each time varying from 41% in the first watering to 20% in the third.

Similar results were obtained in 1905-06. It was found that watering each *kiári* direct from the water course and having the field surface smooth and free from clods, are important items in effecting economy in the use of water. It took twice as much water to irrigate a field which had simply been ploughed and left in a rough state with clods unbroken than it did to irrigate the same field after the surface had been levelled with the *sohága*.

In 1906-07 the results of the experiments were affected by frequent and late rains. The trials, however, show that the *zamíndárs* use too much water and that the extra water is largely wasted by their faulty compartment system.

A second series of experiments was conducted at the same time to determine the best number and depth of waterings for a wheat crop. In both 1905 and 1906 the results were affected by abnormal winter rains which much increased the yields of the plots watered only once. The method of conducting the experiment is described as follows :—

" Information is required on the following points :—

(1) varying the number of waterings per acre and

(2) varying the depth of each watering.

Lay out 25 small square plots as here sketched each 110′ × 110′ (= ¼ *killa*) ; the single black lines showing divisions between each, and the double black lines, the water courses. The dotted lines show two *kiáris* in each, of 110′ × 55′ in area.

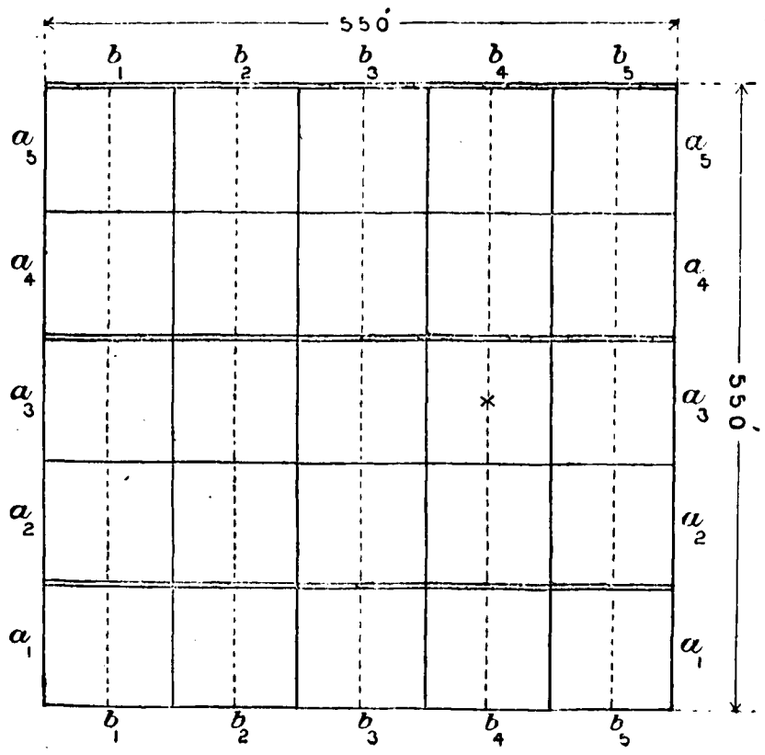
1 These experiments are described in detail in the Punjab Irrigation papers of 1905, 1906 and 1907, entitled *Waste of Water by Cultivators in irrigating their fields* and *Number of waterings required for Wheat crops*.

All the plots along the line a_1 a_1 will receive only one watering during the crop, *i.e.*, before sowing.

Similarly all along the line a_2 a_2 will receive two waterings and so on up to a_6 a_6 which will get 5 waterings.

In the same way those along the lines b_1 b_1, b_2 b_2 etc., will receive different depths of water. On the line b_3 b_3 all should receive just that quantity required to cover the area of each *kiári*, the supply being cut off whenever the water reached the far end. On the line b_4 b_4 they would get 25% more and on b_5 b_5 50% more, b_2 b_2 will get $\frac{3}{4}$ of the quantity on b_3 b_3 and b_1 b_1 $\frac{1}{2}$ that of b_3 b_3.

Any given plot will be denominated by the intersection of the a and b lines, thus that with a cross would be a_3 b_4.



The outturn of each plot, grain and straw, will, of course, be noted and this being tabulated will give the method of watering which results in the best outturn.''

It was found in 1905 that newly broken up land needs far more water than old fields, a fact well known to the *zamíndárs*. Three waterings were found to be sufficient, except on new lands. Five waterings gave a diminished yield and no gain was found from giving excessive depths of water.

In 1906, similar results were obtained, but again abnormal winter rains interfered with the experiments. The results of this year are summed up as follows :—

(1) On the more newly cultivated soil of the lower Jhelum Canal the best results were obtained by 4 canal waterings.

(2) On the more newly cultivated soil of the Lower Chenáb Canal the best grain results were obtained by 3 waterings and the best straw results by 4 waterings.

(3) On the very old cultivated soils on the Upper Bári Doáb Canal where also the rainfall was greater, the best results were obtained from 2 waterings. The same result was also obtained on the Sirhind and Western Jumna Canals.

In 1906-07 experiments were carried out at seventeen places, but in the majority of cases they were interfered with and the results rendered practically useless by heavy rain or hail. Only eight experiments were considered worth recording.

There is one point in which the irrigation experiments with wheat conducted by the Punjab Irrigation Department might be extended with advantage both to the cultivators and also to the Irrigation Department itself. The application of too much water to wheat not only needlessly curtails the area irrigated, thus leading to a loss of revenue, but also lowers the value of the crop. We have frequently observed in the Punjab and the United Provinces the injurious effect of overwatering on the texture of the grain. Millers require wheats uniform in texture as these are handled most easily in the mill. Overwatering gives rise to mottled grain and to samples very uneven in texture and therefore difficult to mill. The irrigation experiments might with advantage consider not only the yield but also the quality of the crop, especially as the Canal Colonies of the Punjab contribute so much to the export trade. Possibly much smaller *kiáris* in the Canal Colonies would not only save water but also tend to produce samples more uniform in texture than those at present obtained.

CHAPTER X.

CULTIVATION EXPERIMENTS.

THE chief cultivation experiments with wheat at the Cawnpore Farm have dealt with the effect of deep cultivation compared with the country method of shallow ploughing. The first series of experiments was begun in 1882 and lasted till 1900. The results in pounds per acre are given in the following table :—

Year.	Ploughed 8″ deep four times with improved plough.	Ploughed 5″ deep four times with improved plough.	Ploughed 4″ deep eight times with ordinary country plough.
Average for four years, 1883-86 ...	980	629	481
Average for 3 years, 1887-1889 and 1890	834	662	602
Average for 4 years, 1891-94 ..	1,025	996	869
Average for 4 years, 1895-98 ...	861	984	967

A detailed examination of the annual yields shows that for the first 12 years of the experiment the deep ploughed plots with one exception gave the highest yield, but that the increase gradually became less, and since 1896 the results have been reversed. The results, although of interest, are vitiated by the fact that it is not good practice to plough deeply for wheat right up to sowing time in the plains on account of the loss of moisture and the consequent danger of a poor germination. Indeed it was noticed towards the end of the experiment that the plot cultivated with the country plough was the moistest at sowing time and gave the best germination.

A second series of experiments to test the effect of deep ploughing in the early stages of preparation followed by later shallow ploughing compared with light ploughings with the country plough was started in 1901 and gave a slight advantage in favour of deep ploughing. (*Cawnpore Farm Report*, 1905.)

Experiments have also been made at Cawnpore and Bhadgaon to test the Jethro Tull or Lois Weedon system of growing wheat against the ordinary method. The system consists in fallowing half the field every year —matters being arranged so that the fallowed and cropped areas are in parallel strips ; the strips bearing a crop one year being fallow the next. It was found, however, that the ordinary method gave the best results.

At the Nágpur Farm the cultivation experiments were designed to test the opinion held by the cultivators in the district that deep ploughing in black cotton soils during the monsoon is injurious to *rabi* crops. Although the yields are not always uniform, the result points to the value of ploughing at least in alternate years instead of the usual scarifying with the *bahkar*.

At the Dumraon Farm in Bihár from 1896 to 1902 a comparative experiment was carried out to compare the effect of deep ploughing for wheat with the Sibpur plough and shallow ploughing with the country plough. The Sibpur plough stirred the soil to a depth of 7 inches, while the country plough did not go below 5 inches. The plots were in duplicate and the deep-ploughed plots gave the best results, as will be seen in the following table :—

Plot.	Treatment.	Yield per acre in lbs.						
		1896	1897	1898	1899	1900	1901	1902
1	Ploughed with the Sibpur plough.	495	1,485	785	535	530	367	985
2		485	1,485	782	532	500	340	1,037
	Average ...	490	1,485	783	533	515	353	1,011
3	Ploughed with local country plough.	566	1,202	600	350	402	297	632
4		567	1,205	605	355	425	310	812
	Average ...	566	1,203	602	352	413	303	722

It must be remarked that the results in the duplicate plots in the above table exhibit a degree of uniformity not often to be met with in other parts of India.

One very important matter in the experiments on the cultivation of wheat in India has been almost entirely neglected. This relates to the best method of managing wheat lands in the alluvium prior to sowing. In growing wheat at Púsa we employ a method of cultivating wheat lands which at the same time increases the nitrogen supply. It is moreover one which does not seem to be sufficiently adopted in practice. To increase the supply of nitrogen for a wheat crop without applying any manure and without the growth of a leguminous crop seems at first sight an absurd statement. This method of nitrogen manuring for wheat consists in the exposure of the soil, by several ploughings, to the sun and wind during the intensely dry

hot weather of April, May and June. The exposure of the soil at this period has an astonishing effect on the succeeding wheat crop and undoubtedly increases the available nitrogen as is seen in the dark green luxuriant foliage. When the soil for wheat is not weathered during this hot dry period, the crop is yellow and stunted and exhibits all the characteristics of nitrogen hunger. We observed the extraordinary effect of weathering the soil on wheat and other *rabi* crops soon after taking up land at Púsa in 1905, and we have frequently noticed the poor crops which result when this weathering has been omitted. In the Punjab, the wheat stubbles are often left untouched after the harvest and are not ploughed till September or October just previous to sowing. This practice is in our opinion most objectionable. More advantage both in quality and yield would probably result from a proper weathering of the alluvial wheat soils of India immediately after the previous harvest than from any other treatment. The Indian cultivator has at his command a method of nitrogen manuring for wheat which is perhaps the cheapest in the world. A series of well-designed demonstrations in the Indo-Gangetic plain to show the great effect of weathering the soil before wheat would, we consider, confer a great advantage on the cultivators.

The explanation of the extraordinary manurial effect of weathering is no doubt due to the partial sterilisation of the soil by the intense dryness heat and light of an Indian hot weather. In all probability these causes bring about a similar result to that produced by artificial heating and by poisons such as has been found in England by Russell and his pupils (*Journal of Agricultural Science*, Vol. III, 1909, page 111). These investigators have found that partial sterilisation of the soil kills off the phagocytes which live on bacteria, and also large soil organisms inimical in other ways to bacteria. At the same time the soil bacteria themselves are killed off, but the spores remain which germinate and rapidly multiply when the soil is moistened. The new bacterial cultures increase at an enormous rate and the resulting nitrogenous plant food becomes so great that plant growth is greatly stimulated. Russell's results seem to afford an adequate explanation of the extraordinary manurial effect of weathering Indian wheat land. For exposing the soil during the hot season iron ploughs are more effective than the native wooden plough. This is no doubt due to the soil inversion produced by the former resulting in a more complete weathering and sterilisation of the soil.

Apart from the manurial effect, weathering the soil during the hot months leads to a great improvement in the texture of the grain of the next wheat crop. The texture or consistency of wheat in India appears to be closely bound up with the even supply of moisture to the crop. Soils which

are weathered during the hot season and also occasionally ploughed up during the breaks in the rains give rise to much more uniform wheat crops, both as regards the stand and also as regards the texture of the grain, then those which are not broken up till just before sowing time. The preliminary weathering seems to lead to a uniform absorption of water by the soil and to prevent local excess and defect of soil moisture. This in turn results in an even supply of moisture to the crop and to grain uniform in texture.

Seed rate.

Several experiments have been made in India to determine the effect of varying the quantity of seed per acre. In considering this class of experiment it must be remembered that, other things being equal, the quantity of seed sown within reasonable limits is hardly likely to affect the yield, for when thinly sown, the wheat plant tillers considerably. As the moisture conditions of the fields at sowing time may be irregular, and plants may be lost through the ravages of white ants, the usual seed rates are merely a means of insurance against losses so as to prevent too thin a stand.

At Cawnpore in 1880 and 1882 seed rate experiments were tried in which the usual sowing was compared with a much smaller seed rate.

The results in 1882 are given in the following table :—

Method of sowing.	Seed rate per acre.		Yield per acre in lbs.		Value of produce per acre in rupees.
	Amount.	Value.	Grain.	Straw.	
Sown behind the plough ...	60	Rs. 3	1,978	3,008	60·8
Dibbled 2 grains per hole (holes 6" apart, lines 1' apart).	5	As. 4	1,986	2,412	57·8

Further experiments were carried out in 1883 with similar results, but it was observed that weeds are much more troublesome in the thinly sown plots than in those in which the usual seed rate at Cawnpore, 120 lbs. per acre, was adopted.

At the Nágpur Farm from 1891 to 1893 seed rate experiments were carried out in which the quantity of seed varied from 60 to 120 lbs. per acre. The results confirmed the ordinary experience of the locality that the best seed rate is 90 lbs. per acre.

At Lyallpur the seed rate experiment in 1907 showed that the most economical rate varies from 56 to 64 lbs. per acre.

Drilling *versus* sowing behind the plough.

In Bombay and the Central Provinces, wheat is often sown by means of a three-tined drill, the seed being dropped into a small hopper by hand. In the Indo-Gangetic plain the custom from time immemorial has been to drop the seed by hand into an open furrow behind the country plough and to cover the seed and consolidate the seed-bed with the *sohága*. These different methods have developed on account of the totally different character of the alluvial soil of the plains and the black cotton soils of Bombay and the Central Provinces. Sowing behind the plough in open furrows in the black cotton soils would often lead to great loss of moisture and to defective germination, while in the alluvium the moisture can be brought up by the *sohága* at will. Trials with the Bombay drill have been made at the Cawnpore Farm, but the results were no better than with the ordinary method which is one not likely to be readily displaced.

Transplanting.

During the years 1896 to 1899 several experiments were made at Cawnpore with transplanted wheat. It was found that seedlings from 20 to 30 days old could be transplanted with success and as good crops obtained as by sowing in the ordinary way. Use has been made of this process in filling up the blanks and corners in the experimental plots, but it is not likely that it will ever be taken up in ordinary practice.

Grazing young wheat.

In the case of wheat fields in England, where from various causes the crop is too forward in the early spring, it is a common practice to graze the wheat with sheep. Experiments on this subject were made at Cawnpore from 1889 to 1891, and the results, which are given in the following table, are very much the same as in England. If the winter rains are early and the young crop is too leafy, grazing gives rise to an increased yield.

	1888-89.		1889-90.		1890-91.		1891-92.	
	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.	Grain.	Straw.
1. Grazed by sheep ...	1,016	3,340	1,102	3,399	2,148	3,999	813	3,048
2. Cropped with a sickle ...	1,089	3,412	1,122	2,881	1,053	2,845	857	3,261
3. Left untouched ...	1,041	2,710	1,169	3,698	951	2,140	846	3,387

Mixed Crops.

A comparison between the yield of plots of wheat with a mixed crop of wheat and gram was the subject of experiment at the Nágpur Farm from 1891 till 1902. The result showed that on that farm a mixed crop gives a decidedly smaller yield than wheat in pure culture, a result opposed to practice and experience in the black cotton soils of the Nárbadá Valley and the northern Districts of the Central Provinces. The results seem to be due to the fact that the moisture-retaining capacity of the soils at Nágpur in which this experiment was tried was far too low.

At the Cawnpore Farm in 1885 a similar experiment was tried in triplicate and in each case considerably higher yields were obtained with the mixed crop than with wheat alone.

No experiments seem to have been made to test the yield of definite mixtures of different wheats. As is well known, the wheats grown in India by cultivators are usually mixed and it may be said that most of the wheat grown in the country consists of several distinct sorts mixed together. Moreland[1] states that in Bundelkhand it is usual to mix varieties for sowing as a form of insurance against accidents of season, but the exact nature of the mixtures preferred in this case has not yet been ascertained with precision.

The advantages of sowing mixed wheats for various types of soil in France has been fully dealt with by Vilmorin[2] in *Les Meilleurs Blés*. In this work it is stated that it is a fact well established by numerous trials that a mixture of two distinct varieties of wheat gives almost invariably a better yield in grain than either of these varieties cultivated alone.. He considers that this result is due to less root competition in a mixture than in a pure culture. It is further stated that the samples resulting from a mixture are of better quality than those from each sown separately and that laying is prevented in cases where one of the constituents is liable to lodge. At the end of the chapter on wheat mixtures a list of suitable mixtures is given for early and late sowing on several types of soil such as a rich alluvium, calcareous clays, typical clays and poor gravelly soils.

Von Rumker[3], in a recent paper, refers to the advantages of mixing varieties especially on the poorer soils and gives as an example "Löhmer Weizen," a wheat mixture of four English and two Silesian kinds which

1 *Proceedings of the Board of Agriculture in India*, 1906, p. 56.

2 Vilmorin, *Les Meilleurs Blés*, Paris, 1880, p. 16 and p. 167.

3 Von Rumker, *Uber Sortenauswahl bei Getreide mit Rücksicht auf Boden, Klima und Kulturzustand*, Berlin, 1907.

was made by Amtsrat Schmidt in Löhme bei Bernan-i-M. All these six varieties are red wheats and it is said that the mixture yields well and is both resistant to rust and to damage by frost.

It is possible that in India on the various wheat soils mixtures could be found which would give higher yields than pure cultures. In deciding on suitable kinds for such mixture experiments it would be necessary to confine the choice to wheats of one milling grade.

CHAPTER XI.

THE TRIALS OF IMPLEMENTS AND MACHINES.

THE great contrast between the labour-saving devices and the use of machinery in the agriculture of the West and the primitive methods of India cannot fail to strike the most casual of observers. Consequently it is not surprising that in the early period of the Agricultural Department of India attempts were made to test in India the implements and machines in general use in England. The experimental farms speedily became museums of all kinds of European implements which were for the most part quite useless in a country like India. European and American agriculture have developed in the direction of labour-saving machinery on account of the dearness and scarcity of labour and the increased size of holdings. In a country like India with a large agricultural population, with areas considerably overpopulated and where the holdings are minute, both the poverty of the cultivator and the need for the employment of the greatest number are powerful arguments against the introduction of labour-saving devices. More will be gained by developing the existing system than by trying to change it. In the following pages we have attempted to review what has been done in the past and to give a short account of those implements, the introduction of which has met with a certain amount of success. Some useful introductions have been made in the United Provinces and in the Central Provinces, but the most promising field for such introductions would seem to be the Canal Colonies in the Punjab where labour is very sacrce and dear (as much as Re. 1 a day being paid at harvest time) and the holdings are, for India, large. In Bengal, on the other hand, the introduction of implements not only from England but also from other parts of India has proved a failure owing to the extreme cheapness of labour and also to its unskilled character.

PLOUGHS.

One of the first pieces of work undertaken by the Agricultural Department of the United Provinces was an enquiry into the means of improving the native plough and the methods of obtaining a suitable tilth. It was found by Buck and Fuller[1] that a plough suitable for use in these Provinces must fulfil the following conditions :—

[1] *Report of the Cawnpore Experimental Farm for the year* 1878-79 *and for the rabi season* 1879-80.

(1) The maximum weight should be 32 lbs., so that the plough can be carried easily on a man's shoulder.
(2) The average draught should not exceed 140 lbs., this draught having been found by actual dynamometer trials to be easily within the power of good ordinary country bullocks.
(3) The price should not exceed Rs. 8.
(4) It should plough a furrow at least 5 inches deep.

Actual trials with the dynamometer showed that none of the American or English ploughs fulfilled these conditions. They were all too heavy, too dear and required more force for draught than that within the means of even the best cultivators. Accordingly these were discarded and new forms of swing ploughs (intermediate in weight, cost and draught between the Indian and foreign ploughs) were devised at the workshops in connection with the Cawnpore Farm. An account of the best of these ploughs is given below (p. 79).

It is not without interest, however, to draw attention to the work of Fuller[1] in 1879 in collecting at Cawnpore the native ploughs in use in all the Districts of the Provinces. It was found that some striking differences were to be met with and that the native ploughs are by no means of one simple pattern. In the Saharánpur, Muzaffarnagar and Meerut Districts, the home of the best cultivators perhaps in the whole of the Indo-Gangetic plain, the ploughs were nearly double the ordinary size and weight. From the Bundelkhand districts came the *nagár* weighing 3 maunds and 14 seers (=268 lbs.) which worked the soil to a depth of nine to twelve inches and which was drawn by three pairs of cattle. These heavier instruments however are only used by the best cultivators who have found by experience the benefits of occasional deep cultivation.

One of the first objections to the use of the improved Watts (adapted from the American Watts plough) and Kaisar ploughs sent out for trial from Cawnpore was their inability to supersede the country plough for sowing purposes and accordingly in 1882-83 a new alterable form, the Duplex, was devised. This could be used both as an improved tillage plough and could also be altered for use in sowing. The Duplex soon gained in favour and was more appreciated than the old Kaisar form. The Watts however seemed to be unquestionably the best for early ploughings and for breaking up stubbles. Other forms introduced were the Baldeo and improved Baldeo ploughs invented by the blacksmith at the Cawnpore Farm.

1 *l. c.*

In 1897-98 the Meston plough was brought out. Its weight was 26 lbs. and it was found to be especially suitable for lighter soils and could be worked without difficulty by even inferior cattle. The price was only Rs. 4. This plough had a considerable sale after its first appearance and has been altered, strengthened and completely reconstructed by Hayman[1] and is now said to be greatly superior to the original.

The opposite table, taken from the *Report on the Operations of the Department of Land Records and Agriculture of the North-West Provinces for the year ending September* 1900, gives an account of the improved ploughs which have been successfully tried at Cawnpore and distributed to cultivators.

It must be confessed that a critical examination of the records connected with these improved ploughs and some practical experience of their use in India, convinces us that although they are admirable for the early stages of preparation for wheat, nevertheless they are not suitable for sowing or for the later stages of cultivation after the monsoon is over and before sowing takes place. It is at this stage, often a critical one, that the native plough shows its great superiority in conserving soil moisture. On the other hand, the slowness of the native plough in obtaining a deep and well ærated furrow in the hot season and especially after slight showers at the beginning of the rains is a great disadvantage. Our experience at Púsa has been that the improved ploughs are admirable before and during the monsoon for preparing land for wheat, but that after the rains are over, it is desirable for the purpose of conserving soil moisture, to use the common country plough for the final preparation and for sowing.

Two main causes have to a large extent prevented the successful introduction of improved ploughs in the production of the wheat crop in the black cotton soils of the Central Provinces. In the first place, the local custom is decidedly against frequent ploughing during the rains in preparation for wheat and other *rabi* crops, the place of the plough being taken by the *bakhar*. In addition, only heavy draught ploughs are of the slightest value in black cotton soils, a circumstance which places their use, except occasionally, beyond the means of the cultivator. The natural conditions are widely different from those obtaining in the Indo-Gangetic alluvium, and it is a foregone conclusion that the light Cawnpore ploughs, such as the Watt's improved and the Meston plough, would prove useless at Nágpur. Such trials have been made at the Nágpur

1 Hayman, *Report of the Cawnpore Experimental Station*, 1907.

List of ploughs successfully tested at the Cawnpore Experimental Farm.

Name.	Special use.	Advantages.	Price.	Opinion on its value.	Extent to which used by native agriculturists.
Kaisar.	Breaking land and inverting the soil.	Cheapness, lightness (32 lbs.), share removable, iron parts of sheet iron, repairs can be done by village blacksmith.	Rs. 5.	A good strong soil inverting plough. It can plough an acre of land in 16 hours, furrows big, 4 to 4½ inches deep and 5 inches wide.	The plough is used by some well-to-do agriculturists in different parts of the United Provinces, but is being gradually superseded by the Watts plough.
Watts chain plough.	Ploughing heavy lands and inverting the soil.	Easy draught and adaptable to the various modes of preparing the ground.	Rs. 7 (not including chain).	More effective, stronger and more durable than the Kaisar plough. This implement is in common use at the Government Experimental Farm, Cawnpore, and maintains the reputation it acquired in previous years. It goes from 5 to 6 inches deep in the ground, making a furrow of almost 9 to 10 inches wide. It ploughs an acre of *dumat* land in a day.	Is specially appreciated and used by several well-to-do cultivators throughout the Provinces. Is also often indented for from other Provinces.
Watts beam plough.	Inversion of soil and ploughing heavy lands.	Easy draught and adaptability to the various modes of preparing the ground. No chain is used for working the plough.	Rs. 8.	As effective as the Watts chain plough, but used to a small extent.	Used chiefly by cultivators in the neighbourhood of Bulandshahr.
Baldeo.	Ploughing light soil.	Inversion of soil, simplicity of construction, cheapness and efficacy.	Rs. 2-8.	Suitable for districts in which the cattle are small and weak. It ploughs an acre of *dumat* land about 3½ inches deep in a day.	Used by native cultivators, notably in Hardoi and Farukhabad.
Improved Baldeo.	Breaking and inverting light soil.	Stronger and more durable than the old Baldeo.	Rs. 3-8.	Larger, stronger and more efficient than the Baldeo. An acre of *dumat* land can be ploughed in 16 hours, the width of the furrow being 6½ inches and the depth 4 inches.	Used and much appreciated by native cultivators. Has been indented for from various parts of India.
Meston.	Breaking and inverting soil.	Strong, durable, light, cheap, suitable for all kinds of soils, easy of repair and simple in construction.	Rs. 4.	Has all the good qualities ordinarily desirable in a plough. Weight about 26 lbs. and though suitable for light soils also works satisfactorily on clayey soils. Can easily be worked by inferior bullocks. The ploughman has to undergo little exertion in working it. The mould board being made of wrought iron is particularly strong and the cast-iron standard and share are much more substantial than the improved Baldeo. For the price it is the best soil inverting plough so far invented at the Cawnpore Farm.	Has attracted much attention from the ordinary cultivators and Managers of Court of Wards Estates; much appreciated by some agriculturists who have given favourable opinions regarding it after actual trial.

Farm, but they only served to add to the long list of failures in the use of introduced appliances.

In the Nágpur Farm Report for 1884-85 mention is made of two Swedish ploughs obtained from the Superintendent of the Saidapet Farm in Madras which gave promising results. One pair of bullocks was able to plough a furrow five inches deep and to produce better results with half the labour than the local *nagár*. Besides the saving in cattle, the Swedish ploughs thoroughly broke up and inverted the soil instead of the uneven grubbing of the *nagár*. The introduced plough was also found specially useful in extracting deep-rooted grasses like *káns* (*Saccharum spontaneum*).

A simpler and cheaper Swedish plough is now made locally at Nágpur and sold at the Nágpur Farm for Rs. 16, and this according to Clouston[1] is quite an efficient instrument for use in the black cotton soils. A small number of these ploughs has been sold every year by the farm, as many as 28 in 1903-04.

Among the heavier foreign ploughs tried at Nágpur, Ransome's turn wrest plough, sent to the farm in 1904 by Mollison,[2] has proved of most service. It is recommended by Clouston[3] for breaking up waste land, for ploughing *káns* infested land in the cold weather and for ploughing in green manure. It is a strong plough and has a mould board which can be used on either side and is comparatively cheap, the cost being Rs. 40. It is said to be in favour among the better class cultivators and a small number have been distributed in the Central Provinces. The sale of ploughs at Nágpur has however been small compared with that at Cawnpore and it does not appear likely that their introduction into ordinary practice will be other than a gradual one.

Among the ploughs tried by the Punjab Agricultural Department, in 1901-02, the Cawnpore Watts plough proved to be the best and is said to be liked by the *zamíndárs*.

Reapers.

Four types of reapers have been tried in India. At Hoshangábád a self-binder has been purchased, but it is not likely to be of use on such a rough soil as that of the Narbadá Valley where the surface of the wheat-fields is strewn with large clods and where the straw is often too short and too brittle for a self-binder. Further, the cost and draught are

[1] Clouston, *Agricultural Journal of India*, Vol. I, 1906, p. 31.

[2] Mollison first introduced this plough into India and showed its utility in the black soils of Bombay. An account of the early trials is given in the *Annual Report of the Poona Farm*, 1895.

[3] Clouston, l. c.

against its use in this part of India. At Lyallpur in the Chenáb Colony, three types of reapers have been used, a self-deliverer, a combined reaper and mower with two side wheels and a simple reaper with a large central wheel. A great impetus was given to the use of reapers in the Chenáb Colony in the wheat harvest of 1908 by Milligan[1] who has given an account of this innovation in a recent paper.

Steam threshers.

Attempts have been made to introduce steam threshers for wheat into India but so far without much success. In 1878, Messrs. Ransome, Sims and Head endeavoured to obtain a trial of their machines in India with the assistance of Government. Their proposals were laid before the Government of India by the Secretary of State, and some of the local Governments were duly consulted especially that of the Province known at present as the United Provinces of Agra and Oudh. The opinions of a large number of District officers and planters of this Province were ascertained as to the chances of success of such an experiment, and, with the exception of two large planters, the feeling was unanimous against such an undertaking.

The correspondence[2] was published in 1879, and as the conditions of Indian agriculture have not materially changed since these letters were written, we do not consider it out of place to briefly summarise here the arguments against the use of steam threshers in India, arguments which in our judgment have considerable force in connection with the introduction of the majority of costly machines for agricultural purposes. The difficulties, the expense and delay and often the impossibility of transporting such heavy machines about the country in India where roads are bad, streams and canals unbridged and *naláh* often abundant were emphasised. Stress was laid on the expense of fuel, if wood or coal were used, as well as the disadvantage of the loss of *bhúsa* in the case of a straw burning engine. The danger of fire also must be remembered. The cost of the machine, the difficulties that would arise in threshing a large number of small lots of grain, the expense and trouble of moving the crops to the thresher and the removal of the threshed produce presented difficulties, which, to men of experience of Indian agriculture and with an intimate acquaintance with local conditions, were considered insuperable. Lastly, it was pointed out that if steam threshers were used, the cattle would be nearly idle and would have to be fed at a time when no other agricultural

[1] Milligan, *Agricultural Journal of India*, Vol. III, 1908, p. 326.
[2] *The Wheat Production and Trade of India*, Simla, 1879.

work was possible. A consideration of these difficulties led the Government of India to believe that it was premature to entertain the idea and accordingly the matter was dropped.

The first trial of a steam thresher for wheat, gram and linseed seems to have been the one with a Marshall's machine at the Bhadgaon farm in Bombay between the years 1887 and 1890. There is an account of its working by Mehta in the farm report for 1887-88.

It is stated at one period in the history of planting enterprise in Bihár, when considerable areas of wheat were grown along the banks of the Ganges, that steam threshers were in very general use, but that their use was confined to the European planters. Since those days, however, planting enterprise has gradually decayed and with it the growth of wheat in those areas of Bihár where previously it was of much more importance. As a consequence at the present day steam threshers are very rare. Comparisons have been made by Shearer[1] at Púsa in Bihár in oat threshing between a *bhúsa* producing steam thresher which cost 4,500 rupees and treading out by cattle. In trials extending over a week it was found that whereas treading out by bullocks and winnowing by hand cost 5½ annas a maund, the machine did the work for three annas and 8 pies a maund. Various difficulties with the machine, however, disclosed themselves such as the effect of change of humidity on the leather belting, the heating of bearings, the jamming of the machine due to bad feeding and the danger of fire.

The great extension of wheat growing in the Canal colonies of the Punjab in recent years has suggested the possibility of the profitable employment of steam threshers there on account of the dearness of labour which, during the last few years, has been paid at the rate of one rupee per day at harvest time. The great success which has attended the use of reaping machines in these tracts during the last year and the probability of their introduction on the large scale will no doubt soon have the effect of solving the labour difficulty. The use of steam threshers, however, is not likely to be general on account of the fact that their prime cost is beyond the means of the cultivators, and unless co-operation develops more rapidly than it has done heretofore in India, it is not probable that steam threshers will ever be more than curiosities in the Punjab. Unless the wheat is stacked as in England (a proceeding which is hardly likely to arise on account of the damage by rats, and the fact that *bhúsa* and also grain and money are wanted as soon as harvest is over), the machines could only be employed

[1] Shearer, *Agr. Jour. of India*, Vol. 2, 1907, p. 246.

every year for a very short time and the transport difficulty in a country with few roads and numerous canal distributaries is a real one. Except in the case of rich *zamindárs* who cultivate a large continuous area of wheat or of a large Government seed distributing farm, the difficulties which have been emphasised above seem to be too great for the general adoption of steam threshers in the Punjab.[1]

Hand and bullock threshers.

Besides steam machines, bullock power threshers and hand threshers have been tested in India. Thus at the Cawnpore farm between the years 1879 and 1895 several threshers were tried and some trials were made with this process compared with the country method. In some cases there was a slight saving in favour of the machine, but there were also several drawbacks noticed—unthreshed ears passed through and the straw was not always broken up sufficiently for use as fodder. It does not appear from the records that these machines ever got beyond the trial stage at the Government farm, and in the list of useful implements introduced into general practice by the farm, there is no mention of a bullock thresher or of a hand thresher. Several grain separators were also tried at Cawnpore, but the only one adopted was a hand sieve for separating large and plump wheat seed from the small and inferior grains. It consists of a sieve with a wooden rim with rings at the four corners. The sieve is hung by four ropes from a roof or a tree, wheat is poured in and the sieve is worked backwards and forwards by a boy. The small grains fall out, leaving the large plump grain behind. In this way the wheat distributed to cultivators for seed is cleaned and kept up to a good grade.

At the Nágpur farm between the years 1884 and 1904 many trials of hand threshers and bullock power threshers have been made, the machines tried at Cawnpore having been used in the experiments. Although they have proved useful on the farm in threshing experimental plots, their superiority over the primitive bullock treading method has not been great enough to ensure their adoption in the district. Harder's thresher seems to be the best of those tried, but its cost is 225 rupees.

At Lyallpur in 1907, one of these bullock threshers was tried, but without any great success, much adjustment having been found necessary. On the whole neither steam nor bullock threshers in India have

[1] Since this paragraph was written, a Marshall steam thresher was tried with wheat at the Lyallpur farm in 1909. The output of grain per day was found to be small and insufficient in volume to make this method of threshing remunerative.

so far shown any great superiority over the country method and until conditions change very much, it is not likely that they will supersede treading out by cattle.

Winnowers.

The separation of the grain from the chaff in the country process of threshing is performed by pouring the mixed *bhúsa* and grain from a hand tray (*súp*), at a suitable height into the air in the wind. By this means the grain and *bhúsa* can be separated. As a rule, the west winds do not often fail in the United Provinces during the months of March and April. If there is a calm, however, artificial draught is obtained by two men agitating a cloth. The final cleaning is done by the *súp*, an operation usually performed by women.

At the Cawnpore farm during the early years (1879 to 1899) of its existence, considerable attention was paid to the use of winnowing machines to take the place of the native method. Several introduced forms were tried, of which Dell's was found to be the best. A simpler and cheaper form of this was made at the farm workshop in 1880-81, when trials were made between the English winnower, the Cawnpore form and the native method. The results are given in the following table:—

Method.	Labour required.		Results.		Result per 100 maunds.	
	No.	Cost in annas.	Amount winnowed in lbs.	Time taken in minutes.	Time taken for 100 mds. in hours & minutes.	Cost in annas.
			(1) in a gale of wind.			
English winnower ...	4	6½	561½	80	18·58	15·4
Farm ,, ...	3	5¼	376	91	32·16	21·1
Native method ...	3	5¼	537½	113	28·33	18·7
			(2) in a slight breeze.			
English winnower ...	4	6½	448	70	20·50	16·9
Farm ,, ...	3	5¼	410	125	40·39	26·6
Native method ...	3	10¼	503	195	51·41	67·8

It is therefore evident that during the west winds the cultivators are able to separate their grain as cheaply as by the use of winnowers, but in periods of calm their methods are exceedingly tedious and expensive. During the season in question as many as 22 farm winnowers were sold, at the cost of Rs. 30 each. The cost of the Dell winnower was Rs. 200 to 250—a prohibitive price—but in trials made in 1882 the cost of separating a maund of grain was only 4·7 pies—36 maunds being cleaned per day of

eight hours. During the next two years 14 more farm winnowers were sold, but it was found in 1884 that it was not possible to make them sufficiently strong to stand heavy and continuous work, and so their manufacture was discontinued. They were on the whole found to be too costly for the irregular service which they were designed to render, and when the west winds did not fail, the buyers always regretted their purchase. With the comparatively small holdings in the United Provinces and the infrequent failure of the west winds at threshing time it is hardly likely that there will be a great demand for winnowing machines.

The trials of grain winnowers has been more successful at Nágpur than at Cawnpore. This result is perhaps due to the fact that the winds are less constant in the Central Provinces than in the plains. Of the forms tried, Harder's American winnower first used in 1901[1] has given by far the best results and a cheaper form with teak woodwork is now made at Nágpur for Rs. 90. In tests made with this machine compared with the native method it was found that the winnower separated 12,298 lbs. of wheat, while the country method gave only 5,600 lbs. In each case four men were employed for 8 hours. The machine and its method of working have been described by Clouston[2] who states that 27 of these machines were sold from Nágpur during 1906.

In the Punjab, on account of the large holdings and the extensive area under wheat, as well as the danger of damage by rain at threshing time, there would appear to be considerable openings for the use of a good winnower. Trials were made in 1906 and 1907 by the Agricultural Department at Lyallpur, but although they were looked on with favour by the *zamíndárs*, it does not appear that their use has spread to any extent. Possibly the Nágpur winnower would prove of use in the Punjab.

Flour Mills.

In the reports of the Cawnpore farm for 1887, and from 1895 to 1897 there are references to the trials of small flour mills with steel grinding plates compared with the country methods of making flour. It was found in 1887 the machines with steel plates got too hot and spoilt the quality of the flour. A flour mill invented at the Cawnpore farm by the blacksmith proved defective, and the trials of flour mills were given up. Modern roller mills, however, have been successfully adopted in the large cities of India. This aspect of the subject is dealt with in section III.

[1] *Report of the Nágpur Farm*, 1901-02.
[2] Clouston, *l. c.*

SECTION II.

THE DISEASES OF WHEAT IN INDIA.

THE DISEASES OF WHEAT IN INDIA.

The enemies of wheat with which the Indian cultivator has to contend are, in order of importance, climatic extremes, fungi, insects and vermin.

THE DISEASES OF WHEAT IN INDIA.

CHAPTER I.

WHEAT RUSTS.

INTRODUCTION.

RUSTS are the most important diseases of wheat in India. Indeed the damage caused every year by these diseases far exceeds that resulting from all the other wheat pests put together. In this respect India is no exception to the other wheat-growing tracts of the world, and the rust problem is as great a question here as in the United States, Europe and Australia.

The economic significance of wheat rusts can best be realised if the estimates in sterling of the damage done be considered. Thus in 1891, the Prussian Statistics Bureau calculated the loss through wheat rusts in Prussia alone at £3,593,758 or 31 per cent. of the whole crop. The loss on all the cereal crops—wheat, rye and oats—from rusts reached the enormous sum of £20,628,147 or almost a third of the total value of these grain crops. The year 1891 was a very unfavourable one to cereals in Prussia but, even taking the estimate at half of the above sum, we have a yearly loss by grain rusts amounting to £10,000,000 sterling. In Australia, the annual loss through wheat rusts alone has been put at from £2,000,000 to £3,000,000. In the United States, Carleton[1] states that in his opinion the average annual loss from grain-rusts throughout that country far exceeds that due to any other enemy and often equals that from all others combined.

In India, the ravages of rust vary greatly from year to year, and it is obvious that anything like an accurate estimate of the annual loss is impossible. Further, the damage done in the great wheat-growing tracts of the North-West is generally slight, while in Bombay, the Central Provinces, and in parts of the United Provinces and Bengal the crop may be reduced 50 per cent. or even more. One of the first estimates of the damage done by rust was made by Barclay[2] in 1889. He calculated the loss at one per cent. or Rs. 40,00,000 on a crop of 6,510,797 tons raised from 26,508,000 acres

[1] Carleton, *Bulletin No.* 16, *Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture*, 1899.

[2] Barclay, *Journal of Botany*, Vol. XXVIII, 1890.

and valued at Rs. 4,10,191,677. Indeed Barclay himself considered this estimate too low and that the loss was likely to be five times as great. In 1896, Watt[1] estimated the annual loss at rather over than under 10 per cent. For the 1889 crop this would work out to be more than 400 lakhs of rupees. Whether the lower or the higher of these two estimates be accepted as nearest the truth, it is evident that wheat rusts are of the greatest economic importance in India and that a study of these diseases and of the means of combating them is imperative.

Rust is by no means a modern occurrence in the wheat fields of India. Sleeman[2] in 1839 speaking of rust in the Central Provinces wrote :—"I have seen rich sheets of uninterrupted wheat cultivation for twenty miles by ten in the valley of the Narbudda so entirely destroyed by this disease that the people would not go to the cost of gathering one field in four," and further :—" I believe that the total amount of the wheat gathered in the harvest of 1827 in the District of Jubbulpore was not equal to the total quantity of seed that had been sown."

In 1883, the subject received attention from the Government of India. A paper dealing with wheat rust by Carruthers[3] was reprinted and circulated widely in India. Specimens of wheat rust and other diseases were collected in the various Provinces and sent to the Royal Agricultural Society of England for examination by the Society's Consulting Botanist. At the same time a general enquiry was instituted as to whether, as was sometimes alleged, rust was more common in fields in which mustard was grown than elsewhere. The result of the investigation was, as was only to be expected, a negative one, and in no Province could any evidence be obtained in support of the view that the growth of mustard with wheat increased the amount of rust on the cereal crop.

The first investigation of rusts in India, including those on wheat, was made by Barclay. The main portion of his work, however, was not of an economic character but dealt with the scientific aspect of the various rust fungi found growing on wild plants in the Simla District. A general account of Barclay's work together with a review of the literature of some of the blights of Indian crops was published in 1895 by Watt. In his papers on wheat rust, Barclay drew attention to the great differences in weight between the seeds from healthy and those from rusted plants. The number of grains from rusted plants that were found to be

[1] Watt, *Agr. Ledger*, No. 20, 1895.
[2] Sleeman, *Transactions of the Agricultural and Horticultural Society of India*, Vol. VI, 1839.
[3] Carruthers, *Journal of the Royal Agricultural Society of England*, Vol. 18, 2nd series, 1882, p. 495.

equal in weight to ten healthy seeds varied from twenty to ninety. He further dealt at length with the influence of the weather on rust and sums up his conclusions in the following statement :—"The weather during January, February and March is most important in this connection, not only because it has a maximum effect on the growth of the wheat plants but also because this is the season during which rust attacks these plants."

A more extended investigation of wheat rust was made in 1896, by Cunningham and Prain[1] at the instance of the Government of India. This research dealt not only with the characters and distribution of the various wheat rusts in Bengal and Northern India, but also with the possibility of a connection between these rusts and that found on the common weed of wheat fields—*Launea asplenifolia*, DC., known as *tikchana* in Bengal. However, no connection was found between the rust on this weed and those on wheat and later Butler and Hayman[2] showed by direct infection experiments that none exists.

In 1897, Prain,[3] at the request of the Government of India, published a digest of the papers relating to the five Inter-Colonial wheat-rust Conferences held in Australia from 1890 to 1896. Besides this information the paper contains interesting comments on the bearing of Australian experience on the wheat-rust question in India. The damage done to the wheat crops in Australia by rust had caused much anxiety to wheat-growers in that country and the subject became of such importance that the Australian Government called together an Inter-Colonial Conference to discuss the matter in 1890. The first Conference was followed by several others during the succeeding years.

It may not be out of place to refer briefly to these wheat-rust conferences in Australia which are interesting examples of a combined effort on the part of the State to deal with this plague in one of the important wheat-growing districts of the Empire. The delegates were selected by the various Governments and were either members of the Agricultural Departments or leading farmers. In the discussions which arose all the scientific information and practical experience available at the time were brought to bear on the rust question. The minutes of the various Conferences include all that was known of the practical aspect of the subject. The many discussions which took place on the suggestions for the prevention of rust are summed up by Prain as follows: "Reviewing briefly the proposals for the prevention

[1] Cunningham and Prain, *Records of the Botanical Survey of India*, Vol. I, No. 7, 1896.
[2] Butler and Hayman, *Memoirs of the Department of Agriculture in India* (Botanical Series), Vol. I, No. 2, 1906.
[3] Prain, *Agricultural Ledger*, No. 16, 1897.

of rust, it may be said that drainage *per se* is not a palliative nor is irrigation *per se* an excitant; it seems to be on the whole advisable to sow in a dry seed bed. Rotation of crops seems to be advisable for practical reasons as well as on theoretical grounds; a thin crop is advisable in Australia as it probably also is in India, although the experience of cold countries is the reverse to some extent; a comparatively poor soil is preferable to a rich or heavily manured soil; this, for the very reasons that prevail in Australia, is probably true of India also. Treatment of the soil with preparations is a mere throwing-away of time and money; special disinfection of the seed before sowing and the disinfection of the growing crop are equally valueless. The use of rust-shrivelled seed is not *per se* a cause of rust, but it is to be avoided because the fact that it is rust-shrivelled indicates that it belongs to a rust-liable stock. The one great palliative is early sowing."

Although no method of curing rust attacks was discovered, nevertheless these Conferences led to the adoption of a method of preventing, to a large extent, the ravages of this pest, a method which has since been carried out in Australia with marked success. At the second Conference held at Sydney in 1891, Farrer, then a private agriculturist, expressed the opinion that the best method of combating rust lay in the securing and creating of rust-resistant varieties of wheat possessing the characters demanded by the special requirements of Australia. In addition to their rust-resistance it was imperative that the wheat should possess high milling qualities. Farrer's experiments in wheat-breeding began privately in 1889 on a very small scale and were developed during the following years. In 1899 he became a member of the New South Wales Department of Agriculture and from that time his work was continued on behalf of the Government. An account of Farrer's earlier experiments was published in the *Agricultural Gazette of New South Wales* in 1898, in a paper entitled—"The making and improvement of wheats for Australian conditions."

The great importance of rust-resistant wheats for Indian conditions was recognised by Prain and referred to in his summary of the Australian literature as follows:—"Practically the only hope for India in combating rust in wheat is to adopt the method of selecting from among the various kinds of wheat those that show themselves little liable to rust. For, while probably no wheat is absolutely immune, it is a recognised fact that in certain areas particular wheats are relatively proof against rust. By a system of cross-breeding with kinds valuable on other accounts, new kinds can be made that will combine these qualities with the character of resistance to rust."

From 1896 to 1901 several consignments of rust-resistant cross-bred Australian wheats raised by Farrer were received by the Government of India and grown at Cawnpore, Nágpur and in the Punjab. Several of these wheats are still grown on the various experimental farms in India and one beardless variety, Australian No. 27, has been adopted to some extent by the cultivators in the Punjab.[1] None of the varieties, however, have been found to be immune to rust in India.

The success which had attended Farrer's work in raising new varieties of rust-resistant wheats in Australia suggested to the Government of India the desirability of deputing an officer to study the matter on the spot with a view of adopting similar methods in India. Accordingly, the Director of Land Records and Agriculture of the North-West Provinces and Oudh (now the United Provinces) was selected for this important mission in 1900 and his report appeared the following year.[2] It was recommended that cross-breeding should be taken up at a central station and the first work should be an attempt to produce wheats which will stand drought and resist or escape rust. As a result of these proposals wheat-breeding on the lines of the Australian work was taken up at the Cawnpore farm in 1901.

Soon afterwards the post of Cryptogamic Botanist to the Government of India was created and for the first time a scientific officer was available for the sole study of the diseases of Indian crops. In 1903, Butler[3] published a general account of the wheat-rust problem in India, and in 1906 Butler and Hayman's paper[4] on Indian wheat-rusts appeared together with a note on the relation of weather to rust in cereals by Moreland.[5] Further reference will be made to these investigations below.

The distribution of Wheat Rusts in India.

Three distinct species of rust have been found by Butler and Hayman to attack wheat in India.

1. Black rust. *Puccinia graminis*, Pers.
2. Yellow rust. *Puccinia glumarum*, Eriks. & Henn.
3. Orange rust. *Puccinia triticina*, Eriks.

The two former were found to occur in all the wheat-growing districts, while the third occurs principally in Bengal and the United Provinces.

1 *Proceedings of the Board of Agriculture in India*, 1906, p. 66.
2 Moreland, *Agricultural Ledger*, No. 2, 1901.
3 Butler, *Bulletin No.* 1, *Department of Agriculture in India*, 1903.
4 Butler and Hayman, l. c.
5 Moreland, *Memoirs of the Department of Agriculture in India*, Vol. I, No. 2, 1906.

The reader is referred to Butler and Hayman's paper for a technical account of these wheat rusts and for the experiments which the authors have recently carried out in India on this question.

The following naked eye differences between these rusts may be noted. It must be remembered, however, that it is not easy to distinguish them in the field and that more than one form may occur on the same plant at the same time.

Black rust attacks the stem most severely. The sori are large and elongated, run together and burst early, often throwing up fragments of the epidermis around them. The uredosori, at first brown, become darker through the development of teleutospores. As a rule, black rust is the last to appear.

Yellow rust attacks the leaves most seriously. In mild attacks the sori are arranged in long rows on elongated discoloured parts of the leaf and remain long covered by the epidermis. They are small, oval and regular, and do not usually run together. They are lemon in colour and occur on both surfaces of the leaf. The teleutospores form black crusts usually on the under-surface of the leaves.

Orange rust attacks the leaves almost exclusively. The round, orange-coloured uredosori burst early and are generally found on the upper leaf surface only, and do not often run together and are never arranged in regular rows. The dull black teleutosori remain long covered by the epidermis. Orange rust generally makes its appearance first, often before the flowering period.

Propagation of rust from season to season.

No satisfactory explanation has yet been given as to the manner in which the wheat rusts pass from season to season in India. In the present state of our knowledge four possibilities have to be considered.

1. Infection from the rust spores, whether uredo or teleutospores or from old mycelium, left after the last crop. Until we know more definitely the conditions of germination of uredospores, we cannot say that it is impossible for these spores to remain dormant in the soil like the seeds of *rabi* weeds through the hot weather and the rains and to infect the next crop of wheat. Indeed recent researches on the subject would appear to indicate that there is much more than a possibility for this infection to take place. Thus Marshall Ward[1] has found that drying uredospores promotes their germination and Gibson[1] has found that the

[1] Marshall Ward, *Annals of Botany*, Vol. XLX, 1905. (Gibson's work is referred to in this paper.)

uredospores of chrysanthemum rust can be kept for at least ninety-four days without losing their power of germination. Barclay[1] gives as the limits of germination capacity for the spores of various species of Indian rusts two to eight months. There is, however, every possibility, judging from the behaviour of wheat rusts elsewhere, that the teleutospores and their sporidia will not themselves infect the next crop of wheat. What part the teleutospores play in India we cannot say.

2. Infection from wind-borne rust spores, whether uredospores or aecidiospores, from distant countries or districts. The possibility of infection by wind-borne spores has been suggested by Klebahn[2] in a recent work on rusts, and it would seem that the suggestion is not an impossible one. Rust spores are exceedingly light and would easily be carried great distances by the wind. Further it appears probable that drying does not destroy their germinating power. The difficulties of obtaining reliable direct evidence on this subject in India would be considerable. Even if uredospores and aecidiospores were found in the atmosphere in the autumn, it would in the first place be very difficult to identify them in all cases and in the second place it would be hard to say whether they came from distant countries or were produced close at hand.

3. Infection from wheat rust growing on other plants during the hot weather and monsoon in or near the wheat-growing districts. At present there is no evidence available to show that after harvest the wheat rusts pass over and live on other host plants till the next *rabi* season. Further it is unlikely that they live on self-sown wheats ("volunteer wheat") during the hot weather and rains. Hayman in the Report of Cawnpore Experimental Farm for 1906 states that he has found volunteer wheat on August 15th, but free from rust.

4. Infection by means of the wheat grains. The hypothesis that wheat rust may pass from season to season in the wheat grains themselves was put forward some years ago by Eriksson,[3,4] as the mycoplasm theory. He supposed that the protoplasm of the rust fungus mingles with that of the wheat plant and that this mixed protoplasm (mycoplasm) sometimes passes into the seed and appears under favourable conditions as rust during the next crop. On the histological side this theory has been vigorously assailed by Marshall Ward[5] who has shown that there

[1] Barclay, *Transactions of the Linnean Society*, Vol. III, 2nd series, 1891.
[2] Klebahn, *Die Wirts-wechselnden Rostpilze*, 1904.
[3] Eriksson, *Annales des Sciences naturelles, Ser.* 8, *T.* 14 and 15, 1901-2.
[4] Eriksson, *Annals of Botany*, Vol. XLX, 1905.
[5] Marshall Ward, *l. c.*

is at present no evidence in favour of the hypothesis. The mycoplasm theory has been further tested in another direction, namely, by growing the seeds of rust-liable wheats under conditions which prevent infection either by means of the air or the soil—a method designed by Eriksson himself. In Germany Aderhold & Ruhland[1] have conducted experiments on these lines, while Bolley[2] in the United States and Butler and Hayman[3] in India have attacked the problem in a similar manner. In all cases the results were negative. Recently Bolley[2] has found that the grains from rusted wheats sometimes contain living rust mycelium and spores underneath the bran layer, but so far it has not been proved that such infected grains when sown will produce rusted plants.

The propagation of the wheat rusts of India from season to season is therefore still an unsolved problem and it is hoped that further investigations will clear up the question. As soon as we know with precision the course of the life-histories of the Indian wheat rusts between the harvesting and the sowing periods, it will then be possible to consider how far rust can be checked by direct means.

The influence of the weather on rust.

In reviewing all that is known on this aspect of the rust question we are struck by the remarkable unanimity expressed among practical men as to the great influence which weather has on the amount of damage done by rust. The most diverse statements are, however, to be found as to the particular kind of weather which is responsible for the spread of the disease. This is true, not only of India, but also of all countries where the rust problem has been discussed. Indeed on the burning question of the conditions most favourable to the spread of rust, the reports of the Australian Conferences may be said to be a mass of contradictions.

There are numerous references in the literature to the influence of the weather on the spread of rust in India. Thus Barclay[4] in 1892 showed the relation between the price of wheat and the factors which favour rust in January, February and March, namely, the humidity of the air, the cloud proportion and the rainfall. Whenever cloud, humidity and rain in these months were considerable, the prices rose. Later

[1] Aderhold and Ruhland: *Mitteilungen aus der kaiserlichen biologischen Anstalt fur Land und Forstwirtschaft*, Heft 2, 1906, pp. 3 and 4, and Heft 4, 1907, p. 8.

[2] Bolley, *Bulletin* 68, *North Dakota Exp. Station*, 1906.

[3] Butler and Hayman, l. c.

[4] Barclay, *Journal of Botany*, Vol. XXX, 1892.

Moreland[1] in discussing the relation between the weather and rust in the United Provinces in recent years concluded that, as far as the eastern and southern parts of the Province are concerned (the area where rust causes the greatest loss), the following inferences may fairly be drawn:—

(1) The amount of October rainfall is not a determining factor.
(2) Where the harvest is earliest, the extent of rust varies generally with the humidity of January, though the weather of February is apparently not without some influence.
(3) Elsewhere the extent of rust varies generally with the humidity of the months of January and February taken together.

In general the most widely accepted view is, that long-continued rain or cloudy weather in January or February gives rise to those conditions under which rust spreads with greatest rapidity. The opinion is also met with that rust sometimes follows an excessively wet seed bed in October (in places where the sowing rains have been abnormally great) and is also caused by over-irrigation. Occasionally, however, instances occur where rust appears early in the season on land where there has been no wet and cloudy weather and when the sowing rains have either failed altogether or have been very deficient. Such an example has been observed by us on the Púsa farm during the autumn of 1906. The field in question was sown with various varieties of wheat including the local kind on October 15th and 16th. The September rains were scanty and no rain fell during October, November and December. The seed bed was distinctly dry and the crop was very thin and the plants very spindly in appearance. The first ears appeared six weeks after sowing and the first signs of rust appeared on the edges of two of the plots during the last week in November. By the end of December it had spread all over the plots which were at that time very yellow and sickly in appearance. Here we have an example of the spread of rust on thinly sown wheat in the entire absence of rain and of cloudy weather and when the crop was growing in a distinctly dry seed bed. On the other hand, the same varieties were grown by us in another part of the Púsa estate under irrigation where a normal crop was produced. No rust had made its appearance on these plots at the time of writing (December 31st, 1906) five weeks after the time when rust was first noticed on the farm.[2] It has occurred to us that, in considering the effect of the various weather conditions on rust attacks, it is very easy to lose sight of one of the main factors in the

[1] Moreland, l. c.

[2] Similar observations were made at Púsa in 1908.

case, namely, the plant itself. It is usual to regard the matter as concerning only the fungus and the influence of the weather on the spread of the disease. It is most important, however, that the question should not be regarded from too narrow a standpoint. Three main factors have to be borne in mind, namely, the wheat plant, the rust fungus and the influence of external conditions on both. The chief external conditions are: the amount of moisture in the soil, the humidity of the air, the temperature, the light and the amount of air movement. We must consider how these external conditions affect the well-being of the wheat crop as well as of the fungus. It is well known that if the sowing and the winter rains are seasonable and the weather up to harvest time is bright and clear but not too cold, we have all those conditions which favour the rapid and healthy growth of the wheat crop, and although a little rust may be noticed here and there, no great damage is done and a bumper harvest results. In such cases external conditions favour the wheat and are against the spread of the fungus. If, on the other hand, we have too moist or too dry a seed bed or if long-continued wet or cloudy weather sets in during any period of the growth of the crop, we have the conditions which check the host plant and bring about unhealthy development. Wheat sown in a seed bed which is too dry either dies off altogether or else develops into a weak spindly growth almost certain to succumb to the first attack of rust. That this rust attack is only moderate in most cases and does not develop into an epidemic is due to the fact that dry weather is not so favourable to the fungus as wet and cloudy weather. In a seed bed which is too wet a good tilth is impossible, and healthy root-development cannot take place. Either a weak plant results which is incapable of much resistance to the attack of the fungus, or, as sometimes happens, the excessive wetness of the soil rots the young seedlings and the crop fails altogether and resowing is necessary. Long-continued wet and cloudy weather is very unfavourable to the healthy growth of the wheat even when established. Transpiration is lowered and the whole plant tends to become suffused with water. An enhanced wateriness of the crop results and at the same time the other activities in the leaf become abnormal and the protoplasm of the cells lose to a large extent their powers of resistance to a possible fungoid attack. At the same time the moist weather favours the germination of the rust spores and we have a state of things where the conditions are not only against the host plant but also favour the development of the parasite. Unless the weather changes for the better, a rust epidemic results and the damage will be complete or partial, depending on its duration and on the period in the growth of the crop when the attack occurs.

High temperatures accompanied by high winds and low humidity have the effect of inducing rust attacks. Thus at Púsa in May 1907, and again in May 1909 we observed that cultures of Einkorn which up to that date had remained immune to rust became covered with uredo-pustules to black rust. The high temperatures experienced in both years at this time lowered the vitality of this very rust-resistant wheat to such an extent that it became as rusty as any ordinary susceptible Indian wheat. Similar results were observed by us at Lyallpur in April 1907 in the case of the European and North American wheats grown there. These wheats were caught by the hot weather of the Punjab in the flowering stage and the first result of the hot winds was to bring out a copious production of uredo-pustules of black rust, although up to this point they remained practically rust free. A similar result was observed in March of the same year when these wheats were grown at Púsa. Mr. A. C. Dobbs is of opinion, that the great rust epidemic in the Chenab Colony in 1907 was directly due to the premature hot weather of March of that year which lowered the vitality of the local wheat crop to such an extent that it became an easy prey to the subsequent rust attack.

In addition to the influence of external conditions on both the wheat plant and the fungus, the inherent rust-resisting capacity of the variety itself has to be considered. While apparently the intercellular spaces of all wheats are invaded by rust mycelium, the resisting power of the protoplasm of the wheat cells varies greatly among the various varieties. Some varieties are easily overcome, others like some types of Einkorn and Emmer are markedly resistant and the invasion of the parasite comes to nothing. Marryat[1] and the writers[2] have recently dealt with this aspect of the question.

If we regard rust attacks from this wider point of view and bear in mind the wheat as well as the fungus and the weather, it will be easy to understand how it is that apparently contradictory causes bring about the same result. It will also be evident that the only way in which we can hope to turn the struggle between the wheat and the rust in favour of the cultivator will be to give him wheats which under the most unfavourable conditions will partly, at any rate, resist the fungus. This is one of the problems with which at the outset those concerned in the improvement of Indian wheat cultivation must grapple.

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1 Marryat, *Jour. of Agr. Science*, Vol. 2, 1907, p. 129.
2 Howard and Howard, *Jour. of Agr. Science*, Vol. 2, 1907, p. 27.

The means of combating rust.

As in other parts of the world, attempts have been made in India to check the ravages of rust by direct means. About the year 1900 the statement was brought to the notice of the Government of India that some of the Australian agriculturists had found that two-year-old wheat seed gave rise to a crop more resistant to rust than that derived from one-year-old seed. Experiments to test this idea were accordingly carried out on the Cawnpore[1] and Nágpur[2] farms. At both of these stations it was found that two-year-old seed germinated so badly that very thin plots resulted. Rust appeared in due course at Cawnpore where it was found that the plants from the older seed were attacked to a similar extent to those from the fresh seed.

The crops resulting from the seed of rusted and healthy plants have also been compared at the Cawnpore[3] and Nágpur[4] farms, but the results were negative in each case. No differences as regards rust-resistance were noted between the two plots. In some cases, however, the rusted seeds germinated very badly and gave rise to poor crops.

Pickling the seeds with copper sulphate solution also gave negative results as far as rust was concerned, a result which was only to be expected. Spraying the growing crop with solutions of copper sulphate and iron sulphate proved useless.

Early sowing, a palliative for rust which has given some success in Australia is, however, a dangerous expedient in India. In many districts wheat cannot be sown with safety till the temperature falls sufficiently to prevent the seedlings being damaged by the heat. Further, very early sown wheat may be destroyed by heavy rains in October, and even when this danger is avoided, early sown crops may be too forward during the cold weather and may be injured by frost.

The only real remedy in combating rust known at present lies in the cultivation of rust-resistant varieties. Several wheats at present in cultivation in India are said to be rust-resistant to some extent, *e.g.*,—*Mundia Pissi*, *Bansi*, and the Nágpur hybrid in the Central Provinces, *Bakshi* in the Western Deccan and *Majhi* in Bengal. But these varieties are by no means immune to rust, and it is necessary to produce in India new varieties by hybridisation which are much more resistant than any of these at

[1] *Report of the Cawnpore Experimental Farm*, 1900-1901.
[2] *Report of the Nágpur Experimental Farm*, 1900-1901 and 1901-1902.
[3] *Report of the Cawnpore Experimental Farm*, 1891-1892.
[4] *Report of the Nágpur Experimental Farm*, 1893-1894 and 1894-1895.

present in cultivation. In this connection a very promising discovery has recently been made in England by Biffen[1] who has produced by crossing, rust-resistant wheats which possess as well all the other desirable qualities. The method adopted consisted in crossing ordinary rust-liable wheats with Einkorn—a variety from the mountainous districts of Eastern Europe which belongs to the spelt group of wheats and which is known botanically as *Triticum monococcum* L. Einkorn has been found to resist rusts to a greater extent than any other cultivated wheat and, when this form is hybridized with other rust-liable wheats, some of the offspring are found to possess the rust-resistance of the spelt-like parent and the good qualities of the other. Work on these lines was commenced by the writers at Púsa in 1905 and since extended to the wheats of the North-West at the Lyallpur Experiment Station.

The rotation of crops on wheat lands in India may be found to be a method of checking the damage done by rust. If, as we suspect, it is eventually found that the wheat rusts in India pass over from one wheat crop to another in a resting condition in the form of uredospores in the soil (in a similar manner to that in which the seeds of *rabi* weeds tide over the hot weather and the monsoon) then the rotation of crops on wheat lands becomes much more important. If the rust spores are in the soil, a change of crop might greatly limit the amount of reinfection.

[1] Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 109.

CHAPTER II.

OTHER FUNGOID DISEASES OF WHEAT.

Smut.

The disease of wheat known as smut is of very minor importance in India at the present time. It is caused by the fungus *Ustilago tritici* (Pers.) Jensen, and makes its appearance as the wheat is flowering. Infected ears are found to be black in colour and to be composed of a loose dusty mass of spores. These spores are usually entirely blown away by harvest time, leaving only the naked stalk where the ear should be.

The disease is propagated by means of spores and the recent investigations of Brefeld & Falck[1] and of Hecke[2] go to show that infection through the flower of the previous generation is the sole method of spreading the disease. These observers have further shown that seed infection, as is common in oat smut, does not occur in wheat. The seed arising from infected flowers gives rise to smutted ears. These discoveries show that disinfection of the seed for wheat smut is useless and that the only remedy is to burn the smutted ears as quickly as possible and to avoid the use of seed from infected fields.

Mildew.

Wheat is sometimes attacked by mildew (a disease caused by the fungus *Erysiphe graminis*) but the damage done is slight.[3]

Bunt.

The disease known as "stinking smut" or "bunt" which is due to two species of fungi of the genus *Tilletia* does not appear to be common in the plains of India. Butler[4] has reported it on wheat in Gilgit, while the writers observed the disease on wheat at Lyallpur in May, 1908, and in samples from Baluchistán in 1909. The best method of prevention is to steep the seed grain in dilute formaline solution (1 pint of formaline to 50 gallons of water) for four hours.

1 Brefeld and Falck, *Untersuchungen aus dem Gesammtgebiete der Mykologie, XIII*, Münster i.W., 1905.

2 Hecke, *Berichte der deutsch bot. Gesellschaft*, XXIII, 1905, p. 248.

3 *Proceedings of the Board of Agriculture in India*, 1906, p. 85.

4 Butler, *Agricultural Journal of India*, Vol. III, 1908, p. 180.

CHAPTER III.

DISEASES CAUSED BY INSECTS.

Several pests attack wheat, but with the exception of the weevils which destroy the stored grain, the insect diseases of wheat are not very serious. The following is the list of wheat pests known at present in India. It is not proposed to go into details of their life-history here. For this information the reader is referred to Lefroy's "Indian Insect Pests" from which the following account is largely taken.

Insects attacking the wheat crop.

The wheat stem borer (*Nonagria uniformis*, Ddgn.). This caterpillar bores out the stem of the wheat giving rise to white, prematurely withered ears which are easily distinguished among the green crop. The chrysalis is found in the wheat stem and the moth is the colour of dry grass. During the hot weather and the rains the pest passes over to *sorghum*, rice and sugar-cane. The small white rounded eggs are laid in clusters on the lower leaves of the wheat near the stem. In Gujarát and Nágpur, considerable damage is done. The best remedy is to collect and burn the wheat straws which are first attacked so as to destroy the caterpillars and thus check the spread of the pest. Prevention is possible if attention is paid to the destruction of the stubble of the previous crop (rice or *sorghum*), from which the pest usually comes over to the wheat crop.

2. The wheat aphis (*Macrosiphum granarium*, Khy.) appears on the young plant, feeds on the young leaves and during the ripening period is often found in large numbers sucking the juices out of the ear. If the weather during January, February and March is favourable to the wheat, little damage results, but if wet and cloudy weather, which gives rise to an unhealthy condition of the crop, occurs at this time of the year, the ravages of this pest are considerable and poor grain is formed. In many cases, especially in the Punjab, the wheat aphis is kept in check by the seven-spotted ladybird (*Cocinella septempunctata*, *L.*). Both the ladybirds and their black larvæ feed on the green fly and immense numbers of these useful insects are frequently seen on the wheat ears in search of their prey. The appearance of these insects in abundance early enough to cheek the wheat aphis is very largely dependent upon the cultivation of an early oil-seed crop (mustard or rape) which provides food for another aphis on

which this beetle is able to breed and multiply and so be sufficiently numerous to cope with the wheat aphis and check it from the start. The aphis is also checked by a Braconid parasite (*Aphidius avenæ*, Hal.) which is an important factor in reducing its numbers.

Experimental wheats could easily be cleared of green fly by spraying with soft soap wash (4 to 8 lbs. of soft soap to 100 gallons of water depending on the hardness of the water). No artificial remedy is practicable in wheat fields.

3. White-ants (*Termites*) often attack young wheat and do considerable damage if the seed bed is too dry and if, owing to the partial failure of the autumn rains, the young crop is not vigorous. The danger from this pest is in general almost entirely confined to the period when the wheat is in the seedling stage. There is far less risk after the plants form their permanent root system and begin to tiller. The seedlings are killed not so much by the destruction of their roots as by the eating through of the first internode, the portion of the stem between the seed and the first node, where the second set of roots are formed and where tillering takes place. Hence the importance of sowing wheat in a moist and well cultivated seed bed where germination takes place rapidly and the dangerous seedling stage is short. When white-ants attack young wheat, it is always noticed that the crop seems to recover after a time. What really happens is that the seedlings which escape, tiller and then grow rapidly past their enemy. After this very little damage occurs unless the moisture in the soil fails and the wheat begins to wither. In this case the white-ants soon complete the destruction of the crop.

Water is the great remedy for this pest in wheat cultivation. Where the sowing and winter rains are favourable or where irrigation water is abundant, the wheat grows rapidly and this pest is of little consequence. In cases where the sowing rains fail, the land, if possible, should be irrigated and cultivated before sowing so as to start the crop as well as possible and further waterings should be given as required.

4. Surface grasshoppers. In years of short moisture grasshoppers of a peculiar type do extensive injury to young wheat; these insects live in the soil and are constantly found feeding on seedling crops; they are themselves the colour of the soil and are found principally in fallow or newly-sown lands. *Chrotogonus trachypterus*, *C. lugubris* and *Epacromia dorsalis* are the common species, widely spread in the plains and constantly reported as injurious. Large areas of land can be freed from them at very small cost by the use of the bamboo frame and cloth bag, described in Lefroy's "Indian Insect Pests" (p. 72).

5. Surface weevils (*Tanymecus indicus*, Log.), flea beetles, and caterpillars sometimes attack wheat in the seedling stage, and eat off the young shoots. Considerable damage may be done if the seed has been sown in a dry seed bed and if the plant is making slow growth. As in the case of white-ants, the preventive seems to be water, preferably in the form of seasonable sowing rains. By this means the wheat speedily grows past all danger and reaches the tillering stage when such pests are negligible. Experimental wheats should always be sown in a previously irrigated seed bed in cases where the sowing rains have failed.

6. The Rice Stem Fly. Young wheat sown after rice at Harnai in the Sibi Agency of Baluchistán in 1909 was somewhat severely attacked by a fly, said to be the rice stem fly. The flies emerge from the old rice stems and lay eggs in the young wheat shoots. The resulting larvæ feed on the sap of the young wheat stems and produce a deformity and weakening of the shoots. The obvious remedy is to give up the growth of wheat after rice in the same year and to cultivate very thoroughly after the rice crop.

It will be seen that none of the insect pests of wheat need be feared if the weather has been favourable to the crop and if the supply of moisture has been abundant. It is only when external conditions have been unfavourable to the wheat and the crop is unhealthy that any of these insects cause appreciable damage. Except in the case of experimental wheats, which have to be protected artificially if necessary, remedies on the large scale are clearly out of the question.

Insects attacking stored wheat.

1. The grain weevil (*Calandra oryzæ*, L.) is the most important pest which attacks stored wheat in India. The eggs are laid just inside the grains in little indentations made by the jaws of the insect. The larvæ eat out the floury part of the wheat and emerge as weevils.

The damage done to stored wheat is considerable especially during and just after the monsoon when the air is very moist. The recent investigations of Cole[1] have shown that moisture is of the greatest importance to the grain weevil and that a non-ventilated atmosphere at about 80° F. charged with water vapour (no matter how poor in oxygen and contaminated with carbon dioxide) provides the most favourable conditions for the life and reproduction of these insects. It appears that the wheat in city godowns

[1] Cole, *Journal of Economic Biology*, 1906.

and at the ports is much more damaged by weevils than that stored by the cultivators in pits or in houses (Punjab and Sind). Grain in sacks is also said to be more liable to attack than grain in large heaps.[1] The storage of wheat in India appears to be a matter well worthy of investigation. It is quite possible that much might be learned and applied on a large scale from a careful study of the methods pursued by the natives in storing grain during the monsoon. Simple means of limiting the damage done by weevils might be discovered.

The loss from this pest chiefly falls on the wheat which is stored for use in India. Except in the Punjab, most of the exported wheat is moved before the rains and thus escapes the weevils. In the Punjab, the greater dryness of the climate during the monsoon seems to result in much less damage by weevils, and the importance of moving the exported wheat at once seems to be not so great as in the wetter parts of India. Of the various wheats grown, the soft varieties are much more damaged than the harder wheats. Such varieties as Emmer and Macaroni wheats are often entirely left alone by the weevils even in so moist a climate as that of Púsa. Possibly the grains are too hard to be easily punctured by the insect for egg-laying. Even if punctured, the young larvæ would have some difficulty in eating out the interior of the hardest wheats during the monsoon.

Small quantities of experimental wheats can be freed from weevils by fumigating with carbon bisulphide. Lefroy recommends a wooden box, the lid of which fits into a groove filled with water which forms an air-tight cover. Any air-tight box, however, will do for fumigating. For this purpose liquid carbon bisulphide is employed at the rate of one fluid ounce per 15 cubic feet for 24 hours. The vapour of the liquid kills all insects including their eggs and is said not to damage the grain. Afterwards the fumes are allowed to evaporate and the wheat is stored in air-tight vessels.

The storage of a large number of wheat samples during the monsoon is one of the difficulties in experimental work with wheat. If possible the samples should be thoroughly dried during the hot weather after harvest and kept in stoppered glass bottles with a little naphthalene or in air-tight uniform cases with calcium chloride. In plant-breeding work, where a large number of ears and small samples of grain have to be kept, we have found uniform cases to be very satisfactory. To absorb the moisture given off continually by the wheat two or three open bottles, half-filled with calcium chloride, should be placed in the cases and changed from time to

1 Cotes, *Notes on Economic Entomology*, No. 1, 1888.

time. Larger quantities can be kept safely in earthen jars (*gharás*) closed down with unglazed saucers and clay or in unbaked clay jars (*kothis*) packed with *nim* leaves and *bhúsa*. None of these vessels should be opened during the monsoon.

Experiments on the treatment of wheat with carbon bisulphide have been carried out at some of the experimental farms in India, *e.g*, at Nágpur[1] and at Khándesh[2]. At the former the results were not very conclusive, but at the latter much benefit was found from the treatment.

A suggestion has recently been made[3] that wheat can be freed from weevils by means of carbonic acid gas. Coles' researches referred to above appear, however, to indicate that moist carbon dioxide is not sufficient to kill the insects and that almost any accumulation of this gas in the atmosphere in which the weevils are living may be disregarded as a preventive agent.

A moth (*Ephestia cautella*, Wlk.) attacks wheat grains in India: the eggs are laid on the grain, the larvæ eating straight into it and feeding within. A considerable amount of webbing is produced, binding the grains together.

A small, rather active beetle larva has been found by the writers attacking stored wheat.[4] It is a cosmopolitan insect (*Trogosita mauritanica*) whose larva eats only the embryo of the wheat leaving the rest, thus destroying the wheat for seed purposes. If infested grain is spread out in the sun, the insects leave it at once. The beetle and its grub are known to feed on other grain-feeding insects and are in some cases beneficial. Other beetles found in wheat are the saw-tooth beetle (*Silvanus surinamensis*), the Red Grain Beetles (*Tribolium ferrugineum* and *T. confusum*), the Grain Dermestid (*Aethriostoma undulata*), and a Bostrichid (*Rhizopertha dominica*). The Grain Dermestid is known to feed on the other insects and is, in Gujarát, sold for the purpose of putting into wheat to check the other insects. Like *Trogosita*, it will, in the absence of other insects, subsist upon the grain.

Wheat is also attacked by small ants and, on the threshing floor, is attacked by a bug (*Aphanus sordidus*) which carries off the grains to feed on at its leisure.

1 *Reports of the Nágpur Experimental Farm*, 1889-1893.
2 *Reports of the Khándesh Experimental Farm*, 1889-1891.
3 *Indian Trade Journal*, January 24th and 31st, 1907.
4 Howard, *Agricultural Journal of India*, Vol. II, 1908, p. 210.

It will be seen that the extent of the damage done by the insects which attack stored wheat is largely a question of storage. Before any remedies can be suggested for use on the large scale, much work remains to be done in investigating the different methods of keeping wheat in India.[1]

[1] *Proceedings of the Board of Agriculture in India*, 1906, p. 37.

CHAPTER IV.

DAMAGE DUE TO OTHER CAUSES.

Besides the diseases due to insects and fungi which have been described above, the wheat crop suffers damage through other causes.

Rain.

Although the sowing rains are of such great importance to the crop, nevertheless excessive rainfall at this period leads to loss. Sometimes, as in Berár (1894 crop) and Bombay (1898 crop) the rainfall may be so high as to curtail the area under wheat by preventing sowings. In the Central Provinces (1886 crop) and in Berár (1895 crop) heavy rain after sowing, made the soil too wet for germination and rotted the seed to such an extent that resowing was necessary. Besides the damage which follows too much rain in January and February, much loss is sometimes suffered through copious precipitation at harvest time. Thus, in Bengal in 1891, the heavy rain, accompanied by hail, which fell between March 6 and 14, just as the harvesting operations had begun, reduced the yield from half to a quarter in Patna, Champáran, Gaya, Muzafferpur, Monghyr and Murshidábád. In the Central Provinces in 1893, the early sown crop was damaged by February rain and sprouted in the ear. In the Punjab in 1901, a fall of rain in May did damage to the grain on the threshing floors and in the same year the crop in Hissár was injured by floods.

Frost.

There are occasional references to the damage done by frost in the crop reports issued by the Agricultural Departments. In the northern parts of Bombay the references are more frequent, while in Bengal they are very rare. In the Punjab and the North-West Frontier Province, where the greatest cold is experienced, the damage done by frost is not very considerable. This is due to the later time of sowing (November and December) and to the fact that the wheat does not generally come into ear until the coldest weather is over.

In 1905, however, the whole of the wheat-growing area in India was severely affected by frost at the end of January and the beginning of February. In the Punjab the crop was checked everywhere, while palpable damage was done to all early sown and advanced crops, especially in the south-eastern Districts. In the United Provinces, the loss was greatest in the centre and south where the harvest is earlier. In Bombay the des-

truction was greatest in Sind, Gujarát and parts of the Deccan. The northern Districts of the Central Provinces (Saugor especially) and the wheat-growing Districts of Upper Bengal also suffered loss.

HAIL.

Hail storms are responsible for damage in all the chief wheat-growing Provinces. These falls usually take place while the wheat is ripening or during the harvesting operations. The storms appear to be most violent and to cause the greatest damage in the North-West Frontier Province and in the Indo-Gangetic plain (Punjab, United Provinces and Bengal), the great wheat-growing tracts. They occur, however, occasionally in Khándesh and in parts of the Central Provinces and Berár.

WIND.

Hot winds just before harvest sometimes dry up the crop and lead to shrivelling of the seed in the Punjab and the western parts of the United Provinces where the crop ripens later than in the rest of the Province. Dry winds similarly affect the yield in Sind, and sometimes in the Bombay Presidency (Carnatic and Khándesh). Occasionally high winds accompanied by rain during the ripening period bring about laying of the crop.

VERMIN.

In Bombay, the Central Provinces and Berár and also in the United Provinces, field rats sometimes invade the ripening wheat and do considerable damage. Thus, in 1892, in Berár, rats destroyed in some localities almost the whole crop of a field in a single night. Ten years later in Gujarát the crop was almost entirely ruined by a very severe plague of rats which overran both the British Districts and the Native States. The history of the rat plague in Bombay is summed up by Lawrence in the *Statistical Atlas of the Bombay Presidency* published in 1906.

EELWORMS.

The well-known disease of wheat known as Ear cockle[1] which is caused by Eelworms (probably of the genus *Tylenchus*) we have found to be exceedingly common in Baluchistán, the Punjab and the United Provinces and has been known for many years under the name *sehwan*.[2] Instead of producing seed, affected flowers develop into small dark coloured galls which are filled with Eelworms. Good cultivation and early ploughing appear to be all that is necessary to reduce the damage done by this pest. Attention has recently been drawn to this disease by Milne.[3]

1 Ritzema Bos, *Agricultural Zoology*, 2nd Ed., 1900.
2 Duthie and Fuller, *Field and Garden Crops of the North-West Provinces and Oudh*, 1882.
3 *Agricultural Journal of India*, Vol. III, 1908, p. 292.

SECTION III.

THE IMPROVEMENT OF INDIAN WHEAT.

A. General and Historical.

B. Recent Investigations.

THE IMPROVEMENT OF INDIAN WHEAT.

A. General and Historical.

CHAPTER I.

THE INTRODUCTION OF EXOTICS.

In the records dealing with wheat improvement in India references to the trials of exotic kinds are frequent. Various Canadian, American, English and Australian varieties (including Farrer's hybrids) have been grown, as well as isolated samples from Palestine, Mexico and Russia.

Australian Varieties.

A great deal of attention has been paid to the introduction into India of Australian varieties. The most important work in this direction was a careful trial of Farrer's hybrids extending over several years, which was made in all parts of India.

The great success obtained by Farrer in Australia in the production of rust-resistant hybrids led him to hope that the introduction into India of hybrids between good rust-resistant wheats, such as Canadian Fife and Indian varieties, might be equally successful. Accordingly, from 1896 to 1901, a large number of cross-bred wheats were sent to the Government of India for trial and were distributed to the Cawnpore and Nágpur Farms and to the Lahore Botanical Gardens.

Almost without exception the results were disappointing. It was found that the varieties which resisted rust successfully in Australia were attacked to a greater extent in India than the indigenous kinds and also ripened too late for Indian conditions. Another disadvantage was due to the fact that most of the hybrids sent out were not fixed but continued to split and give rise to very various forms.

The reports from the Cawnpore and Nágpur Farms[1] were unfavourable, and none of the wheats were found suitable for introduction into general cultivation. In the Cawnpore Farm report of 1900-01 it is stated that "for rust-resisting quality, for hardiness and prolificness Muzaffarnagar wheat has been equalled by few and surpassed by none."

A small amount of success was obtained in the Punjab. From 1898-99 onwards the New South Wales cross-breds were tried at Lahore and a certain number which proved to be fixed, free from rust and also prolific, were

[1] *Report of the Nágpur Farm*, 1896-97, and following years.

selected for further experiment at the Lyallpur Farm. Some of these varieties were in 1901 distributed to various Districts in the Punjab.[1] Of the various Australian varieties grown in the Province, No. 27[2] was considered to be the most promising and has been distributed to cultivators in the Chenáb Colony. In milling and baking characters, however, this wheat is notably defective.[3]

On the whole, the experiments showed conclusively that the hope of introducing a rust-resistant wheat from abroad must be given up, and that the introduction of the Australian methods of wheat improvement must be aimed at rather than the introduction of Australian wheats. The realization of this led to the deputation of Mr. W. H. Moreland to Australia to study Farrer's methods.

Besides the trial of Farrer's cross-breds, various attempts have been made at different times to introduce well-known Australian varieties. In the United Provinces several Austrailan wheats were tried at the Cawnpore Farm[4] between 1877-78 and 1884-85, but the results were uniformly unsuccessful as the varieties were too late for the district and were dried up by the hot winds before ripening took place. Similar results were obtained at the Lucknow Botanical Gardens[5] between 1886-87 and 1890-91.

Trials of Australian wheats have also been made in the Punjab—firstly, at the Lahore Botanical Gardens[6] and afterwards in various Districts and at the Lyallpur Farm.[7] Thus in 1893-94 and in the following season Purple Straw, White Tuscan and Trampton were grown at Lahore. All these varieties were found to be entirely unsuited to the country. Various varieties from South Australia were grown at Lahore in 1899-1900 and in subsequent years. Many of them were, however, attacked by rust and their culture was discontinued.

In the older Bombay records mention is made of the trial of Adelaide wheat at the Khándesh Farm[8] in 1884-85, and in 1885-86 Purple Straw,

[1] *Report of the Department of Land Records and Agriculture, Punjab*, 1901.
[2] *Proceedings of the Board of Agriculture in India*, 1906, page 68.
[3] Howard and Howard, *Bull.* 14, *Imperial Department of Agriculture in India*, Calcutta, 1908.
[4] *Report of the Cawnpore Farm*, 1877-78 and following years.
[5] *Report of the Lucknow Botanical Gardens*, 1886-87 and 1890-91.
[6] *Report of the Government Agri-Horticultural Gardens, Lahore*, 1893-94 and following years.
[7] *Reports of the Lyallpur Farm.*
[8] *Report of the Khándesh Farm*, 1884-85 and 1885-86.

Ashly's Prolific, Tuscan and White Essex were grown both dry and irrigated. In all cases the result was a complete failure. At the Hyderábád Farm[1] in 1885-86 the four Australian varieties referred to above were also tried, but were found to be later than the Sind and Bombay sorts and to give a poor yield. The trials were continued at this farm with varying results up to 1888-89, and in all cases these wheats were found to be too late for the country. None of the varieties of Australian wheats grown at Poona have been adopted in the Bombay Presidency.[2]

In 1885, Australian wheat was tried in Goalpur, the only district in Assam[3] where wheat is grown, but the crop withered away for want of rain.

In Bengal at the Dumraon Farm[4] Australian wheats were tried from 1895-96 onwards. It was found that none of the varieties were equal to Muzaffarnagar white either in yield or rust-resistance.

English Varieties.

During the season of 1886-87 trials of English Pedigree wheats[5] supplied by Messrs. Oakshott & Co., of Reading, were made in Madras, the Punjab, Bombay, United Provinces and also in the Central Provinces. In most cases the samples did not germinate and where, as in the Nílgiris and in the United Provinces, any growth was produced, only a few shrivelled ears containing no grain were formed. The experiment was a total failure and showed that ordinary English wheats will not mature sufficiently rapidly under Indian conditions.

In the records of the Cawnpore Farm[6] there are several references to the trial of English wheats. Thus, in 1879-80 Trump, Rough Chaff and Champion White were grown, but the plots remained green at harvest time and were dried up by the hot winds. Rough Chaff and Red Bearded failed in 1881-82, and failures are again reported in 1882-83 and between the years 1887-88 and 1890-91. Red Nursery tried in 1889-90 did not thrive.

At the Nágpur Farm,[7] the English varieties—Buff Talavera, White Foster and Short Essex—were total failures.

[1] *Report of the Hyderábád Farm*, 1885-86 and 1888-89.
[2] *Proceedings of the Board of Agriculture in India*, 1906, page 40.
[3] *Report of the Agricultural Department, Assam*, 1885-86.
[4] *Dumraon Farm Reports*, 1895-96 and following years.
[5] *Proceedings of the Revenue and Agriculture Department of the Government of India*, No. 516, July 1886, Agriculture, and Nos. 23 to 28, October 1887, Agriculture.
[6] *Report of the Cawnpur Farm*, 1879-80 to 1890-91.
[7] *Report of the Nágpur Farm*, 1877-78 to 1879-80.

Egyptian and Palestine Wheat.

A variety known as the Golden Grain of Palestine—apparently a macaroni wheat—has been tested at the Saharánpur Botanical Gardens[1] at Lahore[2] and also in various Districts of the Punjab.[3] It was said to closely resemble the wheat known to the Punjab cultivators as *Pamman* or *Wadának*. The results of the trials on the whole were fair and showed that this wheat would thrive under Indian conditions. There is nothing in the records, however, to show that it was any better than the country macaroni wheats of the Punjab.

Egyptian[4] varieties were tried in 1898-99 in the Almorá District and did well.

North American Wheats.

There have been several trials in the United Provinces of wheats from the North American Continent. At Cawnpore in 1879-80, the American varieties—Fultz, New Defiance and Clawson—were grown, but were green at harvest time and were dried up by the hot winds. A so-called rust-proof American wheat was grown from 1895 to 1902 and gave a fair yield but did not prove to be rust-resistant. Fultz and Velvet Chaff tried at Saharánpur in 1891 are said to have given high yields of poor grain. Various Canadian varieties—Ladoga, Red Fern, Judket, Red Fife, White Fife and Saponka were tried at Cawnpore,[5] Meerut,[6] Lucknow[7] and Saharánpur[8] from 1890 to 1893. At Cawnpore, Ladoga did best, but all the sorts were late, and required twice the amount of water to that given to the Indian wheats and all gave very poor yields. At Saharánpur, the results were similar, but on the whole better than at Cawnpore. At Lucknow, they proved too late for the district and gave a very poor outturn. At Meerut it is stated that Red Fife did best.

Three Canadian wheats—White Fife, Saxonka and Safonky—were grown at the Lahore Botanical Gardens[9] from 1890-91 to 1893-94, but proved to be useless.

[1] *Report of the Saharánpur Botanical Gardens*, 1889, and following years.
[2] *Report of the Lahore Botanical Gardens*, 1887-88 to 1902-03.
[3] *Report of the Department of Land Records and Agriculture, Punjab*, 1894-95 to 1899-1900.
[4] *Report on the Operations of the Department of Land Records and Agriculture, North-West Provinces and Oudh, for the year ending 30th September* 1899, Allahábád, 1900.
[5] *Report of the Cawnpore Farm*, 1890-91 to 1892-93.
[6] *Report of the Meerut Farm*, 1890-91 and 1891-92.
[7] *Report of the Lucknow Botanical Gardens*, 1890-91.
[8] *Report of the Saharánpur Botanical Gardens*, 1891.
[9] *Report of the Lahore Botanical Gardens*, 1890-91 to 1893-94.

In the trial of a Mexican wheat sent from Kew to Saharánpur[1] in 1887 it is stated that the samples of this wheat sent to the Commissioner of Kumaun and to Arnigadh failed to germinate, while that sown at the Saharánpur Botanical Gardens gave rise to "*a few plants, the majority of which were local varieties, the seeds of which must have got into the ground through the agency of the manure.*"

It will be seen that the introduction of exotic wheats into India has been a long record of failure. This general result has been partly due to the fact that the introduced varieties are too late for India, and, either do not form ears at all or are dried up by the hot winds, and partly to rust attacks. Curiously enough little or no attempt seems to have been made to try in India the only class of wheats likely to be of value, namely, rapidly maturing varieties from localities where the conditions are to some extent like those in India. Mediterranean, South Russian and possibly wheats from Persia and China might succeed as well as very early Australian kinds.

[1] *Report of the Saharánpur Botanical Gardens*, 1887-88.

CHAPTER II.

SEED DISTRIBUTION.

THE extension of the cultivation of Indian varieties of wheat and their introduction into new localities have yielded results of some value, which stand out in strong contrast to the failure of the imported kinds. The results in this direction are not only important in themselves but also serve to indicate the direction in which still better results are likely to be obtained in the future. We do not yet know with anything approaching precision the value of the wheats indigenous to India for the simple reason that but few of these have as yet been isolated in pure culture and grown on a sufficient scale for their agricultural and milling qualities to be determined. From the results obtained by us at Púsa and in the Punjab[1] it has been shown that there are wheats now in India very much more valuable both for local use and export than any of the soft white sorts like Muzaffarnagar and the *Desí Pissí* of the Narbadá Valley or Buxar soft white which have been so much recommended to the notice of cultivators.

Extensive trials of wheat from the United Provinces (apparently Muzaffarnagar white) have been made in the Northern and Southern Shan States in Burma for the purpose of providing food for the troops. At Lashio[2] in the Northern Shan States the experiments made in 1891-92 and 1892-93 were a total failure as the soil was too light for wheat and the rainfall in October, November and December not sufficiently abundant. In the Southern Shan States,[3] through the energy and perseverance of Hildebrand, the experiments were successful and a supply of good wheat was obtained for the army. After seven years' experiments it was found possible to make over the industry to the people and wheat became a recognised crop in the country. The cost of transport to Rangoon, however, and the fact that the Burmese do not consume wheat, limited the cultivation to the wants of the troops, and made a successful export trade impossible. One of the difficulties encountered in the work was the trouble in keeping a supply of seed

[1] Howard and Howard, l. c.
[2] *Report of the Experiment Farm at Lashio*, 1891-92 and 1892-93.
[3] *Report of the Experimental Cultivation in the Southern Shan States*, 1893-94 to 1898-99.

wheat through the rains on account of the damp and the damage done by weevils. An interesting result of the trials was the discovery of the fact that the seed obtained from the United Provinces proved much better than the local wheats then in cultivation in Burma.

The soft white wheat of the Central Provinces known as *Pissí* has been tried in other parts of India. In 1891, *Pissí* from Nágpur was tried at Káthiáwár[1] on black cotton soil and was found to give a fair yield and to mature earlier than the local variety. In Madras, *Pissí* or Seoni wheat was tried in the Kollimalai Hills[2] from 1889-90 to 1891-92. The result was a failure, due, it is said, to unfavourable seasons.

Between the years 1886-87 and 1893-94 the soft white wheat of Buxar was distributed to all the districts of Bengal and a very large number of trials were made. The results are referred to in the reports of the Department of Land Records and Agriculture of Bengal during this period and are summed up in a paper entitled *Notes on the results of Buxar wheat cultivation in Bengal from 1886-87 to 1893-94* published by the Bengal Agricultural Department. In about 30 per cent. of the experiments, the results appeared to have either been successful or to have been encouraging; the rest were unsatisfactory. A good deal of this Buxar wheat was distributed from the Dumraon Farm during this period, and in 1886-87 it was tried at Cawnpore and found to be very free from rust and to be about ten days earlier than Muzaffarnagar white—a point of some importance in localities where the hot winds are liable to set in early. At Cawnpore, however, it was found to be liable to damage by frost.

The most important example of the successful distribution of an indigenous wheat is that of Muzaffarnagar white. In Bombay this variety gave remarkably fine yields at the Khándesh Farm[3] in 1890-91. In Sind,[4] promising results were at first obtained in the Thar and Párkar District and also in the Nára Valley. It was found, however, that this variety was less resistant to cold than the Sind wheats and also more liable to the attacks of weevils. The trials appear to have been discontinued as the introduced variety compared on the whole unfavourably with the indigenous kinds. In the Punjab this wheat grows well at Lyallpur and has been distributed to the cultivators, and in Bengal extensive trials have been made in

[1] *Report of the Department of Land Records and Agriculture, Bombay*, 1891-92.
[2] *Proceedings of the Department of Revenue and Agriculture of the Government of India*, 1892.
[3] *Report of the Khándesh Farm*, 1890-91.
[4] *Report of the Department of Land Records and Agriculture, Bombay*, 1889-90 to 1895-96.

Bihár. At the Dumraon Farm[1] in 1885 and subsequent years, Muzaffarnagar white gave a much heavier return than the local kinds or the other Indian and Australian wheats grown at this station. It was distributed to the ryots of the Dumraon Raj, with the result that it was taken up by the cultivators and largely grown. Further attempts to introduce this wheat into the other wheat-growing districts of Bengal were not so successful. In 1905, 50 maunds were distributed by the Bengal Agricultural Department[2] to all the principal wheat-growing Districts of the Province, but the results were on the whole disappointing.

It is in the United Provinces themselves that the best results have been obtained with this variety. In the early Reports of the Department of Land Records and Agriculture[3] of these Provinces (then called the North-West Provinces) references are to be found to the distribution of Muzaffarnagar white wheat for the purpose of stimulating the cultivation of wheat for export to Europe. The work was gradually developed and a system of seed distribution by the Agricultural Department was evolved which has been, thanks to the efforts of Moreland and Hadi, a great success and has led to similar work being undertaken in other Provinces. The development of the system of seed depôts is to be traced in the annual reports of the Department of Land Records and Agriculture. In the report of 1906, Moreland states:—"Apart from the benefits which the depôts have conferred on the people by the provision of pure and sound seed at reasonable rates, the chief result of their organization has been the introduction of Muzaffarnagar wheat into considerable parts of South Oudh where the local strains of wheat are inferior both in productivity and in quality. During the past year arrangements were made with certain cultivators to sow part of a field with the imported wheat and the rest with the local strain under similar conditions, the whole field being tilled and irrigated as a unit and the only difference between the two portions lying in the kind of seed. Measured parts of the fields were then harvested by experienced members of my staff and the outturns carefully determined. It seems worth while to give the results in some detail. The outturns were as follows.

[1] *Report of the Department of Land Records and Agriculture, Bengal*, and also *Reports of the Dumraon Farm*, 1889-90, and following years.

[2] *Report of the Department of Land Records and Agriculture, Bengal*, 1905-06.

[3] *Reports of the Department of Land Records and Agriculture, North-West Provinces and Oudh*, 1883, and onwards

No. of experiment.	Outturn in lbs. per acre.		Excess of Muzaffarnagar wheat.	Value of excess at 16 seers per Rupee.
	Muzaffarnagar wheat.	Local.		
I. Grain.				Rs. a.
1	1,020	700	320	9 12
2	860	840	20	0 10
3	1,500	1,200	300	9 6
4	1,220	1,700	150	4 9
5	2,050	1,460	590	18 0
6	1,200	848	352	10 12
7	1,024	768	256	7 13
		Average	284	8 11
II. Fodder. (*Bhúsa.*)				(at 3 mds. per rupee.) Rs. a.
1	1,140	980	160	0 10
2	1,940	1,580	360	1 7
3	2,400	2,060	340	1 6
4	2,130	1,960	170	0 11
5	3,300	2,260	1,040	4 3
6	1,904	1,328	576	2 5
7	3,136	2,880	256	1 0
		Average	414	1 7

The average increase per acre in the seven experiments is grain valued at Rs. 8-11-0 and *bhúsa* valued at Re. 1-7-0, or over Rs. 10 in all.

In the lowest case (No. 2) the increase was over Rs. 2 per acre; in No. 4 it was Rs. 5-4-0, in the remainder it was well over Rs. 8. Added to this, it has to be remembered that the Muzaffarnagar wheat fetches a higher price than the local varieties; the difference is usually one seer in the rupee which at normal rates is from two to three annas a maund, and from two to three

rupees on a normal outturn. These results are in agreement with those obtained in previous seasons, and after making every conceivable allowance I think it must be concluded that these cultivators would, in an ordinary year, clear at least eight rupees an acre, and considerably more in years of high prices. In other words, the extra value of the new crop would more than cover the rent of their land. Oudh grows about two million acres of wheat, so that an improvement producing only an extra rupee per acre would be worth 20 lakhs a year to the country.

My object in giving these figures in this detail is to bring out the vast possibilities of operations of this kind. I have no doubt that what has been proved to be possible for wheat in Oudh is also possible for many other crops in other parts of the Provinces; some of them are less valuable, but others such as sugarcane are more valuable than wheat, and an increased net yield of a rupee an acre on the whole cropped area of the Provinces would pay two-thirds of the land-revenue. The rate of progress in this direction depends of course on the supply of expert officers, as prolonged series of experiments are necessary in each case before confident recommendations are possible."

The mode of working of the Oudh seed depôts is described in a paper by Moreland[1] and should be read by all interested in the subject in India. Seed is distributed to groups of cultivators (so as to avoid a large number of petty accounts) who after harvest replace the seed at 25 per cent. interest, that is to say, a cultivator who takes a maund of seed undertakes to repay 50 seers of its produce after harvest. It is hoped to convert the groups of cultivators into co-operative societies and to assist them with seed from time to time. In this way the people will be taught to help themselves and take up on their own account the distribution of seeds. Similar depôts to these now being conducted by the Agricultural Department are being established by the District Boards. One of the reasons for the establishment of these depôts in Oudh was the inability of the cultivators through poverty to carry an adequate stock of good seed from harvest till the following seed time. At harvest time, the whole crop of wheat is handed to the grain dealer and at seed time the cultivators go to him for the loan of the necessary seed. Inferior wheat is often given for this purpose with the result that in the course of time the Oudh wheats are said to have greatly deteriorated.

The method of storage of seed in the godowns at the seed depôts is described by Hadi[2] as follows:—"Seed-grains may be stored either in pits (under ground) or in chambers (over ground) in a building (two-storied

[1] Moreland, *Agricultural Journal of India*, Vol. II, 1907, page 217.
[2] Moreland, l. c.

preferable) having but one entrance to the north or south. The most suitable shape for the pits or chambers is oblong, the dimensions, of course, depending on the amount of grain which has to be stored. The pits or chambers should be perfectly dry to begin with. The walls and the floor thereof should then be well coated with coal tar and allowed to dry. Before storing the seed, about half an ounce of sulphur should be burnt in each chamber and the door of the building should be closed while the sulphur is burning. Leaves of 'Mahua' (*Bassia latifolia*) and 'Nim' (*Melia indica*) should be collected beforehand and dried. A layer of Mahua leaves about 6 inches thick should first be spread on the floor and over this a thinner layer of Nim leaves. On the latter should be spread a six-inch layer of *bhúsa* (the common wheat or barley straw). The grain should be *thoroughly* dried in the sun before storage and should be packed in bags in the *hot sun of June* (which is the best time for storing *rabi* seeds). Before the bags are stitched after being filled, two or three one-inch bits of naphthaline should be put in each bag. The bags should now be removed from the sun to the chamber and placed on the layers mentioned above. The upper surface of the bags should then be covered with a two-inch layer of *bhúsa*, and on this layer should be placed a fresh layer of bags and so on till the chamber is full. A space of about one foot should be left all around the chamber inside to be closely filled with *bhúsa* as each layer of bags is placed in it. The chamber should in this way be filled up to the top when a thick layer of *bhúsa* should be spread and covered with a piece of *tat* or some sort of matting. In the rainy season the bags should be examined once a fortnight with an instrument well known to grain-dealers. It is called *parkhi* and is similar to the instrument used in Europe for examining cheese. Should any traces of an attack of weevils be found in any bag, the latter should be removed from the granary at once. The use of naphthaline minimizes injuries from the common granary pests but renders the seed unfit for eating purposes owing to the disagreeable odour which it imparts to the grain. It may be added to the foregoing account that losses from weevils have on the whole been trifling."

In the Punjab,[1] there are two seed farms for wheat distribution—at Lyallpur and Sargodha—and in Bengal a system of seed depôts on the lines of those in the United Provinces has recently been established.[2]

Enough has been said to show that much valuable work can be done by the provision of seed depôts, but it is clear that the subject is, as yet, only in its infancy. As soon as improved varieties of wheat have been thoroughly

[1] *Reports of the Department of Agriculture, Punjab.*
[2] Smith, *Agr. Jour. of India*, Vol. III, 1908, p. 283.

tested at the experiment stations, it will be necessary to multiply them rapidly on seed farms so as to supply the depôts with seed. The provision of a few well-conducted seed farms in the various wheat tracts of India would do much to extend the cultivation of superior varieties and thereby raise the quality of Indian wheat both for home consumption and also for the export trade.

CHAPTER III.

THE PRODUCTION OF NEW VARIETIES.

New and improved varieties may be obtained in two ways:—

(*a*) By selection.
(*b*) By hybridization.

The production of new varieties by selection.

Of the means by which the wheat crop in India can be immediately improved the method of selection is likely to be the most valuable. During recent years considerable attention has been paid both to the fundamental principles involved in selection and also to the methods themselves. A brief general explanation of the subject is attempted in the following paragraphs.

The origin of species and varieties. At the present day two ideas of the mode in which species and varieties originate hold the field—the older one is associated with Darwin,[1] the newer one with De Vries.[2] Darwin considered that species and varieties have arisen by means of natural selection. He showed that the individuals of a species differ from one another to some extent and that many of these differences increase or decrease their chances of survival. In the struggle for existence between these individuals the fittest survive, the unfit perish. In the process it is easy to understand that the result of this struggle would leave the mean of the species changed to some slight degree. If the variation is continuous and if the process went on for millions of years, more and more change might take place often to such an extent that a new species or variety would be produced. Of late, the sufficiency of Darwin's explanation of the origin of species and varieties has been called in question among others by De Vries who has advanced the idea that new species and varieties arise by sudden changes,—mutations or sports—and he has brought forward a considerable body of evidence, some of which is experimental, in favour of his views.

Fluctuating variability. The extent to which variation takes place in wheat has been studied by Hays[3] who found that in characters such as yield, which can be expressed numerically, the variation follows what is

[1] Darwin, *The Origin of Species*, 1859.
[2] De Vries, *Die Mutations-theorie*, Leipzig, 1901.
[3] Hays, *Bull. 29, U. S. Dept. of Agr., Div. Veg. Phy. and Path.*, 1901. In this Bulletin Hays gives a good account of fluctuating variability.

known as Quetelet's law of variability. Quetelet showed that variation follows a definite rule. He found in measurements of parts of the human body that the numbers agree with the law of probability and further that variation is limited. An example will make this law of fluctuating variability, clear. If 1,000 men of the same race are placed in a row and arranged in order of height, it will be found (1) that the man in the middle represents the average height of all the men, (2) that a line drawn over their heads will deviate from the horizontal but slightly throughout nearly its entire length falling slightly towards the end where the shorter men stand, (3) that near the upper end the line will rapidly curve upward and that near the lower end the curve will rapidly curve downward. Fig. 1 is the graphic repre-

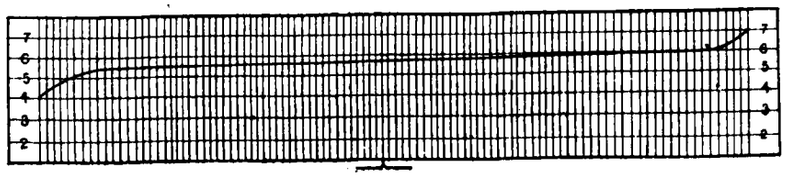

Fig. 1.—Graphic expression of Quetelet's Law. (After Hays.)

sentation of these facts. Hays shows that if the yield of plants of wheat varieties are arranged in order of weight, similar curves to the above are obtained. (Fig. 2.)

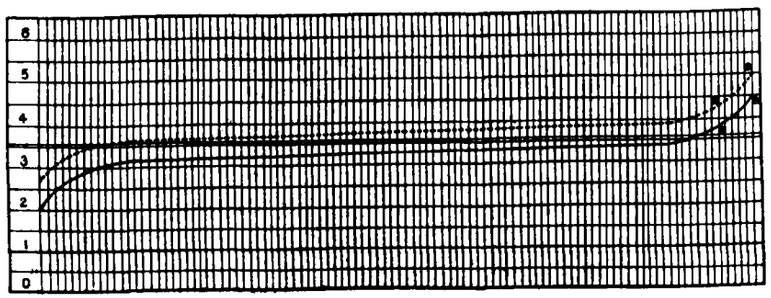

Fig. 2.—Yields, in grams, of 100 Blue Stem and 100 Fife wheat plants compared, the broken line representing the former and the solid line the latter. The mean yield is indicated by the double horizontal line. (After Hays.)

The Constitution of a Wheat Field. An examination of an ordinary wheat field in India at harvest time discloses the fact that the crop consists of a mixture of botanically different varieties sometimes belonging to two or three sub-species. These botanical varieties can be readily distinguished

from each other by an examination of the ripe ears. The variety represents the lowest limit to which wheats can be divided in the laboratory with precision and is, as it were, the botanical unit of the species or sub-species. Each variety, however, may comprise several agriculturally distinct types. Such types while botanically identical differ in field characters, such as length and strength of straw, earliness or lateness, tone of colour of chaff and straw, erectness of the ear and susceptibility to rust. These differences between types can only be readily distinguished in the field in plots grown side by side. The types are the agricultural units of the variety in a similar manner as the varieties are the botanical units of the species or sub-species.

The type itself, however, is formed of an assemblage of individuals which may differ from each other to a very slight extent. Such an assemblage of individuals is termed a population and forms the raw material as it were of the selectionist. If individual plants of this population are selected and grown separately, their progenies are termed pure lines. The individuals of a pure line exhibit variation about a mean value in accordance with Quetelet's law and Johannsen[1] considers that selection within a pure line leads to no permanent improvement. The mean value of any particular character such as yield may differ, however, in the various pure lines composing the population, and it is on these differences that the possibility of any improvement by selection depends.

The methods of selection.[2] The earlier attempts to improve the wheat crop consisted in the continued selection of a number of the best grains, ears, or plants. Such methods have been described as mass selection. Of these, the selection of the best plants marks a great advance on the selection of grain or ears as it is only by selecting plants that individuals possessing the most desirable characters for cultivation can be isolated. Large grains and large ears are often to be found on poor plants. These older methods of mass selection were really attempts to hasten the process of natural selection by propagating the race from the very best individuals and excluding all the rest. They were based entirely on Darwin's conception of the origin of species, and it was hoped that, by the continued selection of a number of *élite* plants, whether obtained from grains, ears or plants, the race would gradually be improved.

The question soon arose as to whether by mass selection any permanent improvement could take place. It was often found that the quality of

[1] Johannsen, *Ueber Erblichkeit in Populationen und in reinen Linien*, Jena, 1903.

[2] A discussion on the methods of selection will be found in the following: Fruwirth, *Die Zuchtung der land. Kulturpflanzen*, Bd. 1, 1909, and *Zeitschr. f. d. land. Versuchswesen in Oesterreich*, 1907.

the improved races was not maintained in practice but rapidly reverted when the process of selection stopped. De Vries[1] maintains that no permanent improvement is obtained by mass selection. Fruwirth,[2] on the other hand, considers that while mass selection is uncertain, nevertheless some permanent improvement may take place when the process results in the separation of a few of the best pure lines as seems to have been accomplished by Hallett.

The modern methods of selection are based on the isolation of single plants and a comparison of their progeny in succeeding generations. It is to the work of Hays and Nilsson that these methods are largely due. In the early part of the 19th century, Le Couteur[3] in Jersey with the help of La Gasca of Madrid, first developed the idea of the improvement of wheat by selection from single plants. La Gasca pointed out that Le Couteur's wheat cultures were not pure but were a mixture of many forms. The Jersey improver then separated out the constituents by growing single ears and single plants and multiplied and tested the progeny. In this way, new and inproved varieties were produced, some of which remain in use to the present day. Later Shireff in 1879 in Scotland independently used the same principle. He found, in some of his wheat fields, plants which appeared to be better and different from the rest. These he propagated separately and with great care. Some new and improved forms were the result which rapidly spread in Scotland. These methods of Le Couteur and Shireff, however, were forgotten and the discovery of the principles underlying them was rendered impossible by the rise of the ideas of the origin of species by natural selection associated with the work of Darwin. It was not till the ideas of De Vries on the origin of species and varieties by mutation gained ground and until the work of Nilsson at Svalöf and Johannsen in Denmark was appreciated that the significance of Le Couteur's and Shireff's work became apparent.

Nilsson[4] at Svalöf, after subjecting the older methods of mass selection to an exhaustive critical examination, adopted the method of single plant selection which had previously been used by Le Couteur and Shireff. The Svalöf methods of single plant selection were immediately successful and many useful races were introduced into general cultivation.

Hays' method consisted in the selection of individual plants (which were grown separately) and a comparison of their offspring. Further selec-

[1] De Vries, *Plant Breeding*, 1907.
[2] Fruwirth, l. c.
[3] Le Couteur, *On the varieties, properties and classification of wheat*, Jersey, 1872.
[4] Holtmeier-Schomberg, *Landwirtschaftliche Jahrbücher*, Bd. XXXVII, 1908.

tion was made among the progeny of single plants and the process was continued. If Johannsen's views are accepted that selection in a pure line leads to no result, Hays' second and subsequent selections would not produce any further improvement. The point emphasised by Hays that it is necessary to select a large number of plants in the first instance and to consider their progeny is an important one, for it is always possible that the selected plant is merely a high variant in a line of low mean value.

It is now necessary to explain in greater detail the possible ways of obtaining improved wheats by the method of selection :—

1. *Form separation* or the resolution of a variety or mixture of varieties into the constituent agricultural types. This enables one to obtain wheats of definite and uniform agricultural and grain characters in place of a fluctuating mixture.

2. *Selection of so-called spontaneous variations or mutations*[1] which, however, only rarely occur. In pure cultures and in mixed fields wheat plants are sometimes found quite different from the rest. On multiplication these new forms sometimes breed true. It is probable that some of the new wheats found by Shireff were of this character. New wheats also arise in nature in another way, namely, as the result of natural cross-fertilization. It is not always possible therefore to say whether forms which arise from so-called spontaneous variations have been produced by mutation or by natural cross-fertilization. Undoubted mutation in wheat can only be proved in pure line cultures in which contamination and natural cross-fertilization is impossible. We have so far found no records of mutation in such cultures.

The methods adopted at Svalöf consist mainly in the isolation and testing of types obtained by form separation and mutation. When such wheats are better than existing sorts, they are issued to the farmers.

3. *Separation of pure lines*, that is, the selection of plants botanically similar but differing very slightly in field and physiological characters. This is the method of selection adopted by Hays[2] in America and by Fruwirth,[3], [4] in Germany. It is necessary to start with a fairly large number of single plants and to study the progeny of these when grown separately. If, as seems probable, physiological mutations occur independently of morpho-

[1] Farrer, *Agr. Gas. of N. S. Wales*, 1898. In this paper some evidence is to be found that mutation may occur in wheat, but it cannot be considered as altogether convincing.
[2] Hays, l. c.
[3] Fruwirth, *Zeit. f. d. land. Versuchswesens in Oesterreich*, 1907.
[4] Fruwirth, *Die Zuchtung*, Bd. I, 1905.

logical mutations, this method may easily give rise to results of the greatest importance. A good account of this aspect of the question has just been published by Von Römer[1] of Jena.

The improvement of wheats by selection in India. In considering the attempts which have, till recently, been made in India to improve the wheat crop by selection, it must be borne in mind that at the time the work was done, the modern methods of selection were not generally understood even in Europe.

At the Cawnpore Farm in 1880 and 1881 experiments were made in mass selection of wheat seeds. Selected and non-selected samples were grown side by side with and without irrigation. In all cases the selected seed gave the best result, due no doubt to the greater chance of success of well-nourished seedlings over the produce of a sample containing small and shrivelled seed. An attempt to raise pedigree seed was made in 1901, but the subject is not mentioned in succeeding reports.

At Nágpur an attempt was made in 1887 to produce pedigree *Haura* wheat after Hallett's method, and in 1891 this pedigree seed was tested against the ordinary sample. The ordinary sample gave the highest yield on manured plots, while on one of the plots not manured the results were reversed. The results of the succeeding years were equally inconclusive. In 1894 and again in 1901, selected and unselected seeds were compared. The selected seed was a sample obtained by removing all small and shrivelled seed. As a rule, the selected seed gave the best result.

During the years 1903 to 1905 a somewhat different set of selection experiments was carried out at the Poona Farm. The produce of large and small ears was compared and also the progeny of large and small seeds from the same ear.[2]

None of these methods tried in India have yielded any permanent improvement in the variety and, from what has been said above, are not likely to be of any use if tried in the future.

In 1906, both at Púsa and Lyallpur, we commenced a system of selection from single plants which is being continued. The results of the work on the Punjab wheats at Lyallpur has already been published. In both cases the separation of forms and of pure lines was successfully accomplished, but no cases of undoubted true mutation have so far been observed

[1] Von Römer, *Fuhlings landwirt: Zeitung*, Aug. 1st, 1908.

[2] A large number of experiments on the influence of the size of the seed on the crop are summed up by Hunt in *The Cereals in America*. As is to be expected, a good sample will give a better result on the average than a poor one, as, in the former, the seedlings will be better nourished at the beginning of their growth.

in the pure line cultures. Natural cross-fertilization, however, was proved in a large number of cases at Lyallpur. The use of this method of selection in India has already enabled us to produce several wheats of much greater value than the mixtures now in cultivation.[1]

Association of characters.

Intimately bound up with selection is the question of correlation. By this is generally meant the co-ordination of morphological characters with physiological attributes. Much work has been done by German, Australian and Swedish investigators on this question, but the results are somewhat discordant—a result easy to understand when one reflects on the great influence of external factors such as climate, soil, moisture, cultivation and manuring, on the development of the wheat crop and on the fact that, until recently, the work has been done with mixed cultures instead of pure lines. The subject has been recently summed up by Tschermak[2] whose exhaustive account has been made use of in this section. True correlations, as has been pointed out by Johannsen, must be maintained in spite of any change in external conditions such as soil and climate. This observer, in the case of barley, has shown that in pure line cultures the correlations obtained from a consideration of an ordinary mixed crop are not always realised in pure cultures, and pure lines can be isolated in which the correlation in question is almost or quite wanting. These exceptions must be borne in mind when considering the correlation "laws" given below for wheat. Exceptions are not unlikely to be met with in pure cultures and the so-called "laws" should be looked upon more as rules or indications. Hence the idea held by breeders of the impossibility of uniting such characters as high yield, large size of grain and high nitrogen content in the same plant must not be too rigidly held. For instance, Johannsen has found it possible in barley to obtain the hitherto considered impossible correlation between high yield and nitrogen content and to isolate lines with both advantages. The most important correlation rules for wheat are given in the following table:—

I. With *the degree of tillering* varies in the same sense the following:—
   - (*a*) total weight;
   - (*b*) length of the period of growth;

[1] Howard and Howard, *Memoirs of the Imperial Department of Agriculture in India* (*Botanical Series*), Vol. II, No. 7, 1908.

[2] Tschermak in *Die Zuchtung der landw. Kultur-Pflanzen*, Bd. IV, 1907.

(*c*) the number of spikelets;
(*d*) length of ear;
(*e*) absolute number of grains;
(*f*) number of grains per 100 mm. of ear (d);
(*g*) weight of the grains;

and in the opposite sense:—

(*a*) length of the straw;
(*b*) density of the ear or number of spikelets per 100 mm. of the rachis (d).

II. With *the length of stem* varies in the same sense:—

(*a*) absolute weight of the stem;
(*b*) length of the ear;
(*c*) weight of the ear;
(*d*) number of grains per 100 mm. of the rachis (d);

in the opposite sense:—

(*a*) number of spikelets per 100 mm. of the rachis (d)

III. The *length of the period of growth* influences in the same sense:—

(*a*) yield of grain;
(*b*) size of grain;
(*c*) starch content;

in the opposite sense:—

(*a*) nitrogen or gluten content.

IV. With *the weight of grain* varies in general in the same sense:—

(*a*) size of grain;

and in the opposite sense:—

(*a*) nitrogen content.

The longer the vegetative period—especially if brought about by climatic conditions—the greater is the yield of grain and the relative starch content and the less the nitrogen content and quality of the grain. Further, yield, size of grain and starch content on the one hand and nitrogen content, resistance to rust, heat and frost on the other hand show in general, though not without exception, an inverse variation, that is to say, a difficulty in connecting both qualities. Thus it will be difficult to combine rust-resistance, high yield and high quality in the same race in India, whereas it will be easier to produce forms which are rust-resistant and which give high quality of grain. Short periods of growth such as obtain in India and high yields are antagonistic.

Another point of considerable interest to India is referred to by Tschermak, namely, the influence of the locality on the consistency and nitrogen content of the grain. He states "Der vergleichende Anbau verschiedener Weizenrassen unter denselben äusseren Bedingungen liefert bezüglich der Kornqualität häufig keine eindeutigen Resultate, weil allmählich ein Ausgleich im Stickstoff gehalt bezw. in der Glaseit oder Mehligkeitikg eintritt, und zwar nach dem Character der Landrasse hin. So erhalten in Südungarn alle Weizensorten bereits nach ein oder zwei Generationen ein glasiges, hartes Korn von hornigem Bruch und rötlich-braungelber Farbe. Besonders variabel in N-gehalt seines Kornes erweist sich der englische Weizen bei Verpflanzung. Klima, Dauer der Vegetations-periode, Kultur, Düngung, Fruchtfolge (Hülsenfrüchte stick-stoffsteigernd) sind von grösserem und nachhaltigerem Einfluss auf den Stickstoffgehalt als der Sortencharacter.''[1]

During recent years, according to De Vries,[2] the association of small botanical characters with agricultural properties has been developed in great detail at Svalöf. Oats and barley, however, seem to have been more particularly studied, and in these crops the system appears to have yielded very valuable results.

HYBRIDIZATION.

The improvement of Indian wheats by cross-fertilization is a subject both of greater difficulty and of less immediate importance than selection. The production of a new hybrid and its subsequent testing is a time-consuming operation and cannot be done under at least five years. The most modern investigations on heredity indicate that hybridization can only safely follow the isolation and testing of pure lines produced from a once-for-all selection of a single plant. Hence in India where the wheat fields of the country are mixed to an extent unknown in Europe, selection must precede hybridization and indeed must come before any other form of experiment with this crop. The recent rediscovery of Mendel's law by De Vries, Correns and Tschermak, has led to great attention on the part of many investigators to the behaviour of hybrid offspring, and wheat is among the crops investigated. Passing over the earlier hybridization, work on wheat of Rimpau, Garton and Farrer, which was done before

[1] Tschermak, l. c.
[2] De Vries, *Plant Breeding*, 1907.

Mendel's work was appreciated, the recent papers of Spillmann,[1] Tschermak,[2] and Biffen, [3], [4], [5] contain most of what is known on the subject. Biffen has shown that not only do such morphological characters as red and white chaff, red and white grain form allellomorphic pairs of characters but also immunity and susceptibility to yellow rust and strength and weakness of the grain behave as Mendelian characters.

The following tables give the inheritance of characters in wheat breeding as stated by Biffen and Tschermak. Biffen's conclusions are based entirely on his own researches at Cambridge, while Tschermak's account includes his own observations and those of other investigators.

BIFFEN (Cambridge).

A. Characters showing pure dominance after Mendel's pea type :—

Dominant.	Recessive.
Beardless ears.	Bearded ears.
Felted glumes (where Rough Chaff is the felted parent).	Smooth glumes.
Keeled glumes.	Rounded glumes.
Lax ears.	Compact ears.
Red chaff.	White chaff.
Red grain.	White grain.
Thick & hollow stem.	Thin & solid stem.
Rough leaf surface.	Smooth leaf surface.
Bristles on stem.	Smooth stem.
Large sclerenchyma girders associated with an angular stem outline.	Small sclerenchyma girders and an almost circular outline.
Hard, translucent endosperm.	Soft, opaque endosperm.
Susceptibility to the attacks of yellow rust.	Immunity to yellow rust.

[1] Spillmann, *Science*, Vol. XVI, 1902.

[2] Tschermak, *Zeitschr. f. d. landwirt Versuchswesen in Oesterreich*, 1901, and *Die Zuchtung der landwirt Kultur-Pflanzen*, Vol. IV, 1907, p. 130.

[3] Biffen, *Jour. of Agr. Sc.*, Vol. I, 1905, p. 4.

[4] Biffen, *Jour. of Agr. Sc.*, Vol. II, 1907, p. 109.

[5] Biffen, *Jour. of Agr. Sc.*, Vol. III, 1908, p. 85.

B. Those showing irregular dominance; in F_1 some individuals show one of the pair in almost full intensity, but in others it may be hardly visible.

In the F_2 the segregation follows the pea type.

Dominant.	Recessive.
Felted glumes (where rivet wheat is the felted parent).	Glabrous glumes.
Grey colour of the glumes.	Red or white glumes.

C. Characters in which there is no dominance of either character and the F_1 is intermediate.

Lax and dense ears.
" Large and small glumes.
Long and short grains.
Early and late ripening.

In the F_2 two of the intermediates occur to each of the pure characters corresponding to D : 2 DR : R (Zea type splitting).

TSCHERMAK (Vienna).[1]

Dominant or prevailing.	Recessive.	Equal.	
Hairy leaves.	Smooth leaves.	Thin stem (varies from equal to prevailing).	Thicker stem.
Solid stem (prevailing) in *T. polonicum, durum, turgidum* (Polonicum type).[2]	Hollow straw.	...	...
...	...	Longer straw (varies from equal to prevailing).	Shorter straw.

[1] A full discussion of the inheritance of the various characters in wheat-breeding is given by Tschermak (loc. cit.) and the several ways in which splitting takes place in the second and succeeding generations is dealt with in considerable detail.

[2] In the Polonicum type of inheritance after an intermediate first generation there result a splitting series, which ranges from purity of one parental character by intermediate steps to a much diminished admixture of the first character, pure carriers of the second character not occurring in the later generations (Tschermak).

TSCHERMAK (Vienna)—*contd.*

Dominant or prevailing.	Recessive.	Equal.	
...	...	Long ear (varies from equal to prevailing).	Short ear.
...	...	Lax ear (varies from equal to prevailing).	Dense ear.
...	...	Narrow ear (varies from equal to prevailing).	Broad ear.
Normal ear form.	Branched ear form.	...	...
Strongly keeled glumes (prevailing) *T. Spelta, turgidum, polonicum* (Polonicum type).	Rounded glumes.	...	...
Broad blunt glumes (*T. Spelta*).	Narrow pointed glumes.	...	...
Spikelets rounded on both sides.	Spikelets flat towards the rachis.		
Firm closing of glumes, *i.e.*, covered grain (prevailing to equal in *T. Spelta* and *dicoccum*).	Loose closing of the glumes.	...	...
Brittle rachis (prevailing in *T. Spelta* and *dicoccum*).	Tough rachis.	...	...
Beardlessness.	Bearding.	...	...
Felted glumes.	Smooth glumes.		
Violet chaff colour (prevailing in *T. durum* and *turgidum*)	White and brown chaff colour.	...	...
Black chaff colour (prevailing to equal).	White or brown chaff colour.	...	...
Brown chaff colour.	White chaff colour.	...	...
Red or brown grain.	White or yellow grain	...	...
...	...	Long grain (equal to prevailing).	Short grain.
Flinty grain.	Floury grain.	...	...
Winter form (late shooting equal to prevailing).	Spring form (early shooting).	Early maturity (equal to prevailing).	Late maturity.
Susceptibility to yellow rust.	Immunity to yellow rust.	...	...

THE METHODS EMPLOYED IN HYBRIDIZING WHEATS.

Some account of the actual method of crossing wheats seems desirable. We have, with some few modifications described below, found the method described by Biffen to be both rapid and effective. Biffen describes his technique as follows :—

"The actual operation of crossing wheats is a simple one and may be carried out rapidly with a little practice. After many trials I have found the following method the most satisfactory. The ear to be operated upon is selected at the stage when the anthers of the median spikelets are full-grown and beginning to show a slight tinge of yellow, indicating that they will be ripe on the following day. If the ear belongs to a dense or a compact variety, alternate spikelets are removed on both sides of the rachis, preferably by tearing them off whole with a pair of forceps. The median florets of about a dozen spikelets are then removed by pressing them outwards and then pulling sharply downwards. In this way only the two outermost florets of each spikelet are allowed to remain. The remaining spikelets are then completely removed. The florets are opened by gently pressing the apex of the paleæ, or if a bearded variety is used, by pressing outwards the previously cut back awn, and the stamens are carefully removed. Should an anther break during the operation, the spikelet is cut off. Pollination is effected by immediately placing a freshly opened anther into the emasculated floret. To secure a supply of these, an ear of the variety chosen as the pollen-parent is selected, in which the anthers are a full yellow colour. The edges of the spikelets are trimmed off with a pair of scissors so as to open a number of the florets at the apex. The filaments of the mature stamens elongate in the course of a few minutes and push the anthers out of the opening at the apex of the paleæ. They split open and by inserting one top downwards into the emasculated floret a plentiful supply of pollen is showered on the stigma. Before making a fresh set of crosses, or in the event of a stamen from the mother-plant breaking, the forceps are sterilized by dipping them into methylated spirit. There is no necessity for removing the stamens from a floret and pollinating the following day, nor yet of carrying out the operation at an early hour in the morning. If there is any difficulty in securing the varieties in flower at the same date, it is feasible to remove the stamens from the earlier variety and protect it from outside pollen. I have never examined the matter in any detail, but I have frequently pollinated flowers successfully a week after the stigmas would normally have been in a receptive condition. They were then feathery and unwithered. After pollination the ears are protected by means of folded tissue paper bags

previously water-proofed by soaking in melted paraffin wax. Numerous control experiments have shown that muslin bags are unsuitable for the purpose. An ear for instance on which 12 emasculated florets were left was covered with muslin. Each floret set a grain, pollination having been brought about by wind-borne pollen carried through the meshes of the muslin. The protecting bags may be removed a week after pollination or they may remain on the ears until the grain ripens. If the latter course is adopted, the bags should be slit open at the base to allow the water to escape which accumulates, as the result of transpiration, in considerable quantities.''

We have found the above process can be very considerably shortened by cutting off the upper parts of the glumes of the spikelets of the female parent. This enables castration to be easily effected and the emptying of the ripe anther of the pollen parent on to the stigma is much facilitated. Further, any flowers too ripe to be safely castrated are at once evident by the immediate extrusion of the anthers. Less damage to the castrated flowers is likely by the use of this method and the tips of the stigmas are not so likely to be caught between the closed glumes leaving their extremities exposed to the outer air. In the crosses carried out at Lyallpur in 1907, no instances of self-pollination were met with and in all cases castration and cross-pollination were done through the opening made at the top of the flower by cutting off almost a quarter of the upper portion of the glumes.

In the damper parts of the wheat-growing region of the Gangetic plain very heavy dews are often experienced at flowering time and one of the difficulties of the work is to find a waterproof bag. Even when gummed paper bags are soaked in melted paraffin, the gum is sometimes dissolved by the dews and the bags open. We have found it is best to sew the bags with a sewing machine before soaking in paraffin. In our first series of crosses at Púsa in 1906, a large number of unpollinated control ears were made to test our technique. Only one grain per 200 ears set seed or about 1 in 2,400 flowers. No cases of self-pollination were found in the second set of crosses made at Lyallpur in 1907.

The crossed seeds are always somewhat small and shrivelled and therefore cannot be safely sown in the field. Our system has been to grow them separately in small flower pots and to transplant them out later in the field.

In the first generation, the crosses and their reciprocals should be grown in separate lines side by side. In wheat, the crosses and their reciprocals are identical and the choice of the mother parent makes no difference.

The dominant characters can be made out in this generation and as many plants as possible should be grown.

In the second generation the seeds of the F_1 plants should be sown singly, so that the resulting F_2 plants can be examined and reaped plant by plant.

In the third generation the types isolated in the F_2 generation should be again sown, examined and reaped plant by plant, and in this generation the splitting and constant forms can be determined. Subsequent work deals with a careful examination by single plants of the constant forms and their final testing in the field and bakehouse. In reaping a large number of cultures plant by plant in India, the work is considerably simplified by irrigating the plots a day or two beforehand.

In carrying out cross-fertilization work in India the necessity of first growing and studying the parents in pure lines cannot be too strongly emphasised. It is necessary to grow the parents from single plants and to first determine all their characters both botanical, field and physiological. Crossing botanical varieties is a very dangerous and unscientific proceeding as the botanical variety in India especially is complex and often consists of a large number of wheats differing in field characters, rust-resistance and in the quality of the grain.

Natural cross-fertilization.

In a previous paper[1] the occurrence of natural cross-fertilization in wheat in India has been dealt with. In the dry climate of the Chenáb Colony of the Punjab, where wheat is grown entirely by canal irrigation, natural cross-fertilization is common. The extent of this occurrence seems to depend in India mainly on the irregular supply of moisture to the plant combined with the great dryness of the air, and to be exceedingly rare in non-irrigated tracts.

Under canal irrigation in the Punjab wheat is usually watered twice after sowing, the last watering taking place after the plants are in ear. Often before the last irrigation the supply of water in the soil is so small that the plants partly wilt during the hottest part of the day, the glumes open and the stigmas are exposed to the air. Under such circumstances in the dry hot climate of the Punjab, cross-fertilization is easy, and it is therefore not surprising that it is so frequent. Experimental cultures might be largely protected from natural crossing by more frequent and even watering.

One parent of most of the natural hybrids found at Lyallpur appears to be Punjab type 9. This is a bearded common wheat and at flowering

[1] Howard and Howard, l.c.

time the flowering glume and pale open to such an extent that the stigma is freely exposed to the air and can easily be seen. The appearance of such ears is not unlike that observed when a rapidly growing bearded ear is cut off at flowering time and allowed to wilt in the sun. It seems possible, as was suggested to us by Mr. A. C. Dobbs, that the wide opening of the glumes of this bearded wheat is largely assisted by the weight of the awn and that one of the uses of the awn to the plant is to promote natural cross-fertilization. In the case of Punjab type 9 the awns are especially thick and heavy, while the strong stiff straw gives rise to exceedingly erect ears.

The mixed character of the wheat fields of the country is probably to some extent both the cause and the result of natural hybridization which would also fully account for the numerous varieties of wh at. It may be that spontaneous crossing is the natural means of keeping up the vigour of wheat in India and that without it the vicissitudes of the season would lead to a slow degeneration of the crop.

Hybridization work in India.

The importance of the work of Farrer in New South Wales on the improvement of Australian wheats was early recognised by the Government of India, and in 1900 Mr. W. H. Moreland, the Director of Agriculture of the North-West Provinces (now the United Provinces), was sent by the Indian Government to Australia to study Farrer's methods on the spot and to report on their suitability for Indian conditions. The results of this mission are summed up in an admirably written article which was published in the *Agricultural Ledger*[1] in 1901. As a consequence, a wheat-breeding station was started at Cawnpore in 1902 with the help of a grant from the Revenue and Agricultural Department of the Government of India. The objects of the station are principally to produce wheats resistant to drought and rust for use in the black soils of the Bundelkhand Districts.

At the Poona Farm a further impetus was given to hybridization work by Mr. J. Mollison, who visited the United States in 1901 to study the methods of Agricultural improvement in use in that country. A large number of crosses were made at Poona, but no new varieties obtained in this way seem to have been introduced into general cultivation.

At the Nágpur Farm in the Central Provinces, some cross-bred wheats are said to have been produced in 1895-96 among which one was found (*Haura* × *Mundia Pissi*) which was at first considered to be rust-proof.

[1] Moreland, *Agricultural Ledger*, No. 2, 1901.

We obtained single plants of this wheat from the Hoshangábád Farm in 1906 when we were impressed by its close resemblance to the ordinary bearded *Pissi* wheat of the Narbadá Valley. It was grown in pure line culture at Lyallpur in November 1906, side by side with bearded *Pissi*, and was found to resemble in all characters the *Pissi* of the Narbadá Valley. Both forms were practically destroyed by yellow rust at Lyallpur in 1907 and its general behaviour led us to conclude that it was not a new form at all, but simply the Narbadá Valley bearded *Pissi* under another name.

CHAPTER IV.

THE TESTING OF VARIETIES.

THE testing of varieties, whether produced by selection or crossing or whether newly introduced into the country, falls into three divisions—(1) field trials; (2) examination of the grain; and (3) milling and baking tests. These three operations will be considered separately.

1. FIELD TRIALS.

Field trials consist in the growth of the varieties on a fairly large scale and the observation of all the characters up to harvest time. Under Indian conditions, the most important field characters are the following :—

Straw characters. One of the first observations which strikes the European investigator of the Indian wheats is the weakness of the straw of many of the types in cultivation. Most of the wheats of the United Provinces and Bihár and especially Muzaffarnagar white have very weak straw and in this direction much room for improvement exists. Forms with weak straw are especially liable to become laid in wet weather or by wind and are very brittle at harvest time. There seems to be a connection among the Indian forms between strength of straw and erectness of the ears, but further observations on this point are desirable. A good example of the effect of laying on yield is given by Middleton[1] in a field of rivet wheat at Cambirdge.

The influence of laying on the yield of wheat at Cambridge.

No. of plot.	Condition of plot.	Good grain in lbs. per acre.	Weight of light grain in lbs. per acre.
1.	Very badly laid, cut by scythe.	1,655	352
2.	Moderately laid.	1,968	172
3.	Standing very well, cut with binder.	3,336	70

Thus laying not only increases the percentage of light grain but also greatly diminishes the yield.

[1] Middleton, *Fifth Annual Report of Field Experiments*, Cambridge, 1902-03.

It is very difficult to determine experimentally the strength of straw of various varieties. The subject is dealt with by Fruwirth[1] and by Kraus[2] and the various methods tried and suggested were tested at Hohenheim in 1905 by Lang, who came to the conclusion that the strength of straw can better be estimated in the field than by laboratory tests on single plants. At present there is nothing better than to observe the strength of the straw in the field and especially after irrigation. One or two years' observations are not of much use unless nature in the form of wind and rain eliminates the weak-strawed forms.

All observers seem to agree in believing that laying does far more harm if it occurs at the flowering period than later on during the ripening stage. At this earlier period the straw is weak and the hardening process has hardly begun. Early rust attacks in India also have the effect of greatly weakening the resistance of the straw to wind and rain, and to this indirect effect a good deal of the damage done by rust is due.

Early maturity. The shortness of the Indian wheat season, the danger of rust attacks about the time of flowering and the possibility of drying up by premature hot winds in the spring are all great arguments in favour of early maturing varieties. In particular, it is desirable to obtain varieties which rapidly pass through the stage between flowering and ripening. While such considerations obtain all through India, they have special force on the black cotton soils of Central India where the damage done by rust is greatest. Closely bound up with early maturity is the question of drought resistance on the black cotton soils and on some of the drier tracts of the alluvium where besides early maturity it is desirable to find wheats which will ripen with the minimum amount of moisture.

Rust-resistance. The idea of ever finding a rust-proof wheat is, we consider, merely a counsel of perfection. Immunity and susceptibility are merely relative terms and all that is possible is to find rust-resistant kinds. As has been mentioned before, (p. 93) there are no less than three different wheat rusts in India, of which the period of attack and also to some extent the geographical distribution are distinct. The problem is to some extent a local one, and will have to be solved separately for each of the well-marked wheat-tracts. In estimating the rust-resistance of wheat varieties in the field we have been impressed by the necessity of considering this question together with others, such as soil moisture. We have observed that if the same variety is sown in different parts of the same field on soils differing

[1] Fruwirth, l.c.
[2] Kraus, *Die Lagerung der Getreide*, Stuttgart, 1908.

in moisture-retaining capacity, the plots on drier soil are much more easily attacked by rust and to a far greater extent than the plots on more typical wheat land with good moisture-retaining capacity. Other observers have made similar observations. Thus Moreland[1] states :—

"I believe it is the case that those parts of India where rust is most severe are also most liable to suffer from drought ; certainly this is so as far as the United Provinces are concerned. Rust is rarely more than a slight calamity in any part of these Provinces except in the Bundelkhand Districts which are notoriously most liable to suffer from any failure of the rains."

Similar observations were made on this point by Farrer[2] in Australia.

Shedding of grain at harvest time. The fact that the wheat fields of India are only cut when dead ripe, on account of the method of threshing and the necessity for the easy production of *bhúsa*, makes shedding of the grain an undesirable character. Bearded wheats, which, as a rule, hold the grain better than beardless forms, are, therefore, more popular with the cultivators. In the Punjab, where the fields are left uncut longer perhaps than in other parts of the country, it is especially desirable to lay stress on this quality.

Yield. It has already been indicated (p. 132) that high yielding wheats of good quality are hardly likely to be obtained in India, and that it is probable that only moderate yielders can ever be grown. In the alluvium, higher yielding wheats are more possible than on the black cotton soils where if quality, rust and drought resistance can be combined with rapid maturity, yielding power will be of minor importance.

2. Grain Characters.

Absolute weight. By this is generally meant the weight of 1,000 grains. In wheat this should be high. Fruwirth gives the limits in Germany as 15 to 70 grammes, the usual numbers lying between 25 and 40 grammes. Any number above 35 is good for wheat. No definite correlation has yet been found between absolute weight and nitrogen content in wheat. In cases where the grains are not well developed, however, there is generally an increase in the percentage of nitrogen on account of the defective formation of starch in undeveloped grains.

Volume weight. The volume weight for wheat and other cereals is not, for many reasons, considered of the same degree of importance as the absolute weight. In England and America this is usually expressed as the

[1] Moreland, l. c.

[2] Farrer, *The making and improvement of wheats for Australian conditions*, Sydney, 1898.

weight per bushel in lbs., in Germany and Austria as the weight of a litre in grammes. Soule and Vanatter give the limits as 54 to 63lbs. per bushel in their investigations, and Fruwirth in Germany gives 710 to 820 grammes per litre as the extremes, the usual numbers running between 730 and 770, and anything above the latter being considered very good. If high volume weight and high absolute weight go together, this circumstance has considerable weight in commercial valuation.

Colour. Wheats are classed as white or red. The former include the amber coloured wheats and the latter the brownish red kinds. It must be remembered that light affects the colour and old samples do not correctly give the tone of colour of any variety. Often, the darker coloured wheats are the best for milling and have the highest nitrogen content. Very light reds and whites generally give weak flours. Contrary to the often expressed opinion in India there is hardly any distinction now made by modern millers in England in favour of white wheats. Fife wheat, one of the best Canadian wheats, is a hard red.

Consistency. Hard wheats are most valued because they are often rich in nitrogen and give strong flour and are generally easier to mill. It is important for export purposes that a variety should, as far as possible, be uniform in consistency and not be made up of soft, white and mottled grains. We have in a later chapter dealt at length with this question of consistency in India and have concluded that it is too variable to be of any systematic value. As has been observed by Tschermak in Hungary and by many other observers in Europe and as we have also found in India, wheats introduced into a new district soon tend to acquire the consistency of the local sorts. Thus hard wheats introduced into a soft wheat district tend to become soft and *vice versâ*. The question is one of great importance in seed distribution in India. It must not be expected that when a soft white wheat like Muzaffarnagar white is distributed in a hard wheat tract that the grain will retain its original character. Indeed we have already found that Muzaffarnagar white at Púsa and Muzaffarnagar in the same year varies considerably in consistency, nitrogen content, and in milling and baking value.[1] When an accurate survey of the Indian wheat districts has been made and the influence of the season, soil, and moisture on consistency has been ascertained, the hard and soft wheat tracts of the country will be known with precision and a scientific scheme of seed distribution will then be possible.

[1] Howard and Howard, *The varietal characters of Indian wheats*, l. c.

Composition. Although a large amount of work has been done on the chemical composition of wheat and of wheat flour yet no accurate relation has hitherto been found between the chemical composition and the bread-making value. The only determination of any value is the nitrogen content which is usually determined by Kjeldahl's method and which when multiplied by Retthauser and Osborne's factor 5·7 gives the percentage of proteids. Soule and Vanattar in America give 8·1 and 13·6 as the range in the American wheats investigated by them. Far higher values, however, are obtained in some of the stronger wheats of Hungary, Roumania and South Russia which often contain 20 per cent. of gluten or more. The percentage of proteids in the ten samples of Indian wheat referred to on page 241 as determined by Leather varies from 7·64 in the case of Muzaffarnagar white grown at Muzaffarnagar to 14·36 in Púsa 6 grown at Púsa.

Climate in Europe has a considerable effect on the composition of wheat according to Fruwirth[1] who states :—"Dryness and poverty of the soil plainly increase the gluten content. Besides this, it must be remembered that, according to Wollny, high summer warmth and low rainfall in Hungary, Roumania and South Russia favour nitrogen content and flintiness ; cooler, damper climates, on the other hand, favour starch production and flouriness. In agreement with this the nitrogen content of wheat in Europe in general diminishes from South to North and from East to West. Thus the gluten content in South Russia, Roumania, and Turkey is 20 per cent. or over, in Germany and France 10 to 15 per cent. and in England seldom more than 10 per cent." Tschermak[2] gives several cases of change of composition when European wheats were moved from one country to another, and we have with Muzaffarnagar white grown at Lyallpur, Muzaffarnagar and Púsa observed decided differences in nitrogen content in 1908. The nitrogen and starch content of a variety, therefore, are subject to variation depending on external conditions.

3. Milling and Baking Tests.

Milling. When considering the work which has been done on the subject of the milling of wheats, it is well to bear in mind what a wheat grain really is and in what the modern process of milling consists.

From the point of view of the plant, the wheat grain is the means by which the variety is enabled to pass through the resting period between harvest and sowing. The grain consists of a small embryo at one end and a

[1] Fruwirth, l. c.
[2] Tschermak in *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Vol. IV.

large amount of food material (endosperm) for the nutrition of the embryo during the early life of the seedling, the whole being surrounded by a hard indigestible protective skin. The outermost layer of the endosperm is the aleurone layer, rich in proteids. In order that the embryo can dissolve the starch, fats and proteids of the endosperm during germination various ferments are present. It is clear, therefore, that a wheat grain is exceedingly complex, and this complexity is still further increased by the fact that we are dealing with a structure which is alive and in which slow changes associated with a dormant existence are taking place. It is well known that wheat improves in its milling qualities by keeping, and this is probably connected with the slow changes which are taking place in the seed.

In the production of flour by the modern methods of milling there are two main processes—(1) the removal of the skin and the germ with as little loss of flour as possible, and (2) the reduction of the endosperm to an even flour of a good colour.

The removal of the germ is simple ; the whole complicated machinery of modern mills is concerned with the removal of the skin (bran) from the grain and flour. The more perfectly the bran is separated, the better the colour of the flour ; but it is imperative to carry out this separation with as little loss of flour by adhesion of the endosperm to the skin as possible.

In the country mills, wheat was milled wet in order to render the removal of the skin easier, as the wet skin does not tear so readily, but this has now been superseded by the modern roller mill system in which, in passing through a series of steel rollers, the previously conditioned grains are first deprived of the germ and most of the skin, and are then gradually reduced to smaller and smaller pieces with separation of the bran at each stage. The advantage of this system over the old method in which the grain was reduced to flour in one stage lies in the greater ease with which the bran is separated from the endosperm when the latter is in large pieces than when it is already in the form of flour. The centre of the grain gives the whitest flour, but the outside layers give the strongest flour, as most of the gluten is present in the layers just under the skin. The colour of the flour derived from this part of the grain is generally darker, as it contains small portions of the bran. Very good accounts of the modern systems of milling are given by Girard and Lindet[1] and also by Maurizio.[2] The maximum amount of flour theoretically obtainable from a wheat grain is

[1] Girard et Lindet, *Le froment et sa mouture*, Paris, 1903.
[2] Maurizio, *Getreide, Mehl und Brot*, Berlin, 1903.

8₄ % (Girard and Fleurent), but in practice the amount varies from 67—74·6% (according to Soule and Vanatter), and as a rule is about 70% (Maurizio).

The chief desiderata of a wheat from the miller's point of view are therefore:—

(1) The capacity of absorbing as much water as possible during the process of conditioning without losing the property of free grinding. The dryer the wheat, the more moisture it absorbs while being conditioned, and it is one of the desirable characters, from a miller's point of view, of Indian wheats that they are exceedingly dry.

(2) A thin and tough skin which will not tear but which is easily removeable from the endosperm. It is said that hard wheats often mill more freely than soft ones.

(3) Uniformity of sample as regards size and consistency as the process required to reduce hard and soft wheat to flour differs in many details. A mixture of hard and soft grains will often fetch a lower price in the market than a uniform sample of either hard or soft grains. Consequently where wheat-growing is carried on on a large scale, systems of grading are now adopted by which samples, uniform as far as possible in size, colour and consistency, are maintained.

(4) The flour yielded should be of a good colour. Miller's marks for flours are generally given on the colour—as determined by Pekar's process. In this process about 5 grammes of flour are placed on a flat piece of wood or glass and are smoothed and pressed into a uniform layer by means of a spatula. The colour of the layer thus obtained is compared with the colour of some standard flour treated in the same way. This test is carried out continually in a good mill, as it affords very good evidence of the quality of the flour production during the day. Some flours only show their colour when wet; in such a case the board is dipped into a vessel of water for 5 minutes. Flours treated in this manner can be kept for years.[1] Yellow flours are often bleached by means of oxides of nitrogen.

Although Pekar's method is exceedingly useful from a practical standpoint, it is not quite exact enough for all purposes, and other more scientific methods have been proposed, but so far none has proved quite satisfactory. In 1893, Vedrodi[2] proposed that flours should be numbered according to the

[1] Each country has its own system of miller's marks. The Australian colour system is given in *Notes on the milling qualities of different varieties of Wheat* by Guthrie, Sydney, 1895.

[2] Vedrodi, *Zeitschr. f. Analyt. Chemie*, 1893.

percentage of ash they contained, but in 1895 Cerlez[1] showed the grading according to these numbers to be erroneous and proposed the use of the fat content. This method was again attacked by Vedrodi[2] who successfully proved it to be faulty, but was not able to vindicate fully his own method.

The methods of testing the baking capacity of flours. The value of flour from the baker's point of view largely depends on its "strength," *i.e.*, its capacity to produce large, well-shaped loaves. The demand for strong wheats and strong flour in the United Kingdom has arisen from several causes, the principal of which is the starchy character of most of the wheats of the world, including the English-grown wheats, and their poorness in gluten and the heavy bread their flour produces. Starchy wheats, as a rule, give weak flours. In order to improve the weak wheats they are mixed with strong flour obtained from some of the wheats imported from Canada, America, Roumania, and South Russia. In the English market, the strong wheats of these countries fetch a much higher price than the weak varieties. Hence, if Indian wheat is to command the highest price in the English market, we must send there wheats of similar character to the strong South European and North American grades.

The determination of the strength of the flour is one of the most difficult problems connected with wheat improvement, and many have been the methods devised for this purpose. The most obvious and satisfactory one is to make the flour into bread; but as strength is one of the most valuable qualities involved in the production of new varieties, the wheat improver often desires information about his varieties as regards this point before he has sufficient seed to make a thorough baking test. Many methods have been devised to meet this difficulty, but so far none have proved satisfactory. The methods tried fall into three divisions—(1) Chemical methods in which attempts have been made to correlate the strength with the percentage of some chemical constituent of the flour, (2) physical methods such as those founded on the amount of water taken up by a given quantity of flour, and (3) baking tests on a very small scale.

Chemical methods. On analysis it was found that the flinty wheats were higher in gluten than the starchy soft kinds, and at first it was considered that the percentage of gluten determines the strength. It soon appeared, however, that only some of the wheats high in gluten give strong flours, and accordingly the gluten in strong wheats was examined. Girard and Fleurent in Paris and Snyder in America separated gluten into glutenin and

[1] Cerlez, *Zeitschr. f. Analyt. Chemie*, 1895.

[2] Vedrodi, *Zeitschr. f. Analyt. Chemie*, 1899.

gliadin, and put forward the view that the strength of flour was due to the right proportion of these constituents. These results were by no means generally accepted by other investigators. The whole subject has been dealt with by Bruyning[1] in Holland in a paper which contains most of what is known on this subject. Hall[2] at Rothamstead has subjected the various methods and ideas on the relation between the constituents of gluten and the strength of the flour to a critical examination, and has come to the conclusion that strength and gluten constitution cannot in any way be correlated. Wood[3] at Cambridge has gone into the question afresh. He sums up his conclusions as follows :—

"Taking Humphries' and Biffen's definition of strength as the capacity for making large well-piled loaves and applying the above ideas, it is stated that the largeness of the loaf depends chiefly on the capacity of the flour to give off gas when fermented with yeast, especially in the later stages of dough fermentation, and the suggestion is made that shapeliness, and probably gas retention, are dependent on the physicai properties of the gluten as modified by the presence of varying proportions of salts."

In the second part of his paper on this subject Wood has shown that the properties of gluten depend on the nature and the concentration of acids and salts in the solution with which it is in contact.

The effect of the enzymes in wheat flour on strength has been investigated by Baker and Hulton,[4] and also by Ford and Guthrie.[5] These papers give a good account of the present aspect of this side of the question. Ford and Guthrie found a proteolytic ferment in some flours of low baking value, and consider this circumstance furnishes an explanation of the cause of what is known as "rotten gluten."

Physical investigations. Several methods of determining the baking value of flour by physical tests of the gluten have been put forward. Thus Guthrie[6] considered the strength of flour was determined by the amount of water taken up by the gluten. Maurizio, however, disposes of this method and shows that many poor flours took up much water, but did not hold the

[1] Bruyning, *La valeur boulangère du Froment*, *Archives Teyler*, 1906.
[2] Hall, *Jour. of the Board of Agr.* (England), Vol. XI, No. 6.
[3] Wood, *Jour. of Agr. Sc.*, Vol. II, 1907, p. 139.
[4] Baker and Hulton, *Jour. of the Soc. of Chem. Industry*, Vol. 27, 1908, p. 368.
[5] Ford and Guthrie, *Jour. of the Soc. of Chem. Industry*, Vol. 27, 1908, p. 389.
[6] Guthrie, *Notes on the milling qualities of different varieties of Wheat*, Sydney, 1895.

carbon dioxide during baking. Hays[1] considers the volume of the fermented dough of great importance. This is described as the baker's sponge test, and is expressed by a number which is obtained by dividing 100 grammes of flour into the volume of loaf of dough produced from the 100 grammes of flour. It is assumed that the expansion depends on the amount of gluten. It must be remembered, however, that although in general the better flours give the highest dough volumes, yet the fermenting powers of various samples of yeast vary. The yeast therefore affects the value of the test.

Another method is to measure the expansion of a certain amount of wet gluten by means of an instrument known as an aleurometer, and the quality of the gluten is also determined by washing it out and determining its stretching power. None of these methods, however, are very reliable.

Saunders[2] has recently laid stress on the value of the chewing test. He describes the method as follows :—

"It has been well known for a long time to practical wheat-buyers that some rough idea of the baking strength of flour can be obtained by chewing for about four or five minutes a few of the kernels of the wheat from which the flour is to be made and then examining in the fingers the gluten thus obtained. As a general rule, it may be said that the strongest flour will be obtained from those wheats which produce gluten having the greatest ability to recover its shape after being squeezed between the fingers." A very similar chewing test has been used by the natives of India probably from time immemorial.

Baking Tests.[3] It will be seen that there are no really reliable methods of testing the baking value of flour by means of a chemical or

[1] Hays, l.c.
In this paper Hays deals with score cards in comparing varieties of wheat and suggests the following :—

Yield per acre	... ...	45
Grade of grain	... ...	20
Rust-resistance	... ...	10
Quality of gluten	... ...	10
Amount of gluten	... ...	5
Co-efficient of rise of gluten	... ..	10
		100

[2] Saunders, *Bull.* 57, *Canadian Department of Agriculture*, Ottawa, 1907.
[3] The determination of the volume of the bread is generally made by measuring the amount of sand, shot or glass beads displaced by it in a measured vessel. The error involved in the determination is large and inconstant. Another method has been devised of coating the loaf with paraffin and measuring the amount of water displaced in a pyknometer (Komers & Haunalter, *Zeit. f. d. land. Versuchswesen in Oester.*, 1902), but in practice it is found impossible to make the coating water-tight.

physical examination, and the necessity of a baking test is now generally accepted.

The methods of carrying out such baking tests fall into two classes :—

(1) Baking tests carried out in the laboratory under exact scientific conditions in specially constructed ovens.

(2) Baking tests carried out by bakers in ordinary bakehouses.

In both methods the criterion adopted in the past has been the volume of the bread produced from a given volume of flour. In a few cases the volume of 100 grs. of bread has been taken. There has been much controversy as to the merits of these two methods as neither is free from objection. The advocates of the first system have proved by elaborate experiments that the volume of the resulting bread is influenced by :—

(1) The amount and quality of the agent used to induce fermentation and that the quality of the latter (whether it be yeast, zymin, etc.) varies from day to day.[1]

(2) The amount of water used in making the dough. Each flour requires a different amount of water to make a dough of the same consistency.[2]

(3) The temperature at which fermentation is carried out.[3]

(4) The length of time of fermentation.[4]

It is obvious that in an ordinary bakehouse all these conditions must vary from day to day, and also in different batches baked on the same day, and that no exactitude can be expected when the experiments are carried out by an ordinary baker. Moreover, baking tests in the laboratory can be performed on small samples of flour and are of more help to the breeder.

Baking tests in the laboratory have been carried out by Kreusler, Sellnick, Kunis, Komers and Haunalter, Maurizio, Guthrie, and Saunders. Good accounts of the apparatus and methods employed in each case are given by Maurizio and also in the paper by Komers and Haunalter.

Bakehouse tests were used by Fischer and by Maercker (see Maurizio and Komers). In support of the bakehouse methods it has been urged that :—

(1) A good baker only varies his conditions to suit his flour.

(2) No two flours require dough of the same consistency.

[1] Guthrie, l. c.
[2] Saunders, l. c.
[3] Maurizio, l. c.
[4] Komers and von Haunalter, l. c.

(3) The laboratory methods in which only small rolls are made, do not produce bread of a good quality (indeed, often the product can only by courtesy be called bread).

(4) Laboratory methods often give a different result to that obtained by a baker and that the baker's verdict is the consumer's[1] verdict, and therefore final.

The difficulties connected with the baking test have been to a very large extent met by Humphries and Biffen[2] in England. In the first place, they have pointed out that the volume of the bread is not a sufficient criterion of the strength of the flour.[3] It is possible by increasing the volume of the water used to get a much larger volume, but the bread instead of rising makes a flat cake.[4] They have therefore defined strength as the "capacity to make well-piled loaves" and have adopted the baking test on a large scale in an ordinary bakehouse. As regards the amount of yeast and addition of water, etc., they use such conditions as experience has *shown will produce the best result from that class of flour*, i.e., instead of striving for exactitude of conditions, they strive to attain the best result possible for each particular flour. In thus following the procedure which could be adopted by any good baker in dealing with the flours in question, they claim to obtain a real consumer's verdict and therefore one valuable in commerce. The trials are carried out by an experienced baker, and only samples of at least 60lbs. are tested. The volume of the resulting loaves is determined and photographs are taken to show the shape.

The weakest point at present in the work of improving the wheat crop undoubtedly lies in the methods of estimating the value of the grain. Chemical science has so far failed to produce any reliable analytical method by which the bread-making value of a wheat can be determined. In the absence of such a method, the only means that now exists of deciding between the grain of varieties is to grind a sample, about 60lbs. in weight, and to make the resulting flour into bread. Based on the milling and baking aspects of this test, a judgment of considerable value can be obtained, provided the work is carried out by a reliable and experienced miller and baker. It is clear that the method is subjective and depends largely on the personality of the human agents concerned in the work.

[1] Komers and von Haunalter, l. c.
[2] Humphries and Biffen, *Jour. of Agr. Sc.*, Vol. II, 1908.
[3] Komers and von Haunalter, l. c.
[4] Saunders, l. c. In his laboratory method Saunders also takes notice of the texture of the loaf, relation of height to diameter, etc.

As it would be exceedingly difficult to arrange in India for reliable and systematic tests, such as those carried out by Mr. Humphries in England, we have availed ourselves of his offer to carry out such tests on Indian wheats for us, and many samples of wheat have already been sent to be tested.

B. RECENT INVESTIGATIONS.

CHAPTER V.

THE INDIAN WHEAT PROBLEM.

A PERUSAL of the earlier unsuccessful efforts to improve the production of wheat in India discloses the fact that there existed no definite scheme of work on the subject and that there was but little continuity of effort and absolutely no correlation between the various farms concerned with the improvement of the wheat crop. It is not surprising, therefore, that practically few useful results were obtained, and that the work on the experimental farms had but little influence either on the production of wheat or on the trade in that product.

The formation of the Board of Agriculture in 1905 by the Government of India rendered possible the discussion of the general lines of work on the development of Indian Agriculture and the adoption of definite schemes of experiment applicable to the whole of India. In consequence of this most notable advance in the organization of agricultural work in the Empire, the subject of Indian wheat was selected as one of the main topics for discussion at the second annual meeting of the Board of Agriculture held at Púsa in January 1906. One of us was requested by Mr. F. G. Sly, I.C.S., then Officiating Inspector-General of Agriculture in India, to prepare an outline of future work on the improvement of wheat in India which would apply to the whole of the country. The following scheme was therefore submitted to the Board of Agriculture for consideration.

SUGGESTIONS FOR FUTURE WORK ON THE IMPROVEMENT OF INDIAN WHEAT.

1. *The Agricultural Survey of the Wheats in each Province.* It is clear that a reliable survey of the wheats of each Province must be made before the question of wheat improvement can be seriously taken up. It will be necessary to know, with a fair degree of accuracy, the general agricultural characters, distribution as regards area and type of soil, rust and drought-resisting power, and the suitability of the grain for local use and export in the case of the chief varieties grown. Without this preliminary knowledge of the question any hybridization experiments and indeed any fundamental experiments whatsoever must be haphazard and much valuable time might

easily be lost by working in the dark. Considerable progress has already been made in the direction indicated and before long it is expected that this introductory work will be completed in all the Provinces concerned.

2. *Milling and Baking Tests.* The export of wheat from India, although small as compared with the total production, is already of considerable importance. Most of the wheat sent away is used for bread-making, the rest for the manufacture of macaroni. It appears desirable therefore that reliable milling and baking tests should be made of the chief varieties of Indian wheats so as to determine their relative value and also their behaviour as compared with other wheats imported into the United Kingdom. The milling and baking characters largely determine the export value of any variety, and it appears impossible at present to determine the value of any wheat except in this manner. The simplest method of obtaining this information, when the provincial wheat survey is completed, would be to secure the co-operation of the Incorporated National Association of British and Irish Millers. Suitable samples of the various types grown in India could be sent to England and their milling and baking characters determined. Photographs of loaves made from equal weights of flour of each variety could be made and compared with those of the best American and Canadian wheats imported into England. The Association of Millers referred to are conducting similar tests in England in connection with the experiments now in progress on the improvement of English wheats. It would not be difficult therefore to enlist their assistance with regard to Indian grown wheats. The information thus collected could not fail to be of the greatest value and interest generally and especially useful to those in charge of experiments on wheat improvement in India. It is extremely doubtful whether small laboratory experiments would give such reliable information as that obtained from actual milling and baking tests. In addition to the wheats used for bread-making, information could also be obtained from Europe with regard to the macaroni wheats of India.

3. *Uniformity of Sample.* Although some cultivators do their best to keep the varieties pure, it is clear that a large amount of the wheat grown in India consists of mixtures of various types. Both from the point of view of local consumption and export, the growth of a mixture of varieties is, on the whole, to be deprecated. In the first place, the varieties are not likely to ripen at the same time and secondly, an impure sample gives rise to difficulties from the miller's point of view and consequently commands a low price. No doubt when suitable wheats have been found for districts like Bundelkhand where, at the present time, varieties are sometimes intentionally mixed as a form of insurance against a total failure of the crop, the practice of mixing will be discontinued. It seems probable that purity of sample may be encouraged in three ways: firstly, by extending the present system of distributing pure seed from the experimental farms so as to admit of cultivators obtaining seed, true to type, independently of the local grain dealers and money-lenders; secondly, by the publication, in the vernacular, of the difference in price obtained for pure and mixed samples; and thirdly, by a system of seed distribution on a large scale upon the lines already successfully worked in the United Provinces.

4. *Rotation Experiments.* In the Punjab especially the growth of leguminous crops in the rotation does not seem to be adopted to the same extent as in other parts of India. It seems desirable therefore that experiments should be made on this question in districts where it is not usual to grow leguminous crops on wheat lands.

5. *Adulteration.* As the admixture of foreign matter to exported wheat takes place after it has left the grower, it is impossible for the Agricultural Departments to take any action to prevent this adulteration. The remedy seems to be in the power of the wheat trade itself.

6. *Storage.* The damage done to grain during storage by damp and weevils seems to be worth attention, and the method adopted in the Punjab of keeping grain in houses instead of in pits might be tried. How far the use of insecticides like carbon bisulphide is applicable in India is a matter which will no doubt receive the attention of the entomologists.

7. *Transport Difficulties.* Most of the wheat exported is moved before the rains, and on the railway to Karáchi especially the supply of waggons is said to be too small to cope with the volume of wheat ready for transport. Definite information on this point and also on the railway charges for wheat in India might be collected with advantage.

8. *Experiments on the Improvement of Indian Wheats.* In wheat, as in the case of other crops, the growth of exotic varieties in India has not proved a success, nor is it likely that any particular variety will be found suitable for the whole of the wheat-growing tract. Each Province seems to have its own problems, and it appears desirable therefore to develop the present experiments and experimental farms conducted by the Provincial Agricultural Departments.

At the present time the local consumption of wheat in India is far greater than the export trade. The local aspect of the question is therefore of considerable importance. In some of the wheat-growing tracts, the problem is to find a wheat which will mature at all under the moisture and soil conditions prevailing, and in these regions the question of export need not for the present be considered.

The importance of the variety in the case of wheat cannot be overestimated. It would appear to be of greater importance than any of the other factors concerned, such as soil, cultivation, or manurial treatment. Efforts should therefore be directed to the production of new varieties by cross-fertilization suitable for the various districts. In the southern portion of the wheat-growing tract (Bengal, the Central Provinces, Bombay and parts of the United Provinces) the need of rust-resisting varieties is of the greatest importance. In regions of precarious rainfall where irrigation is not available, varieties which mature with the minimum of moisture are wanted. In more favourable districts the aim of the breeder should be in part to produce wheats with milling and baking qualities suitable for export purposes. The hybridization experiments will, therefore, have to be modified according to circumstances, and the aim of the plant breeder in the various Provinces will not necessarily be the same.

Of equal importance to the production of new varieties is the method adopted in distributing them to the actual cultivator. Unless this distribution is adequately controlled and the resulting crops kept under observation, it will be easy to obtain results which would condemn a variety of real value. The question as to the best method of introducing a good variety into general cultivation seems to be one which requires the most careful consideration. It is clear that unless the cultivator can be reached when the time comes, the whole effort must be regarded as useless.

PUSA:
14th January, 1906.

ALBERT HOWARD,
Economic Botanist,
Agricultural Research Institute, Púsa.

The proposals in the above memorandum were adopted by the Board of Agriculture[1] and put forward as a scheme for future work on the improvement of Indian wheats.

Since the beginning of 1906 we have been largely occupied with the actual carrying out of the proposals put forward in the above programme of wheat improvement and in the various developments of the subject which have since arisen.

AGRICULTURAL SURVEY OF THE WHEATS OF INDIA.

The first step in the agricultural survey of the wheats at present grown in India was necessarily as complete a botanical classification as possible, and this we have now completed, thanks to the assistance of many officers of the Agricultural Department. A detailed botanical classification of

[1] *Proceedings of the Board of Agriculture in India*, 1906.

the wheats of India is necessarily the first step in arriving at an accurate knowledge of the wheats now grown as well as their general character. A botanical variety, however, often consists of several different wheats of quite distinct agricultural characters and of very different value to the cultivator. The resolution of the botanical varieties grown in any Province in India into the various constituent agricultural types can only be done by means of a very large number of field cultures, each starting from one plant or one ear and repeated for several years. Such an agricultural survey of the wheats of the Punjab has been completed by us at Lyallpur and the results are described below. The agricultural survey of the wheats of Bengal which has also been undertaken by us at Púsa will shortly be completed, and the results will be published in a forthcoming paper. A detailed agricultural survey of the wheats of the United Provinces is now being undertaken by Mr. H. M. Leake at Cawnpore. This will complete the agricultural survey of the wheats of the Indo-Gangetic plain, and it is hoped that a similar survey of the wheats of the black cotton soils will be undertaken in Bombay and the Central Provinces. In the following chapters our botanical classification of the wheats of India will be found.

The isolation and testing of the agricultural types of wheat grown in the Punjab has already yielded results of great importance. It was found that some of these types are far better wheats from the cultivator's point of view and also possess far superior milling and baking qualities to the mixtures, largely composed of inferior soft white wheats, grown for the export trade. Pure wheats of known quality are for the first time available in this Province for experiments and for seed distribution.

THE PRODUCTION OF IMPROVED VARIETIES.

In addition to the work on the botanical and agricultural survey of the wheats of India, we have made considerable progress at Púsa and at Lyallpur in selection and hybridization work, and some of the new Púsa hybrids will probably be sent to England for milling and baking tests in 1910. Eleven selections made at Púsa in 1906 have so far been tested in England for milling and baking. A large number of others will be ready for testing in 1910 and 1911. While all the Púsa selections already sent have been favourably reported on, five bread wheats have done remarkably well and have shown themselves, both in the mill and bakehouse, to be of the same class as American and Canadian Spring wheats, the strongest and best wheats on the English market. These five Púsa selections are far superior to any Indian wheats yet sent to England. A selected macaroni wheat has also been very favourably reported on. Most of the new

Púsa wheats possess very good agricultural characters and their distribution to cultivators will doubtless do much to raise the standard of wheat production in India.

Important results have also been obtained on the influence of environment on the grain characters of wheat in India, and this work is being greatly extended in collaboration with Mr. H. M. Leake, Economic Botanist to the Government of the United Provinces. The results obtained in 1909 will be published shortly. It is probable that the results already obtained will have considerable bearing on the distribution of wheat to the cultivators in India and will enable a scientific scheme for seed distribution in the Indo-Gangetic plain to be formulated.

In the following chapters we have attempted to describe the work which has been done on the improvement of Indian wheats since the subject was discussed by the Board of Agriculture in 1906. In the first place, an account is given of the method of classification adopted, after which the wheats of India are dealt with Province by Province.

CHAPTER VI.

THE PRINCIPLES OF CLASSIFICATION.

All the cultivated races of wheat belong to the genus *Triticum*. In order to understand the points of difference in the numerous cultivated forms of wheat in India, it is necessary first to briefly consider the structure of the ear.

A wheat ear is composed of a number of units called spikelets, which are arranged in two rows alternately on either side of a central stalk known as the rachis or axis of the ear. The rachis is not straight but is notched, the notches being arranged alternately on opposite sides. It is at the notches that the spikelets adhere to the central rachis, and according to the distance between the points of insertion of the spikelets we get lax,

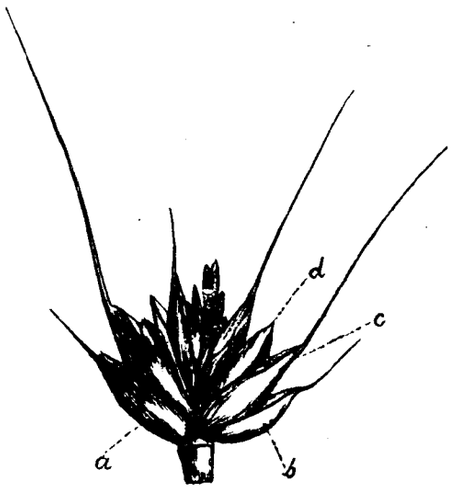

Fig. 3.—A SPIKELET OF WHEAT.
a, *b*, outer glumes; *c*, flowering glume; *d*, pale. (After Vilmorin.)

medium and dense ears. The rachis remains entire when the ears are threshed in the case of wheats belonging to the sub-species *Triticum vulgare*, *T. compactum*, *T. turgidum*, *T. durum* and *T. polonicum*. In the case of the speltlike wheats, however, which belong to the sub-species *Triticum*

spelta, *T. dicoccum* and *T. monococcum*, the rachis is brittle, breaking up at the notches into short pieces each attached to a spikelet.

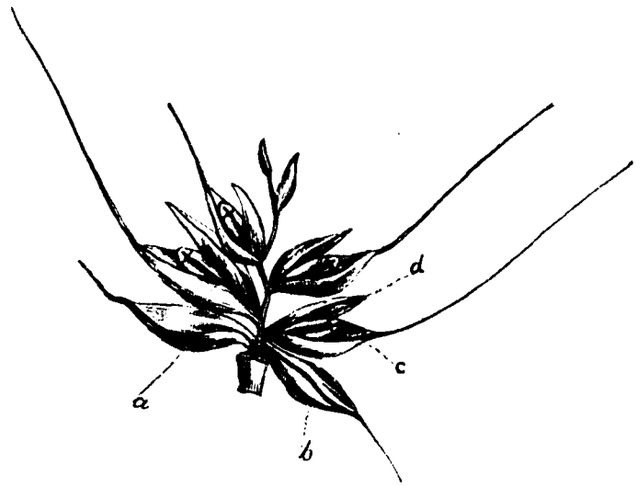

Fig. 4.—A WHEAT SPIKELET with the rachilla purposely elongated to show the constituent flowers : *a*, *b*, outer glumes ; *c*, flowering glume ; *d*, pale. (After Vilmorin.)

The spikelet (Fig. 3) is composed of several flowers, usually from 2 to 8, which are enclosed in two pieces of chaff—the outer glumes, *a* and *b*. Inside these glumes are the flowers arranged alternately on a short axis, the rachilla, or stalk of the spikelet. In Fig. 4 a spikelet is shown with the rachilla purposely elongated to show the structure of the spikelet. Each flower is enclosed in a pair of glumes—a large outer boat-shaped flowering glume, *c*, and a smaller inner glume, *d*, the pale. Within the flowering glume and the pale is the flower composed of three stamens and an ovary surmounted by a bifid feathery stigma. In addition there are two small bodies known as lodicules which serve to force open the flowering glume and pale for the liberation of the stamens after pollination has taken place.

The number of fertile flowers in the spikelet varies, the rest remaining sterile. In *T. monococcum* only one grain is formed ; in *T. spelta* and *T. dicoccum* two are produced ; in *T. vulgare*, *T. durum*, and *T. compactum* the number is 3 or 4 ; while in *T. turgidum* as many as five grains may be formed. At the base of the ear the spikelets are usually aborted.

In some cases, especially in the Rivet wheats, the spikelet elongates and ramifies, giving rise to a branched ear (Fig. 9, Plate I). This phenomenon sometimes occurs in common wheats.

As a rule, the grains easily separate from the glumes (chaff) when the ears are threshed, but in the case of the spelt-like wheats which have a brittle rachis the grains remain firmly invested by the glumes and the threshed grain consists of spikelets to which a short piece of the rachis is attached. We thus have two classes of wheat which are also characterised by other well-marked differences.

After the nature of the rachis, whether brittle or entire, the character of the glumes is next in importance in classifying the various forms of cultivated wheat. The outer glumes may be keeled to the base, as in macaroni wheats, or only in the upper portion as in common wheats. They may be covered with hairs when they are said to be felted, or they may be smooth and the colour may be either black, red or white. The character of the apex (Mittelzahn) and of the tooth (Seitenzahn) on either side of this are also of importance for purposes of classification. The apex may be blunt or acute, and the teeth rounded or pointed as in *T. monococcum*. The flowering glumes may have awns as in bearded wheat, or these may be absent as in beardless wheats. The ears as a whole may be lax, medium or dense, according to the distance between the notches of the rachis. The character of the grain varies considerably among cultivated wheats. In the macaroni group (*T. durum*), the grains are usually long, hard and pointed. In the Rivet wheats (*T. turgidum*) they are usually soft and very large. In the dwarf wheats they are small and rounded and quite unlike the well-known grain of the common bread-making wheats. The colour of the grains is either red or white. Yellowish grains, like those of some of the Australian wheats introduced into India, are classed as white. The consistency of the grain is either hard (flinty) or soft. In many cases, however, mottled grains consisting of hard and soft portions are met with.

THE SPECIES AND SUB-SPECIES OF CULTIVATED WHEATS.

The cultivated wheats of the world fall into three well-defined species—*Triticum sativum* Lam., *T. polonicum* L., and *T. monococcum* L.

CONSPECTUS OF THE SPECIES.

I. The tooth (Seitenzahn) of the outer glume acute or acuminate, stiff, the ripe pale divided into two halves.

1. *T. monococcum* L. Einkorn or one-grained wheat.

II. The tooth (Seitenzahn) of the outer glumes blunt, rounded or absent. Pale undivided. Apical spikelet fertile.

2. *T. polonicum* L. Polish wheat. Outer glumes as long or longer than the flowering glumes, papery.
3. *T. sativum* Lam. Outer glumes shorter than the flowering glumes, parchment like. Pale the same length as the flowering glume.

TRITICUM SATIVUM LAM.

Ears with a fertile terminal spikelet and brittle or tough rachis. Outer glumes shorter than the flowering glumes, with or without a blunt tooth (Seitenzahn). Pales as long as the flowering glumes, undivided.

I. RACHIS BRITTLE. GRAIN ENCLOSED IN THE GLUMES WHEN THRESHED.

1. *Triticum spelta* L. Spelt. Ears bearded or beardless, long and thin, lax and somewhat square. Outer glumes very broad and truncated with a very short and blunt apex (Mittelzahn) and a rather undeveloped keel.
2. *Triticum dicoccum* Schrk. Emmer. Ears nearly always bearded, dense, broader on the two-rowed side, outer glumes sharply keeled with an acute apex.

II. RACHIS TOUGH. GRAINS SEPARATING FROM THE CHAFF WHEN THRESHED.

3. *Triticum compactum* Host. Dwarf wheats. Ears bearded or beardless, extremely short and very compact, more or less quadrangular. Outer glumes keeled above, rounded below. Straw very short and stiff. Grains rounded.
4. *Triticum turgidum* L. Rivet wheats. Ears bearded, large and four-sided with the spikelets closely packed on the rachis. Straw very tall, stiff, often solid. Grains large, short and plump with a blunt apex.
5. *Triticum durum* Desf. Macaroni wheats. Ears large, dense with long awns. Outer glumes sharply keeled to the base. Straw stiff, usually solid. Grains long, somewhat pointed and hard.
6. *Triticum vulgare* Vill. Common wheats. Ears bearded or beardless, more or less lax (much laxer than *T. compactum*). Outer glumes keeled above, rounded below. Straw hollow

PLATE I.—THE SPECIES AND SUB-SPECIES OF CULTIVATED WHEAT.

Fig. 1. Einkorn—(*T. monococcum* L.)
Fig. 2. Polish wheat—(*T. polonicum* L.)
Fig. 3. Bearded spelt—Epeautre noir barbu. } (*T. spelta* L.)
Fig. 4. Beardless spelt—Epeautre noir sans barbes }
Fig. 5. Emmer—Amidonnier blanc } (*T. dicoccum* Schrk.)
Fig. 6. Emmer—Amidonnier noir }
Fig. 7. Macaroni wheat—Médéah—(*T. durum* Desf.)
Fig. 8. Rivet wheat—Nonette de Lausanne } (*T. turgidum* L.)
Fig. 9. Rivet wheat (branched)—Mirácle }
Fig. 10. Dwarf wheat—Jondhala C. P.—(*T. compactum* Host.)
Fig. 11. Common wheat—Muzaffarnagar white } (*T. vulgare* Vill.)
Fig. 12. Common wheat—Chiddam }

1 2 3 4 5 6

7 8 9 10 11 12

THE WHEATS OF CULTIVATION.

medium in length. Grains not rounded, more than twice as long as beard.

NOTES ON THE VARIOUS GROUPS.

EINKORN (*T. monococcum* L.). This interesting primitive species is grass-like in habit and possesses a short, flat, compact, bearded ear which closely resembles barley (Fig. 1, Plate I). The spikelets are two-flowered, but one of these flowers is aborted while the other produces a single grain. The rachis is very brittle and the straw is stiff and almost solid. It is extremely resistant to rust attacks.

Einkorn was grown by the Greeks for pigs' food but was not known to the Romans. It is at present cultivated on the poor soils of the mountainous districts of Spain, Switzerland, Wurtemberg and Thuringia. In the south of France it is a troublesome weed, difficult to eradicate as the ripe rachis breaks so easily and scatters the spikelets. This wheat has not been found in India.

POLISH WHEAT (*T. polonicum* L.). This species has long ears of glaucous tint, and is readily distinguished by its empty glumes which are often an inch long and enclose all the flowers in the spikelet (Fig. 2, Plate I). The grains are very long, hard and flinty, and the straw is almost solid.

Polish wheat has not been found in India. It is cultivated to a small extent in Spain, Italy and Abyssinia. The grain is sometimes fraudulently sold as a specially large rye, and samples actually obtained prizes at the Denver Exhibition in the United States. The yield of this wheat is very poor as the plants tiller badly and the large ears do not contain many grains.

SPELT WHEATS (*T. spelta* L.). The varieties of this form have lax ears with reddish, white or black chaff; some are felted and a few awned (Figs. 3 & 4, Plate I). Each spikelet contains two or three grains which are triangular in section.

Spelt wheats have not been found in India, the so-called spelt wheat being really emmer. They were commonly cultivated in Europe and Egypt in the earliest times and are frequently referred to in the writings of the Greeks and Romans. At the present time spelts are grown in Italy, Spain, France, Switzerland, South Germany and Austria and also in Brazil. In the Rhine valley, the most northerly limit of spelt wheat cultivation in Europe, the crop is grown mixed with rye or other wheat. These forms are winter wheats and are sown in Europe in the autumn. It is unlikely, therefore, that they will be found in the ordinary wheat-growing regions of India.

EMMER (*T. dicoccum* Schrk.). The varieties of emmer are sometimes confused with spelt wheats. They differ from spelt in having dense ears which are nearly always bearded (Figs. 5 & 6, Plate I). Each spikelet ripens only two grains.

Emmer is met with in India in Bombay, Madras and Mysore and apparently to a small extent in the Central Provinces. In Bombay, emmer is said to be rust-resistant. When grown, however, at Púsa (Bihár, Bengal), it has been attacked to a slight extent by early rust (*Puccinia triticina* Ericks.) for the last two years. Emmer is grown in South Germany, Switzerland, Spain, Italy, Servia and Russia, and it has been introduced as a crop into Canada and the United States.

DWARF WHEATS (*T. compactum* Host.). The dwarf wheats have very short, stiff straw and exceedingly compact ears, scarcely ever more than two inches long (Fig. 10, Plate I). The outer glumes are keeled in the upper portion and rounded below, and the grains are rounded and quite unlike ordinary wheat.

Dwarf wheats are found in India, chiefly in the Multán and other western Districts of the Punjab and to a small extent in the Central Provinces and in the United Provinces. In the Western Punjab, these wheats are grown on unirrigated lands and are said to ripen with a very small supply of moisture, which would be expected from their characteristic tufted habit. Dwarf wheats are grown in Chili, Turkestan, Germany and Switzerland. The awned forms are sometimes called Hedgehog wheats.

RIVET WHEATS (*T. turgidum* L.). The ears of these varieties are large and four-sided, very dense and bearded (Figs. 8 & 9, Plate I). The chaff is sometimes felted and the outer glumes are keeled to the base. The grains are large, short and thick, generally soft, and the straw is stiff, long and solid in the upper portion. It is often a matter of great difficulty to distinguish Rivet wheats from the members of the macaroni group (*T. durum*), as the consistency and shape of the grains of the latter may vary in such a manner as to resemble closely those of Rivet wheat. Indeed, it is sometimes a matter of personal opinion to which of these classes certain wheats may be assigned.

Undoubted Rivet wheats have been found in India in Baluchistán only. They are chiefly met with in the Mediterranean region and are grown to a very small extent in England.

MACARONI WHEATS (*T. durum* Desf.). The ears of these wheats are long and bearded, and the glumes are often felted and the awns black (Fig. 7, Plate I). The outer glumes are keeled to the base and the straw

is stiff and solid in the upper portion. The grains are usually hard and flinty, and long and pointed.

Macaroni wheats are met with in all the wheat-growing regions of India and especially in the southern portion of the wheat tract—Bombay, the Central Provinces, Madras and Mysore. In Bengal, macaroni wheats are almost entirely confined to one tract, the Málda District. The grains are very rich in gluten and at one period were much exported from India to Europe for the manufacture of macaroni. Of late years, however, the export has fallen off. Macaroni wheats are spring-sown in Europe and are chiefly cultivated in the countries around the Mediterranean.

COMMON WHEATS (*T. vulgare* Vill.). The ears of these wheats are either bearded or beardless, and the outer glumes are keeled in the upper portion only (Figs. 11 & 12, Plate I). The chaff may be red or white, smooth or felted. The grains are either red or white, and the consistency varies from hard to soft.

Most of the wheats of India are common wheats and, as is usual in hot and dry countries where this crop is grown, bearded forms predominate. Beardless forms are grown most in north and central Europe.

THE METHOD OF CLASSIFICATION.

Up to the sub-division of *Triticum sativum* Lam. into six sub-species, arranged in two groups, most modern botanists are in agreement and the classification of Koernicke in the *Handbuch des Getreidebaues* which we have quoted above is the one now in general use. Concerning the further classification of the wheats within these groups, however, the greatest diversity of opinion exists. Each sub-species contains a very large number of forms distinguished from one another by one or several characters, and different systems of classification have been drawn up according to the degree of value assigned to the various characters. For instance, the colour of the grain has been considered by some observers[1] to form a distinctive mark for varieties, whereas others[2] consider it of very little value. The characters which distinguish one wheat from another are partly botanical, partly agricultural, and as none of the schemes of classification proposed up to the present appear to give adequate emphasis to the latter characters, we have been obliged to draw up a new one which combines both classes of characters and which it is hoped will be of use in India.

[1] Koernicke, *Die Arten und Varietäten des Getreides*, Berlin, 1885.
[2] Eriksson, *Die landwirtschaftlichen Versuchs-Stationen*, Bd. 45, 1894.

It is not proposed to criticise in detail the numerous schemes of classification already brought forward for wheat, but only to touch briefly on the more important modern systems. A very good historical account of the older attempts at classification is given by Eriksson.[1] The most important modern system is that of Koernicke, who may be said to represent the German school. His system is excellent so far as it goes, but it only takes into account the morphological characters and stops short at the botanical variety. The supplement by Werner[2] consists merely of a description of numerous wheats and has no classificatory value. Vilmorin[3] is the best representative of the French school of wheat systematists. The chief objection to his scheme and those allied to it lies in the want of clearness and definiteness in the diagnosis of the lower sub-divisions. In 1894, Eriksson[1] proposed a new system designed to carry the classification of wheat varieties to a further point than is possible by Koernicke's method. One of the chief characters on which he relies is the structure of the ear, *i.e.*, its length and the density of the spikelets which is expressed by von Neergard's method, *i.e.*, by counting the number of spikelets on 100 mm. of the rachis (D). The value of D is, however, a character which in India is absolutely untrustworthy. Conditions of moisture and of season may cause more variation in the ears of one plant than occurs between two widely different varieties, and no system founded on this value would be applicable to India. No serious attempt to evolve a satisfactory system of classification has, up to the present, been made by English observers. Among American writers Schofield[4] has drawn up a table of the most important points to be noticed in the description of wheats, but no system or scheme of classification is proposed. Cobb[5] in New South Wales proposes to classify the wheats by a microscopic examination of the aleurone layer, but such a system besides its difficulty and general impracticability for all except an experienced botanist rests on a somewhat doubtful foundation if the great effect of climate on the quality of the grain is considered (p. 228).

Before adopting any scheme of classification for the wheats of India, it appeared necessary to undertake a study of the varietal characters of wheat and of their constancy under different conditions of climate and season.

[1] Eriksson, *Die landwirtschaftlichen Versuchs-Stationen*, Bd. 45, 1894.
[2] Werner, *Handbuch des Getreides*, Vol. 2, Berlin, 1885.
[3] Vilmorin, *Catalogue Methodique et systematique des Froments qui composent la collection*, Paris, 1889.
[4] Schofield, *Bulletin* 47, *Bureau of Plant Industry, U. S. Dept. of Agr.*, 1903.
[5] Cobb *Agr. Gaz. of N. S. Wales.*

The details of this work are published elsewhere[1], and it will only be necessary to refer briefly to the results here. The varietal characters of wheat are most conveniently dealt with under two heads: (1) botanical or morphological and (2) field or agricultural characters.

BOTANICAL OR MORPHOLOGICAL CHARACTERS are those which remain constant with change of environment or season and which are inherited. They can be determined in the laboratory from properly developed specimens. The most important botanical characters of wheat are the presence or absence of awns, the presence or absence of hairs on the glumes, the colour of the grain, the structure of the straw, the character of the leaves, the form or shape of the ear and the character of the spikelets and glumes.

FIELD OR AGRICULTURAL CHARACTERS are less conspicuous and cannot be distinguished in the laboratory nor from individual plants. They can only be fully appreciated in the field in pure cultures grown side by side under uniform conditions. The erectness of the ear, the tone of colour of the chaff and straw are field characters influenced less by season and environment than such agricultural characters as the strength and length of straw, earliness and lateness, the density of the spikelets and susceptibility to rust. All the above are characters of the greatest use and are inherited.

The above characters may now be considered in detail :—

1. *The presence or absence of awns.* We have found this to be a constant character. It must be remembered, however, in examining specimens that some of the bearded wheats of India show a tendency to shed their awns and so simulate beardless wheats.

2. *Chaff characters.* The nature of the chaff surface, whether smooth or felted, is a most important varietal character owing to its constancy. The chaff colour (red, white or black) is equally constant, but is a character needing great care in use. In bad seasons, the red or black colour of the chaff is not developed, in dry years owing to the ears drying up before maturity, in wet years owing to rust attacks and want of sufficient sunshine. The same is true of the colour of the awns which may be either black, red or white. Tone of colour is useful in many cases to separate nearly allied but not identical wheats.

3. *Grain characters.* The colour of the grain is either red or white. On the constancy of this character the most diverse opinions have been

[1] Howard and Howard, *Memoirs of the Dept. of Agr. in India* (Bot. series), Vol. 2, No. 7, 1909.

expressed. We agree with Koernicke and those observers who are of opinion that it is a character unchanged by environment and of the very highest systematic importance. The consistency of the grain is either hard or soft. After much careful and detailed work on this subject, we have come to the conclusion that this character is most variable and is greatly influenced by season and environment. It is therefore quite useless for systematic purposes. A fuller discussion of the colour and consistency of the grain is given on p. 228. The shape of the grain is useful in differentiating the sub-species from one another, but we have not found it to be of systematic value within the sub-species.

4. *Straw characters.* The strength of the straw is a field character of considerable importance from the agricultural standpoint on account of the damage by laying. It is also of some systematic value, and appears to be connected with the erectness of the ear. The structure of the straw has only been used in differentiating sub-species. The length of straw is a field character which is of use when combined with others in distinguishing between two agricultural types. The colour of the straw in some cases is most distinctive; the stems appear pink before maturity and turn grey or black when fully ripe.

5. *Earliness and lateness.* This character is not easy to determine with precision in India as it is apt to be masked by the result of differences in soil moisture. It is, however, useful when the wheats can be grown for several seasons next to next on uniform soil and under uniform moisture conditions.

6. *Susceptibility to rust.* The importance of this character agriculturally need not be emphasised. There is much detailed work, however, still to be done as regards the rust-resistance of the various Indian wheats.

7. *Form or shape of the ear.* This character is only of use in certain cases, as in India most of the wheats resemble each other very closely in the shape of the ear. The density of the ear in the case of many of the common wheats of India is of little or no systematic value, as the variation in density between the ears of one plant is often greater than that between different varieties. The erectness of the ear is a character which we have found most useful in distinguishing agricultural types in the field which are very similar morphologically.

In the system of classification adopted in the following pages the wheats contained in any one sub-species are first divided into varieties, and the variety is, when possible, subdivided into agricultural types. The varieties are founded on differences in botanical or morphological characters,

while the agricultural types are differentiated as their name implies by field characters. As all such terms as variety, race, type, etc., have been used by plant breeders and others in a very loose manner, it is desirable to define the terms employed in the following pages. In the conception of variety the definition of Koernicke has been followed. By it is understood those forms of a sub-species or species which can be differentiated in properly developed single individuals by definite, inherited and easily distinguishable characters such as the presence or absence of awns, smooth or felted chaff. The varieties are therefore the botanical units of the sub-species and represent the lowest limit to which wheat can be divided in the laboratory with precision. Each botanical variety, however, often comprises many wheats which in agricultural characters and in economic importance may differ very widely. The types represent the agricultural units of a variety in the same way as the varieties are the botanical units of the species or sub-species. To determine the agricultural types it is necessary to grow the wheats in pure culture, beginning from one ear or one plant for several years under uniform conditions.

The following is the scheme of classification proposed for Indian wheats after the division into sub-species :—

1. Varieties based on the following characters in the order given :—
   - (*a*) Presence or absence of awns.
   - (*b*) Felted or smooth chaff.
   - (*c*) Colour of the chaff (red, white, black).
   - (*d*) Colour of the grain (red or white).

2. Agricultural types based on the following characters in the order given :—
   - (*a*) Tone of colour of chaff.
   - (*b*) Erectness of ear.
   - (*c*) Straw characters (length, strength and colour).
   - (*d*) Earliness and lateness.
   - (*e*) Susceptibility to rust.

The necessity for considering the agricultural characters in classifying and studying the wheats of any tract cannot be overestimated. It is the agricultural characters which render a wheat useful or otherwise both for indigenous and export use. For wheat-breeding experiments, manurial, cultivation and variety trials and seed distribution, it is necessary to have agriculturally pure types; botanically pure varieties are not sufficient. Botanical classification is necessarily the first step and is important in

itself, but it is not sufficient if really useful work is to be done on the improvement of wheat.

It has been impossible for us to carry out for each Province such a detailed classification involving actual cultivation of the wheats for several years. Owing to the facilities afforded us at Lyallpur we have been able to complete not only the botanical but also the agricultural classification of the Punjab wheats, and a similar survey of the wheats of Bengal is in progress at Púsa. For the other Provinces as complete a botanical classification as possible has been made. In order to prevent confusion by a double use of the words type or variety the wheats have been grouped into classes. Each class represents wheats which are identical in morphological characters and are therefore indistinguishable in the laboratory. Further subdivision of the classes into agricultural types will only be possible when the wheats in any one class have been grown from single ears or single plants for several years under uniform conditions.

After dealing with each Province separately we have given a list of the botanical varieties of wheat occurring in the whole of India with their distribution.

CHAPTER VII.

THE WHEATS OF THE PUNJAB, SIMLA HILLS AND BALUCHISTAN.

PUNJAB. At the request of Mr. Renouf, Director of Agriculture of the Punjab, an exhaustive study of the wheats of that Province was undertaken in 1906. The material at our disposal consisted of a large collection of the wheats of the various Districts of the Province made at Lyallpur a few years ago by the Punjab Agricultural Department. The botanical varieties were segregated at the harvest of 1906 and pure line cultures of the various agricultural constituents of each variety were grown and carefully examined at Lyallpur during the wheat seasons of 1907 and 1908. We have thus been enabled to carry the classification of the Punjab wheats beyond the botanical varieties to the agricultural types.[1]

Besides our own cultures at Lyallpur a duplicate set of the Lyallpur collection of Punjab wheats, grown at Saharánpur, was placed at our disposal by the Economic Botanist to the United Provinces. Many of the Punjab wheats have also been grown at Púsa. In addition, local collections were made in the neighbourhood of Lyallpur and also at Jullundur. A note on the botanical varieties of wheat grown in the Simla Hills is appended to this chapter.

The Punjab is rich in types of wheat, and possesses forms belonging to the three sub-species *Triticum durum* Desf., *T. vulgare* Vill. and *T. compactum* Host. The macaroni wheats, known locally as *waddánaks*, are widely distributed but are cultivated only on a small scale. The dwarf wheats are chiefly confined to the dry districts to the north-west of Multán. The common bread-making wheats of the Canal colonies are of great importance owing to the large export trade from Karáchi, and any improvement of the varieties cultivated would be of the greatest economic importance. The twenty-five types isolated by us were submitted to Mr. A. E. Humphries, Past President of the Incorporated National Association of British and Irish Millers, for his opinion as a British miller and a few were also submitted for baking tests. Among the wheats already in cultivation in the Province there appear to be several promising types.[2]

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[1] For the full account of the work on the Punjab Wheats, see Howard and Howard, *Memoirs of the Agricultural Department of India* (*Botanical series*), Vol. 2, No. 7, 1909.

[2] Howard and Howard, *Bulletin* No. 14, *Agricultural Research Institute, Púsa*, 1908.

CLASSIFICATION OF THE PUNJAB WHEATS.

TRITICUM DURUM DESF. MACARONI WHEATS.

1. Glumes felted.
   A. Glumes white, awns often black.
      a. Grain red.
         var. *africanum* Kcke.
         Type 2.
      b. Grain white.
         var. *melanopus* Al.
         Type 1.

2. Glumes smooth.
   A. Glumes white, awns always white
      a. Grain white.
         var. *leucurum* Al.
         Type 3.

TRITICUM COMPACTUM HOST. DWARF WHEATS.

I. Ears bearded.
   1. Glumes smooth.
      A. Glumes red.
         a. Grain red.
            var. *erinaceum* Kcke.
            Type 4.

II. Ears beardless.
   1. Glumes felted.
      a. Grain white.
         var. *linaza* Kcke.
         Type 5.

   2. Glumes smooth.
      A. Glumes white.
         a. Grain red.
            var. *Wernerianum* Kcke.
            Type 6.
         b. Grain white.
            var. *Humboldti* Kcke.
            Type 7.

TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
   1. Glumes felted.
      A. Glumes red.
         a. Grain red.
            var. *barbarossa* Al.
            Type 8.
      B. Glumes greyish-white, awns black.
         a. Grain red.
            var. *fuliginosum* Al.
            Type 9.

   2. Glumes smooth.
      A. Glumes re..
         a. Grain red.
            var. *ferrugineum* Al.
            Type 13.
         b. Grain white.
            var. *erythroleucon* Kcke.

Type 10. Chaff dull light red, heads bend over when ripe, early, straw short and weak, D = 21.

Type 11. Chaff bright red, heads erect when ripe, late, straw tall and strong, D = 25.

Type 12. Chaff dull light red with a somewhat bluish tone and with occasional blackening of the awns, chaff sometimes blackish also, heads bend over when ripe, grain easily shed, straw pink turning black on ripening, tall, of medium strength, D=21.

      B. Glumes white.
         a. Grain red.
            var. *erythrospermum* Kcke.

Type 14. Heads bend over when ripe, grain shed easily, early, straw weak, short, somewhat resistant to yellow rust, D = 25.

Type 15. Heads erect, less readily threshed than type 14, late, straw strong, tall, liable to yellow rust, D=25.

         b Grain white.
            var. *græcum* Kcke.
            Type 16.

II. Ears beardless.

1. Glumes felted.

A. Glumes red.

a. Grain white.

var. *Delfii* Kcke.

Type 17. Chaff with a bluish tinge, straw medium, D = 19.

Type 18. Chaff yellowish red, ears erect when ripe, straw stronger than in type 17, later in ripening, D = 26.

B. Glumes white.

a. Grain white.

var. *leucospermum* Kcke.

Type 19.

2. Glumes smooth.

A. Glumes red.

a. Grain red.

var. *milturum* Al.

Type 22. Sometimes slight bearding, chaff dark brownish red and shiny, grain dark red, D = 19.

Type 23. Chaff dull yellowish red, grain easily shed, light red, D = 23.

b. Grain white.

var. *alborubrum* Kcke.

Type 20. Chaff light yellowish red, heads more erect and later than in type 21, straw taller and stronger, D = 24.

Type 21. Chaff brownish red and dull, heads bend over when ripe, earlier than type 20, straw medium, D = 20.

B. Glumes white.

a. Grain white.

var. *albidum* Al.

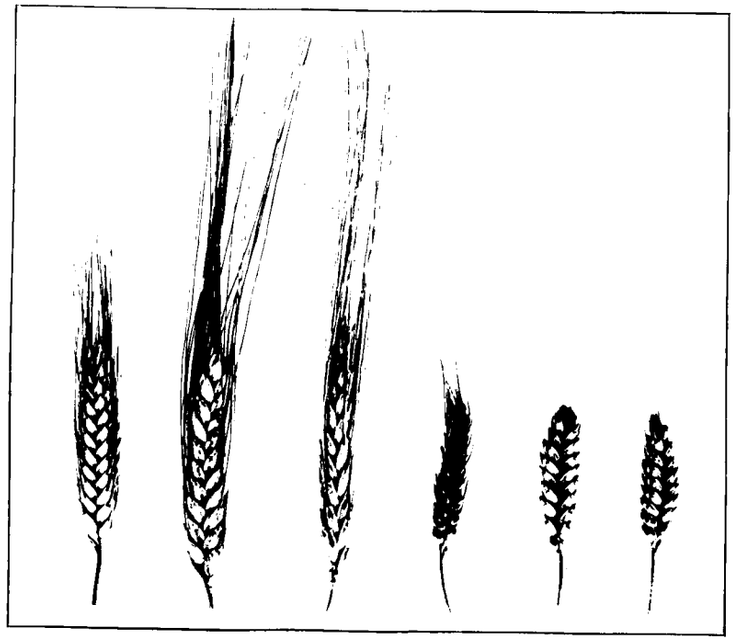
Type 24. Spikelets blunt, outer glumes short and rounded, chaff white with a reddish border, ears bend over slightly, straw strong, D = 20.

Type 25. Spikelets pointed, outer glumes long and pointed, chaff yellowish white shiny, ears erect, straw strong, D = 20.

DESCRIPTION OF THE TYPES.

TRITICUM DURUM, DESF. MACARONI WHEATS.

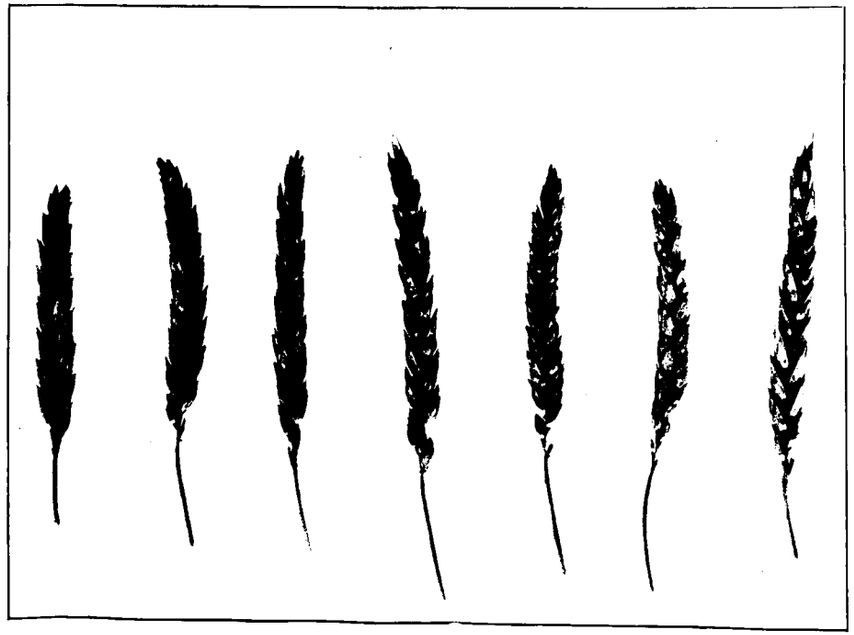
Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid, grains long.



Type 1 2 3 4 5 6

Type 13 14 15 16 17 18

Type 7 8 9 10 11 12



Type 19 20 21 22 23 24 25

There are three varieties of *Triticum durum*, Desf., found in the Punjab, var. *melanopus* Al., type 1, var. *africanum* Kcke., type 2, var. *leucurum*, Al., type 3. Of these, the first is the most common and represents the so-called *Wadának* wheat of the Province. The other two were only found in very small quantities, especially type 3. Macaroni wheats, on account of their large water requirements, are in general only grown round wells and their cultivation is very limited. The flour is used mostly for confectionery. These wheats ripen late and are more attacked by birds than the ordinary wheats. This may be due to the stiff straw and heads on which it is possible for birds to perch and also to the fact that on account of their tall straw they range above all other wheats. These macaroni wheats have broad long leaves smooth on the upper surface with hairs on the claws. Even when thinly sown they do not tiller much.

var. *melanopus* Al.

Type 1.—Awns long, black, but lose their black colour very easily; chaff densely felted, white with a pinkish tinge, often spotted with mould fungi, grains long, amber, generally hard[1] and flinty, although occasionally, mottled ones are found; density[2] varies with the rankness of growth; straw tall, slender but stiff; somewhat liable to rust; ripens late.

This is the common macaroni of the Punjab and was found in the Wadának of Zíra, Wadának of Siálkot, Wadának of Batála, Wadának Kalchingari of Montgomery, Wadának of Amritsar, Dagar of D. G. Khán, Dagar of Wazirabad, Dagar of Shahpur, Pamman of Ferozepore, Dagar of Muzaffargarh, Dagar of Multán, Dagar of Montgomery and in the Wadánaks of Lyallpur, Ferozepore and Amritsar and the Palestine of Lahore.

var. *africanum* Kcke.

Type 2.—Similar in most respects to type 1 but the ears taper to a point and are slightly longer: grain very dark red, hard on the whole with a very few mottled grains; length of ear 84 mm.[3]; D = 28. This type is more liable to rust than type 1.

[1] The descriptions of the consistency refer to the samples obtained in the harvest of 1908 when the types were grown in small plots next to each other.

[2] Both the length of ear and the density vary very much in type 1. At first it seemed possible that there might be two types differing only in density, but from the single ear cultures we were unable to isolate two strains constant in different density.

[3] Length of ear and D were both measured in specimens from the harvest of 1908 and are the average of 20 typical ears. As explained previously, no great stress can be laid on such measurements. They are merely given as an indication of the values of these quantities.

Type 2 was only met with as an impurity in the Wadának Kalchin gari of Montgomery.

var. *leucurum* Al.

Type 3.—Awns long, white with a reddish tinge; chaff smooth, shiny white with a pinkish tinge due to the veins on the glumes being red; grain very long and thin, white, much lighter in colour than type 1, generally very hard and translucent, hardly a mottled grain to be found; length of ear 75 mm.; D = 22; straw good; ripens late; not so liable to rust as type 1.

Type 3 was only found as an impurity in the Wadának of Lyallpur in very small quantity. The grains of this type are so long that in the opinion of the Chairman of the Home-grown Wheat Committee of England they would pass over the standard sieves with the large impurities.

TRITICUM COMPACTUM HOST. DWARF WHEATS.

Ears exceedingly dense and short, rarely over 2 ins. long, outer glumes keeled in the upper half and rounded in the lower half, straw very short and stiff, grains rounded.

There are four varieties of *Triticum compactum* grown in the Punjab. They are drought-resisting and are generally grown on inundation moisture with little rain. They are also said to be good yielders, and type 7 has a good reputation for bread-making. Owing to the smallness of their grain, they can, however, only be used for indigenous consumption and are, therefore, being gradually replaced by common wheats. They agree with the common wheats in time of ripening and showed themselves exceedingly susceptible to early rust, *P. triticina*, when grown at Púsa; in fact, they were almost destroyed by it. They are, however, fairly resistant to yellow rust. The ears are short and erect, the straw stiff, short (generally about 3′ 6″ or 4′), hollow throughout as in common wheats but much stouter.

The Chairman of the Home-grown Wheat Committee of England remarks that "types 4 and 7 are extraordinarily small in the berry, so small that millers would hesitate to buy them if they contained any small seeds because the machinery used for extracting the small seeds would take out simultaneously a very large proportion of the wheat berries themselves."

var. *erinaceum* Kcke.

Type 4.—Ears bearded with short, bristly, spreading awns very irregular in length, red; chaff smooth, dark red; grain very small, round,

rather a light dirty red in colour, very difficult to distinguish from a dark amber, hard on the whole with a few soft grains; ear length 50 mm.; D=38.

To this type belongs the Makkhi of Chiniot.

var. *linaza* Kcke.

Type 5.—Ears beardless, chaff felted with short hairs, white with a pinkish tinge due to the pink colour of the edges and veins of the glumes; grain round, small but larger than in type 4, amber-coloured, hard on the whole with a few soft and mottled grains; ear length 49 mm.; D=38; straw pinkish, turning greyish on ripening.

This type was only met with in small quantity in the Makkawali of Dera Gházi Khán.

var. *Wernerianum* Kcke.

Type 6.—Ears beardless, but with occasional very slight bearding; chaff smooth, with a pinkish tinge; grain round, about the same size as in type 5, a clean light red, all soft; ear length 44 mm.; D=39; straw has no pink colour.

This type was only found in small quantity in the Makini of Multán.

var. *Humboldti* Kcke.

Type 7.—Ears beardless; chaff smooth, white with a pinkish tinge; grain round, about the same size as in type 5 but possibly a little smaller; amber-coloured, consistency very variable, hard, soft and mottled grains found in about equal proportions; ear length 45 mm; D=41; straw pinkish, turning black on ripening.

This is the common dwarf wheat of the Punjab and was found in the Rodi of Sháhpur, Rangrih or Ghiali of Kángra, Makini of Multán, Daud of Muzaffargarh, Daudan of Multán, Makkawali of D. G. Khán and in the Daudi of Multán.

Mr. A. C. Dobbs of Lyallpur found that this wheat was grown at Ráwalpindi and that it was considered in that District as the best for bread-making.

TRITICUM VULGARE VILL. COMMON WHEATS.

Eighteen of the twenty-five types of wheat found in the Punjab belong to this sub-species, and among them are found the wheats most commonly grown. These eighteen types belong to eleven botanical varieties and are equally divided into bearded and beardless, there being nine types belonging to each class. Among the eighteen types only five are felted, but

among these are to be found the two best wheats of the Punjab. The range in quality is very great, type 9 the best being a good strong wheat fit for export, whereas some have a most inferior grain hardly worth growing for local consumption.

var. *barbarossa* Al.

Type 8.—Ears bearded; awns red; chaff felted with short rather sparse hairs, yellowish red; grain dark red; consistency variable, hard, soft and mottled grains found in about equal proportions; ear length 78 mm.; D=24; straw good; ears erect and rather slender.

This type was found in the Lal Kasar Wali of Lyallpur in very small quantity.

var. *juliginosum* Al.

Type 9.—Ears bearded; awns stiff, stout rather short, black but lose their colour very easily; glumes sharply keeled to the base; chaff densely felted with long hairs, the felting resembles very closely that found on the macaronis, chaff greyish white, pink or brown at the edges, generally with black spots of *Cladosporium*; grain very dark red, on the whole hard with a few mottled grains, the shape resembling that of an ordinary wheat; ear quadratic in section, sometimes club-shaped at the top, somewhat compact; ear length variable, about 70 mm. on the average; D=25; straw stiff, stout, hollow throughout; ears very erect.

This type was found in the Lal of Batála, Ratti of Montgomery and in the Lal Kale Kasar Wali of Lyallpur; it was also found in small quantity in the Lal Desi of Jhelum, Lal of Delhi, Pamman of Ferozepore, Dagar of Multán, and Kunjhari of Muzaffargarh. This wheat is one of the most interesting types found in the Punjab, for although it must be classed as a common wheat, it appears to possess many of the characters of the macaronis. The felting resembles very closely that of the macaroni wheats and is quite different to that found on the other felted common wheats or on the felted dwarf wheat. The shape of the glumes with the keeling continued sharply to the base is that characteristic of macaronis. The hollow straw and the shape of the grain are, however, those of a common wheat. The shape of the ear with its compact sometimes club-shaped top, the stoutness of the straw and the stiff awns are reminiscent of a dwarf wheat, and it seems quite possible that this type which is unique in India (except for a variety probably derived from it and cultivated in Nimár), may have arisen from a natural cross between a dwarf and a macaroni wheat or it is possible that the Rivet wheat

obtained from Baluchistán which resembles it in some particulars may be one of the original parents. At flowering time this wheat (type 9) appears to shed a vast amount of pollen and probably gives rise in this manner to further natural crosses (p. 139). It is interesting to note that this is marked by Mr. Humphries as being the best of the twenty-five Punjab types submitted to him.

var. *erythroleucon* Kcke.

Type 10[1].—Ears bearded; awns red; chaff smooth, dull light red; grain amber coloured, liable to sprout in the ear, consistency variable, hard, soft and mottled grains found in equal proportions; length of ear 82 mm; D=21; straw short and weak; heads bend over when ripe; early.

This type was found in the Safed of Moga, Mundi of Ludhiána, and the Jogia of Karnál.

Type 11.—Ears bearded; awns red; chaff smooth, a more intense and brighter red than in type 10; grain amber coloured, liable to sprout in the ear, consistency variable but with a majority of soft grains; ears squarer and denser than in type 10; ear length 76 mm.; D=25; straw tall and strong; heads stand erect; later than type 10.

This type was found in the Safed of Amritsar, Sohan of Chiniot, Kunjhari of D. G. Khán, Daudi of Lyallpur, and in the Jogia of Karnál.

Type 12.—Ears bearded, awns red with occasional blackening; chaff smooth, dull light red with a somewhat bluish tone, occasional blackening on the chaff; grain amber coloured, hard on the whole; ear length 86 mm.; D=21; straw intermediate in strength between that of types 10 and 11, pink turning grey on ripening, tall; heads bend over when ripe; early, grain easily shed.

This type was found in the Rangrih of Pálampur.

var. *ferrugineum* Al.

Type 13.—Ears bearded; awns red; chaff smooth, shiny, yellowish or brownish red; grain red, intermediate in colour between the dark and light red grained types, rather small, consistency variable about two-thirds being hard; ear length 96 mm.; D=18; straw medium; heads fairly erect; rather late.

This type was found in the Lal Kasar Wali of Lyallpur. The hard red wheat of Gujar Khán also belongs to this type but ripened a little later

[1] We have found some difficulty in describing the difference between these thre types (10, 11 and 12); the differences are best seen in the field.

than the Lal Kasar Wali. This difference may easily disappear after the hard red of Gujar Khán is acclimatised at Lyallpur.

var. *erythrospermum* Kcke.

Type 14.—Ears bearded ; awns pinkish yellow ; chaff smooth, white with a reddish tinge when ripe ; grain light red, hard and soft grains in about equal proportions ; ear length 80 mm. ; D=23 ; straw weak and short, heads bend over when ripe ; early ; fairly rust-resistant ; sheds its grain more easily than type 15.

This type was found in the Lal of Karnál, Lal of Siálkot, Lal of Attock, Safed of Sirsa, Lal of Zíra, Kasalu or Surkh of Ferozepore, Ratti or Lal of P. D. Khán, Lal of Ludhiána, Desi Surkh of Jullunder, Lal Desi of Jhelum, Lal of Ráwalpindi, Lal of Delhi, and the Kunjhari of Muzaffargarh.

Type 15.—Ears bearded ; awns pinkish yellow ; chaff smooth, white with a reddish tinge when ripe ; grain light red, consistency variable, but the majority are soft grains ; ear length 80 mm. ; D = 25 ; straw tall and strong, heads erect when ripe ; late ; susceptible to rust ; grains less easily shed than in type 14.

This type was found in the Ratti or Lal of P. D. Khán, Watni of Sháhpur, and the Kunjhari of Multán.

Types 14 and 15 form the common red wheat of the Punjab. A glance at the names of this variety will show that it is cultivated all over the Province. It is very similar if not identical with the common red wheat cultivated in the United Provinces. These two types are absolutely identical in the laboratory, but quite different in the field.

var. *græcum* Kcke.

Type 16.—Ears bearded ; awns rather pinkish yellow ; chaff smooth, white with pink edges and veins ; grain white, rather small, on the whole soft but with some hard and mottled grains ; ear length 78 mm. ; D = 23 ; straw fairly strong.

This type was found in the Ghoni of Lahore, Safed of Ludhiána, Safed of Rohtak, Safed of Batála, Daudkhani of Dasuya, Daudkhani of Delhi, Pori of Montgomery and in the Safed Kasarwali of Lyallpur.

var. *Delfii* Kcke.

Type 17.—Ears beardless ; chaff felted with short rather sparse hairs, red with a bluish tinge ; grain amber-coloured, consistency variable, hard, soft and mottled grains present in equal proportions ; ear length 94 mm. ; D = 19 ; straw medium.

This type was found in the Rodi of Attock, Ghoni of Gujrát, Ghoni of Siálkot, Khoni of Jhelum, Ghoni of Chiniot, Ghoni of Amritsar, Khoni of Batála, Mundli of Karnál, Mundli of Ludhiána, Safed of Lahore, Kanku of Pálampur, Jhakrehun of Pálampur, Safed Brij Sondha of Rohtak and in small quantity in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khán, and the Suthra of Multán. It is a very common wheat in the Punjab.

Type 18.—Ears beardless ; chaff felted with short, rather sparse hairs, yellowish red ; grain amber-coloured, consistency variable, but the majority of the grains are soft ; ear length 72 mm. ; D = 26 ; ears squarer and denser than in type 17 ; straw stronger than in type 17 ; later in ripening.

This type was found in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khán, Suttra of Multán and in small quantity in the Ghoni of Chiniot, Ghoni of Amritsar, Jhakrehun of Pálampur.

var. leucospermum Kcke.

Type 19.—Ears beardless but occasional slight bearding is met with ; chaff felted with short somewhat sparse hairs, white with pink veins or edges to the glumes ; grain whiter than in types 17, 18 and 21 but darker than 16 ; consistency variable but about three-quarters of the grains soft ; ear length 74 mm. ; D = 24 ; straw strong, pinkish, turning grey on ripening.

This type was found only in very small quantity in the Buggi of Leiah at Lyallpur.

var. *alborubrum* Kcke.

Type 20.—Ears beardless with occasional very slight bearding ; chaff smooth, light yellowish red ; grain amber-coloured, consistency variable, but about two-thirds of the grains soft ; ear length 78 mm. ; D = 24 ; straw taller and stronger, heads more erect and later than in type 21 ; grain very easily shed.

This type was only found in the Ghoni of Amritsar.

Type 21.—Ears beardless, with occasional very slight bearding ; chaff smooth, brownish red, dull ; grain amber-coloured but somewhat whiter than in types 17, 18 and 20, consistency variable, about an equal amount of hard, soft and mottled grains ; ear length 90 mm. ; D = 20 ; straw medium ; ears bend over when ripe ; earlier than type 20 ; grain very easily shed.

than the Lal Kasar Wali. This difference may easily disappear after the hard red of Gujar Khán is acclimatised at Lyallpur.

var. *erythrospermum* Kcke.

Type 14.—Ears bearded ; awns pinkish yellow ; chaff smooth, white with a reddish tinge when ripe ; grain light red, hard and soft grains in about equal proportions ; ear length 80 mm. ; D=23 ; straw weak and short, heads bend over when ripe ; early ; fairly rust-resistant ; sheds its grain more easily than type 15.

This type was found in the Lal of Karnál, Lal of Siálkot, Lal of Attock, Safed of Sirsa, Lal of Zíra, Kasalu or Surkh of Ferozepore, Ratti or Lal of P. D. Khán, Lal of Ludhiána, Desi Surkh of Jullunder, Lal Desi of Jhelum, Lal of Ráwalpindi, Lal of Delhi, and the Kunjhari of Muzaffargarh.

Type 15.—Ears bearded ; awns pinkish yellow ; chaff smooth, white with a reddish tinge when ripe ; grain light red, consistency variable, but the majority are soft grains ; ear length 80 mm. ; D = 25 ; straw tall and strong, heads erect when ripe ; late ; susceptible to rust ; grains less easily shed than in type 14.

This type was found in the Ratti or Lal of P. D. Khán, Watni of Sháhpur, and the Kunjhari of Multán.

Types 14 and 15 form the common red wheat of the Punjab. A glance at the names of this variety will show that it is cultivated all over the Province. It is very similar if not identical with the common red wheat cultivated in the United Provinces. These two types are absolutely identical in the laboratory, but quite different in the field.

var. *græcum* Kcke.

Type 16.—Ears bearded ; awns rather pinkish yellow ; chaff smooth, white with pink edges and veins ; grain white, rather small, on the whole soft but with some hard and mottled grains ; ear length 78 mm. ; D = 23 ; straw fairly strong.

This type was found in the Ghoni of Lahore, Safed of Ludhiána, Safed of Rohtak, Safed of Batála, Daudkhani of Dasuya, Daudkhani of Delhi, Pori of Montgomery and in the Safed Kasarwali of Lyallpur.

var. *Delfii* Kcke.

Type 17.—Ears beardless ; chaff felted with short rather sparse hairs, red with a bluish tinge ; grain amber-coloured, consistency variable, hard, soft and mottled grains present in equal proportions ; ear length 94 mm. ; D = 19 ; straw medium.

This type was found in the Rodi of Attock, Ghoni of Gujrát, Ghoni of Siálkot, Khoni of Jhelum, Ghoni of Chiniot, Ghoni of Amritsar, Khoni of Batála, Mundli of Karnál, Mundli of Ludhiána, Safed of Lahore, Kanku of Pálampur, Jhakrehun of Pálampur, Safed Brij Sondha of Rohtak and in small quantity in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khán, and the Suthra of Multán. It is a very common wheat in the Punjab.

Type 18.—Ears beardless; chaff felted with short, rather sparse hairs, yellowish red ; grain amber-coloured, consistency variable, but the majority of the grains are soft ; ear length 72 mm. ; D = 26 ; ears squarer and denser than in type 17 ; straw stronger than in type 17 ; later in ripening.

This type was found in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khán, Suttra of Multán and in small quantity in the Ghoni of Chiniot, Ghoni of Amritsar, Jhakrehun of Pálampur.

var. leucospermum Kcke.

Type 19.—Ears beardless but occasional slight bearding is met with ; chaff felted with short somewhat sparse hairs, white with pink veins or edges to the glumes ; grain whiter than in types 17, 18 and 21 but darker than 16; consistency variable but about three-quarters of the grains soft; ear length 74 mm. ; D = 24 ; straw strong, pinkish, turning grey on ripening.

This type was found only in very small quantity in the Buggi of Leiah at Lyallpur.

var. *alborubrum* Kcke.

Type 20.—Ears beardless with occasional very slight bearding; chaff smooth, light yellowish red ; grain amber-coloured, consistency variable, but about two-thirds of the grains soft ; ear length 78 mm. ; D = 24 ; straw taller and stronger, heads more erect and later than in type 21 ; grain very easily shed.

This type was only found in the Ghoni of Amritsar.

Type 21.—Ears beardless, with occasional very slight bearding ; chaff smooth, brownish red, dull; grain amber-coloured but somewhat whiter than in types 17, 18 and 20, consistency variable, about an equal amount of hard, soft and mottled grains ; ear length 90 mm. ; D = 20 ; straw medium ; ears bend over when ripe ; earlier than type 20 ; grain very easily shed.

This type was found in the Kanku of Pálampur and in small quantity in the Rodi of Attock, Ghoni of Gujrát, Ghoni of Siálkot, Khoni of Jhelum, Khoni of Batála, Mundli of Karnál, Mundli of Jullundur, Mundli of Ludhiána, Jhakrehun of Pálampur, Ratti of Muzaffargarh, Kunjhari of Muzaffargarh, Kunjhari of Multán, in Safed Ghoni and Ghoni Lal.

var. *milturum* Al.

Type 22.—Ears beardless, sometimes slightly bearded ; chaff smooth, shining, dark brownish red ; grain very dark red, consistency variable, but on the whole the sample is hard ; ear length 94 mm. ; D = 19 ; straw medium but rather better than in type 23.

This type was found in small quantity in the Ghoni of Siálkot and Safed Ghoni.

Type 23.—Ears beardless ; chaff smooth, dull, yellowish red ; grain very light red, somewhat small, entirely soft ; ear length 81 mm. ; D = 23 ; straw medium.

This type was only found in the Ratti of Muzaffargarh.

var. *albidum* Al.

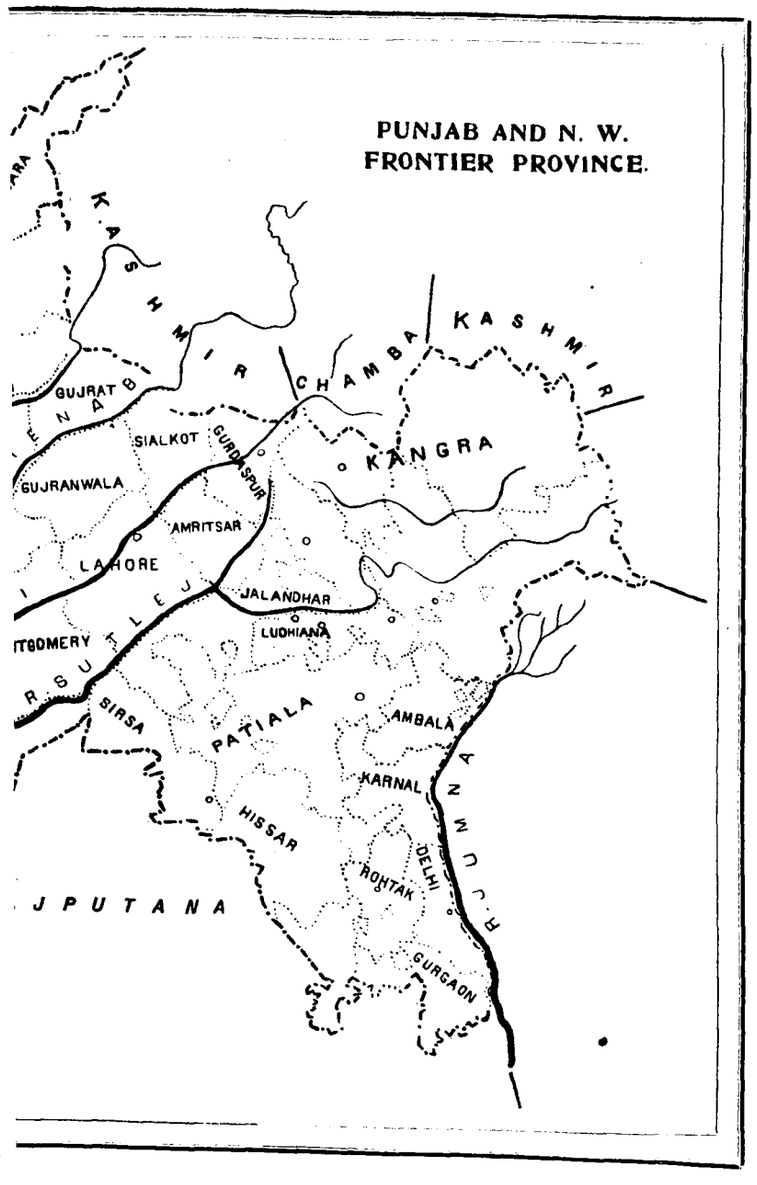
Type 24.—Ears beardless ; spikelets blunt ; outer glumes short and rounded ; chaff smooth, white with a reddish border ; grain yellowish white, resembles 19, rather large, consistency variable, but on the whole the sample is soft ; ear length 93 mm. ; D = 20 ; straw strong ; ears bend over slightly.

This type was found in the Koni of Chakwal, Kunj of Muzaffargarh, Buggi of Leiah and Safed Ghoni.

Type 25.—Ears beardless often slightly bearded ; spikelets pointed ; outer glumes long and pointed; chaff smooth, yellowish white, with a very slight reddish border, shiny ; grain larger than in any of the types of common wheat in the Punjab, greyish white of a different tone of colour, to any of the other white wheats, on the whole soft ; ear length 100 mm. ; D = 20 ; straw very strong ; ears erect.

This type was found in the Buggi of Leiah and Safed Ghoni.

These two types differ in appearance so much from all other wheats of the Punjab and bear such a strong resemblance to the Australian wheats introduced into the Chenáb colony that we cannot help suspecting that they originally came from Australia.



WHEATS OF THE SIMLA HILLS.

In 1908, an examination of the wheat fields in the neighbourhood of Simla was made and specimens were obtained of the wheats in cultivation. The fields were exceedingly mixed and no less than twelve botanical varieties were identified, most of which could be found in any single field. A few of the varieties resemble closely some of the Punjab types, but, on the whole, a good deal of difference from the wheats in the plains was exhibited. It is interesting to note that nearly all the wheats in the Simla district have the peculiar pink straw already noted in some of the Punjab varieties.

Specimens were obtained of two very interesting wheats which appear to be intermediate between *T. vulgare* Vill. and *T. compactum* Host. The ears are 3 inches long, which is longer than most Indian dwarf wheats, although, as a rule, the ears of wheats in the hills are much shorter than in the plains. The ears are also slender and lax, and resemble those of the common wheats in shape. The bearding is, however, entirely that of a *compactum*, the awns are short, stiff and bristly. The shape of the glumes is identical with that found in the dwarf wheats. The grain is short as in *T. compactum* but not entirely rounded. The straw is like that of a common wheat, not stiff and stout. As it appears that these wheats might, with almost equal justice, be referred to *Triticum compactum* or *Triticum vulgare*, we have not assigned the forms to any definite botanical variety, but have merely given a description of the specimens.

CLASSIFICATION OF THE WHEATS OF THE SIMLA HILLS.

TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
  1. Glumes smooth.
    A. Glumes red, awns red.
      a. Grain red.
        var. *ferrugineum* Al.
          Hill wheats Class 1.
    B. Glumes white, awns white.
      a. Grain red.
        var. *erythrospermum* Kcke.
          Hill wheats Class 2.

II. Ears beardless.
1. Glumes felted.
A. Glumes red.
a. Grain red.
var. *pyrothrix* Al.
Hill wheats Class 3.
b. Grain white.
var. *Delfii* Kcke.
Hill wheats Class 4.
B. Glumes white.
a. Grain red.
var. *velutinum* Schübl.
Hill wheats Class 5.
b. Grain white.
var. *leucospermum* Kcke.
Hill wheats Class 6.

2. Glumes smooth.
A. Glumes red.
a. Grain red.
var. *milturum* Al.
Hill wheats Class 7.
b. Grain white.
var. *alborubrum* Kcke.
Hill wheats Class 8.
B. Glumes white.
a. Grain red.
var. *lutescens* Al.
Hill wheats Class 9.
b. Grain white.
var. *albidum* Al.
Hill wheats Class 10.

FORMS INTERMEDIATE BETWEEN T. VULGARE VILL. & T. COMPACTUM HOST.

I. Ears bearded.
1. Glumes smooth.
A. Glumes white.
a. Grain red.
Hill wheats Class 11.

II. Ears beardless.
1. Glumes smooth.
A. Glumes white.
a. Grain red.
Hill wheats Class 12.

DESCRIPTION OF THE WHEATS OF THE SIMLA HILLS.

TRITICUM VULGARE VILL. COMMON WHEATS.

Ears bearded or beardless, outer glumes not keeled to the base, straw hollow, grain neither long nor round.

var. *ferrugineum* Al.

Hill wheats Class 1.—Ears bearded, lax, slender; awns red, much shorter than is usual in bearded wheats; glumes somewhat short; chaff smooth, light red with a somewhat bluish tone; grain short, red; straw pink turning grey on ripening.

This wheat has a somewhat different appearance to the common wheats of the plains.

var. *erythrospermum* Kcke.

Hill wheats Class 2.—Ears medium to lax, bearded; awns white; chaff smooth white; grain red; straw in some specimens yellow, in others pink, turning grey on ripening.

It is possible that there are two agricultural types with different coloured straw. This wheat is similar to the common wheats of the plains and bears a general resemblance to types 14 and 15 of the Punjab. Type 14 also has indications of pink straw.

var. *pyrothrix* Al.

Hill wheats Class 3.—Ears lax, beardless; chaff felted, red with a bluish tone; grain red; straw yellow.

var. *Delfii* Kcke.

Hill wheats Class 4.—Exactly similar to class 3, but the grain is white. This wheat resembles Punjab type 17 in all morphological characters.

var. *velutinum* Schübl.

Hill wheats Class 5.—Ears lax, slender, beardless; chaff sparsely felted, white; grain red.

var. *leucospermum* Kcke.

Hill wheats Class 6.—Ears lax, beardless, with occasional slight bearding ; chaff sparsely felted, white ; grain white ; straw pink, turning grey on ripening.

var. *milturum* Al.

Hill wheats Class 7.—Ears slender, lax ; beardless, sometimes slightly bearded, glumes very short ; chaff smooth, red with a bluish tone ; grain red ; straw pink, turning grey on ripening.

var. *alborubrum* Kcke.

Hill wheats Class 8.—Exactly similar to class 7, but the grain is white.

var. *lutescens* Al.

Hill wheats Class 9.—Ears lax, slender, beardless, sometimes slightly bearded ; glumes somewhat short, chaff smooth, white ; grain red ; straw pink, turning grey on ripening.

var. *albidum* Al.

Hill wheats Class 10.—Exactly similar to class 9, but the grain is white.

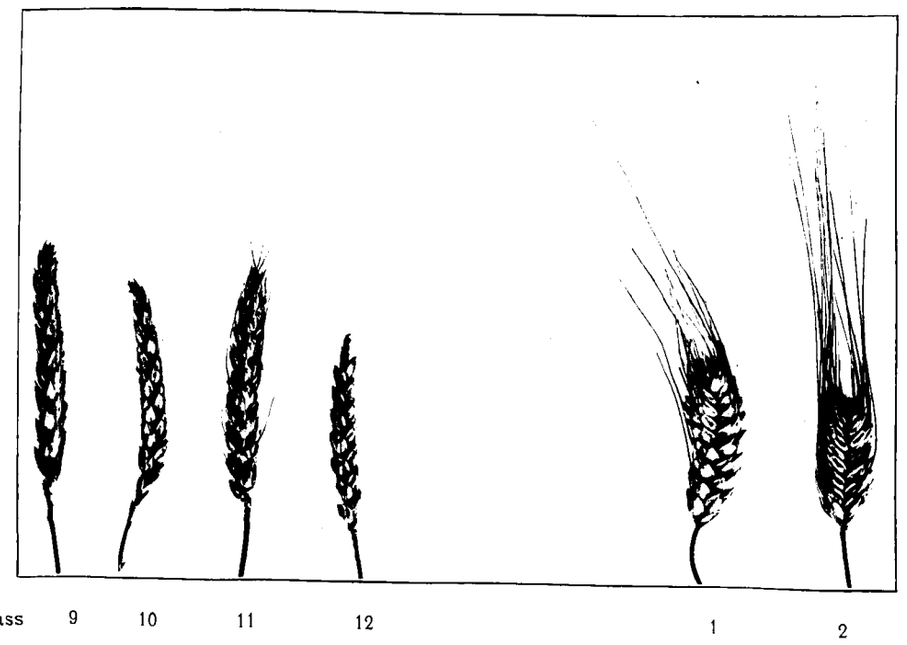
FORMS INTERMEDIATE BETWEEN T. VULGARE VILL. AND T. COMPACTUM HOST.

Hill wheats Class 11.—Ears about 3 ins. long, lax, slender, bearded ; awns stiff, short and bristle-like ; glumes short, rounded, similar to those in dwarf wheats ; chaff smooth, white ; grains short, but not quite round, red ; straw rather weak.

Hill wheats Class 12.—Similar to class 11 but beardless or very slightly bearded. Straw pink, turning grey on ripening.

SOME WHEATS FROM BALUCHISTAN.

Two very interesting wheats have been obtained from Baluchistán. They are the only undoubted representatives of the sub-species *Triticum turgidum* L., Rivet wheats, which have so far been found in India. The ears are dense, square, the glumes keeled to the base and the shape of the grains is unmistakably that peculiar to Rivet wheats. The straw is solid. A botanical survey of the Baluchistán wheats is now in progress and it is hoped that other interesting forms may be obtained.



THE WHEATS OF THE SIMLA HILLS, AND OF BALUCHISTAN.

TRITICUM TURGIDUM L. RIVET WHEAT.

Ears square and dense, bearded; glumes sharply keeled to the base; straw stout, stiff and solid; grain plump, short, rounded, very large.

var. *Salomonis* Kcke.

Baluchistán Class 1.—Awns black; chaff felted, white; grain white, quite soft.

var. *nemausense* Wittm.

Baluchistán Class 2.—Awns black; chaff smooth, white; grain white, quite soft.

CHAPTER VIII.

THE WHEATS OF THE UNITED PROVINCES.

A large collection of the wheats of the Province has been made at Cawnpore. By the kind permission of Mr. W. H. Moreland, C.I.E., I.C.S., the Director of Land Records and Agriculture, one of us was enabled to study this collection in the field during the harvest of 1907 and also to procure specimens from all the plots. A duplicate set of specimens grown at Saharánpur was placed at our disposal by Mr. H. M. Leake, Economic Botanist to the United Provinces. We have also consulted a rough classification of the wheats grown at the Cawnpore Farm by Mr. Hayman, formerly Deputy Director of Agriculture.

The wheats of this Province are remarkably uniform and but few varieties occur. Macaroni wheats seem to be little cultivated and dwarf wheats are very rare. White wheats seem commoner than red wheats.

CLASSIFICATION OF THE WHEATS OF THE UNITED PROVINCES.

TRITICUM DURUM DESF. MACARONI WHEATS.

1. Glumes felted.
   - A. Glumes red, awns black.
     - a. Grain white.
       - var. *apulicum* Kcke.
         - United Provinces Class 1
   - B. Glumes white, awns black.
     - a. Grain white.
       - var. *melanopus* Kcke.
         - United Provinces Class 2.
2. Glumes smooth.
   - A. Glumes red, awns red.
     - a. Grain red.
       - var. *murciense* Kcke.
         - United Provinces Class 3.
   - B. Glumes white, awns white.
     - a. Grain red.
       - var. *affine* Kcke.
         - United Provinces Class 4.

TRITICUM COMPACTUM HOST. DWARF WHEATS.

I. Ears bearded.
   1. Glumes smooth.
      - A. Glumes white.
        - a. Grain white.
          - var. *splendens* Al.
            - United Provinces Class 5.

TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
   1. Glumes felted.
      - A. Glumes white.
        - a. Grain white.
          - var. *meridionale* Kcke.
            - United Provinces Class 6
   2. Glumes smooth.
      - A. Glumes red.
        - a. Grain white.
          - var. *erythroleucon* Kcke.
            - United Provinces Class 7.
      - B. Glumes white.
        - a. Grain red.
          - var. *erythrospermum* Kcke.
            - United Provinces Class 8.
        - b. Grain white.
          - var. *græcum* Kcke.
            - United Provinces Class 9.

II. Ears beardless.
   1. Glumes felted
      - A. Glumes red.
        - a. Grain white.
          - var. *Delfii* Kcke.
            - United Provinces Class 10.
   2. Glumes smooth.
      - A. Glumes red.
        - a. Grain white.
          - var. *alborubrum* Kcke
            - United Provinces Class 11

B. Glumes white.
  a. Grain re .
    var. *lutescens* Al.
      United Provinces Class 12.
  b. Grain white.
    var. *albidum* Al.
      United Provinces Class 13 and Class 14.

DESCRIPTION OF THE WHEATS OF THE UNITED PROVINCES.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat; flowering glumes with long awns, outer glumes sharply keeled to the base; straw stiff and solid; grain long.

var. *apulicum* Kcke.

United Provinces Class 1.—Ears dense; awns black; chaff felted, red; grain white.

To this class belongs Sindhi of Partábgarh. This wheat was grown at Púsa in 1908 and appeared to be very similar, if not identical, with the white grained Gangajali of Bengal.

var. *melanopus* Kcke.

United Provinces Class 2.—Ears dense; awns black; chaff felted. white; grain white.

To this class belongs Bulandshahr Barha.

var. *murciense* Kcke.

United Provinces Class 3.—Ears medium; awns red; chaff smooth, red; grain red.

To this class belongs Kathia wheat.

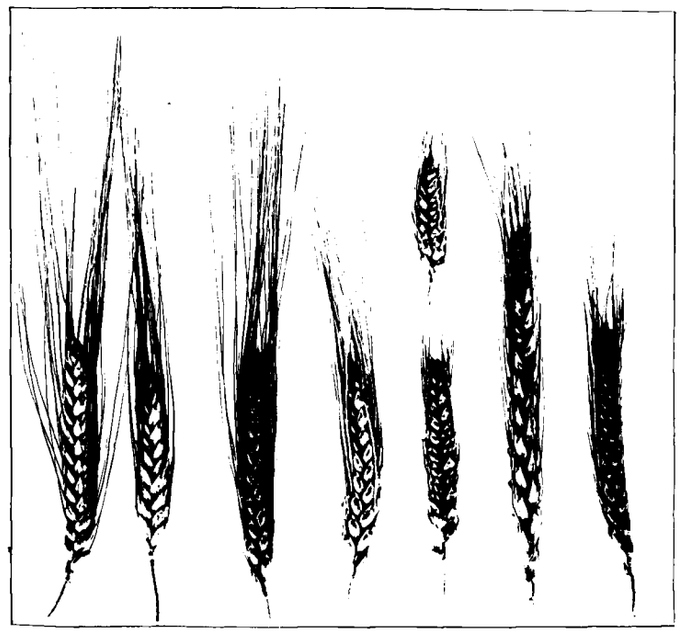
var. *affine* Kcke.

United Provinces Class 4.—Ears medium; awns slightly reddish; glume-tooth straight; chaff smooth, white; grain red.

To this class belongs Bándá Kathia wheat.

TRITICUM COMPACTUM HOST. DWARF WHEATS.

Ears very dense and short, rarely over 2 inches long; outer glumes keeled in the upper half and rounded in the lower half; straw very short and stiff; grains rounded.



Class 1 2 3 4 5 6 7

Class 8 9 10 11 12 13 14

THE WHEATS OF THE UNITED PROVINCES.

var. *splendens* Al.

United Provinces Class 5.—Ears bearded with short stiff awns ; chaff smooth, white ; grains white.

The specimens of this class at our disposal up to the present show marked differences. In one, the ear is much laxer than is usually the case in dwarf wheats, longer (*i.e.*, 3 inches long) and the chaff is reddish. In the other the ear is exceedingly dense, very short and the chaff is undoubtedly white. It is possible, however, that the difference may have been caused by differences in the amount of irrigation. The first specimen, with the long lax ear was obtained by the Cawnpore Experimental Farm under the name Partábgarh Mundia and the second was found as an admixture in a sample of Muzaffarnagar white obtained from Muzaffarnagar.

Triticum vulgare vill. Common wheats.

Ears bearded or beardless, outer glumes keeled to the base, straw hollow, grains neither very long nor round.

The bulk of the wheats of the United Provinces are common wheats. Felted wheats either bearded or beardless are very rare. A fair amount of beardless, smooth chaffed wheat is grown. Among the bearded wheats Muzaffarnagar white is the best known on account of the many attempts (some of which have proved very successful) to introduce it into other parts of India. Most of the wheats of the Province, including Muzaffarnagar white, are characterised by having exceedingly weak straw.

var. *meridionale* Kcke.

United Provinces Class 6.—Ears lax, bearded ; awns with a blackish tinge ; chaff felted, white ; grain white.

Wheats belonging to this class were found in Unao Shambhargehna and in a sample of wheat from Saharánpur.

var. *erythroleucon* Kcke.

United Provinces Class 7.—Ears medium ; bearded with reddish awns ; chaff smooth, red ; grain white.

Wheats belonging to the class were found in Bareilly soft white, Sháhjahánpur Sambhari, Lucknow Hamla, Partábgarh Lalia, Gondá Daudi, Bastí Gangajali, Azamgarh Daudi, Sultánpur soft white, and in small quantity in Bareilly Pissia, Bareilly Kathia, Bándá white, Bándá Pissia, Pissia Gangajali, Bándá Ujaria, and also in samples of wheat from Saharánpur, Unao and Cawnpore.

var. *erythrospermum* Kcke.

United Provinces Class 8.—Ears medium, bearded; chaff smooth, white; grain red.

Wheats belonging to this class were found in Morádábád Red Khadir, Morádábád Surkh, Bahraich soft red, Bándá hard red, Fatehpur Pissia Awal, Bándá Pissia, Bándá red, Lalitpur Pissia Doem, and in small quantity in Morádábád Safed Doem and in samples of wheat from Bulandshahr and Sitápur.

var. *græcum* Kcke.

United Provinces Class 9.—Ears medium, bearded; chaff smooth, white; grain white.

Wheats belonging to this class were found in Aligarh Kathia, Etah Sambharia, Mainpuri Sambharia, Mainpuri Anokha, Cawnpore Tamra, Dehra Dún Mihirta, Muzaffarnagar Safeda, Meerut soft white, Bulandshahr Munia, Bulandshahr white, Bulandshahr Gajar, Muttra Safeda, Morádábád Gajra, Morádábád Khadir Awal, Budaun Ratna, Budaun white, Kherí soft white, Bahraich soft white, Gondá Daudi, Partábgarh white, Benares Daudi, Bándá Gangajali, and in small quantities in Bareilly Kathia, Bulandshahr Safed, Morádábád Cawnpuri, Morádábád Safed Doem, Sitápur soft white, Unao Sambhargehna, Bándá Pissi Gangajali, Bándá Ujaria, and in a sample of wheat from Etah.

var. *Delfii* Kcke.

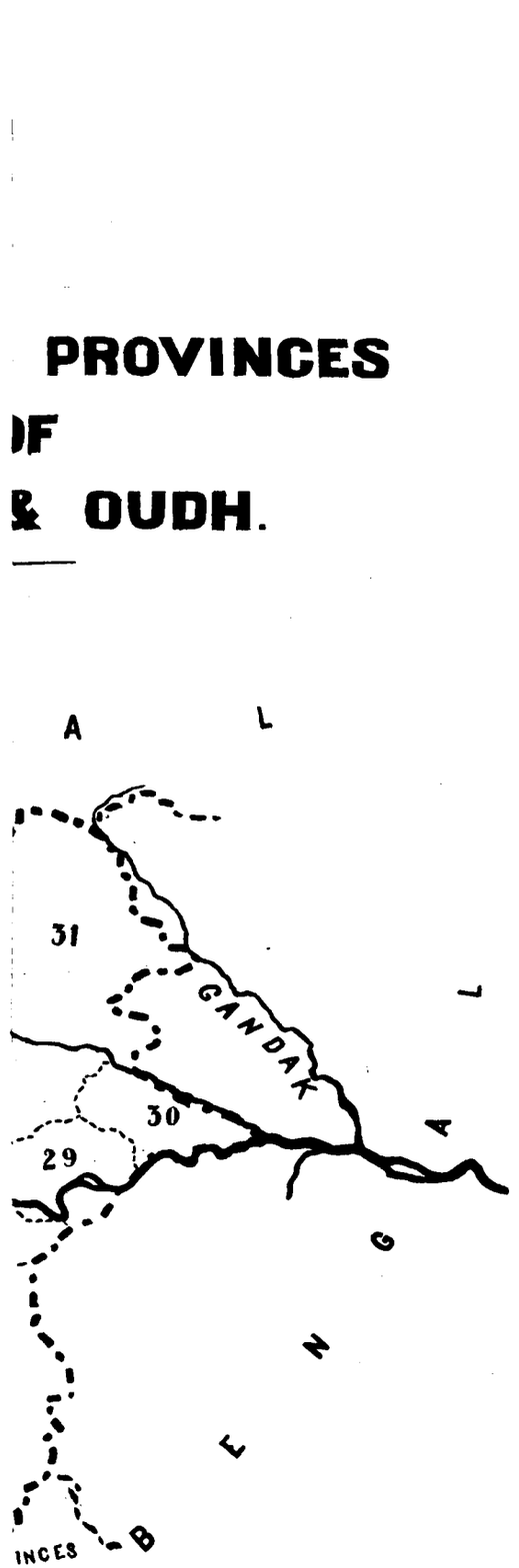
United Provinces Class 10.—Ears somewhat lax, beardless; chaff felted, red; grain white.

Wheats belonging to this class were found in Saharánpur Muria, Saharánpur Munda, and in a sample of mixed wheat from Saharánpur.

var. *alborubrum* Kcke.

United Provinces Class 11.—Ears medium to lax; very slightly bearded; chaff smooth, red; grain white. The wheats belonging to this class differ slightly among themselves as regards density and the slight amount of bearding.

Wheats belonging to this class were found in Bára Banki Marwa, Unao soft white, Partábgarh Daudi, Fatehpur Muria, Fatehpur soft white, Bándá Pissi Gangajali, and in small quantity in Morádábád Katehar Doem, Bareilly Kathia, Bareilly Pissia, Sitápur Mundia, Sitápur Muria, Bándá Ujaria, Saharánpur Munda, Saharánpur Muria.



DISTRICTS OF THE UNITED PROVINCES.

1. Dehra Dún.
2. Saháranpur.
3. Muzaffaranagar.
4. Meerut.
5. Bulandshahr.
6. Aligarh.
7. Muttra.
8. Agra.
9. Farrukhábád.
10. Mainpuri.
11. Etáwah.
12. Etah.
13. Bareilly.
14. Bijnor.
15. Budaun.
16. Morádábád.
17. Sháhjahánpur.
18. Pilibhit.
19. Cawnpore.
20. Fatehpur.
21. Bándá.
22. Hamírpur.
23. Allahábád.
24. Jhánsi.
25. Jálaun.
26. Benares.
27. Mirzápur.
28. Jaunpur.
29. Gházípur.
30. Balliá.
31. Gorakhpur.
32. Basti.
33. Azamgarh.
34. Naini Tál.
35. Lucknow.
36. Unao.
37. Ráe Bareli.
38. Sitápur.
39. Hardoi.
40. Kherí.
41. Fyzábád.
42. Gondá.
43. Bahraich.
44. Sultánpur.
45. Partábgarh.
46. Bára Banki.
47. Almorá.
48. Garhwál.

var. *erythrosp*

United Provinces Class 8.—Ears white; grain red.

Wheats belonging to this class wer Morádábád Surkh, Bahraich soft re Awal, Bándá Pissia, Bándá red, L quantity in Morádábád Safed Doen Bulandshahr and Sitápur.

var. *græcu*

United Provinces Class 9.—Ears white; grain white.

Wheats belonging to this class w Sambharia, Mainpuri Sambharia, Ma Dehra Dún Mihirta, Muzaffarnagar S shahr Munia, Bulandshahr white, B Morádábád Gajra, Morádábád Khadi white, Kheri soft white, Bahraich sof white, Benares Daudi, Bándá Gangajali Kathia, Bulandshahr Safed, Morádá Doem, Sitápur soft white, Unao Saml Bándá Ujaria, and in a sample of whea

var. *Delfi*

United Provinces Class 10.—Ear felted, red; grain white.

Wheats belonging to this class were ránpur Munda, and in a sample of mixe

var. *alborubr*

United Provinces Class 11.—Ear bearded; chaff smooth, red; grain this class differ slightly among themselv amount of bearding.

Wheats belonging to this class were soft white, Partábgarh Daudi, Fateh Bándá Pissi Gangajali, and in small quan Bareilly Kathia, Bareilly Pissia, Sitápur Ujaria, Saharánpur Munda, Saharánpur

var. *lutescens* Al.

United Provinces Class 12.—Ears medium, beardless; chaff smooth, white; grain red.

Wheat belonging to this class was found in Saharánpur Munda.

var. *albidum* Al.

United Provinces Class 13.—Ears lax to medium, beardless; chaff smooth, white; grain white.

Wheats belonging to this class were found in Partábgarh Mundia, Bulandshahr Mendha, Morádábád Mundia Safed Awal, Morádábád Khirta Awal, Morádábád Safed Mundia, Budaun Ratna white, Budaun Bahamaria white, and in small quantity in Morádábád Mundia Safed Doem, Morádábád Kathiar Doem, Morádábád Cawnpuri.

United Provinces Class 14.—Ears medium; very slightly bearded, white; grain white.

Wheats belonging to this class were found in Bándá Ujaria, Bándá white Pissia, and also in a sample of wheat from Cawnpore.

CHAPTER IX.

THE WHEATS OF BENGAL.

During the last three wheat seasons the varieties of wheat grown in the various Districts of Bengal have been collected and grown at Púsa in pure culture from single ears. It is hoped shortly to publish a full agricultural classification similar to that already published of the wheats of the Punjab. As the work is not yet completed only the botanical classification is given in this section. The two short accounts of the Bengal wheats already published by Prain[1] and Mookerji[2] deal only with the grain characters and give no account of the morphological or agricultural characters of the different wheats in cultivation.

The question of the chaff colour in Bengal is an exceedingly difficult one as owing to the dampness of the atmosphere, the red colour often does not develop and the wheats appear white chaffed. It is possible to find the side shoots simulating a white chaffed wheat while the earlier formed ears are red. The same is true of the black colour of the awns and glumes in some varieties. In addition to this most of the white chaffed varieties have a decidedly reddish tone. It is only by careful cultures from single ears or plants for several seasons, that such doubtful cases can be decided. A year in which rust is prevalent or a bad harvest makes identification practically impossible.

Bengal is essentially the Province of the sub-species *Triticum vulgare*. No dwarf wheats or emmers are known and but two forms of macaroni wheats, of which only one is at all common. The isolated occurrence of this macaroni wheat is very interesting. It is cultivated in Málda, Rájmahál, and the surrounding districts and not as might have been expected in those districts which adjoin the United Provinces and Central Provinces where macaroni wheat occurs.

CLASSIFICATION OF THE WHEATS OF BENGAL.

TRITICUM DURUM DESF. MACARONI WHEATS.

1. Glumes felted.
   A. Glumes red, awns black.

[1] Prain, *Bulletin No.* 3, *Department of Land Records and Agriculture, Bengal*, 1896.
[2] Mookerji, *Bulletin No.* 2, *Department of Land Records and Agriculture, Bengal*, 1907.

a. Grain red.
var. *niloticum* Kcke.
Bengal Class 1.
b. Grain white.
var. *apulicum* Kcke.
Bengal Class 2.

TRITICUM VULGARE VILL. COMMON WHEATS

I. Ears beardless.
1. Glumes smooth.
A. Glumes red.
a. Grain red.
var. *milturum* Al.
Bengal Class 3.
b. Grain white.
var. *alborubrum* Kcke.
Bengal Class 4.
B. Glumes white.
a. Grain red.
var. *lutescens* Al.
Bengal Class 5.
b. Grain white.
var. *albidum* Al.
Bengal Class 6.

II. Ears bearded.
1. Glumes felted.
A. Glumes white.
a. Grain white.
var. *meridionale* Kcke.
Bengal Class 7.
2. Glumes smooth.
A. Glumes red, awns red.
a. Grains red.
var. *ferrugineum* Al.
Bengal Class 8.
b. Grain white.
var. *erythroleucon* Kcke.
Bengal Class 9.

B. Glumes white, awns white.
  a. Grain red.
    var. *erythrospermum* Kcke.
      Bengal Class 10.
  b. Grain white.
    var. *græcum* Kcke.
      Bengal Class 11.

C. Glumes black or blackish, awns black.
  a. Grain red.
    var. *cæsium* Al.
      Bengal Class 12.
  b. Grain white.
    var. ?
      Bengal Class 13.

DESCRIPTION OF THE BENGAL WHEATS.

TRITICUM DURUM DESF. MACARONI WHEATS.

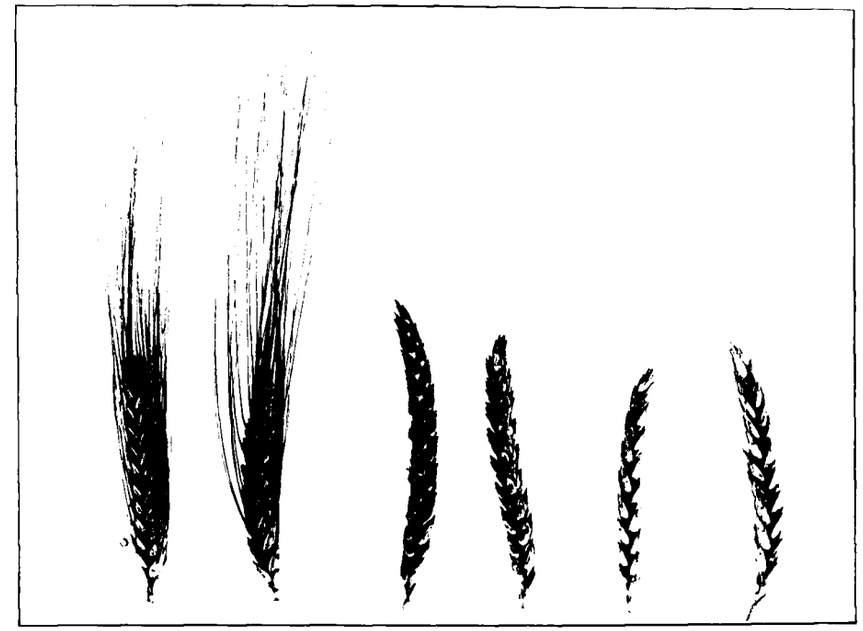
Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid, grains long.

Two varieties of macaroni wheats are cultivated in this Province. In appearance they are alike and the only difference is in the colour of their grain. The white grained variety is the most common, we have so far only obtained the red grained one as an admixture of the other. The awns in both are very readily shed and the red colour of the chaff only developes in good years. The grains are short compared with those of most macaroni wheats. The white grained variety is much liked by the cultivators, and we were informed in Calcutta that it is one of the best that comes into the local market, but that it is so much appreciated by the natives that the supply is entirely reserved for indigenous consumption. According to Mookerji[1] it was formerly exported to Italy and France, but lately the export has fallen off. Both varieties have the peculiar pink straw noticed in some of the Punjab varieties.

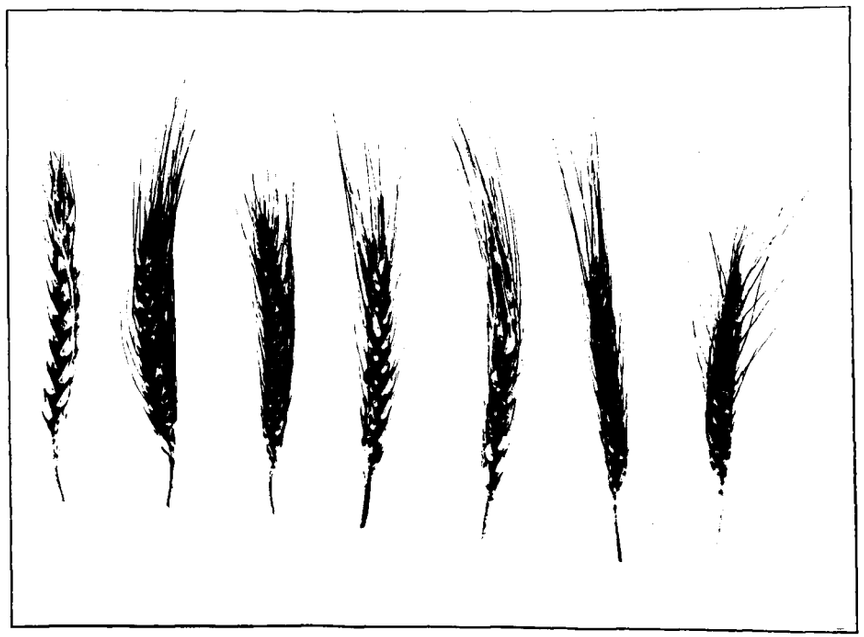
var. *niloticum* Kcke.

Bengal Class 1.—Ears with black awns, which are short for a macaroni wheat and are easily shed, chaff somewhat sparsely felted, red. In an unfavourable year both the chaff colour and the colour of the awns do not deve-

[1] Mookerji, l. c.



Class 1 2 3 4 5 6



Class 7 8 9 10 11 12 13

THE WHEATS OF BENGAL.

lop and the ears may appear grey chaffed with white awns. Grain light red, straw pink, turning grey on ripening.

This variety was found with the Hard grey Gangajali grown at Púsa and also in a field of mixed wheat growing in the Darbhangá District.

var. *apulicum* Kcke.

Bengal Class 2.—Exactly similar to class 1, but the grain is amber-coloured.

To this class belong Hard grey Gangajali, Gangajali from Málda, Bhágalpur, Rájmahál, Sáhibganj and Shah Bagan wheat from Saran Chapra. Wheats belonging to this class were also found in fields of mixed wheat at Semaria Ghat, Katihár and in the Darbhangá District.

No differences in agricultural characters in any of the wheats belonging to this class were observed when grown at Púsa under uniform conditions.

TRITICUM VULGARE VILL. COMMON WHEATS.

Ears bearded or beardless, outer glumes not keeled to the base, straw hollow, grains neither very long nor round.

The bulk of the wheats of Bengal are bearded wheats. Beardless wheat is only grown in small quantity and in a few localities. Felted wheats also seem exceedingly rare. We have so far only obtained a few specimens in a sample of mixed wheats sent by the Collector of Daltonganj. The most interesting of the Bengal common wheats are found in classes 12 and 13. These wheats have black awns and often black chaff, the black colour of the chaff being more or less developed according to the season. In some ears the glumes are quite black, in others the black colour of the awns only spreads to a small extent on to the glumes. The colour of the glumes is generally red or reddish, but in some cases the chaff appears quite white, and it is possible that there are two varieties with different coloured chaff. The question of chaff colour is, however, an exceedingly difficult one in Bengal, and we prefer not to subdivide these classes until we have obtained further evidence by growing the wheats for another season. Koernicke describes a variety *cæsium* with black awns and black glumes on a ground colour of red with red grains and to this we have referred class 12. He makes no mention of any variety with white grain such as we have found in Bengal, and we have so far been unable to trace any such variety in the literature at our disposal. The appearance of the ear both in class 12 and 13 is peculiar.

The ears have a somewhat quadratic appearance due in part to the shape of the grain, this being exceedingly short, somewhat round and with a distinct hump.

var. *milturum* Al.

Bengal Class 3.—Ears beardless or slightly bearded; chaff smooth, red; grain white.

Wheats belonging to this class were found in Muralia from Sáhibganj, Muralia from Buxar, Dudhia from Daltonganj.

var. *alborubrum* Kcke.

Bengal Class 4.—Ears beardless or slightly bearded; chaff smooth, red; grain red.

Wheats belonging to this class were found in Muralia from Sáhibganj, Muralia from Buxar, Bhiralia from Buxar, Dudhia from Daltonganj.

var. *lutescens* Al.

Bengal Class 5.—Ears beardless or very slightly bearded; chaff smooth, white with a reddish tinge; grain red.

Wheats belonging to this class were found in Muralia from Sáhibganj.

var. *albidum* Al.

Bengal Class 6.—Ears beardless or slightly bearded; chaff smooth, white with a reddish tinge; grain white.

Wheats belonging to this class were found in Muralia or Mundi from Khiribau, Muralia from Sáhibganj, Muralia from Bankipore, Dudhia from Daltonganj.

var. *meridionale* Kcke.

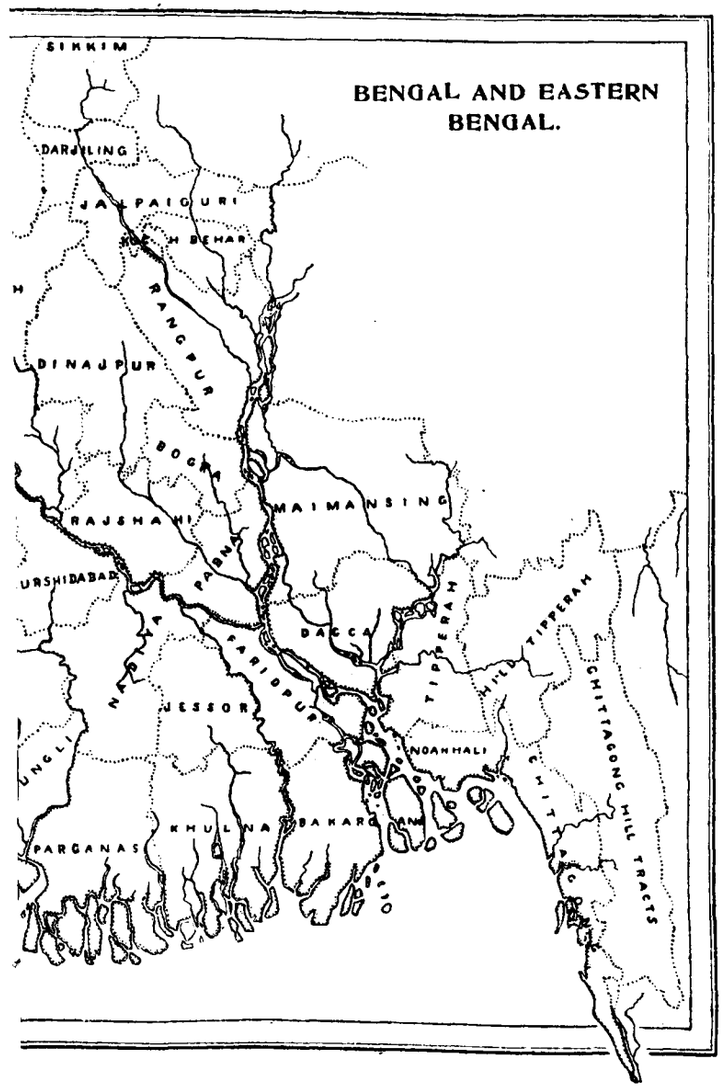
Bengal Class 7.—Ears bearded with white awns, somewhat long and lax; chaff felted, quite white with no reddish tinge; grain white.

The only wheat belonging to this class which has been received up to the present came from Daltonganj.

var. *ferrugineum* Al.

Bengal Class 8.—Ears bearded with red awns; chaff smooth, red; grain red.

Wheats belonging to this class were found in Lurkia from Bankipore, Jamali from Kiul, Jamali from Bhágalpur, Dudhia from Bhabhar Road, Lalka from Baktiyarpur, Janakhar, Gya Chingko wheat and in samples obtained from Darbhangá, Muzaffarpur, Purnea and Katihár.



var. *erythroleucon* Kcke.

Bengal Class 9.—Ears bearded with red awns; chaff smooth, red; grain white.

Wheats belonging to this class were found in Hadda from Champáran, Jamali from Bhágalpur, Lurkia from Bankipore, Jamali from Rájmahál, and in samples from Bhabhar Road, Darbhangá, Muzaffarpur, Katihár and Purnea.

var. *erythrospermum* Kcke.

Bengal Class 10.—Ears bearded with white awns; chaff smooth, white with a reddish tinge; grain red.

Wheats belonging to this class were found in Jamali from Kiul, Jogia Lal from Bhabhar Road, Lal from Buxar, Harahwa from Sasarám, Galphúlia from Bankipore, Harahwa from Sáhibganj, Dudhia from Daltonganj, Dudhia from Sabour, Hara and Gya Chingko wheats, and in samples from Baktiyarpur, Darbhangá, Katihár, Semaria Ghat, Purnea and Muzaffarpur.

var. *græcum* Kcke.

Bengal Class 11.—Ears bearded with white awns; chaff smooth, white with a reddish tinge; grain white.

Wheats belonging to this class were found in Dudhia from Sabour, Dudhia from Buxar, Galphulia from Bankipore, Dudhia from Bhabhar Road, Dudhia Safed from Sasarám, Janakar wheat and in wheat from Darbhangá, Katihár, Muzaffarpur and Semaria Ghat.

var. *cæsium* Al.

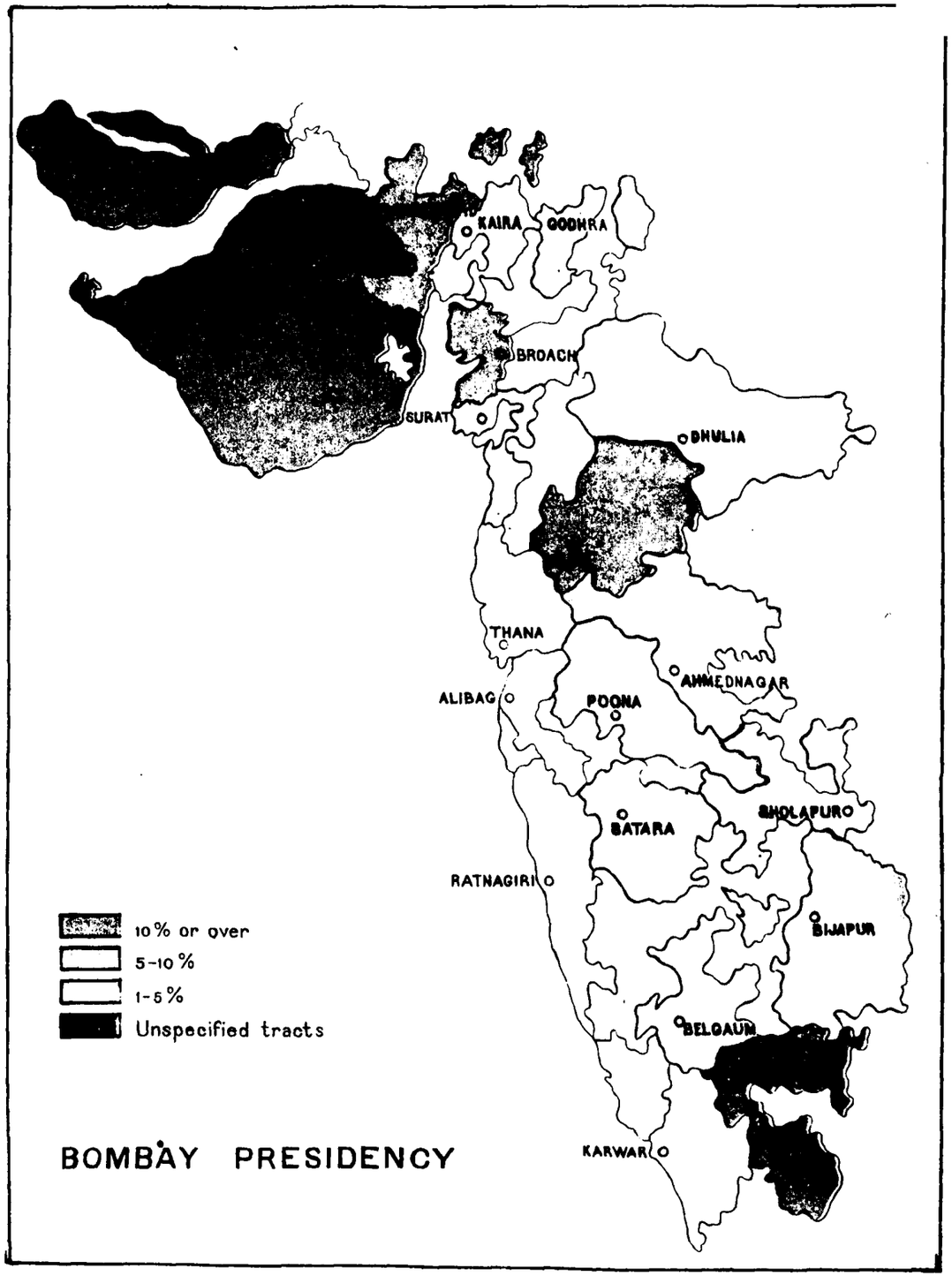
Bengal Class 12.—Ears bearded with black awns, somewhat quadratic owing partly to the shape of the grain; chaff smooth, entirely black or with a certain amount of black colour on a red, reddish or white chaff, both the black colour of the awns and of the chaff may be undeveloped; grain red, very short, rounded.

Wheats belonging to this class were found in Lal from Rájmáhal, Jamali from Sáhibganj, Jamali from Málda, Harahwa from Rájmáhal, Nanbia from Purnea, Harahwa from Málda, Jamali from Bánkurá, Dudhia from Sabour and in wheat from Bhágalpore, Katihár, Semaria Ghat, Darbhangá and Muzaffarpur.

var. ?

Bengal Class 13.—Similar in all respects to class 12 except that the grain is white.

Wheats belonging to this class were found in Jamali from Sabour and in wheats from Darbhangá, Katihár, Semaria Ghat and Purnea.



CHAPTER X.

THE WHEATS OF BOMBAY, MADRAS AND MYSORE.

Bombay. Seeds from the collection of the Bombay wheats grown at Poona by Professor Gammie were sown at Púsa in 1905, and seeds and ears of the varieties grown at the various farms of Bombay were sent by Mr. Fletcher, formerly Deputy Director of Agriculture. Further specimens of Bombay wheats grown at the Nágpur Farm were sent by the Director of Agriculture of the Central Provinces.

Macaroni wheats are of considerable importance in Bombay but dwarf wheats do not appear to be grown. A variety of emmer (*T. dicoccum* Schrk.) known as *khapli* is extensively grown on irrigated land in Bombay; this type has often been referred to as a spelt wheat, but it is an emmer and not a spelt. Our collection of Sind wheats is not so extensive as we should have wished, but the wheats there, as far as we have examined them, are very like those cultivated in the Punjab. The Bombay types are illustrated in Plate VI.

CLASSIFICATION OF THE WHEATS OF BOMBAY.

Triticum durum Desf. Macaroni wheats.

1. Glumes felted.
   - A. Glumes red, awns red.
     - a. Grain white.
       - var. *italicum* Al.
         - Bombay Class 1.
   - B. Glumes white, awns black.
     - a. Grain red.
       - var. *africanum* Kcke.
         - Bombay Class 2.
     - b. Grain white.
       - var. *melanopus* Al.
         - Bombay Class 3.
2. Glumes smooth.
   - A. Glumes red, awns red.
     - a. Grain red.
       - var. *murciense* Kcke.
         - Bombay Class 4.

B. Glumes white, awns white.
a. Grain white.
var. *leucurum* Al.
Bombay Class 5.

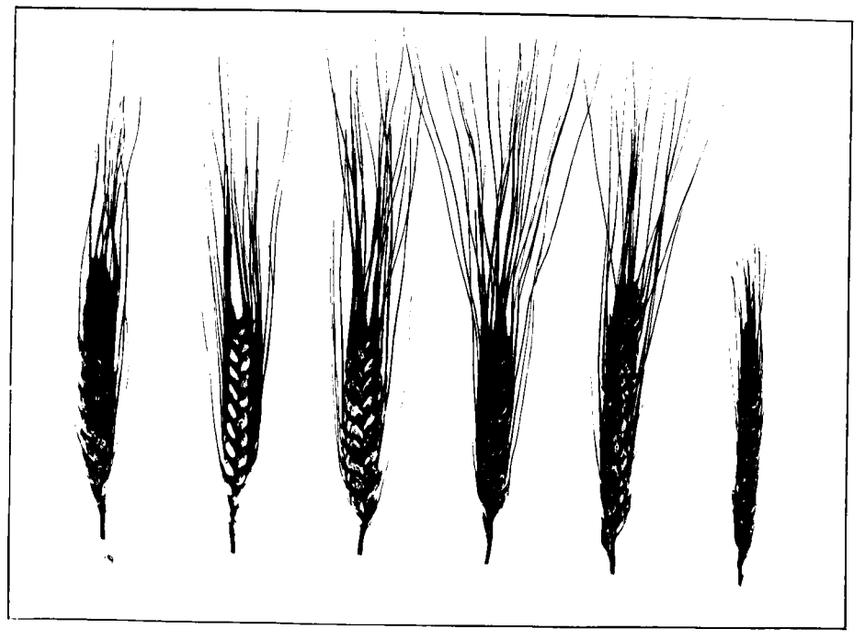
TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
1. Glumes felted.
A. Glumes white.
a. Grain white.
var. *meridionale* Kcke.
Bombay Class 6.
2. Glumes smooth.
A. Glumes white.
a. Grain red.
var. *erythrospermum* Kcke.
Bombay Class 7.
b. Grain white.
var. *græcum* Kcke.
Bombay Class 8.

II. Ears beardless.
1. Glumes felted.
A. Glumes red.
a. Grain white.
var. *Delfii* Kcke.
Bombay Class 9.
B. Glumes white.
a. Grain white.
var. *leucospermum* Kcke.
Bombay Class 10.
2. Glumes smooth.
A. Glumes white.
a. Grain white.
var. *albidum* Al.
Bombay Class 11 and Class 12

TRITICUM DICOCCUM SCHRK. EMMER.

I. Ears unbranched.
1. Ears long, tapering towards the top.



Class 1 2 3 4 5 6

Class 7 8 9 10 11 12 13

THE WHEATS OF BOMBAY.

A. Ears fully bearded with long awns.
a. Glumes white.
var. *farrum* Bayle.
Bombay Class 13.

DESCRIPTION OF THE WHEATS OF BOMBAY.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat; flowering glumes with long awns; outer glumes sharply keeled to the base; straw stiff and solid, grains long.

A very large proportion of the wheat cultivated in Bombay falls into the class of macaroni wheats, no less than five out of the twelve different botanical varieties occurring in the Province belonging to this sub-species.

var. *italicum* Al.

Bombay Class 1.—Ears medium; awns red; chaff felted, red; grain white.

Wheats belonging to this class were found in Kunja of Sind.

var. *africanum* Kcke.

Bombay Class 2.—Ears dense; awns black; chaff felted, white; grain red.

Wheats belonging to this class were found in Katha of Násik, Katha of Khándesh, Black-bearded Athani, White-bearded Athani.

var. *melanopus* Al.

Bombay Class 3.—Ears dense; awns black; chaff felted, white; grain white.

Wheats belonging to this class were found in Kala Kushal of Násik, Kala Kushal of Poona, Kala Kushal of Khándesh, Bakshi of Dhulia, Bakshi of Poona, Bakshi of Sangamnar, Pan Sangli, Bansi of Násik, Kopergaon wheat, Kahno of Sind.

var. *murciense* Kcke.

Bombay Class 4.—Ears dense; awns red; chaff smooth, red; grain red.

Wheats belonging to this class were found in Katha of Baroda, Daudkhani, Potia or Popatia of Nadiád, Kempu from Dhárwár Farm, Kempu Godi of Belgaum, Malaya of Belgaum, Desi Athani of Belgaum, Lal Potia of Dhulia, Lal Bakshi of Malegaon.

var. *leucurum* Al.

Bombay Class 5.—Ears somewhat lax ; awns white ; chaff smooth, white ; grain white.

Wheats belonging to this class were found in Pivala of Khándesh, Pivala of Násik, Hansoti of Dhárwár, Hansa of Broach, Dhola of Nadiád, Bansi from Dhulia Farm, Pan Singhi of Poona, Shet of Parner, Pel of Khándesh, Malthi Safed of Panch Mahál, Laskari of Kopergaon.

Triticum vulgare vill. Common wheats.

Ears bearded or beardless, outer glumes not keeled to the base, straw hollow, grain neither very long nor round.

var. *meridionale* Kcke.

Bombay Class 6.—Ears medium, bearded ; chaff felted, white ; grain white.

Wheats belonging to this class were found in Safed Chaha, and in small quantity in Scindi from Dhárwár Farm and Kahno of Sind.

var. *erythrospermum* Kcke.

Bombay Class 7.—Ears medium, bearded ; chaff smooth, white ; grain red.

Wheats belonging to this class were found in Siaok of Poona, Poptia or Potia of Nadiád, Lal Potia, and in small quantity in Desi white of Sind, Kahno of Sind, Bubak of Sind.

var. *græcum* Kcke.

Bombay Class 8.—Ears medium, bearded ; chaff smooth, white ; grain white.

Wheats belonging to this class were found in Desi white of Sind, Delhi white of Sind, and in small quantity in Khano and Bubak of Sind.

var. *Delfii* Kcke.

Bombay Class 9.—Ears medium, beardless ; chaff felted, red ; grain white.

Wheats belonging to this class were found in Sindhi wheat and Bubak of Sind.

var. *leucospermum* Kcke.

Bombay Class 10.—Ears lax beardless ; chaff felted, white ; grain white.

Wheats belonging to this class were found in Dahyak of Poona and Kallah of Poona.

var. *albidum* Al.

Bombay Class 11.—Ears lax, slightly bearded ; chaff smooth, white ; grain white.

Wheats belonging to this class were found in Pivala Poti of Malegaon, Kakti of Sind, Pivala Botaka Baglan of Násik, Mondhia of Dhulia.

Bombay Class 12.—Ears dense, densest and broadest at the top (fan-shaped), beardless ; chaff smooth, white ; grain white

To this class belongs white Nandero of Sind.

Triticum dicoccum Schrk. Emmer.

Ears nearly always bearded, dense, outer glumes sharply keeled with an acute apex ; rachis brittle, grain enclosed in the glumes when threshed.

var. *farrum* Bayle.

Bombay Class 13.—Ears unbranched, long, tapering towards the top ; bearded, awns long ; glumes smooth, white ; grain red, long and thin.

To this class belong Khapli or Jod, and Paputia of Kaira.

THE WHEATS OF MADRAS.

Wheat is not a crop of great importance in the Madras Presidency and as might be expected but few varieties occur. The wheat most widely grown appears to be an emmer, and although we have received a large number of samples of this wheat with different vernacular names, they all appear to belong to the same agricultural type. We are indebted to Dr. Barber, the Government Botanist of Madras, to Mr. R. C. W. Wood, Deputy Director of Agriculture, and to Mr. Shepperson, Principal of the Agricultural College, Coimbatore, for much assistance in procuring the necessary specimens, most of which were subsequently grown both at Púsa and at Lyallpur.

CLASSIFICATION OF THE WHEATS OF MADRAS.

Triticum durum Desf. Macaroni wheats.

1. Glumes smooth.
   - A. Glumes red, awns red.
     - a. Grain red.

       var. *murciense* Kcke.

       Madras Class 1.

B. Glumes white, awns white.
a. Grain red.
var. *affine* Kcke.
Madras Class 2.

TRITIC UM VULGARE VILL. COMMON WHATS.

I. Ears bearded.
1. Glumes smooth.
A. Glumes white.
a. Grain red.
var. *erythrospermum* Kcke.
Madras Class 3.

TRITICUM DIOCCUM SCHRK. EMMER.

I. Ears unbranched.
1. Ears long, tapering towards the top.
A. Ears fully bearded with long awns.
a. Glumes white.
var. *farrum* Bayle.
Madras Class 4.

DESCRIPTION OF THE WHEATS OF MADRAS.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid, grains long.

Two varieties of *Triticum durum* Desf. occur in Madras. These varieties differ in chaff colour but otherwise are similar in appearance. They are of a somewhat different type to the macaronis of the plains, the ears being much smaller, somewhat laxer and bearing more resemblance to the common wheats than is usually the case.

var. *murciense* Kcke.

Madras Class 1.—Awns persistent ; chaff smooth, red ; grain red.

Wheats belonging to this class were found in Yerva Godhumalu from the Nandikotkúr Táluk of Kurnool, Manchi Godhumalu from the Nandyál Táluk of Kurnool, and in samples of wheat from the Koilkuntla Táluk of Kurnool and from Cuddapah.

var. *affine* Kcke.

Madras Class 2.—Awns easily shed ; glume-tooth straight ; chaff smooth, white ; grain red.

Wheats belonging to this class were found in Yerva Godhumalu from the Nandikotkúr Táluk of Kurnool, Manchi Godhumalu from the Nandyál Táluk of Kurnool, Potta Godhumalu from Alúr, Bellary and in samples of wheat from the Koilkuntla Táluk of Kurnool, the Guntúr Táluk of Guntúr and from Cuddapah.

TRITICUM VULGARE VILL. COMMON WHEATS.

Ears bearded or beardless, outer glumes not keeled to the base, straw hollow, grains neither very long nor round.

var. *erythrospermum* Kcke.

Madras Class 3.—Ears bearded, awns white ; chaff smooth, white ; grain red.

Wheats belonging to this class were found in Akki Gothi from Coonoor.

TRITICUM DICOCCUM SCHRK. EMMER.

Ears nearly always bearded, dense, outer glumes sharply keeled with an acute apex ; rachis brittle ; grain enclosed in the glumes after threshing.

var. *farrum* Bayle.

Madras Class 4.—Ears unbranched, tapering at the top, fully bearded with long awns ; chaff white, very shiny ; grain red, long.

Wheats belonging to this class were found in Gothumai from Ootacamund, Sadharana Godhumai from Coimbatore, Mulloo Gothi from Coonoor, Godhumai from the Kodaikánal Táluk of Madura, Yavalu from the Nandikotkur Táluk of Kurnool, Manchi Godhumalu from the Pattikonda Táluk of Kurnool, Yava Gothumalu from the Nandyál Táluk of Kurnool, Yava Gothumalu from the Rámallakota Táluk of Kurnool, Yavai from the Kodaikánal Táluk of Madura, Budda Godhumalu from the Nandyál Táluk of Kurnool.

All these samples have been grown at Púsa for the last two years and some also at Lyallpur, and it has been impossible to find any difference between them either in morphological or agricultural characters. It was also impossible to distinguish these emmers from the *khapli* of Hoshangábád or from the emmers of Mysore when grown side by side at Púsa. It is, therefore, probable that only one agricultural type of emmer occurs in India.

An interesting point to be noticed with regard to this emmer is the difference in the seedlings from those of macaroni, common and dwarf wheats. The first shoot in this emmer is invariably red instead of yellow and the seedlings can be at once distinguished by this character. This variety of emmer grows well both in Bíhár and at Lyallpur and is remarkable for its rust resistance in both places[1]. As it is cultivated in Bombay, Central Provinces, Madras, and Mysore, it appears to be a wheat which can adapt itself to most conditions.

THE WHEATS OF MYSORE.

Wheat is only grown in Mysore to a very limited extent and the varieties appear to be the same as those cultivated in Madras. The specimens which were afterwards grown at Púsa were kindly sent to us by Dr. Lehmann, formerly Agricultural Chemist to the Mysore Government.

CLASSIFICATION OF THE WHEATS OF MYSORE.

TRITICUM DURUM DESF. MACARONI WHEATS.

1. Glumes smooth.
   - A. Glumes red, awns red.
     - a. Grain red.
       - var. *murciense* Kcke.
         - Mysore Class 1.
   - B. Glumes white, awns white.
     - a. Grain white.
       - var. *affine* Kcke.
         - Mysore Class 2.

TRITICUM DICOCCUM SCHRK. EMMER.

I. Ears unbranched.
1. Ears long, tapering towards the top.
   - A. Ears fully bearded with long awns.
     - a. Glumes white.
       - var. *farrum* Bayle.
         - Mysore Class 3

[1] Howard & Howard, *Journal of Agricultural Science*, Vol. 2, 1903, p. 278.

DESCRIPTION OF THE WHEATS OF MYSORE.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid, grains long.

var. *murciense* Kcke.

Mysore Class 1.—Awns persistent ; chaff smooth, red ; grain red.

Wheats belonging to this class were found in the Hotte Godhi from Chitaldrug.

var. *affine* Kcke.

Mysore Class 2.—Awns easily shed ; glume-tooth straight ; chaff smooth, white ; grain red.

Wheats belonging to this class were found in the Hotte Godhi from Chitaldrug.

TRITICUM DICOCCUM SCHRK. EMMER.

Ears nearly always bearded, dense ; outer glumes sharply keeled with an acute apex ; rachis brittle ; grain enclosed in the glumes after threshing.

var. *farrum* Bayle.

Mysore Class 3.—Ears unbranched, long, tapering to the top, fully bearded with long awns ; chaff white, shiny ; grain red, long, thin and pointed.

Wheats belonging to this class were found in Java Godhi from Chitaldrug.

CHAPTER XI.

THE WHEATS OF THE CENTRAL PROVINCES.

For a collection of the Central Provinces wheats (most of which were grown by us afterwards at Púsa) we are indebted to Mr. L. E. P. Gaskin, I.C.S., formerly Director of Agriculture in the Central Provinces. Mr. G. Evans, Deputy Director of Agriculture, has also kindly sent us samples of all the wheats grown at the Hoshangábád Farm as well as many others from other parts of the Province. A collection of wheats of the Hoshangábád District was also made by one of us in 1906. In 1907, Mr. G. Evans undertook a classification of the Central Provinces wheats and the original draft of this chapter was lent to him. Owing to unavoidable delay in the publication of the present work, Mr. Evans' classification has appeared first and in revising the chapter we have made use of his bulletin.[1] Mention has, however, always been made when the information has been derived from this source and not from examination of the actual specimens.

It is interesting to note that in the Central Provinces representatives of all of the four sub-species of wheat in general cultivation in India (*i.e.*, *T. durum*, *T. compactum*, *T. vulgare* and *T. dicoccum*) occur. Evans considers that there are also to be found representatives of the fifth sub-species, *T. turgidum* (Rivet wheats). In carefully examining the specimens at our disposal, we have, however, so far found no undoubted Rivets, although in one case the resemblance is considerable. Macaroni wheats are of considerable importance, more than half the classes isolated belonging to this sub-species. The wheat commonly exported from the Narbadá valley is the *Desi Pissi* (a common wheat) with a soft white grain. Some of the Districts of the Central Provinces appear to be essentially soft wheat tracts. Not only do many ears of undoubted macaroni wheat contain soft grains, but even the emmer, the grains of which in other Provinces are exceedingly hard, produced some quite starchy grains in the Central Provinces.

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[1] Evans, *Varieties of Wheat grown in the Central Provinces and Berar, Department of Agriculture, Central Provinces & Berar*, 1908.

CLASSIFICATION OF THE WHEATS OF THE CENTRAL PROVINCES.

TRITICUM DURUM DESF. MACARONI WHEATS.

1. Glumes felted.
   - A. Glumes red.
     - a. Awns black.
       - * Grain red.
         - var. *niloticum* Kcke.
           Central Provinces Class 1.
       - ** Grain white.
         - var. *apulicum* Kcke.
           Central Provinces Class 2.
     - b. Awns red.
       - * Grain red.
         - var. *ægyptiacum* Kcke.
           Central Provinces Class 3.
   - B. Glumes white.
     - a. Awns black.
       - * Grain red.
         - var. *africanum* Kcke.
           Central Provinces Class 4.
       - ** Grain white.
         - var. *melanopus* Al.
           Central Provinces Class 5.

2. Glumes smooth.
   - A. Glumes red, awns red.
     - a. Grain red.
       - var. *murciense* Kcke.
         Central Provinces Class 6 and Class 7.
     - b. Grain white.
       - var. *hordeiforme* Host.
         Central Provinces Class 8 and Class 9.
   - B. Glumes white, awns white.
     - a. Grain red.
       - var. *affine* Kcke.
         Central Provinces Class 10.
     - b. Grain white.
       - var. *leucurum* Al.
         Central Provinces Class 11.

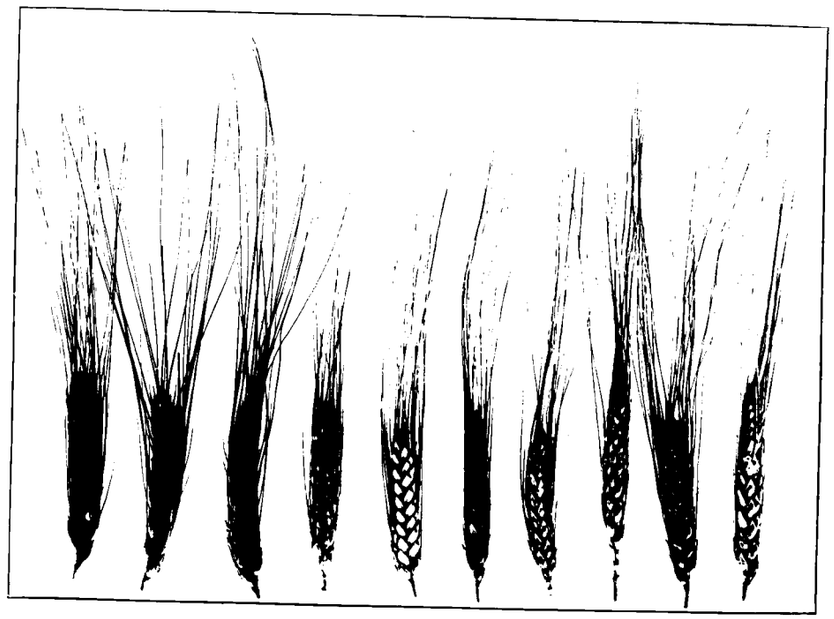
TRITICUM COMPACTUM HOST. DWARF WHEATS.

I. Ears bearded, glumes smooth.
  A. Glumes white.
    a. Grain red.
      var. *icterinum* Al.
      Central Provinces Class 13.
    b. Grain white.
      var. *splendens* Al.
      Central Provinces Class 12.

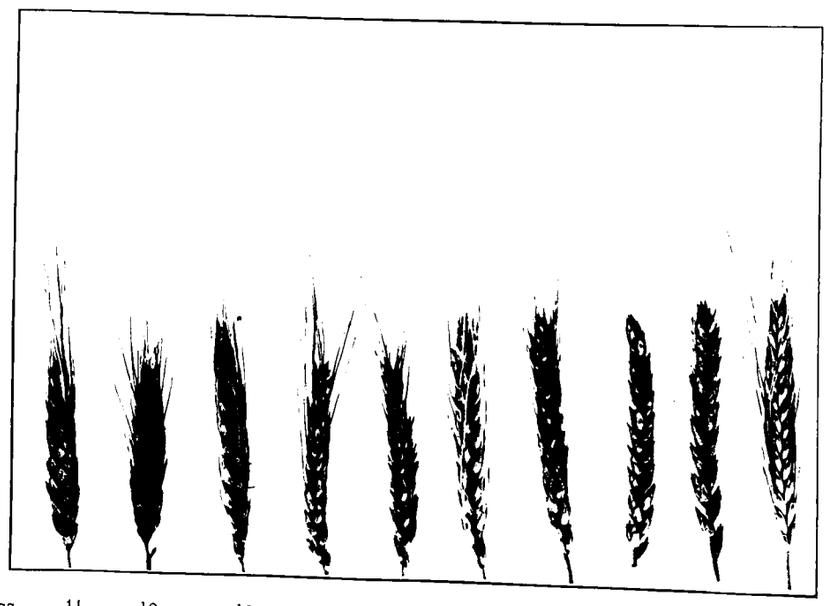
TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
  1. Glumes felted.
    A. Glumes white.
      a. Grain red.
        var. *Hostianum* Clem.
        Central Provinces Class 14.
  2. Glumes smooth.
    A. Glumes red.
      a. Grain red.
        var. *ferrugineum* Al.
        Central Provinces Class 15.
      b. Grain white.
        var. *erythroleucon* Kcke.
        Central Provinces Class 16.
    B. Glumes white.
      a. Grain red.
        var. *erythrospermum* Kcke.
        Central Provinces Class 17.
      b. Grain white.
        var. *græcum* Kcke.
        Central Provinces Class 18.

II. Ears beardless.
  1. Glumes smooth.
    A. Glumes red.
      a. Grain white.
        var. *alborubrum* Kcke.
        Central Provinces Class 19.



Class 1 2 3 4 5 6 7 8 9 10



Class 11 12 13 14 15 16 17 18 19 20

THE WHEATS OF THE CENTRAL PROVINCES.

B. Glumes white.
a. Grain white.
var. *albidum* Al.
Central Provinces Class 20.

TRITICUM DICOCCUM SCHRK. EMMER.

I. Ears unbranched.
1. Ears long, tapering towards the top.
A. Ears fully bearded with long awns.
a. Glumes white.
var. *farrum* Bayle.
Central Provinces Class 21.

DESCRIPTION OF THE WHEATS OF THE CENTRAL PROVINCES.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid, grains long.

No less than nine distinct botanical varieties of *Triticum durum* are cultivated in the Central Provinces. Some of them show great similarity to the *waddnaks* of the Punjab and some resemble very closely the macaronis of Bombay. Certain of the macaroni wheats of the Central Provinces have some resemblance to Rivet wheats, especially in their grain characters. The distinction between *Triticum durum* and *Triticum turgidum* is often very difficult, the difference lying mainly in the shape of the ear which in Rivet wheat is square and dense and in the shape of the grain which is shorter, plumper and generally soft. While undoubted macaronis and undoubted Rivets exist in Europe, there are also to be found many forms which with almost equal justice might be placed in one or other sub-species. Even Koernicke who studied the wheats of Europe for twenty years states that he continually altered his opinion as to which of these sub-species some of his specimens belonged.

Several of the macaronis of the Central Provinces, notably *Dautia* of Hoshangábád, have a shorter grain than is usual in *Triticum durum*. In no case, however, is the typical square ear of the Rivet wheats present, and the tendency of the ears to shed their awns is also in favour of classifying them as macaroni wheats. The fact that the grain is soft is of very

small importance when we remember that many of the tracts of the Central Provinces are soft wheat tracts. We have found no Rivet wheats in any other part of India except in Baluchistán and the occurrence of a few isolated varieties in the centre of India would seem curious, but of course not impossible. As we have after a careful examination of the material at our disposal found no undoubted Rivet wheat, we have classified all the varieties under the sub-species *T. durum.*

var. *niloticum* Kcke.

Central Provinces Class 1.—Ears with black awns; chaff felted, red; grain red.

Wheat belonging to this class was found in Bangasia of Saugor.

var. *apulicum* Kcke.

Central Provinces Class 2.—Ears with black awns; chaff felted, red; grain white.

Wheats belonging to this class were found in the red chaffed Bansi of Bálághát.

var. *ægyptiacum* Kcke.

Central Provinces Class 3.—Ears with red awns; chaff felted, red; grain red.

Wheat belonging to this class was found in small quantity in Kathia of Hoshangábád.

var. *africanum* Kcke.

Central Provinces Class 4.—Ears with black awns; chaff felted, white; grain red.

Wheat belonging to this class was found in Bangasia from Nágpur.

var. *melanopus* Al.

Central Provinces Class 5.—Ears with black awns; chaff felted, white; grain white.

Wheats belonging to this class were found in white-awned Bansi from Nágpur, Bansi from Hoshangábád, black-awned Bansi from Nágpur, long Bansi of Saugor, small Bansi of Buldana.

var. *murciense* Kcke.

There appear to be two classes within this botanical variety.

Central Provinces Class 6.—Ears with red awns; chaff smooth, dark red and shiny; grain red.

Wheat belonging to this class was found in Kathia from Hoshangábád.

Central Provinces Class 7.—Ears with red awns; chaff smooth, light red, not very shiny; grain red.

Wheats belonging to this class were found in Kathia from Nágpur, Lal Pissi, Tigaria of Nimár.

var. *hordeiforme* Host.

In this variety there are also two classes.

Central Provinces Class 8.—Ears with red awns; chaff smooth, light red; grain white.

Wheats belonging to this class were found in Jalalia from Nágpur, Tigaria of Nimár, Jalalia from Hoshangábád.

Central Provinces Class 9.—Ears somewhat denser, with red awns; chaff dark red, shiny; grain white, short and plump, bearing some resemblance to the grain of Rivet wheat.

Wheat belonging to this class was found in Dautia or Daudkhani from Hoshangábád.

var. *affine* Kcke.

Central Provinces Class 10.—Ears with white awns; glume-teeth straight; chaff smooth, white; grain red.

Wheats belonging to this class were found in red Katha of Chánda, Haura of Nágpur, Katha from Hoshangábád, Ekdania and according to Evans in Salya.

It must be noticed that Ekdania differs slightly from the other wheats of this class in the character of the teeth of the outer glumes.

var. *leucurum* Al.

Central Provinces Class 11.—Ears with white awns; chaff smooth, white; grain white.

Wheats belonging to this class were found in Haura from Nágpur, Jalalia from Hoshangábád, white Katha of Nágpur, Bokhara, Central Provinces white-awned Jalalia, Daudkhani from Saugor and according to Evans in yellow Ekdania from Betúl, Mahuja from Seoní-Chappara, Potiya from Akola, Hansia from Saugor, Daudkhani from Damoh, Dautia from Hoshangábád, Soharia from Hoshangábád.

Triticum vulgare Vill. Common wheats.

Ears bearded or beardless, outer glumes not keeled to the base, straw hollow, grain neither very long nor round.

var. *Hostianum* Clem.

Central Provinces Class 14.—Ears bearded, somewhat lax, quadratic; chaff somewhat sparsely felted with long hairs, white with reddish border; glumes keeled to the base but to a lesser degree than in macaroni wheats; grain red.

To this class belongs an irrigated wheat (unnamed) from Nimár.

The existence of this wheat in the Central Provinces is of great interest. In the general appearance of the ear notably its quadratic shape and in the keeling of the glumes to the base it bears a very close resemblance to Punjab type 9 which has already been described. In no other part of India have we found a wheat which is at all similar to these two. On a closer examination, however, certain marked differences appear, *i.e.*, the glumes are yellowish white instead of grey or blackish and the felting is of a different type. The hairs are long like those of Punjab type 9 but sparse and the glumes differ markedly from the closely felted ones of the Punjab wheats. The ears also are much laxer in the specimens from the Central Provinces. In 1907 crosses were made between Punjab type 9 and some common wheats of the Punjab. The ears of the first generation in 1907-1908 exhibited just those differences from Punjab type 9 as are shown by this wheat. Indeed, but for a blackening of the awns and a greater vigour in the crosses, the ears would be indistinguishable. Ears resembling this wheat were also found occurring as natural crosses (p. 139) in Punjab wheat fields in which type 9 was grown. It seems, therefore, possible that this Nimár type may have arisen by natural crossing from the introduction of the Punjab wheat into the district at some time. This view is somewhat borne out by the fact that, according to Evans, this wheat is always grown mixed with a smooth chaffed one which resembles it closely and that it is late in ripening, requires irrigation and is liable to rust. Punjab type 9 is late even for the Punjab, liable to rust and is also known to require more water than other wheats. It may be a fixed product of a natural cross or more probably it is partly unfixed which would explain its cultivation in a mixture. It is difficult otherwise to explain the isolated occurrence of this peculiar wheat in one District of the Central Provinces.

var. *ferrugineum* Al.

Central Provinces Class 15.—Ears lax, bearded; awns red; chaff smooth, red; grain red.

Wheats belonging to this class were found in Hard Pissí of Mandlá and according to Evans in Red Pissí of Biláspur and Pissí Kathe from Jubbulpore.

var. *erythroleucon* Kcke.

Central Provinces Class 16.—Ears lax, bearded; awns red; chaff smooth, red; grain white.

Wheats belonging to this class were found in Hansi Pissí of Mandlá and according to Evans in Raipuri Pissí.

var. *erythrospermum* Kcke.

Central Provinces Class 17.—Ears lax to medium, bearded; awns white; chaff smooth, white; grain red.

Wheats belonging to this class were found in Raipuri Pissí, Kandia of Buldana, red Pissí from Narsingpur, Dausara from Damoh, red Pissi of Raipur, Sambalpur wheat and according to Evans in red Pissí from Chhindwára, Kaudia from Akola, Nimár irrigated wheat, Khairi Pissí from Biláspur, Rakmaris from Chhindwára.

var. *græcum* Kcke.

Central Provinces Class 18.—Ears medium to lax, bearded; awns white; chaff smooth, white; grain white.

Wheats belonging to this class were found in Dausara from Damoh Desi Pissí, Kusali Pissí, Nágpur Pissí, Pissí Kalwa of Khandara, Pissí of Betul, Pissí of Saugor, Pissí Sikhuri of Damoh, Safed Pissí of Narsingpur, Sukasia and according to Evans in Sukerhai Pissí of Mandlá, white Pissí of Raipur, Pissí Khabra, Bhandara and Khamri Chhindwára.

Pissí is pre-eminently the wheat of the Narbadá valley and Jubbulpore, and the cultivation of this wheat has increased considerably of late owing to export demands. It is very liable to rust, of low yielding power and from its appearance obviously a weak wheat. We have grown *Desi Pissí* both at Lyallpur and Púsa and found it to be badly rusted and of small vigour in both places. According to Evans, it is valuable on account of the chalky flour it produces, such flour being at present in demand in Ireland and parts of England. The demand for the flour of this hue is, however, only local in the United Kingdom and possibly temporary and the introduction of a good hard wheat into those Districts of the Province where hard wheats will grow would probably prove of inestimable value. At present, as far as we have been able to ascertain, most of the hard wheats of the Province are macaroni wheats which are unsuitable for export to the

United Kingdom as they are not liked for breadmaking. No really good hard common wheats appears to have been tried. As the cultivators themselves dislike *Pissí* and prefer hard wheats, a good hard variety, if successfully introduced, would probably be readily taken up. It remains to be ascertained by experiment which tracts of the Central Provinces will grow really hard wheats and which are pre-eminently soft wheat tracts, but even in such districts it should be possible to produce a wheat having the advantages of the *Desi Pissí* as regards flour colour without some of its grave defects. Should the demand for chalky white flour decrease, the *Desi Pissí* would seem to have but little to recommend its cultivation.

var. *alborubrum* Kcke.

Central Provinces Class 19. Ears beardless or slightly bearded; chaff smooth, red; grain white.

Wheats belonging to this class were found in red chaffed Mundi.

var. *albidum* Al.

Central Provinces Class 20.—Ears medium, sometimes denser and broader above (fan-shaped), beardless or slightly bearded; chaff smooth, white; grain white.

Wheats belonging to this class were found in Mundi Pissí from Jubbulpore, Mundi Pissí from Hoshangábád, Mundia Pissí from Damoh, Mundi Pissí from Mandlá, Mundi Pissí from Saugor, and according to Evans in Mundia wheat of Hoshangábád and Mandala of Balaghat.

Mundi Pissí is said to be fairly rust-resistant in the Narbadá valley and is often exported.

TRITICUM DICOCCUM SCHRK. EMMER.

Ears nearly always bearded, dense, outer glumes sharply keeled with an acute apex, rachis brittle; grain enclosed in the glumes when threshed.

var. *farrum* Bayle.

Central Provinces Class 21.—Ears unbranched, long, tapering towards the top, fully bearded with long awns; chaff white, shiny; grain red, long, thin and pointed.

Wheats belonging to this class are the Khapli obtained from Hoshangábád Farm and according to Evans, Khapli from Akola.

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Mundi Pissí is said to be fairly rust-resistant in the Narbadá valley and is often exported.

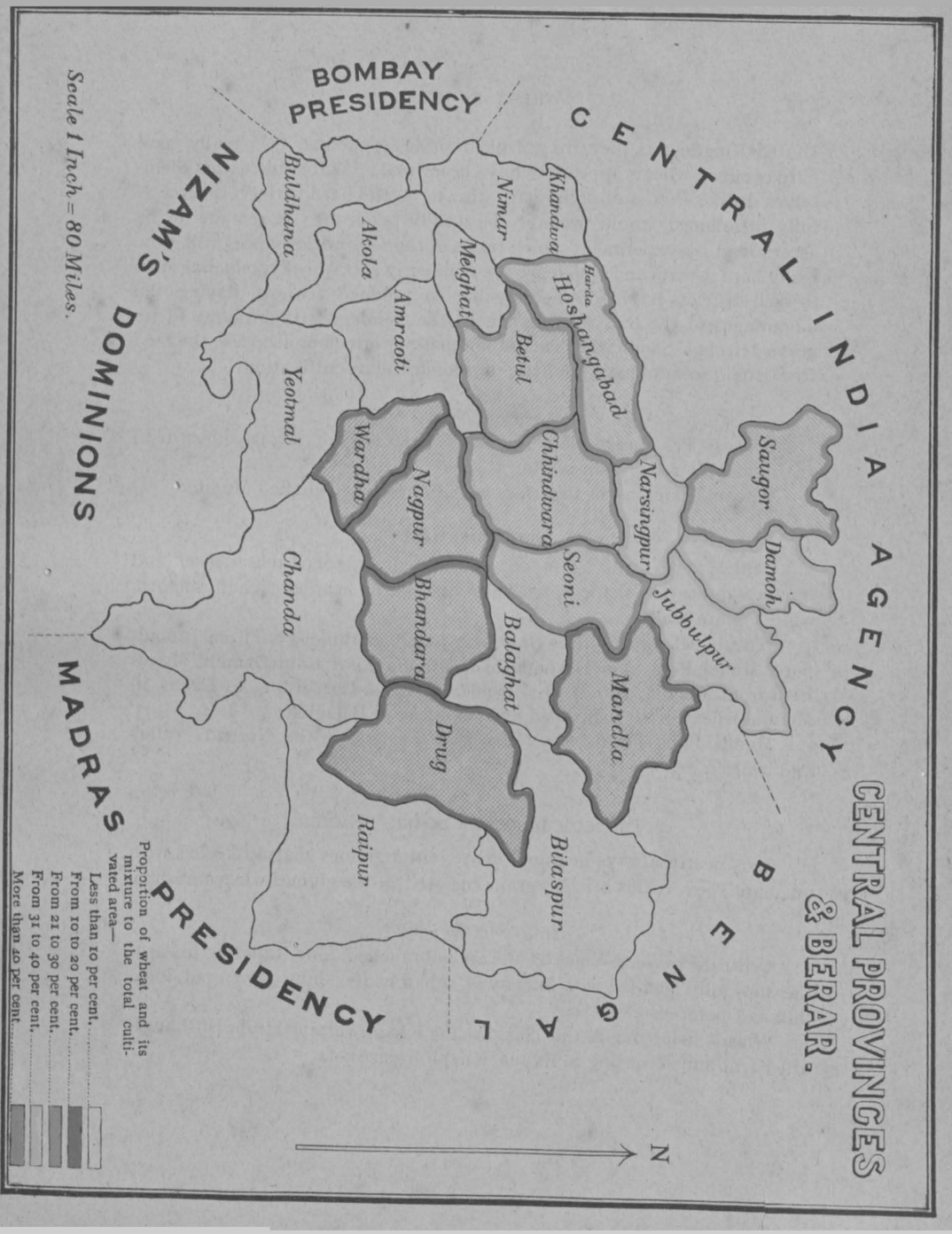
Triticum dicoccum Schrk. Emmer.

Ears nearly always bearded, dense, outer glumes sharply keeled with an acute apex, rachis brittle; grain enclosed in the glumes when threshed.

var. *farrum* Bayle.

Central Provinces Class 21.—Ears unbranched, long, tapering towards the top, fully bearded with long awns; chaff white, shiny; grain red, long, thin and pointed.

Wheats belonging to this class are the Khapli obtained from Hoshangábád Farm and according to Evans, Khapli from Akola.



CHAPTER XII.

CONSPECTUS OF THE WHEAT VARIETIES OF INDIA.

In the following pages the wheats of India, as a whole, are considered and a list of the botanical varieties, so far identified, is given together with the distribution of these varieties. In all probability the list is not yet complete, as it has naturally been impossible in the three years during which this work has been in hand to work completely over so large an area. Moreover, new forms are constantly arising by natural cross-fertilization.

We have identified in all thirty-seven separate botanical varieties of which ten belong to the subspecies *T. durum*, two to *T. turgidum*, six to *T. compactum*, one to *T. dicoccum*, and the rest to *T. vulgare*. It will be seen from the following list that the distribution of the varieties is the natural one that would be expected from a knowledge of the wheat-growing districts. Varieties of wheat common in one Province are found, as a rule, to extend into the neighbouring ones. Macaroni wheats are commonest on the black cotton soils in Bombay and the Central Provinces and extend into the Punjab and to a very slight extent into the United Provinces and Madras. There is, however, the curious exception of the macaroni wheats, isolated as it were, in the Málda district of Bengal. Among the macaroni wheats var. *melanopus* and var. *murciense* appear to have the widest distribution, *i.e.*, var. *melanopus* occurs in the Punjab, United Provinces, Bombay and Central Provinces, while var. *murciense* occurs pre-eminently in the South in Bombay, Central Provinces, Madras and Mysore. There are six varieties of dwarf wheats, which are commonest in the Western Punjab; as they are of no value for export, their cultivation will probably decline still further. They are chiefly valuable on account of their drought-resisting character. There appears to be only one agricultural type of emmer, which is essentially a southern variety, being grown only in Madras, Mysore, Bombay and to a very small extent in Berár, probably introduced from Bombay. Bearded and beardless common wheats are found all over the wheat-growing tract, bearded wheats being the more commonly cultivated. Var. *erythrospermum* (*i.e.*, bearded, smooth white chaffed, red grained wheat) is the only wheat found all over India from Madras to the Simla Hills, although var. *græcum* (bearded, smooth white chaffed, white grained wheat) and var. *albidum*

(beardless, smooth white chaffed, white grained wheat) are almost equally widely distributed.

Although the same botanical variety is often so widely spread over India, it must not be understood that the same wheat has such a wide distribution. In the case of Koernicke's variety *erythrospermum*, at least two different wheats belonging to this variety grow in the Punjab, while the same variety occurring in the Simla Hills, United Provinces, Bengal, Bombay, Madras and the Central Provinces is probably composed of other different agricultural types. The complexity of the botanical variety even in the same Province serves to show how important it is that an agricultural survey of the wheats of each tract should be undertaken in continuation of the botanical survey, which is naturally the first step in the work.

One point worth remarking with regard to the Indian wheats is the large amount of black colour present. Most of the macaroni wheats have black awns, some also a certain amount of blackening of the chaff. Some common wheats have black awns and occasionally black chaff, *e.g.*, Bengal classes 12 and 13 in which the ears may be entirely black. The straw also of several Punjab and hill varieties darkens on ripening. The most interesting common wheats are type 9 of the Punjab belonging to var. *fuliginosum* which shows in its glumes a curious transition between macaroni wheats and common wheats, class 14 of the Central Provinces (var. *Hostianum* Clem.) which is probably related to type 9, Hill wheats classes 11 and 12 which show a transition between common wheats and dwarf wheats and Bengal classes 12 and 13.

The botanical survey of the wheats of India is not without interest apart from its importance in the improvement of the wheat crop. The wheats at present in cultivation in this vast Empire, in which a civilised agriculture has been practised from time immemorial, represent the survival of types most fitted for the conditions of the various tracts. Nature has eliminated the unfit, and the experience of past centuries, handed down by tradition, has taught the cultivator what soils and what tracts are most suitable for this crop. Varieties of wheat introduced by sea from Western Countries have, in recent times at any rate, had no influence on the crop and have not been adopted by the cultivators. No new forms have been introduced by selection or hybridization as has been the case in Europe and America. It will be more than interesting therefore to find what has resulted under such conditions and how the characters and grain qualities of the Indian wheats compare with those of Europe and America.

THE BOTANICAL VARIETIES OF WHEAT CULTIVATED IN INDIA.

TRITICUM DURUM DESF. MACARONI WHEATS.

Ears flat; flowering glumes with long awns, outer glumes sharply keeled to the base; straw stiff and solid; grains long.

var. *niloticum* Kcke.

Glumes felted, red; awns black; grain red.

To this variety belong the wheats in Bengal Class 1, and Central Provinces Class 1.

var. *apulicum* Kcke.

Glumes felted, red; awns black; grain white.

To this variety belong the wheats in United Provinces Class 1, Bengal Class 2, and Central Provinces Class 2.

var. *ægyptiacum* Kcke.

Glumes felted, red; awns red; grain red.

To this variety belong the wheats in Central Provinces Class 3.

var. *italicum* Al.

Glumes felted, red; awns red; grain white.

To this variety belong the wheats in Bombay Class 1

var. *africanum* Kcke.

Glumes felted, white; awns black; grain red.

To this variety belong the wheats in Punjab Type 2, Bombay Class 2, and Central Provinces Class 4.

var. *melanopus* Al.

Glumes felted, white; awns black; grain white.

To this variety belong the wheats in Punjab Type 1, United Provinces Class 2, Bombay Class 3, and Central Provinces Class 5.

var. *murciense* Kcke.

Glumes smooth, red; awns red; grain red.

To this variety belong the wheats in United Provinces Class 3, Bombay Class 4, Central Provinces Class 6 and Class 7, Madras Class 1, Mysore Class 1.

var. *hordeiforme* Host.

Glumes smooth, red; awns red; grain white.

To this variety belong the wheats in Central Provinces Class 8 and Class 9.

var. *affine* Kcke.

Glumes smooth, white; glume-tooth straight; awns white; grain red.

To this variety belong the wheats in United Provinces Class 4, Central Provinces Class 10, Madras Class 2, Mysore Class 2.

var. *leucurum* Al.

Glumes smooth, white; awns white; grain white.

To this variety belong the wheats in Punjab Type 3, Bombay Class 5, Central Provinces Class 11.

Triticum turgidum L. Rivet wheats.

Ears square and dense, bearded; glumes sharply keeled to the base; straw stout, stiff and solid; grain plump, short, somewhat rounded, large.

var. *Salomonis* Kcke.

Glumes felted, white; awns black; grain white.

To this variety belong the wheats in Baluchistán Class 1.

var. *nemausense* Wittm.

Glumes smooth, white; awns black; grain white.

To this variety belong the wheats in Baluchistán Class 2.

Triticum compactum Host. Dwarf wheats.

Ears exceedingly dense and short, rarely over 2 ins. long; outer glumes keeled in the upper half and rounded in the lower half; straw very short and stiff; grains rounded.

var. *erinaceum* Kcke.

Ears bearded; glumes smooth, red; grain red.

To this variety belongs Punjab Type 4.

var. *icterinum* Al.

Ears bearded; glumes smooth, white; grain red.

To this variety belong the wheats in Central Provinces Class 13.

var. *splendens* Al.

Ears bearded; glumes smooth, white; grain white.

To this variety belong the wheats in United Provinces Class 5 and Central Provinces Class 12.

var. *linaza* Kcke.

Ears beardless; glumes felted, white; grain white.

To this variety belongs Punjab Type 5.

var. *Wernerianum* Kcke.

Ears beardless; glumes smooth, white; grain red.

To this variety belongs Punjab Type 6.

var. *Humboldti* Kcke.

Ears beardless; glumes smooth, white; grain white.

To this variety belongs Punjab Type 7.

Triticum vulgare Vill. Common wheats.

Ears bearded or beardless; outer glumes not keeled to the base; straw hollow; grain neither very long nor round.

var. *juliginosum* Al.

Ears bearded; awns black; glumes felted, grey; grain red.

To this variety belongs Punjab Type 9.

var. *barbarossa* Al.

Ears bearded; glumes felted, red; grains red.

To this variety belongs Punjab Type 8.

var. *Hostianum* Clem.

Ears bearded; glumes felted, white; grain red

To this variety belong the wheats in Central Provinces Class 14.

var. *meridionale* Kcke.

Ears bearded; glumes felted, white; grain white.

To this variety belong the wheats in the United Provinces Class 6, Bengal Class 7, Bombay Class 6.

var. *ferrugineum* Al.

Ears bearded; glumes smooth, red; awns red; grain red.

To this variety belong the wheats in Punjab Type 13, Hill wheats Class 1, Bengal Class 8, Central Provinces Class 15.

var. *erythroleucon* Kcke.

Ears bearded; glumes smooth, red; grain white.

To this variety belong the wheats in Punjab Type 10, Punjab Type 11, Punjab Type 12; United Provinces Class 7, Bengal Class 9, Central Provinces Class 16.

var. *erythrospermum* Kcke.

Ears bearded; glumes smooth, white; grain red.

To this variety belong the wheats in Punjab Type 14, Punjab Type 15, Hill wheats Class 2, United Provinces Class 8, Bengal Class 10, Bombay Class 7, Central Provinces Class 17, Madras Class 3.

var. *græcum* Kcke.

Ears bearded ; glumes smooth, white ; grain white.

To this variety belong the wheats in Punjab Type 16, United Provinces Class 9, Bengal Class 11, Bombay Class 8, Central Provinces Class 18.

var. *cæsium* Al.

Ears bearded ; awns black ; glumes smooth, black ; grain red.

To this variety belong the wheats in Bengal Class 12.

var. ?

Ears bearded ; awns black ; glumes smooth, black ; grain white.

To this variety belong the wheats in Bengal Class 13.

var. *pyrothrix* Al.

Ears beardless ; glumes felted, red ; grain red.

To this variety belong the wheats in Hill wheats Class 3.

var. *Delfii* Kcke.

Ears beardless ; glumes felted, red ; grain white.

To this variety belong the wheats in Punjab Type 17, Punjab Type 18, Hill wheats Class 4, United Provinces Class 10, Bombay Class 9.

var. *velutinum* Schübl.

Ears beardless ; glumes felted, white ; grain red.

To this variety belong the wheats in Hill wheats Class 5.

var. *leucospermum* Kcke.

Ears beardless ; glumes felted, white ; grain white.

To this variety belong the wheats in Punjab Type 19, Hill wheats Class 6, Bombay Class 10.

var. *milturum* Al.

Ears beardless ; glumes smooth, red ; grain red.

To this variety belong the wheats in Punjab Type 22 and Punjab Type 23, Hill wheats Class 7, and Bengal Class 3.

var. *alborubrum* Kcke.

Ears beardless ; glumes smooth, red ; grain white.

To this variety belong the wheats in Punjab Type 20, Punjab Type 21, Hill wheats Class 8, United Provinces Class 11, Bengal Class 4, Central Provinces Class 19.

var. *lutescens* Al.

Ears beardless ; glumes smooth, white ; grain red.

To this variety belong the wheats in Hill wheats Class 9, United Provinces Class 12, Bengal Class 5.

var. *albidum* Al.

Ears beardless ; glumes smooth, white ; grain white.

To this variety belong the wheats in Punjab Type 24, Punjab Type 25, Hill wheats Class 10, United Provinces Class 13, United Provinces Class 14, Bengal Class 6, Bombay Class 11, Bombay Class 12 and Central Provinces Class 20.

Triticum dicoccum Schrk. Emmer.

Ears almost always bearded, dense ; outer glumes sharply keeled with an acute apex ; rachis brittle ; grain enclosed in the glumes when threshed.

var. *farrum* Bayle.

Ears unbranched, long, tapering towards the top, fully bearded with long awns ; chaff white, shiny ; grain red, long, thin and pointed.

To this variety belong the wheats in Bombay Class 13, Central Provinces Class 21, Madras Class 4, Mysore Class 3.

CHAPTER XIII.

THE INFLUENCE OF THE ENVIRONMENT ON THE GRAIN CHARACTERS.

Colour.

The colour of the matured grains of the Indian wheats we have so far examined is either red or white. The tint in both classes varies a good deal. The red wheats vary from dark brownish-red to light red, while the white wheats include yellowish and amber tints. We have experienced no difficulty in determining the colour except in cases of unripe ears where the red colour is not so well marked. As a general rule, the Indian white wheats exhibit a clearer and more marked white colour than those of colder countries.

While the various red and white wheats show different and often characteristic tints, we have not used these tints to separate the kinds on account of the influence of soil and temperature during the ripening period on the tone of colour. As will be seen in the next section, the particular tone of colour depends partly on the consistency of the grain, and as consistency varies in the same variety both from year to year in the same locality and also in different localities in the same year, it is not safe to use tone or tint of colour as a distinguishing character. As an example of the change of tone of colour, the cultures from the same sample of Muzaffarnagar white wheat at Muzaffarnagar, Lyallpur and Púsa in 1908 may be quoted. The three samples, when placed side by side, look quite different. The Muzaffarnagar sample is clean white, the Púsa sample amber and the Lyallpur one intermediate.

We have been at great pains to obtain reliable evidence on the question of the change of white wheats to red when introduced into fresh localities. There are a large number of loose statements both in the European and Indian literature on this subject, and many observers consider that white wheats change into red ones when grown on certain soils. One of many Indian examples may be referred to as illustrating the kind of change which is believed to take place. In 1884, a sub-divisional officer of Bárh in the Patna Division of Bengal informed the Commissioner that in the soil called *teliya kewal* in Bárh white wheat changes into red whatever care is taken. The matter was referred to the Superintendent of the Calcutta Botanical

Gardens, who considered that as native wheats are notoriously mixed, there were probably some red grains present in the original seed, which gave rise to plants which throve better in this particular soil than the white wheat. In a very short time the proportion of the hardier plants from the red seed would become so great that the resulting grain would be nearly all red. The matter was taken up by the Government of India in the same year and enquiries were made in the various Provinces on the influence of soil and situation on the colour of wheat. The evidence which resulted was inconclusive. No grounds for belief in any change of colour due to soil or climate could be discovered in the Central Provinces and the Punjab. In the United Provinces it was believed in many Districts that white wheat in certain soil reverts to red. In Bombay the matter received considerable attention. The earlier results were somewhat contradictory, but after six years' experiments it was concluded that soft wheats can be cultivated without appreciable change in colour or consistency in a hard wheat district.[1]

In Europe, Percival[2] states:—"White wheats, however, become red in warm climates or when grown on certain soils, so that this character is of little value in a scientific scheme of classification of the different varieties." Eriksson[3] believes that white wheat becomes red and quotes Werner in support and even goes to the length of stating that the colour of the grain is useless in distinguishing a variety. In no case, however, have we found that these supposed transformations are based on recorded scientific evidence. It is, of course, often found that when an *ordinary sample* of white wheat is tested in a new locality the resulting grain in a few years is entirely or almost entirely red. A little consideration, however, will show that this result is no evidence of the change of a white wheat into a red one. White wheats as *ordinarily grown* in Europe and much more so in India are not pure cultures. They generally contain red wheats as impurities, and, as a rule, red wheats are hardier than white sorts. Consequently when a white wheat containing red impurities is grown in another locality, the struggle for existence between the red "weeds" and the white sort which at once begins may easily result in the gradual victory of the red. In a few years the white wheat may have disappeared entirely. The result of this change from a white to a red sample is, of course, due to the victory of the red sort over the white, and offers no proof of

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[1] *Report of the Department of Land Records and Agriculture, Bombay*, 1890.
[2] Percival, *Agricultural Botany*, New Edition, 1902, p. 504.
[3] Eriksson, l. c.

a change from white to red.[1] We have so far found no evidence in the literature on wheat of a white wheat changing into a red one *when grown in pure culture from a single plant and in land where contamination of the cultures, from stray seeds left from a previous crop or from manure or irrigation water, has been guarded against.*

In seeking to obtain experimental evidence on this point in India we were fortunate enough in 1906 to obtain a very good example. The white wheat known as Muzaffarnagar white has been tested in many parts of India including Oudh and Bihár. In the samples grown at Púsa, Cawnpore, Lyallpur and in the Muzaffarnagar district itself we found that the wheat was not pure but contained among other things a red wheat very similar in appearance in the ear to the true Muzaffarnagar white wheat. Pure cultures of these wheats from single ears have been grown at Lyallpur and Púsa for the last two years. No change from white to red has yet taken place, but at both stations the red form grows more vigorously than the white, and if grown in competition there is no doubt that the red kind would win.

In many other pure cultures of both red and white wheats at Lyallpur and Púsa during the last two years no change of white to red grain or the reverse has been noticed except in cases of natural cross fertilization at Lyallpur (p. 139). We accordingly believe that the colour of the grain is a constant character and one of considerable value in systematic work.

Consistency.

The consistency of a variety of wheat is of importance in two different ways. In the first place, the question arises as to the value of the texture of the grain, whether hard or soft, from the systematic point of view. If this character is of any value from this standpoint, then a soft wheat must always remain soft when grown in a new locality. Hard wheats must, in a similar manner, remain hard when transferred to a new environment. Obviously the only way to obtain accurate information on such a subject is to grow hard and soft wheats in various localities in all cases, using for this purpose pure line cultures obtained from a single plant or ear. A large number of observations have been made on this subject both in Europe and America.

[1] See De Vries, *Species and Varieties, their Origin by Mutation*, 2nd Edition, page 59, and Darwin, *The Variation of Animals and Plants under Domestication*, Vol. 1, page 334.

The general result so far has been to indicate that consistency depends on the soil, on the available moisture and on the nutrition of the crop. Thus in the United States, Le Clerk[1] states in the case of Durum wheats that in humid districts and under irrigation the grain tends to become starchy, while in drier localities the grain remains flinty with a higher nitrogen content. Eriksson[2] in Sweden concludes that consistency is of no systematic value and depends more on the season than on the kind. He found that wheats brought to Sweden from Southern Europe became more and more glassy except in good years. Koernicke[3] at Poppelsdorf found that there was often a change from floury grains to flinty and also the reverse and that these changes depended both on soil and season. Fruwirth[4] in a recent discussion of the subject, concludes that consistency varies with the season, soil and the nutrition of the crop, and that in Europe wheats become increasingly floury from East to West and from South to North. Raum[5] at Munich found that the North German and exotic kinds became more and more flinty each year and tended to resemble the flinty Bavarian kinds. The exotic kinds were also found to be influenced by the season to a much greater extent than the local wheats. Voelcker[6] has found at Woburn that consistency is not constant, but can be altered by the manurial treatment. He found that as the relative proportions of lime and magnesia in a soil approach nearer and nearer to the ratio 1 : 1 so the wheat grain tends to become more glutinous and hard.

Our attention was drawn to this question during the harvest of 1906 in the Punjab. We found that in numerous cases, especially in the so-called soft white wheats, ears could be found which contained soft, hard and spotted grains. Similar observations were made in 1907 and 1908, both at Púsa and Lyallpur, and in the case of numerous samples of ears sent to us from other parts of India. It was found in the case of pure culture wheats from single ears that both at Lyallpur and at Púsa soft wheats tend to become flinty. The reverse change from hard to soft is rarer, but is to be met with in macaroni wheats, *e.g.*, Punjab types 1 and 2 and the Bengal durum wheats at Púsa. A very large number

[1] Le Clerk, *Yearbook, U. S. Department of Agriculture*, 1906, p. 199.
[2] Eriksson, l. c.
[3] Koernicke, l. c.
[4] Fruwirth, *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Bd. IV, 1907.
[5] Raum, *Zur Kenntnis der morphologischen Veranderungen der Getreidekoerner unter dem Einflusse klimatischer Verhältnisse*, Munich, 1906.
[6] Voelcker, *Journal of the Royal Agr. Society of England*, vols. 63 and 68, 1902 and 1907.

of the Punjab white wheats at Lyallpur in 1908 showed hard, soft and spotted grains. There was no question of admixture as the original selection from one ear in 1906 was made by us as well as all the subsequent sowings and harvestings and the samples were kept in safe custody. Our general experience has been that hard wheats do not change in consistency so easily as soft wheats. Both at Púsa and Lyallpur we have obtained samples differing in consistency from the same type grown the same year in different fields or on slightly different soils. In 1908, with large cultures of selected Muzaffarnagar wheat, obtained the previous year from Muzaffarnagar, at both Púsa and Lyallpur the grain was more flinty than the original and also gave a higher nitrogen content on analysis. We conclude, therefore, with Eriksson, Koernicke and Fruwirth that consistency is useless as a varietal character and that it depends on the environment. We further think that it is likely that soft white wheats are only naturally produced in India in certain well-defined localities, such as the western Districts of the United Provinces, in the Narbadá valley and in South Bihár. Other localities, such as North Bihár and Oudh, tend to produce more glassy wheats.

Consistency is also of importance from the milling point of view. In order to handle a sample of wheat to the best advantage in the mill, the wheat should be uniform in consistency and should not be composed of hard, soft and mottled grains. Millers buy chiefly on appearance combined with the general experience obtained with wheats from the country of origin. They prefer that the sample should be uniformly hard or uniformly soft and they do not like grain of mixed texture. Hence every care should be taken in India to produce uniform wheats for the export trade. We have observed that two of the most important causes of this unevenness of sample in India, apart from the growth of a mixture of types, are inadequate preparation of the land and the use of too much irrigation water. One of the best means of producing a uniform sample is to weather the soil during the previous hot weather and to plough it during the breaks in the monsoon. Where the preliminary weathering is neglected and the wheat lands are not broken up till late, the crop, is almost invariably uneven in texture. The preliminary weathering seems to lead to a uniform absorption of water by the soil and to prevent local excess or defect of soil moisture. A uniform condition as regards soil moisture is naturally bound up with an even supply of moisture to the crop and this seems to be the chief cause of grain of even texture. If more attention were paid to preliminary preparation of the wheat land in India, we consider the milling qualities of the present Indian wheats would speedily be improved. In

the Canal Colonies of the Punjab, which furnish so much of the wheat for export, for too little attention is paid to preliminary cultivation. This is due, no doubt, partly to the size of holdings, but every effort should be made to induce the cultivators to till their land well and so improve the grade of wheat shipped from Kurrachee.

Strength.

The most important character of the grain is its strength, or the capacity of the resulting flour to make large well-shaped loaves. Given a wheat with this desirable quality, the question arises, does or does not the strength of a wheat vary with environment? Are we dealing with a character like the colour of the grain or does strength alter just as consistency does? It is too soon to venture a final opinion on this subject. Some wheats like the Fife group have retained their strength when grown in England, and in some cases, at any rate, it would appear that strength is a definite varietal character. Strength does not necessarily go with hardness, but it is true that strong wheats are often hard. On the other hand, some soft mellow wheats are strong, for example, several of the Púsa selections tested in 1909 (p. 253). Much detailed work is required on this subject in India and our investigations on this subject (in collaboration with Mr. H. M. Leake) are now in progress.

CHAPTER XIV.

THE MILLING AND BAKING QUALITIES OF INDIAN WHEATS.

THE opening of the Suez Canal and the action of the Government o India in 1873 in freeing Indian wheat from all export duty were the tw chief causes which led to the somewhat sudden rise of the Indian whea trade. The importance of the subject generally and the need for th improvement of the trade in Indian wheat early occupied the attention o the Secretary of State and of the Government of India. In an importan Resolution of the Government of India, No. 1-39-50 of March 14th, 1877 on the wheat question, the following passage occurs :—

"The Secretary of State for India desires that a paper may be prepare bringing together all the facts procurable regarding wheat cultivation i India. To assist in the preparation of such a paper, the Governor-Genera in Council requests that in each Province a memorandum may be draw up, showing, as far as the information may be available—

(1) the names of the districts in which wheat is grown ;
(2) the area (in acres) under wheat in each of the last five years t the end of 1876-77 ;
(3) the average outturn in pounds per acre ;
(4) a brief account of the cultivation, in which should be stated th kind of land preferred, the quantity of seed sown per acre, the crop which wheat follows, the season of cultivation, and other useful particulars ;
(5) the average wholesale price of wheat ;
(6) average consumption per head of the population of the district ;
(7) total consumption within the district ;
(8) annual imports into the district for five years, and places whence imported ;
(9) annual exports for the same period, places whither exported, and proportion carried by road, rail, or river ;
(10) estimated average cost of cartage to the railway station nearest the district ;
(11) cost of transit to port of shipment (Calcutta, Bombay, or Kurrachee), by rail, by road, and by river ;
(12) local names for the varieties of wheat cultivated, and their description in English ; and

(13) a general summary for the Province, showing the total area under wheat, the average outturn per acre, the total outturn, and the details of the import and export trade.

It is also requested that no time may be lost in obtaining the samples of wheat required by the Secretary of State. It is desirable that these should be put in bags containing two pounds each, properly labelled with the name of the district in which the wheat was grown and its distinctive name. These samples should be forwarded to this office as soon as possible without waiting for the completion of the information asked for."

From this Resolution dates practically the whole of the work which has been done on wheat in this country.

The samples of wheat more than 1,000 in number, sent to the India Office, were examined by Forbes Watson[1], and his opinion thereon is given in detail in a report to the Secretary of State. A second report on the wheats of the Punjab[2] was written by Cooke in 1881.

Some of the samples examined by Forbes Watson were valued as high as any of the foreign wheats on the London market, and it was conclusively shown that India is well adapted for the growth of wheat of the finest quality. It is interesting to note, however, that "*a considerable number of the samples sent from India were far superior to any Indian wheat usually seen in the London market,*" and it is further stated that "on the Bombay side the supply of the best qualities is very limited as compared with the common qualities, and that the prices of the fine wheats are so well kept up in India itself that more profit is to be obtained on the shipment of inferior than of fine wheat."[3]

The necessity for a complete milling and baking test of representative Indian wheats was pointed out by Forbes Watson, and accordingly this was done by Messrs. MacDougal Brothers[4] in 1882. The four samples sent for milling were as follows :—

(1) Soft white from Meerut and Muzaffarnagar, 365 maunds.

[1] Forbes Watson. *Report on Indian Wheat* (C-2348), Eyre and Spottiswoode, London, 1879. Reprinted in *The Wheat Production and Trade of India*, Selections from the Records of the Government of India, Home, Revenue and Agr. Dept., No. CLX, Simla, 1879.

[2] The publication of the reports of Forbes Watson and Messrs. MacDougal Bros. and the view expressed by the former that the Punjab was probably destined to become the chief wheat exporting province of Hindustán, led to the subject of wheat growing being taken up by the Punjab Government. The result of this action is to be found in a pamphlet entitled *Punjab wheat, its varieties, distribution and husbandry* (*being a collection of statistics and correspondence printed by the order of the Punjab Government*). This was printed at Lahore in 1884.

[3] Letter dated 29th October 1880, from Alexander Smith, Esq., to Dr. Royle, of the India Office.—*Wheat Production and Trade of India*, Calcutta, 1883.

[4] Reports on Indian wheats by MacDougal Bros.—*Wheat Production and Trade of India*, Calcutta 1883.

(2) Soft red from Meerut, 363 maunds.
(3) Hard red from Banda in Bundelkhand, 356 maunds.
(4) Hard white from Khandesh.

It is interesting to note in the report to the India Office on the valuations of these wheats in London that it is mentioned that "many of these wheats are much superior to the bulk ordinarily received from India in cleanness, quality, and size of berry, and this is particularly the case with the long-berried hard wheats."

The four above-mentioned samples were milled by Messrs. MacDougal, both by the ordinary process of grinding under mill stones and by the Hungarian or roller system and compared with English, American, Australian, Russian and Egyptian sorts, both in the mill and subsequently in the bakehouse. It is clear from the reports that the Indian hard red and hard white were macaroni wheats, as they are described as "long and arched." The soft red and soft white were common wheats. In the report Messrs. MacDougal state that "there is no probability of the Indian wheats coming into demand for manufacture into flour without a liberal admixture of other wheats. They all possess in a marked degree the same characteristics of great dryness and a distinct beany and almost aromatic flavour inseparable from wheats grown in the climate and soils of the tropics. Also the flours are ricey, the texture of the breads is too close and the crust is hard and brittle." On the other hand, their great soundness and dryness, and the fact that they gave unprecedented yields of flour ranging from 77·46 to 80·52 per cent. as against English 65·2 and American spring 72·2 were great points in their favour.

It is necessary to draw attention to several points in Forbes Watson's report and in the milling tests made by Messrs. MacDougal. This work was carried out at a time of transition in the development of the milling industry of the United Kingdom and in the requirements of the modern baking trade. At the time Forbes Watson wrote his report, most of the wheat was ground under mill stones for which hard wheats were not in favour, partly on account of the wear of the stones caused by the hard grains. The advantages of the modern roller mills were then not fully appreciated and with the subsequent changes in milling, due to the almost exclusive use of roller mills, it has been found possible to deal easily with the hard flinty wheats of Russia and North America. This in turn led to a rise in the standard of flour strength required by modern bakers. Hence it is not too much to say that the present aspect of the milling and baking industries have been revolutionised both as regards method and

material. Further, since these reports were made, colour is of little consequence, red wheats being almost as valuable as white wheats, and free-milling wheats are preferred to soft sorts. These considerations are of the utmost importance as in all the papers on Indian wheats; since Messrs. MacDougal's report was written, the importance of soft white wheats has been constantly emphasised. We venture to doubt the soundness of this view and would lay stress on the fact that Messrs. MacDougal's report was founded on the examination of only four samples, two of which were macaroni wheats and were not usually used for making bread. In a previous paper on the wheats of the Punjab we have shown that the soft white and red forms, similar to those sent to Messrs. MacDougal Brothers are much inferior to other kinds in the country, and we do not consider it at all unlikely that valuable strong wheats are already in cultivation in India, and that their merits are fully appreciated by the people. They, however, do not find their way to England mainly because the cultivation of soft weak types has been so much encouraged. An altogether erroneous idea seems to be common in England on the quality of Indian wheats. Thus Biffen and Humphries[1] state "The fact that India, Australia and California export wheats no stronger than our own makes it clear that abundance of sunshine does not necessarily result in the production of strong wheat." This is no doubt true of the soft wheats exported to England, but we do not think it is true of Indian wheats generally. That strong wheats are grown in India seems to have been first discovered by Farrer[2] in 1899, who, in a letter to the Revenue Secretary of the Government of India, dated August 9th of year, states:

"On account of the high strength of the flour they produce, I take the liberty of recommending to you for extensive propagation the first two varieties of the three mentioned above: for I regard them as the best of all the Indian varieties, which thus far have come under my notice. *Your Indian varieties appear to vary greatly in the quality of flour strength.*"

We have, both in the Eastern Punjab and in other parts of India, been told repeatedly that the cultivators prefer hard wheats and especially hard red sorts as these are the most nutritious. Further, there seems to be a general idea among the cultivators that soft white wheats are much more delicate than the hard sorts, and require greater care in cultivation and often yield less and also need more water. The export ideal seems to be

[1] Humphries and Biffen, l. c.
[2] *Proceedings of the Government of India, Revenue and Agricultural Department*, No. 1/4, October 1899. These strong wheats came from Etawah and Muzaffarnagar in the United Provinces. The Muzaffarnagar form was a beardless wheat.

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quite a wrong one from all points of view, and we consider it might be easier for many of the wheat tracts to grow hard whites and hard reds than the weak soft kinds. The needs of the local and English market seem to be identical and both require free-milling wheats.

When the agricultural types of wheat grown in the various Provinces have been isolated, grown in pure line culture and thoroughly tested from all points of view, we consider that the best and strongest of these types should be grown in the present exporting tracts side by side with the soft white wheats now sent to Europe. After a few years' careful and extensive trial, supplemented by the best expert milling opinion obtainable in England, it will be possible to see whether or not the ryots should be advised to alter their present practice. Without this direct experimental evidence, it would be inadvisable to attempt any change as it might happen that strong wheats may degenerate both in yield and strength in the soft wheat tracts.

That India can produce much better wheats than the weak soft white sorts like Muzaffarnagar white and the *Pissi* of the Narbadá Valley, whose sole merit appears to be the chalky white flour they produce, will be evident on reading the following report[1] of Mr. A. E. Humphries, Past President of the Incorporated National Association of British and Irish Millers, on the ten samples of wheat sent by us to England after the harvest of 1908.

"I duly received *viâ* Calcutta or Kurrachee the ten sample lots of various wheats grown in India, upon which the Agricultural Department of the Indian Government wished me to report and in accordance with the arrangement arrived at with you I have cleaned, conditioned, milled and baked each lot separately and have done each operation in duplicate.

I have regarded the whole matter from the standpoint of a British miller and am accustomed to buy Indian wheats on a commercial basis for the manufacture of flour to be used in England. The methods of milling and baking followed are those which I have used in making a great number of similar tests for the Home Grown Wheat Committee of the National Association of British and Irish Millers.

The ten samples were designated as follows[2]:—

Red wheats.
1. Gujar Khán.
2. Punjab Type 9.
3. Punjab Type 14.

[1] Howard and Howard, *Bull.* 14, *Agr. Research Institute, Púsa*, 1908.

[2] Numbers 2, 3, 4, 6, 8, and 10 were grown by us in pure culture at Púsa and at Lyallpur. Numbers 1, 5, 7, and 9 were obtained from cultivators' fields at Gujar Khán, Lyallpur and Muzaffarnagar, and ears not true to type were sorted out before threshing.

White wheats.
4. Púsa 6 grown at Púsa.
5. Lal Kasar Wala.
6. Muzaffarnagar grown at Lyallpur.
7. ,, ,, ,, Muzaffarnagar.
8. ,, ,, ,, Púsa.
9. Australian 27 Lyallpur.
10. Punjab Type 16.

I do not think that the colour of the husk need be or is likely to be of great importance. British Millers are guided in their preferences principally by the quality and quantity of flour which Indian wheats would yield, but if, on the other points, a red wheat and a white wheat were equal, the preference would be given to the white wheat.

Each of the ten samples was noteworthily free from dirt and extraneous matter. The arrangements arrived at by the joint action of shippers, the leading British Corn Trade Association and the Association of British and Irish Millers have brought about a great improvement on this point in the recent shipments of Indian wheat, and if it be possible to ship wheat as "clean" as the ten samples I have received, the relative value of Indian wheats would be still further enhanced.

As part of the process of cleaning wheat by washing, and to prevent, as far as possible, the pulverizing of the husk in grinding and so secure a better separation of husk from kernel, it is the custom of British Millers to "condition" their wheats.

The most important point in the conditioning is the adjustment of the moistures immediately prior to grinding, so that wheats with high moistures would be dried and wheats with low natural moistures would be damped. Of course, this means that practically all Indian wheats would be damped and that the driest would be worth more to the miller than those with higher moistures. Incidentally I should like to mention the belief entertained here that some parcels of Indian wheat are artificially damped before shipment. Any such action is unwise from the Indian point of view. It is risky as regards the effect on quality, it seems silly to pay railway and ocean freight on water and any gain so obtained on the first few transactions would be much more than lost in the long run because all British Millers of good standing know quite well the moistures of the wheats they receive; that point enters into their calculations to the detriment of sellers on the highest percentage of water the wheats they buy will contain.

The ten samples were all in the best of condition on arrival.

When water is added in the process of cleaning and conditioning, it affects the kernel as well as the husk, and all varieties of wheat are not affected alike.

Some remain "free grinding," that is to say, the kernel, when pulverized, makes lively granular flour which can be separated from the husk with a minimum of trouble to the miller; others become "woolly" in texture, the flour is less granular and the separations in the mill are made with difficulty.

The ten samples show a striking difference in this respect. For free grinding Púsa 6 is very good indeed, Australian 27 poor. The Muzaffarnagars are also poor in this respect, and of the three the one grown at Lyallpur is the worst. The five sorts not specifically mentioned in this connection are good as regards this characteristic.

There are very great differences in the hue of the flours from the ten samples. The three Muzaffarnagars all yield flour very white in hue. Of the three, that grown at Muzaffarnagar is the whitest, that grown in Púsa is substantially the same, whilst the Lyallpur lot of this variety has a comparatively dingy hue. I think this is associated with the "woolliness" I have mentioned, because to get a commercially complete separation of husk from kernel, more force in grinding has to be used and more of the husk accordingly gets pulverised in the grinding. The Australian 27 yields also a white flour. Punjab Type 9 yields a bright but very yellow flour. Gujar Khán, one that is yellow in slightly lesser degree. Púsa 6 is as regards colour in a class by itself, for its very lively granular flour is neither white, of chalky hue nor yellow, but a greyish white which I associate with Canadian Fife wheat. Of the other three sorts not specifically mentioned in this paragraph. Punjab Type 16 yields flour of very good appearance as regards hue medium between the chalky white of the Muzaffarnagar and the yellows of the Punjab Type 9 and Gujar Khán. A large number of British millers use artificial bleaching. In their hands the two last named would give good results as to colour. In some parts of England and in Ireland flour of chalky white hue is required, and for those purposes, the sorts yielding such flour might be preferred, but my own preference as to colour would be Púsa 6 or Lal Kasar Wala, and this, I think, would be the verdict of most English millers.

There are great differences between the ten as regards strength by which I mean the capacity for making large shapely loaves. On this point Púsa 6 is pre-eminent. The loaves are not only larger, but whereas those from all other flours have the appearance typical of Indian varieties, those from Púsa 6 have a quite different and a superior crust and general appearance. Gujar Khán, Punjab Type 9 and Lal Kasar Wala are not behind so far as size of loaf is concerned. Of the three Muzaffarnagars the Púsa lot is distinctly the best, the Muzaffarnagar distinctly the worst, the Lyallpur lot occupies the middle position. The Punjab Types 14 and 16 and Australian 27 are only poor on this point.

As regards the stability of dough in baking, all are good. Púsa 6 is the nearest approach to the toughness which is associated with Canadian or American Spring wheats, but that is not to be compared with those sorts, nor should I expect to find any wheats behaving in that way unless with great summer heat a high summer rainfall be associated.

In summarizing the foregoing, I unhesitatingly express the opinion that Púsa 6 is the best, and I can quite as unhesitatingly say, I do not like Australian 27 or Muzaffarnagar grown at Muzaffarnagar. There is a growing inclination amongst grain merchants to mix their wheats so as to reduce the number of grades in which they deal.

No particular harm would be done if they mixed as follows:—

A. Muzaffarnagar grown at Muzaffarnagar.
" " " Lyallpur.
" " " Púsa.
Australian 27.

B. Lal Kasar Wala.
Punjab Type 16.

C. Punjab Type 9.
Gujar Khán.

Punjab Type 14 might be grouped with C, but would be better handled separately. Púsa 6 might be grouped with B, but would make most money if sold by itself, on its own sample, or reputation. Group A should not be mixed with either B or C nor should any individual of the group A be mixed with group B or C. If group B were mixed with group C, no particular harm would be done, but they are better apart.

Different millers may have different opinions about the same wheat, and, as indicated herein, some sorts may have special values in different localities, but as a miller trading in the London district, I should put the ten in the following order having regard to all the points mentioned:—

	% Nitrogen. (Leather)[1]
1. Púsa 6	2·52
2. Lal Kasar Wala	—
3. Punjab Type 9	2·01
4. Gujar Khán	1·76

[1] The nitrogen determinations for which we desire to thank Dr. J. W. Leather, Imperial Agricultural Chemist, are given here for the sake of convenience, It will be seen that the order of nitrogen percentage and of milling and baking value closely correspond. Nos. 2 and 10 were not analysed.

5.	Muzaffarnagar grown at Púsa	1·86
6.	Punjab Type 16	1·39
7.	,, ,, 14	1·37
8.	Muzaffarnagar grown at Lyallpur ..	1·45
9.	Muzaffarnagar grown at Muzaffarnagar ..	1·34
10.	Australian 27	—

I find great difficulty in answering your question as to the relative money values of these ten Indian wheats and Canadian and American grades. Canada and the U. S. A. grow some poor weak wheats, and I would certainly pay as high or even a higher price for any of the ten as I would for Canadian winters, or for the wheats grown on the Pacific slope of the U. S. A. or for most of the U. S. A. winter wheats shipped as they are with all their uncertainties as to grading, but these Indians are quite different to Canadian or U. S. A. spring wheats, and are not comparable with them. So long as the world grows so much more weak wheat than strong wheat, and so long as millers are compelled to supply flours of good or great strength, wheats capable of yielding flour from which tough, stable doughs and big loaves can be made will command a large premium.

Some authorities measure strength by the number of loaves a given quantity of flour will produce, but a reliable opinion cannot be formed on this point on small lots such as you sent me. It is, however, quite safe to say that the better of your ten would rank high on this point. The relative value of Indian wheats has already gone up a great deal as a result of improved cleaning and greater reliability in quality, and if wheats as good in intrinsic quality, as well grown, as clean and as dry as the first 6 on my last list are shipped here from India, the growers can rely on a still further increase in their relative value in competition with the wheats of the world.''

The publication of these views naturally did not pass without comment. This is not surprising considering that our recommendations, if proved to be well founded, will revolutionise the wheat industry of this country and lead to the rapid advance of India in competition with the wheat-producing countries of the world.

The recommendations contained in the paper[1] referred to were submitted by the Director of Agriculture of the Punjab to the President of the Incorporated National Association of British and Irish Millers and the matter was considered at a meeting of the Council of the Association held in Mark

[1] Howard and Howard, *Bull.* 14, *Agr. Research Institute, Púsa*, 1908.

Lane on April 23rd last. The result of the deliberations which took place were published in the *Miller* of May 3rd, 1909, and are reproduced below :—

" On Friday, April 23rd, a meeting of the Council of the Incorporated National Association of British and Irish Millers was held at the offices of the Association, 59, Mark Lane, when Mr. William Edgar Nicholls presided.

Indian Wheat.

The next item on the agenda was :—To consider correspondence received *re* Indian wheats.

Mr. A. E. Humphries, in placing this matter before the meeting, said considerable importance was attached to this matter by the Indian Government, and he had had a large amount of correspondence with Indian Government officials relating to it. He had conducted the correspondence to the best of his ability, but he had pointed out to the officials of the Indian Government that the expressions of opinion he had made were his own, and that they did not bind the Association in any way. He should like to know whether the members of the Council criticised or confirmed it. The Indian Government had been seeking to make the Indian growers grow wheat suitable for the export trade, instead of growing wheats which were more suitable for local requirements. Continuing, Mr. Humphries said :—

The position disclosed by the correspondence forwarded to the President and a considerable correspondence which I have had with Government officials in India amounts to this :—

The wheats which the natives were inclined to grow about 30 years ago were harder by nature than those which millers in millstone days or in the transitional period from millstones to rolls really wanted.

Following upon the very valuable reports which Messrs. MacDougall Brothers then presented, the authorities met with a great amount of success in getting the natives to grow softer whiter wheats, so as to suit what was then undoubtedly the requirements of the English market. Since then we as millers have entirely discarded millstones, and learnt the advantages of wheat conditioning.

I first of all had a large number of samples sent to me for my opinion, to be ascertained on appearance only. Later I had 10 samples sent to me for milling and baking. All these samples were known by botanical names, and not by commercial ones, but those known as Muzaffarnagar and " Australian 27 " represented approximately the softer weaker whites such as white Delhi.

In arriving at my opinion, I conditioned these wheats carefully to a full commercial extent, and in my opinion any wheats which then became soft in the sense of woolly were not nearly so good as those which remain free milling after full conditioning. Under such conditions these soft white wheats did mill badly. They required greater force to effect separations, and though they gave a white-hued flour, some of them, probably because of the extra force required in grinding, were dingy.

One wheat in particular I singled out as particularly good. It was a white wheat, not unlike white Fife in appearance, very bright, conditioned very well indeed, ground very freely and very well, gave an altogether better lively flour, bright-hued rather than white and the bread had an altogether better appearance than that from ordinary Indian wheat. I understand that this wheat was raised from a single head, which was found growing among others, that it is rust-resistant, a good yielder, and one which weevils do not attack freely. Without telling me so, the Indian Government had submitted the same wheats to a chemist in India, and he, replying principally upon the percentage of total nitrogen, placed substantially the same series into, for all practical purposes, the same order of merit as I had done by milling and baking. This means that whereas the soft white wheats contained only 1·3 per cent. to 1·4 per cent. total nitrogen, the white wheat upon which I reported very favourably contained 2·52, or nearly twice as much a percentage that would compare very favourably with some of the so-called strong wheats of the world. This was, of course very satisfactory to me, for it provided quite indirectly a striking confirmation of the correctness of my work, for after all said and done and in spite of exceptions, total nitrogen is a very useful indication of a flour's strength.

I recently received letters from Government officials, which I do not suppose were meant to be confidential, in which they wanted to know whether it was desirable to send forward bulks of, say, 40 to 100 sacks and get them priced here on the market, the idea being that such evidence would indicate to the grower the superiority of these new sorts, and be an inducement to grow them. My reply in essence was this, I do not think that the true value of new wheats can be ascertained in that way. Any person buying a novelty would regard it with a certain amount of suspicion, and human nature being what it is, would seek to buy at the lowest price possible. But that, having regard to the fact that it was a distinct advantage to the grower on the ground of financial yield, apart altogether from the relative commercial values of the wheats on our markets to grow these new varieties, the proper course was to put it to the agricultural

public of India in that light, adding that opinions which had been obtained indicated that the wheat was likely to obtain higher prices. There is, at any rate, one miller in the kingdom who would willingly absorb several hundred tons, which is more than they are likely to send for some years of "Púsa 6," at prices substantially higher than any Indian wheat he knows at present, and it seemed to me altogether more desirable to distribute such good stuff as seed and get a large bulk to deal with, rather than send it over here to be submitted to an altogether second rate method of testing commercial value.

The Director of Agriculture in the Punjab has written to the Secretary of the Kurrachee Chamber of Commerce drawing his attention to a bulletin, which consists largely of my report, and sent a copy of that letter to the President. I think, instead of reading a rather long document, it may be desirable if I summarised the statements I made, and I do not think that any member of this Council would have any difficulty in agreeing with them.

I have been careful to point out that in some sections of the country a soft white flour is even now preferred, that we English millers realise that a white wheat may be as strong or stronger than a red wheat. That if on other points wheats are the same, preference would be given to a white wheat. That, in any case, we prefer a wheat which after conditioning in the modern sense of the term remains free grinding and does not become "woolly." That on an average of years weak wheat is in more plentiful supply than strong wheat, and that as a consequence strong wheats are usually more valuable than weak ones. That if Indian exporters want to secure maximum value for their wheats, they must not mix common ones with fine ones, also that they must not water their wheats before shipment.

To my mind the most important point of all the foregoing is that the wheats which best suit me, and which I think would suit the majority of British millers, do in point of fact best suit the Indian grower. My belief as regards India as well as England is that the grower should produce what best suits his interests, and that we millers, nowadays, are so much better equipped technically than we used to be 30 years ago that we can tackle any ordinary wheat of commerce at some price or another. If, therefore, the immediate interests of the grower, more particularly as to the yield per acre be considered, we millers will be content, and the grower can rely on getting a fair market value for whatever wheats he produces. If he produces wheats which do not realise quite so much on our markets, it might pay him on account of extra yield to produce them, but nothing

In arriving at my opinion, I conditioned these wheats carefully to a full commercial extent, and in my opinion any wheats which then became soft in the sense of woolly were not nearly so good as those which remain free milling after full conditioning. Under such conditions these soft white wheats did mill badly. They required greater force to effect separations, and though they gave a white-hued flour, some of them, probably because of the extra force required in grinding, were dingy.

One wheat in particular I singled out as particularly good. It was a white wheat, not unlike white Fife in appearance, very bright, conditioned very well indeed, ground very freely and very well, gave an altogether better lively flour, bright-hued rather than white and the bread had an altogether better appearance than that from ordinary Indian wheat. I understand that this wheat was raised from a single head, which was found growing among others, that it is rust-resistant, a good yielder, and one which weevils do not attack freely. Without telling me so, the Indian Government had submitted the same wheats to a chemist in India, and he, replying principally upon the percentage of total nitrogen, placed substantially the same series into, for all practical purposes, the same order of merit as I had done by milling and baking. This means that whereas the soft white wheats contained only 1'3 per cent. to 1'4 per cent. total nitrogen, the white wheat upon which I reported very favourably contained 2'52, or nearly twice as much a percentage that would compare very favourably with some of the so-called strong wheats of the world. This was, of course very satisfactory to me, for it provided quite indirectly a striking confirmation of the correctness of my work, for after all said and done and in spite of exceptions, total nitrogen is a very useful indication of a flour's strength.

I recently received letters from Government officials, which I do not suppose were meant to be confidential, in which they wanted to know whether it was desirable to send forward bulks of, say, 40 to 100 sacks and get them priced here on the market, the idea being that such evidence would indicate to the grower the superiority of these new sorts, and be an inducement to grow them. My reply in essence was this, I do not think that the true value of new wheats can be ascertained in that way. Any person buying a novelty would regard it with a certain amount of suspicion, and human nature being what it is, would seek to buy at the lowest price possible. But that, having regard to the fact that it was a distinct advantage to the grower on the ground of financial yield, apart altogether from the relative commercial values of the wheats on our markets to grow these new varieties, the proper course was to put it to the agricultural

public of India in that light, adding that opinions which had been obtained indicated that the wheat was likely to obtain higher prices. There is, at any rate, one miller in the kingdom who would willingly absorb several hundred tons, which is more than they are likely to send for some years of "Pûsa 6," at prices substantially higher than any Indian wheat he knows at present, and it seemed to me altogether more desirable to distribute such good stuff as seed and get a large bulk to deal with, rather than send it over here to be submitted to an altogether second rate method of testing commercial value.

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could be better both from the English miller's point of view and the Indian grower's than that they should produce and sell separately such fine wheats as the Government officials now seem to have in hand, inasmuch as they are likely to suit British millers and the grower as well.

Dealing with one point arising out of the letter the President has received, I do not know, and would not like to predicate with certainty, what would happen if they grew these fine wheats on irrigated land. That is a matter for investigation, and I might add that a further batch of Indian wheats are now being forwarded from the Government Experimental Stations in India for further milling and baking tests.

I have, throughout this correspondence, been careful to say that I was expressing my own opinions, and not in any degree seeking to bind any body but myself. However much any person in this room may disagree with anything I have said, I am sure we are absolutely unanimous in wishing to see a great increase in the production and export of Indian wheat. Our interest is in that direction, and not in the other, as has recently been suggested in high quarters, and that we are willing to do anything we can to facilitate the production of wheat in India and in the British Empire.

The President said a letter had been addressed to the Association by the Director of Agriculture, in which he said he enclosed a copy of the bulletin, and he would be grateful if the Association would carefully consider the matter. He thought the best plan would be to send a letter on the lines of what Mr. Humphries had just reported. The important thing was that Mr. Humphries had had a good deal to do with this matter, and he was more competent to speak for the Association than any other member, and this report, if adopted, would fully cover the whole ground. He would really suggest that the official reply of the Association should take that form, subject to what any member might happen to have to say in criticising the matter.

Mr. Joseph Rank seconded the proposal.

Mr. Voller said the broad lines recommended by Mr. Humphries were eminently desirable for increasing the export of Indian wheats to this country. The type of wheat sent was a very good one, and he would suggest that further samples, when they arrive, should be sent to members of the Council. Mr. Humphries' report covered broadly what was required from that Association, and he thought the Association might emphasise the point he had made, especially having regard to quality and quantity.

The President thought that if this communication went out over the signature of the President of the Association, itwould cover all the points raised.

The resolution was then formally put to the meeting, and carried unanimously, that the reply of the Association take the form of Mr. Humphries' report.''

It will be seen that the recommendation based on Mr. Humphries' first report were unanimously endorsed by the Council of the National Association of British and Irish Millers and that as far as the Home market is concerned there will be no difficulty in disposing to advantage of any Indian wheats of good strength and high milling qualities.

Out of the large number of hard wheats high in nitrogen isolated by us at Púsa and now in various stages of multiplication from single plants, only one, namely, Púsa 6, was sent for a milling test in 1908.

During the last season, 1908-09, a number of others passed successfully through the preliminary field and laboratory tests, and representative types (Nos. 20 to 29) of these wheats were this year (1909) submitted to Mr. Humphries for complete milling and baking tests. Some of the most promising Púsa selections were not included, however, as the seed at our disposal was insufficient for a full test. These we hope to send to England in 1910. The new Púsa wheats tested in 1909 are for the most part rapidly maturing types with good straw and other agricultural characters combined with grain uniform in texture and high in nitrogen. The Púsa selected wheats Nos. 20 to 29, with four other samples, were as follows:—

No.	Name.	Where grown.	% Nitrogen.
6	Indian Fife	Cawnpore	1·54
7	Beardless Muzaffarnagar	,,	1·74
17	Bombay Pissí	Kareli	1·67
18	Jubbulpore Pissí	Jubbulpore	1·99
20	Selected Gangajali	Púsa	2·52
21	Selected Hara	,,	2·55
22	White selected Janakhar	,,	2·33
23	Red selected ,,	,,	2·58
24	Púsa 6 a	,,	2·51
25	Púsa 7	,,	2·39
26	Púsa 8	,,	2·39
27	Púsa 10	,,	2·10
28	Púsa 11	,,	2·08
29	Púsa 12	,	1·98

For the nitrogen determinations we are indebted to Mr. H. E. Annett, Officiating Imperial Agricultural Chemist. It will be seen that the Púsa selections are generally much higher in this constituent than the two *Pissís* and the two Cawnpore samples. The samples of Bombay *Pissí* and Jubbulpore *Pissí* were obtained from Messrs. Ralli Brothers and were representative trade samples of the soft white wheats grown for export on the black cotton soils of Peninsular India, and they were included for comparison with the Púsa wheats. Indian Fife and beardless Muzaffarnagar were grown on the Cawnpore farm and were included at the special request of Mr. B. C. Burt, Deputy Director of Agriculture in the United Provinces. Indian Fife is said to be derived from a cross made by the late Mr. Farrer of New South Wales between Canadian Red Fife and an Indian wheat. Beardless Muzaffarnagar is said to have been obtained from the Muzaffarnagar District. All the Púsa grown wheats are selections and have been grown from plants found in the exceedingly mixed crops which resulted from the sowings of a large collection of Indian wheats made at Púsa in 1905.

Mr. Humphries' report on these wheats is given below.

REPORT BY MR. A. E. HUMPHRIES, PAST PRESIDENT OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS ON THE SAMPLES OF INDIAN WHEATS SENT FROM PUSA BY THE IMPERIAL ECONOMIC BOTANIST IN MAY 1909.

I duly received the 28[1] sample lots of wheat numbered 1 to 29 inclusive, number 19 omitted, grown in India during the cereal year 1908-09. They arrived without mishap in good condition, particularly free from dirt and extraneous matter, and as the wheats with two or three exceptions were well developed, Nature and the growers by their combined efforts had succeeded in producing very fine specimens of Indian wheat.

I ascertained the natural moisture of each of these sample lots on arrival, cleaned and "conditioned" part of each one according to its individual requirements, milled that part separately, noting how it behaved in grinding and separating, and then baked separately the flour obtained from it. If the baker would in commercial practice make elaborate tests

[1] Fourteen of these samples are concerned with an investigation (in collaboration with Mr. H. M. Leake, Economic Botanist to the Government of the United Provinces), on the factors which influence the quality of Indian wheat. The report on these samples will be published shortly.

of each lot of flour he receives, and finally give it the treatment in fermentation and handling by which it would yield optimum results, many of the wide differences of opinion concerning wheats and wheaten flours would disappear or be most materially minimised, but that is a counsel of perfection and the baker requires in commerce flours which show a minimum of deviation from recognised standards and necessitate little or no adjustment of his usual methods.

With these ideas in my mind, I subjected each of the flours obtained from the first milling of these sample lots of wheat to the same bakehouse treatment, and noted the results. The necessity for variations in treatment, if optimum results were to be obtained, was most clearly shown. Further variations in treatment were also necessary in conditioning and milling. I have recently, in a paper read at the Winnipeg meeting of the British Association, pointed out that the skilful use of water at the right stages, brought about important changes in the quality of flour, that there could be no fixed standard of moisture content applicable to all flours, and that to secure optimum results some wheats or flours should have a low moisture content, some a high one. I applied these ideas in milling and baking the 28 sample lots a second time, some of them a third time.

In different countries, or even in different parts of the same country, opinions as to what constitutes ideal quality differ very widely. For instance, in London practically all bread is made by professional bakers, in Yorkshire by housewives; in some parts loaves are baked in tins whereby the dough is not required to maintain its shape unaided, as it would be if tins were not used. Again, for some purposes flours are not subjected to yeast fermentation at all, whereas for others they have to withstand a very long fermentation.

There are similar divergencies as to what constitutes good colour in flour. Some like flour to be white of chalky hue, some prefer it to be white of creamy hue. All this means, that wide differences of opinion can properly be entertained by various authorities as to some points of quality. But there are points on which all millers are agreed. They want all samples of wheat to be uniform in texture. That is absolutely necessary if optimum results in milling are to be obtained, and the most recent developments in milling are making this more important than ever. I know that these irregularities in texture may be due to the effects of soil, season, and water supply, but in so far as they are due to varietal causes they should be avoided, and I am very pleased to see how very regular in texture some of the 28 sample lots sent me are. Millers are also unanimous, or practically unanimous, in preferring wheats which "mill freely;" in other words,

those wheats which can be ground easily and which can be divided out into their ultimate commercial constituents of flour and offal (husk) with the greatest ease. In this connection I should like to point out an error frequently made, when it is said without qualification that millers want hard wheats. Some wheats are said to be hard when, in fact, they are merely dry. If water be added to them they become soft, perhaps "woolly." Other wheats are really hard even when their moistures are relatively high. Millers do not like wheats which are soft and woolly when their moistures are adjusted. Such wheats would require 20 to 50 per cent. more grinding to effect a proper separation of husk from kernel in the early stages of milling, and in the later it is difficult to effect separations at all easily. At the other extreme are the Durums, which are really hard by nature and remain hard even if their moistures be raised very considerably. Within the last few years millers have learned how to minimise their objections to these wheats, but the objections remain, though in diminished degree. , We do not want wheats to be as hard as Durums, and in particular we do not like any sort to be horny as well as hard. It is difficult to specify a word which exactly fits the case. On the one hand, we certainly do not want soft woolly wheats ; on the other, we do not want really hard or horny wheats. What we do like are those which, when conditioned, are mellow and free grinding. We want an adjective which expresses the commercially important point better than "hard" and for lack of better I suggest "free-milling." This is meant to express a characteristic highly esteemed by all millers, which enters into their calculations in estimating relative commercial value.

I want now to amplify a statement of opinion indicated in a former Report, and endorsed unanimously by the Council of the National Association of British and Irish Millers. I entertain the view very strongly, that the grower in any country or district should produce those varieties of wheat which yield him the best possible financial return. In that way, the public interest also is in my view best served. Within the last 20 years, the technical equipment of the best mills has been very greatly improved. Millers can now make better use of a wheat's potentialities and overcome the objections which their predecessors had to certain varieties. To a very great extent, some wheats have realised relatively low commercial values, not so much because they were bad according to some definite standard of real excellence, but because they did not conform to some preconceived ideas on the part of millers, bakers or the public as to their behaviour or appearance. Many people still think that it is wrong to adopt any new process of making food, merely because it is new, especially if it

be introduced or worked by chemists, but fortunately this unintelligent prejudice is entertained by a minority. Millers are, therefore, able to make vital changes in their recommendations to Indian wheat growers. Messrs. MacDougall Bros., whose ability to form correct opinions no one will question, in reporting to the Indian Government 30 years or so ago, pointed out that the varieties of wheat which Indian growers favoured, were unsuitable for export; and they recommended the encouragement of certain other types of wheat. Fortunately for the growers and the world generally, this advice can now be superseded. The attitude of British millers towards Indian and other wheats is, that they are willing to pay relatively high prices for the best varieties, but they will buy at fair but lower prices wheats of inferior quality. They believe, however, that a combination of fine quality and high yield per acre is no longer an impossibility, if it ever were so, but they are content to leave to the growers and their competent botanical advisers, the decision as to what varieties shall be produced. Applying these ideas to important details, British millers are now able to obtain flour of first rate colour from red skinned wheats. They would give a preference to white wheats if in all respects they were equal to red, but the difference in commercial value due to the whiteness of husk is nowadays very small. On the other hand, millers know quite well that "strength" as applied to baking values is not caused by or correlated with redness of skin, so on this point of appearance growers can now please themselves. Much more important points concern hardness and softness of endosperm, and toughness or friability of skin. The miller for generations has sought to exclude as much husk as possible from his flour. Thirty years ago, millstones were in common use, and as they applied a great amount of friction in an intense form, the miller wanted, and for the highest commercial purposes would have mellow wheats with tough skins. Hence Messrs. MacDougall's recommendations. But now that the change in the nature of wheats available has imposed on millers the adoption of modern gradual reduction by rollers, with its concomitant diminution in the amount and intensity of friction applied in grinding, mellow wheats with tough skins are no longer a necessity. If, therefore, the grower can get better results by producing harder and as they used to be called commoner wheats, he will satisfy the miller in doing so. Indeed, most millers, now that they are properly equipped with modern machinery, prefer the wheats which I have called "free-milling" to softer ones.

Another point of change concerns colour. Some wheats of the *Triticum vulgare* type and all the Durums yield flour which is intensely yellow in hue. I am not aware that extreme yellowness implies either goodness or bad

ness in dietetic value. As a rule, the Durums seem to contain more natural sugar and produce more by diastatic action during baking processes than "ordinary" wheats. They certainly yield bread of relatively pleasant flavour and at least several varieties of that type contain relatively high percentages of nitrogenous matter. Yet apart from the troubles in milling them, the popular taste and demand, which in the last resort determines commercial values as regards some important qualities, hold their extreme yellowness of hue in low esteem. But now that artificial bleaching has been successfully applied, and so long as our authorities continue to regard that process as permissible in the public interest, the British miller, knowing that in certain districts Durums withstand drought and rust better than "ordinary" wheats, will acquiesce in their production and will buy them at their fair commercial value. He knows, however, that the application of Mendelism to wheat may render it possible to get the desirable characteristics of Durum combined with other desirable characteristics of some "ordinary" wheat, and he lives in the hope and expectation that great improvements in both yield and quality will result from the most recent applications of botanical science.

It should be borne in mind also, that India is not at all likely in the near future to supply the entire wants of the United Kingdom, so that British millers can by blending Indian wheats with other sorts, take almost anything that comes, whatever it may be as regards quality.

The cumulative effect of all the foregoing considerations is to emphasise the point that the interests of the Indian producer should be paramount, but it is true also that some Indian wheats are much better and will command higher prices than others.

After the detailed and elaborate tests I have made of the 28 samples submitted to me, I entertain no doubt as to the great superiority of some of them and shall be extremely pleased to find that one or more of the varieties which I esteem the best, are also those which best suit the average Indian producer.

For the sake of lucidity, and as an aid to myself in arriving at my conclusions, I have divided the 28 lots into groups.

Pissis.

No. 17 is described as Bombay *Pissí*, No. 18 as Jubbulpore *Pissí*. These might properly have been grouped with the Muzaffarnagars, inasmuch as they are very mellow and yield a soft white flour. The Bombay *Pissí* sample contains a few red grains. The Jubbulpore might be described as

a mixture of white and red grains, and contained a few red ones which appeared to be Durum. However, both behaved in milling as soft woolly wheats.

The Bombay yielded flour of a chalky white hue, and the bread produced from it had an unattractive appearance both in crumb and crust. The Jubbulpore sample yielded a soft feeling flour not so chalky white as the Bombay, and the bread made from it had a better appearance in crumb and crust than the Bombay. This was probably due to the presence of the Durum grains which would act as a corrective to the chalky whiteness of the *Pissí* part of the sample. I entertain a poor opinion of these wheats for bread-making purposes if used by themselves, but they would be useful for blending if a miller wished to counteract the extreme yellowness of some varieties, and they would be suitable for making pudding or biscuit flour, so if the natives of any district wish to grow them, they need not be discouraged from doing so. I am quite sure, however, that in my opinion they are far from being the best of the 28 lots sent me. They behave poorly in milling, and I do not like the bread they yield, which is not only in my opinion poor in appearance, but poor or bad as regards flavour. For size and shape of loaf they are about equal to the better Muzaffarnagars.

The Pusa Nursery Group.

Numbers 24 to 29 inclusive of the set sent me are known under the laboratory numbers Púsa 6*a*, Púsa 7, Púsa 8, Púsa 10, Púsa 11, and Púsa 12. They are mellow wheats not unlike the Muzaffarnagars in general external appearance, but as a group they are superior to the *Pissís* and Muzaffarnagars. The size and shape of berry is attractive. Some of them remind me of the New Zealand Tuscan and the English Talavera wheats at their best, but of course these Indian wheats are much drier. All of this group behaved well in milling with the exception of No. 28 (Púsa 11). They yielded white flour with the exception of 29 (Púsa 12). No. 26 (Púsa 8) contained a fair proportion and No. 29, a large one of translucent grains. That means, that the flours from these lots were not so white as the others; indeed, the produce of 29 would have to be described as yellow and granular, but both were bright and attractive. For colour of bread No. 26 came out first of this group. No. 29 is too yellow without bleaching if used by itself. The bread from No. 28 had a particularly nice external appearance; No. 25 a much better flavour than ordinary Indian. The strength of this group is a great surprise to me. I should not have thought from the appearance of the wheats that they could be described as strong, and though they are not so strong as Manitoba or United States Spring wheat, they are

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Numbers 24 to 29 inclusive of the set sent me are known under the laboratory numbers Púsa 6*a*, Púsa 7, Púsa 8, Púsa 10, Púsa 11, and Púsa 12. They are mellow wheats not unlike the Muzaffarnagars in general external appearance, but as a group they are superior to the *Pissís* and Muzaffarnagars. The size and shape of berry is attractive. Some of them remind me of the New Zealand Tuscan and the English Talavera wheats at their best, but of course these Indian wheats are much drier. All of this group behaved well in milling with the exception of No. 28 (Púsa 11). They yielded white flour with the exception of 29 (Púsa 12). No. 26 (Púsa 8) contained a fair proportion and No. 29, a large one of translucent grains. That means, that the flours from these lots were not so white as the others; indeed, the produce of 29 would have to be described as yellow and granular, but both were bright and attractive. For colour of bread No. 26 came out first of this group. No. 29 is too yellow without bleaching if used by itself. The bread from No. 28 had a particularly nice external appearance; No. 25 a much better flavour than ordinary Indian. The strength of this group is a great surprise to me. I should not have thought from the appearance of the wheats that they could be described as strong, and though they are not so strong as Manitoba or United States Spring wheat, they are

very much stronger than any Indian wheats I had previously handled. By appearance I had placed No. 26 (Púsa 8) at the head of the group, and the baking results confirm that estimate. It does yield in a substantial degree that toughness of dough characteristic of American Spring wheat ; in other words, it is quite unlike and much superior to the Indian wheats we ordinarily get in commerce. No. 29 is only slightly behind 26, in this respect, and Nos. 27 & 28 are only a little behind 29. I can, however, unhesitatingly say that 26 is the best of the group. It represents a combination of good milling points, first rate behaviour as dough, and first class colour in bread.

Nos. 21, 22 & 23. These wheats labelled respectively "Selected Hara," "White selected Jana Khar" and "Red selected Jana Khar" are, in my opinion, very attractive. The Hara is a small round berried red wheat of a particularly deep red hue, very even in texture, and contains no soft or pale grains. The hue is peculiar and that point is not a good one. The Red Jana Khar may be called a sister wheat to the Hara. This also has a peculiar hue, almost that of dark mahogany. It is larger in berry than the Hara, and like it contains no pale or soft corns whatever. The white Jana Khar is of particularly nice appearance, mostly round berried, of Fife shape, distinctly hard as received, very translucent, without any pale or soft corns in the sample. These three wheats behaved particularly well in conditioning and milling, and that weighs greatly in my opinion. Of the three, the White Jana Khar is the best on that point. Although they are hard, the flours they yield are not yellow, and the bread has the hue which one associates with Manitoba wheat, a greyish but bright white. In these three cases the toughness of dough characteristic of American Spring wheat again occurs ; and is in my view most noteworthy. The breads are very attractive in appearance, with first rate pile and beautiful crusts. The loaves are not so big as those which British bakers obtain from Manitoba or American Spring wheat flours, but they yield that type of bread, and if some Malt Extract were added in milling or baking to break down still more the effects of great hardness, I believe that truly superb bread would be obtained from them. With only small quantities of wheat available I could not experiment more than I have done with these wheats, and in all these trials I have used flour, yeast, salt and water only, but if I had more wheat of these three sorts, I would have carried on still further modifications in conditioning, milling and baking, in the belief that they, fine though they now are, would have responded satisfactorily to further treatment. Millers or merchants buying wheats on appearance would prefer the White Jana Khar. It also mills better than the other

two, but the Red Jana Khar behaves best in the bakehouse. On balance, however, and having regard to the results which would probably ensue from further adjustments of milling and bakehouse treatment, I should say that the White Jana Khar is the best of the three.

No. 20 (Selected Gangajali) appears to be Durum, the only one in the entire set of samples. It is very good of its kind, and because it is not horny in texture, mills better than many Durums do. The flour is a good colour of its class, the bread made from it was of very fair colour and of distinctly pleasant flavour. This means that if for economic or botanical reasons it be desirable to grow Durums, this variety is one to be recommended.

Remainder.

I have now dealt with all but Indian Fife (No. 6), Beardless Muzaffarnagar grown at Cawnpore (No. 7). The 'Indian Fife' is fine looking white wheat. I understand it is neither the red nor the white Canadian Fife, but quite a different wheat obtained by Farrer in Australia as a result of crossing Fife and an Indian variety. The sample lot sent me is very irregular in texture, so it cannot be handled to the greatest advantage in milling and baking. Several of the other wheats sent me yield better flour and bread than this one.

The Beardless Muzaffarnagar is altogether stronger in appearance than the ordinary Muzaffarnagars sent me. It contains a large proportion of translucent berries, so the flour is neither soft nor white looking. It mills very freely, and makes bread of yellow hue. It is about as strong as the best ordinary Muzaffarnagars, but as it is uneven in texture and is somewhat nondescript in its characteristics, I prefer several others of the 28 lots sent me.

Summary.

From the foregoing remarks it will be gathered that several of the wheats sent me are very good. The most significant is No. 26 (Púsa 8). In No. 22 (White Jana Khar) regarded as typical of its group, we have a wheat which looks really good and is so. It yields a granular lively flour, and in the estimation of most bakers a really stable and strong flour is granular. But in the case of No. 26 (Púsa 8), we have a flour which seems to be a compromise between the lively granular flour just mentioned, and the soft white flour such as that from the *Pissis*, yet it is really strong. If as a miller I could not have both, I would choose the White Jana Khar, but many millers would not, and it seems to me that No. 26 (Púsa 8) should

be tested exhaustively in several districts. It is in my opinion a most promising wheat. Several others are also well worth attention, and I hope that from among the very best, or from among the merely better sorts of those submitted to me, one or several may be found to give best possible yields of grain and money to the producer in many or all parts of India.

WEYBRIDGE, SURREY:
The 23rd October 1909. ALBERT E. HUMPHRIES.

The significance of the above milling report to the wheat production and trade of India is very great. There is now no doubt that India can produce wheats with far greater flour strength and with far better milling qualities than the soft whites like the Muzaffarnagar of the alluvium and the *Pissis* grown on the black soils of Peninsular India, both of which are so largely grown for export. Such wheats as the new Púsa wheats are worth more both to the cultivator for his own consumption and to the Home miller than the weak soft whites. We believe it will soon be demonstrated that several of the wheat-growing tracts of India can grow wheats of a grain quality of the same class as Canadian and American Spring wheats, and that these will command a much higher price in England than the present Indian wheats of commerce.

APPENDICES.

APPENDIX A.

THE IMPORT AND EXPORT TRADE IN WHEAT.

THE EXPORT TRADE IN INDIAN WHEAT.[1]

"On the average of the last five years the value of the wheat exported represents 32·9 per cent. of the exports of all food-grains, and 6·6 per cent. of the total value of Indian merchandise exported. The wheat exports of the statistical year are mainly drawn from the crop of the previous year, and the figures for 1907-08 represent chiefly the exportable surplus of the harvest of 1906-07 which, though estimated to be somewhat smaller in volume than that of 1905-06, was 10 per cent. greater than the average for the quinquennium ending 1904-05.

The following table shews the outturn in tons and exports, quantities and values, for the past five years:—

		1903-04.	1904-05.	1905-06.	1906-07.	1907-08.
Outturn	Tons.	7,971,446	9,641,145	7,582,040	8,579,140	8,491,700
Exports.						
Quantity	,,	1,295,565	2,150,025	937,523	801,445	880,459
Value	Rs.	11,08,89,546	17,90,60,692	8,53,43,996	7,25,44,650	8,58,50,350
	£	7,392,636	11,937,379	5,689,599	4,836,310	5,723,357
Percentage of exports to outturn	...	16·2	22·3	12·4	9·3	10·7

"India, however, contributes but a small proportion of the world's supply of wheat as the following figures will shew. The crop in the principal wheat-growing countries in 1907 has been estimated as follows:—

	Tons.	Percentage.
EUROPE—		
Russia	13,610,000	16·1
France	9,860,000	11·6
Italy	4,930,000	5·8
United Kingdom	1,500,000	1·8
Other countries	15,790,000	18·6
Total ...	45,690,000	53·9

[1] Cotton, *Review of the Trade of India in 1907-08*, Commercial Intelligence Department, India, Calcutta, 1908. (A further issue of this publication giving a review of the trade of India in 1908-09 has appeared while this book was passing through the press. As it deals with the wheat crop of 1908, which was abnormal owing to the disastrous rainfall conditions which characterised the monsoon of 1907, the more typical account of the trade in 1907-08 is retained.)

ASIA			
	India	8,360,000	9·9
	Other countries	3,210,000	3·8
AMERICA	Total ...	11,570,000	13·7
	United States	16,930,000	20
	Argentine	4,710,000	5·6
	Other countries	2,820,000	3·3
AFRICA	Total ...	24,460,000	28·9
	(Algeria, Tunis, Egypt, Cape Colony)	1,460,000	1·7
AUSTRALIA	... .	1,500,000	1·8
	Grand Total ...	84,680,000	100

"The export trade during the year under review was decidedly brisk. The improvement in the quality of grain shipped in consequence of the new contract reducing the proportion of dirt and foreign matter has perhaps influenced prices less than had been expected, but the general shortage of crops all over the world except in the Argentine and Australia has greatly improved demand, and it is unfortunate, in view of the higher rates likely to continue for some time to come, that the last wheat harvest (1907-08) was so poor, owing to the failure of the rains. The advance in the specific value of wheat exported from India amounts to 7·7 per cent. The distribution of exports was practically confined to three ports, Karáchi, Bombay and Calcutta, and of these the first with a virtual monopoly of the Punjab wheat harvest accounts for no less than 96 per cent. Complaints continue to be made from there both of delays in moving the crop by rail to the port and of insufficient storage accommodation at the port itself, but measures for improving the situation have been discussed by the Railway Board with the local Chamber of Commerce, and in this connection the investigation of the adaptability of the elevator system to India has once more been undertaken.

The following table shews the principal customers for Indian wheat during the past three years (in tons) :—

	1905-06.	1906-07.	1907-08.
United Kingdom ...	709,168	730,526	771,525
Belgium	56,532	39,539	70,432
France	92,749	9,706	15,909
Spain	44,266	2,369	.....

"The imports of wheat into India are inconsiderable and come almost entirely from Asiatic Turkey and Persia, their cont
8,293 and 1,364 tons, respectively, amounting to a to

"The exports of *wheat flour* generally bear a close relation to those of wheat, but the figures for the year under review shew a further decline of 9 per cent. in quantity and 4·3 per cent. in value on those of the previous twelve months. The export trade in flour is confined to the East, chiefly with Aden, Asiatic Turkey, East Africa, Ceylon, and the Straits Settlements, and the fall is more than accounted for by restricted shipments from Bombay to Arabia. The total shipments were 37,219 tons valued at Rs. 56·05 lakhs (£374,000) as compared with 40,923 tons valued at Rs. 58·57 lakhs (£390,500) in 1906-07. The rise in specific value was one of 5·2 per cent."

WHEAT EXPORTED FROM BRITISH INDIA, 1886-87 TO 1905-06.[1]

	Value in Rupees.	Cwts.
1886-87 ...	8,62,59,856	22,263,624
1887-88 ...	5,56,23,733	13,538,169
1888-89 ..	7,52,32,794	17,611,408
1889-90 ...	5,79,26,147	13,802,209
1890-91 ..	6,04,24,260	14,320,496
1891-92 ..	14,38,20,022	30,306,700
1892-93 ..	7,44,03 835	14,973,453
1893-94 ..	5,19.39,850	12,156,851
1894-95 ...	2,56,62,468	6,890,130
1895-96	3,91,43,765	10,004,171
1896-97 ...	83,64,498	1,910,626
1897-98 ...	1,34,11,515	2,392,607
1898-99 ...	9,71,96,877	19,520,496
1899-1900 ..	3,90,94,963	9,704,097
1900-01 ..	3 00,832	50,021
1901-02 ..	3,25.59,204	7,321,818
1902-03 ...	4,51,53,570	10.292,150
1903-04 ...	11,08,89,546	25,911,312
1904-05 ..	17,90,60,692	43,000,502
1905-06 ...	8,53,43,996	18,750,467

[1] *Financial and Commercial Statistics of British India*, Calcutta, 1907, pp. 502-505.

THE COUNTRIES TO WHICH INDIAN WHEAT AND WHEAT FLOUR ARE EXPORTED.[1]

	Quantity.					Value.				
	1903-04	1904-05	1905-06	1906-07	1907-08	1903-04	1904-05	1905-06	1906-07	1907-08
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	R	R	R	R	R
WHEAT										
United Kingdom	21,231,863	28,928,757	14,183,363	14,610,524	15,430,509	9,04,93,695	11,99,14,523	6,41,49,721	6,59,52,106	7,58,19 910
Gibraltar	....	....	58,914	....	....	....	....	2,76,906	....	....
Aden and Dependencies	30,008	32,500	25,160	28,366	22,815	1,77,870	1,80,210	1,49,106	1,72,263	1,46,978
Bahrein Islands	....	....	....	916	2,408	....	....	....	4,130	11,525
Ceylon	982	806	848	2,006	724	5,642	4,582	4,779	13,544	4,849
Straits Settlements	5,098	14,433	9,197	7,288	2,191	22,981	64,480	36,391	32,388	14,177
Hongkong	26,035	71,865	24,454	15,717	287 524	1,08,910	2,89,295	1,16,226	87,040	13,66,255
Cape Colony	22	54,008	14	17	....	117	2,43.035	66	150	....
Mauritius and Dependencies	7,431	5,471	7,811	6,431	1 139	34 328	22,902	31,624	28,869	5,348
Zanzibar and Pemba	—	—	—	—	4.724	—	—	—	—	32,918
British East Africa	6,738	7,287	6,422	5,788	3,053	40,055	42,806	38,815	38,058	21,859
Somaliland (*a*)	128	203	140	141	25	776	1,220	855	1,365	202
Australia—										
West Australia	2,998	....	....	....	....	12,703	.....	....	....	....
Victoria	44,676	....	..	....	....	1,78,167	....	....	....	....
New South Wales	2,003	....	....	....	....	8,792	....	....	....	....
Other British Possessions	29	68	74	66	40	179	450	436	393	253
Total British Empire	21,,58,011	29,115,398	14,316,397	14,677,260	15,755,152	9,,9,84,215	12,07.63.358	6 48,04,925	6,63,30 306	7,74.24,274
Sweden	....	74,,20	172,760	194,900	79,704	.. ..	3,15,860	8,16,720	8,72,560	3,57,438
Denmark	..	156,660	....	. ..	....	....	6,40,890	....	....	....
Germany	72,267	1,195,533	36,052	51,224	....	3,19,070	48,81,992	1,65,495	2,38,550	....
Free Ports	—	—	—	—	13,702	—	—	—	—	62,860
Holland	145,496	371,284	180,804	....	....	5,97,679	14,40,500	7,95,268	....	....
Belgium	2,802,610	7,588,857	1,130,644	790,774	1,408,651	1,21,80,426	3,19,98,502	51,38,000	35,56,827	63,63,986
France	991 849	3,428,374	1,854,98:	194,125	331,186	42,97,446	1.43,79,427	86,55,067	8,87,508	14,44,309
Spain	....	531,816	826,417	47,376	....	....	22,17.959	38,72,080	2,53,194	....
Italy	76,000	23,100	62,002	....	5,000	3,27.436	1,04,250	2.85,890	....	21,500
Turkey, Asiatic—										
Ports in the Persian Gulf	220	3,958	155	3,081	9,676	1,200	21,444	744	19,037	61,161
Arabia—										
Muscat	9,820	35,811	9,550	4,782	1,747	46,429	1,60,987	49,117	28,269	11,882
Arabian Ports other than Muscat	35,495	126,769	36,,15	38,573	11,683	2,06,599	6,55,860	1.60,853	2,28,528	69,145
Persia	8.343	12,641	806	1,938	2,228	39,951	64,182	4,209	9,682	11,748
Mekran and Sonmiáni	932	1,778	50	215	1,532	4,323	7,160	259	903	3,042
China (exclusive of Hongkong and Macão)	2	4,619	1,600	.. .	2	10	14,810	7,100	....	18
Japan	179,091	15,683	64,043	..	2	7,88,231	71,945	2,70,945	....	12
Egypt	185,716	262,464	54,256	20,048	231	3,08,509	11.27,292	2,64,216	90,281	1,631
German South-West Africa	202	....	....	....	....	1,296	....	....	....	....
Portuguese East Africa	102	178	182	138	184	635	1,101	1,210	1,662	1,511
German East Africa	609	682	1,219	1,376	1,485	3,589	4,116	7,821	9,259	10,655
Abyssinia	....	13	7,738	3,010	4	....	80	41,529	18,070	32
Somaliland (*a*)	....	150	322	15	....	....	1,000	1,750	80	....
United States of America	44,391	50,050	....	.. ..	—	1,81,610	1,87,687	....	....	—
Other Foreign Countries	156	64	154	79	14	892	290	816	534	110
Total Foreign Countries	4,553,301	13,885,104	4,434,070	1,351,654	1,854,031	1,98,05,331	5,82,97,334	2,05,39, 71	62,14,344	84,,16,076
Share of Bengal	4,832,819	8,646,680	2,297,499	129,996	126,635	1,99,80.378	3,42,60,132	1,03,31,622	6,12,055	6,24,745
,, Bombay	3,690,762	5,965,438	3,455,263	459,537	553,462	1,60,56,396	2,55,29,086	1,65,02,337	23,52,384	27,83,549
,, Sind	17,385,110	28,380,715	12,956,926	15,434,060	16,928,864	7.48,41,747	44,927	5,83,55,876	6,95,59,421	3,24,40,753
,, Madras	119	71	144	108	122	592	369	795	730	703
,, Burma	2,502	7,598	40,635	5,213	100	10,433	26,178	1,53,366	20,060	600
TOTAL	25,911,312	43,000,502	18,750,467	16,028,914	17,609,183	11,08,89,546	17,90.60,692	8,53,43.996	7.25,44,650	8,58,50,350

THE COUNTRIES TO WHICH INDIAN WHEAT AND WHEAT FLOUR ARE EXPORTED.—(*Contd.*)

	Quantity.					Value.				
	1903-04	1904-05	1905-06	1906-07	1907-08	1903-04	1904-05	1905-06	1906-07	1907-08
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	R	R	R	R	R
WHEAT FLOUR										
United Kingdom	50	52,523	15,802	1,800	6,367	325	3,71,755	1,06,099	12,452	32,289
Aden and Dependencies	238,990	223,376	243,282	192,304	202,399	16,99,230	15,52,980	17,39,583	14,58,067	15,14,711
Bahrein Islands	....	....	....	3,018	4,613	....	....	..	18,314	29,708
Ceylon	107,433	113,100	105,096	113,202	116,632	7,12,460	7,68,241	7,57,880	8,00,563	9,29,221
Straits Settlements	9,935	27,541	54,234	49,579	47,357	63,403	1,82,628	4,11,143	3,36,190	3,52,860
Hongkong	746	1,088	743	1,240	2,079	4,597	7,412	5,013	8,851	17,356
Cape Colony	190	1,304	55	2	....	1,272	7,3.5	396	15	....
Natal	434	3,058	617	164	246	3,087	20,232	4,436	1,246	1,900
Mauritius and Dependencies	142,450	176,901	91,761	103,108	74,600	9,37,077	11,48,492	6,23,618	6,86,461	5,25,039
Zanzibar and Pemba	—	—	—	—	28,353	—	—	—	—	2,27,538
British East Africa	51,442	57,799	48,047	55,640	43,232	3,29,805	4,00,605	3,40,157	4,02,113	3,30,778
Seychelles	—	—	—	—	2,638	—	—	—	—	21,302
Somaliland (*a*)	5,580	8,083	1,447	2,297	1,762	37.342	60,121	11,458	18,094	14,707
Other British Possessions	13	26	47	22	13	68	186	272	118	81
Total British Empire	557,269	664,799	561,131	522,376	530,291	37,88,666	45,19,987	40,00,055	37,43,384	39,97,490
Germany	....	250	....	....	....	....	1,600	....	....	....
Free Ports	....	—	....	....	133	....	—	....	. ..	332
Belgium	....	3,981	11	....	....	....	10,664	78	...	....
Turkey, European (including Crete or Candia)	.. .	262	....	....	....	....	1,556	....	....	....
Turkey, Asiatic—										
Ports in the Persian Gulf	1,692	3,194	4,225	2,727	104,073	11,925	18,213	25,285	17,258	8,52,575
Arabia—										
Muscat	15,162	8,065	8,163	6,811	4,955	82,467	46,524	50,565	42,822	32,747
Arabian Ports other than Muscat	140,684	261,604	250,595	211,748	28,438	8,49,278	17,41,808	17,81,496	15,31,665	1,84,299
Persia	46,386	20,778	6,128	10,350	10,970	2,42,292	1,10,397	37,088	61,755	70,764
Mekran and Sonmiáni	4,321	5,139	3,066	4,998	7,875	20,852	26,097	16,382	25,158	45,100
Java	3,393	....	34	....	138	20,635	....	242	....	998
Siam	114	629	1,353	625	357	772	4,171	9,476	4,514	2,641
China exclusive of (Hongkong and Macão)	....	22,486	1,789	....	2	....	1,63,519	12,158	....	24
Japan	7,598	336	118	25	21	51,774	1,936	961	189	192
Egypt	9,859	21,645	38,572	34,889	30,461	70,489	1,50,099	2,79,225	2,56,246	2.04,983
German West Africa	....	....	....	....	941	..	....	....	....	6,864
,, South-West Africa	14,353	1,641	378	....	....	94,783	11,700	2,592	..	. ..
Portuguese East Africa	6,937	8,456	7,120	8,044	8,887	47,663	57,272	51,104	57,267	68,995
German East Africa	1,208	3,698	10,933	13,916	16,209	8,089	25,110	77,718	1,03,363	1,32,501
East Africa (other Ports)	1,262	47	22	....	....	8,536	334	158	....	....
Abyssinia	....	3,745	1,603	1,512	567	....	25,669	12,257	10,503	4,212
Somaliland (*a*)	...	567	3,763	341	.. .	....	3,780	26,103	2,316	....
Other Foreign Countries	90	173	52	100	62	622	1,174	391	676	536
Total Foreign Countries	253,153	366,696	337,925	296,089	214,086	15,10,177	24,01,623	23,83,209	21,13,732	16,07,763
Share of Bengal	93,700	136,373	73,247	52,584	49,434	5,77,748	8,65,840	5,24,498	3,55,242	3,66,237
,, Bombay	666,991	851,050	773,963	661,368	568,751	44,67,913	58,16,107	55,38,386	48,60,099	43,73,614
,, Sind	49,715	43,486	51,757	104.505	126,171	2,53,063	2,36,082	3,19,708	6,41,722	8,65,163
,, Madras	7	207	29	3	24	59	1,423	230	25	239
,, Burma	9	379	60	2	....	60	2,158	442	28	.....
TOTAL	810,422	1,031,495	899,056	818,462	744,380	52,98,843	69,21,610	63,83,264	58,57,116	56,05,253

[1] *Annual Statement of the Sea-borne Trade and Navigation of British India* (Forty-second issue), 1908, Calcutta, Vol. I, p. 416.
(*a*) Distinction of British from Foreign made from 1904-05.

THE COUNTRIES FROM WHICH WHEAT AND WHEAT FLOUR ARE IMPORTED INTO INDIA.[1]

	Quantity.				Value.			
	1903-04	1904-05	1905-06	1906-07	1903-04	1904-05	1905-06	1906-07
WHEAT	Cwts.	Cwts.	Cwts.	Cwts.	R	R	R	R
Aden and Dependencies ..	..	..	..	..	..	..	..	..
Australia—								
South Australia (including Northern Territory) ..	..	..	..	..	..	..	..	..
Victoria	..	..	..	..	..	..	..	..
Other British Possessions ..	11	92	395,666	34	206	193	19,33,457	405
Total British Empire ..	11	92	395,730	135	106	193	19,33,682	588
Turkey, Asiatic—								
Ports in the Persian Gulf ..	5,346	37	58,798	186,511	26,841	239	3,19,634	10,22,332
Arabia								
Muscat	420	..	..	..	2,240	..	..	..
Persia	13,075	..	..	21,952	68,577	..	..	1,10,564
Japan	..	..	..	1,098	..	..	..	5,490
Other Foreign Countries ..	..	..	86	..	..	..	332	2
Total Foreign Countries ..	18,841	37	58,884	209,561	97,658	239	3,19,966	11,38,388
Share of Bengal	11	97	213,069	..	33	290	9,369	5,254
,, Bombay	18,818	6	241,310	206,524	97,565	39	1,37,937	1,11,24,589
,, Sind	9	4	86	3,075	36	16	13,14,854	13,954
,, Madras	14	22	24	6	130	87	332	28
,, Burma	..	..	125	111	..	..	103	405
TOTAL ..	18,852	129	454,614	209,636	97,764	432	22,53,648	11,38,976
WHEAT FLOUR								
United Kingdom	344	2,227	1,164	494	4,096	26,316	9,869	5,254
Aden and Dependencies ..	8	41	235	213	38	362	1,743	1,553
Ceylon	44	41	118	80	376	427	1,012	910
Straits Settlements	2,610	2,893	1,323	733	16,924	17,189	9,953	5,854
Hongkong	12,828	1,463	7,935	169	83,566	11,402	62,035	3,621
Australia—								
West Australia	..	7	..	..	200	54	..	..
Victoria	22	67	1,273	2,443	15	697	8,195	15,468
New South Wales	..	1	2	20	..	8	14	222
Queensland	9	1	..	..	..	21	..	..
Fiji Islands	58	52	73	..	5	366	500	..
Other British Possessions ..	118	26	133	93	241	178	610	593
Total British Empire ..	16,041	6,823	12,256	4,354	48,146	57,443	91,931	35,480
Austria-Hungary	678	539	544	455	493	6,639	6,112	5,233
Free Ports	—	—	—	—	—	—	—	—
Egypt	1,838	867	252	9	1,131	10,738	3,470	86
Other Foreign Countries ..	21	117	46	85	220	961	421	676
Total Foreign Countries ..	2,537	1,523	842	549	823	28,338	10,003	5,995
Share of Bengal	1,208	1,342	1,863	935	3,266	11,442	13,474	12,395
,, Eastern Bengal and Assam ..	(a)	(a)	(a)	..	1	(a)	(a)	..
,, Bombay	2,274	2,971	2,075	3,061	13,699	25,930	19,244	21,383
,, Sind	80	15	43	36	31	217	495	416
,, Madras	15,076	4,018	9,117	871	1,587	97,432	70,721	7,281
TOTAL ..	18,578	8,346	13,098	4,703	84,759	1,55,041	1,03,934	41,475

1 *Annual Statement of the Sea-borne Trade and Navigation of British India* (Forty-second issue), 1908, Vol. I, p. 52.

(a) Included with Bengal.

APPENDIX B.

THE AREA AND YIELD OF WHEAT IN INDIA.[1]

Province.	Acres.	Tons.	Character of Season.
Punjab			
1893-94 ...	8,265,200	2,560,341	Very favourable, though crop injured by rust in places.
1894-95 ...	8,051,800	2,395,353	Winter rain sufficient and harvest excellent.
1895-96 ...	6,893,400	1,753,766	Very unfavourable for dry crop owing to deficient rain.
1896-97 ..	6,584,300	1,872,066	Sowings restricted owing to weak monsoon, but winter rains copious.
1897-98 ...	8,013,800	2,358,975	Favourable, but late crop damaged at harvest time.
1898-99 ...	7,729,200	1,977,777	Not favourable. Outturn affected by deficient rain, rust, insects.
1899-1900 ...	6,366,500	1,823,182	Monsoon rains scanty, but winter rains beneficial.
1900-01 ...	8,766,400	2,940,602	Very favourable, except for damage by rust and excessive rain.
1901-02 ...	7,227,100	1,846,332	Unfavourable owing to early cessation of monsoon and failure of winter rains.
1902-03 ...	6,995,200	2,314,714	Favourable, except for damage by drought in the middle of the season.
1903-04 ...	7,765,700	3,075,161	Distinctly favourable.
1904-05 ...	7,712,100	2,855,300	Favourable.
1905-06 ...	8,572,100	3,510,300	Very favourable.
1906-07 ...	9,100,100	3,266,900	Favourable, except for local damage by excessive rain, rust and hail-storms.
1907-08(*a*) ...	8,268,500	2,495,400	Unsatisfactory. Monsoon ceased early. Winter rains late and scanty.
N.-W. Frontier(*b*)			
1901-02 ...	796,500	159,279	Unusual drought throughout season.
1902-03 ...	822,900	234,594	Favourable on the whole.
1903-04 ...	994,062	302,094	Very favourable.
1904-05 ...	882,200	267,600	Favourable.
1905-06 ...	1,024,600	279,700	Favourable on the whole.
1906-07 ...	1,146,400	305,200	Favourable on the whole.
1907-08 ...	977,700	213,200	Restricted sowings; but late rains beneficial.

1 *Agricultural Statistics of India for the years* 1902-03 *to* 1906-07, Calcutta, Vol. I, p. 376.

(*a*) Including Native States.

(*b*) Constituted in 1901 out of the Punjab.

Note.—The figures for 1907-08 are subject to revision.

Province.	Acres.	Tons.	Character of Season.
United Provinces			
1893-94 ...	6,674,889	1,854,695	Generally favourable, except for damage by high winds and rust.
1894-95 ...	6,33[illegible],688	1,469,996	Rain excessive. Crop injured by high winds and cloudy weather.
1895-96 ...	5,177,261	1,591,294	Rain deficient throughout season.
1896-97 ...	4,931,710	1,850,914	Autumn rain irregular and scanty. Winter rain well distributed.
1897-98 ...	5,985,146	2,249,633	Favourable generally.
1898-99 ...	6,348,688	2,277,414	Favourable on the whole.
1899-1900 ...	6,202,826	2,410,052	Rainfall deficient at first but favourable later.
1900-01 ...	6,790,440	2,384,605	Favourable, except for damage by cloudy weather and rust.
1901-02 ...	6,461,729	2,401,940	Rainfall late and deficient.
1902-03 ...	6,909,549	2,972,497	Favourable on the whole.
1903-04 ...	7,788,753	3,230,018	Remarkably good.
1904-05 ...	7,706,500	1,897,000	Favourable at the beginning but disastrous afterwards.
1905-06 ...	6,478,900	2,428,700	Favourable for irrigated crop.
1906-07 ...	7,044,000	2,164,500	Favourable at first but unfavourable afterwards.
1907-08 ...	4,406,500	1,674,700	Unfavourable on the whole.
Central Provinces			
1893-94 ...	3,986,000	575,000	Fair on the whole.
1894-95 ...	3,393,348	502,275	Crop suffered from heavy rain and fungoid diseases.
1895-96 ...	2,714,454	368,038	Unfavourable.
1896-97 ...	1,969,623	332,645	Winter rains generally favourable.
1897-98 ...	2,171,714	543,095	Crop suffered somewhat from insufficient moisture.
1898-99 ...	2,505,299	456,169	Not favourable.
1899-1900 ...	1,633,070	201,803	Very unfavourable.
1900-01 ...	2,055,736	440,909	Favourable, except for damage by rust.
1901-02 ...	2,620,138	571,040	Unfavourable owing to insufficient rainfall.
1902-03 ...	2,284,908	666,589	Favourable, except for damage by frost and insects.
1903-04 ...	2,921,161	751,388	Favourable, except at the end of the season.
1904-05 ...	3,068,500	751,900	Favourable, except for damage by frost and rust in places.
1905-06 ...	3,019,500	773,700	Favourable on the whole.
1906-07 ...	3,274,100	831,500	Favourable on the whole.
1907-08 ...	2,470,600	466,300	Unfavourable owing to deficiency of moisture.

Note.—The figures for 1907-08 are subject to revision.

Province.	Acres.	Tons.	Character of Season.
Bengal (*a*)			
1893-94 ...	1,461,000	459,000	Rainfall excessive at first, but deficient afterwards.
1894-95 ...	1,413,000	686,300	Crop suffered somewhat from drought.
1895-96 ...	1,427,400	345,600	Autumn rains ceased early, and winter rains failed.
1896-97 ...	1,341,700	386,900	Unfavourable at first but slightly better afterwards.
1897-98 ...	1,569,500	592,600	Favourable.
1898-99 ...	1,582,500	656,400	Uniformly favourable.
1899-900 ...	1,550,300	572,700	Not favourable on the whole.
1900-01 ...	1,498,700	472,600	Unfavourable.
1901-02 ...	1,408,300	391,500	Unfavourable owing to failure of rains.
1902-03 ...	1,417,000	485,900	Unfavourable on the whole.
1903-04 ...	1,508,600	527,800	Generally favourable.
1904-05 ...	1,324,900	433,200	Unfavourable on the whole.
1905-06 ...	1,248,300	396,600	Crop seriously damaged by continuous rain and hail-storms.
1906-07 ...	1,402,600	388,700	Unfavourable.
1907-08 ...	1,003,100	299,200	Very unfavourable.
Eastern Bengal			
1904-05 ...	180,700	62,000	On the whole not favourable.
1905-06 ...	159,800	50,000	Not favourable owing to ill-distributed rainfall.
1906-07 ...	135,900	31,900	Unfavourable.
1907-08 ...	92,700	21,400	Very unfavourable.
Bombay (*including Native States*) (*b*)			
1893-94 ...	2,525,000	762,000	Outturn satisfactory, though rain excessive in parts.
1894-95 ...	2,678,665	744,961	Favourable, though crop injured by cloudy weather, rust and frost.
1895-96 ...	2,288,838	454,865	Unfavourable owing to deficient moisture.
1896-97 ...	1,446,741	288,002	Unfavourable. Rains failed.
1897-98 ...	3,004,832	627,914	Rain continuous and excessive.
1898-99 ...	2,470,998	737,385	Not favourable on unirrigated but good on irrigated land.
1899-1900 ...	1,157,077	99,408	Very unfavourable. Rains failed.
1900-01 ...	1,433,810	298,479	Unfavourable owing to want of rain.
1901-02 ...	1,510,459	179,034	Unfavourable owing to deficient rainfall. Damage by rats.

(*a*) Includes Eastern Bengal up to 1903-04.
(*b*) Includes the State of Baroda also.
Note.—The figures for 1907-08 are subject to revision.

Province.	Acres.	Tons.	Character of Season.
Bombay (including Native States)—contd.			
1902-03 ...	1,797,245	532,601	Favourable on the whole.
1903-04 ...	2,174,076	560,279	Fairly good on the whole.
1904-05 ...	2,260,900	356,600	Not favourable owing to deficient rain, cold and frost.
1905-06 ...	1,347,200	275,100	Unfavourable owing to insufficiency of moisture.
1906-07 ...	1,662,900	338,200	Not favourable on the whole.
1907-08 ...	1,505,500	315,600	Generally unfavourable owing to deficient water-supply.
Berar			
1893-94 ...	928,000	170,893	Favourable on the whole.
1894-95 ..	889,326	150,232	Not very favourable owing to heavy rain.
1895-96 ...	747,025	103,084	Unfavourable owing to early cessation of monsoon.
1896-97 ...	381,425	23,413	Crop failed owing to want of rain.
1897-98 ...	390,378	41,983	Unfavourable on the whole.
1898-99 ...	436,362	53,571	Not favourable on the whole
1899-1900 ...	17,910	414	Disastrously bad owing to failure of rains.
1900-01 ...	243,554	29,900	Unfavourable on the whole.
1901-02 ...	280,085	34,385	Favourable, but crop damaged by rats.
1902-03 ...	216,955	34,625	Favourable, but sowings restricted.
1903-04 ..	452,663	70,052	Not very favourable owing to heavy rain and hail-storms.
1904-05 ...	428,600	80,000	Favourable on the whole.
1905-06 ...	424,300	60,700	Not very favourable owing to deficient monsoon.
1906-07 ...	440,300	72,600	Favourable on the whole.
1907-08 ...	286,900	33,500	Not favourable owing to deficiency of moisture.
Sind (including Native States)			
1893-94 ...	531,000	161,000	Inundation insufficient.
1894-95 ...	673,251	215,361	Favourable.
1895-96 ...	315,559	71,683	Unfavourable.
1896-97 ...	406,752	116,470	Not unfavourable on the whole.
1897-98 ...	591,621	177,160	Inundation seasonable and sufficient.
1898-99 ...	369,706	81,231	Decidedly bad owing to insufficient inundation.
1899-1900 ...	364,522	68,226	Unfavourable.
1900-01 ...	479,487	123,160	Generally good.
1901-02 ...	534,004	109,009	Fairly good.

Province.	Acres.	Tons.	Character of Season.
Sind (including Native States)—contd.			
1902-03 ...	331,608	75,987	Unfavourable owing to poor inundation.
1903-04 ...	586,895	202,171	Favourable.
1904-05 ...	522,700	126,100	Not very favourable owing to low inundation and frost.
1905-06 ...	628,100	196,200	Favourable on the whole.
1906-07 ...	672,300	186,300	Favourable, but crop suffered in places from rain and hail.
1907-08 ...	431,500	108,200	Not favourable owing to low inundation and frost.
Rajputana			
1893-94 ...	1,646,000	389,000	Not reported.
1894-95 ...	1,529,146	368,168	
1895-96 ...	1,306.868	315,573	
1896-97 ..	1,374,346	293,932	Rainfall deficient.
1897-98 ..	1,302,233	307,062	Not reported.
1898-99 ...	1,196,014	276,388	
1899-1900 ...	360,733	79,289	
1900-01 ...	713,290	170,682	Not favourable.
1901-02 ..	541,834	103,869	Unfavourable.
1902-03 ...	818,399	190,841	Fairly good.
1903-04 ...	1,125,277	297,162	Favourable.
1904-05 ...	1,023,800	189,000	Not favourable.
1905-06 ...	665,600	136,600	Not very favourable.
1906-07 ...	842,400	181,600	Favourable.
1907-08 ...	603,800	118,500	Unfavourable owing to want of moisture.
Central India			
1893-94(*a*) ...	1,537,143	227,819	Not reported.
1894-95 ...	2,042,531	396,567	
1895-96 ...	1,740,608	290,745	
1896-97 ...	1,366,269	179,949	
1897-98 ...	1,501,013	279,492	
1898-99 ...	1,613,851	287,749	
1899-1900 ...	692,950	100,276	
1900-01 ...	1,244,330	220,116	
1901-02 ...	1,459,116	255,027	
1902-03 ...	1,182,298	408,843	
1903-04 ...	1,956,069	523,855	
1904-05 ...	2,227,400	473,200	
1905-06 ..	1,852,100	420,600	
1906-07 ...	2,447,500	614,600	
1907-08 ...	1,679,700	322 600	

(*a*) Incomplete.

Note.—The figures for 1907-08 are subject to revision.

Province.	Acres.	Tons.	Character of Season.
Hyderabad. (*a*)			
1893-94 ...	1,162,503	109,234	Not reported.
1894-95	1,412,562	69,413	Not favourable owing to heavy rain late in the season
1895-96 ...	1,454,451	85,331	Not reported.
1896-97 ...	772,990	18,585	Unfavourable.
1897-98 ...	1,003,175	30,139	Not very unfavourable.
1898-99 ..	1,113,431	33,098	Favourable, but crop damaged by rats.
1899-1900 ...	339,136	1,538	Disastrously bad owing to failure of rain.
1900-01 ...	636,247	12,279	Unfavourable owing to holding off of rain.
1901-02 ...	603,182	38,853	Not favourable, crop damaged by rats.
1902-03 ...	614,092	53,724	Favourable, but sowings restricted.
1903-04 ...	1,134,769	100,535	Favourable.
1904-05 ...	1,126,600	89,700	Not favourable owing to deficient winter rains.
1905-06 ..	934,500	41,800	Unfavourable owing to want of late rains.
1906-07 ...	1,039,500	109,000	Favourable.
1907-08 ...	932,900	67,200	Unfavourable owing to insufficient rainfall.
Mysore			
1893-94 ...	(*b*)	(*b*)	
1894-95 ..	4,534	304	
1895-96 ...	5,456	363	
1896-97 ...	3,871	413	
1897-98 ...	4,363	331	
1898-99 ...	4,029	492	
1899-1900 ...	2,758	254	
1900-01 ...	2,556	197	Not reported
1901-02	3,714	256	
1902-03 ...	5,123	531	
1903-04 ...	5,718	630	
1904-05 ...	5,300	440	
1905-06 ...	2,400	140	
1906-07 ...	4,500	700	
1907-08 ...	2,500	600	
Total			
1893-94 ...	28,716,735	7,268,982	Not unfavourable on the whole.
1894-95 ...	28,421,851	6,998,930	Not favourable owing to heavy rain at sowing time.

(*a*) The figures for the years previous to 1902-03 exclude *jagir* areas.
(*b*) No information
Note.—The figures for 1907-08 are subject to revision.

Province.	Acres.	Tons.	Character of Season.
1895-96 ...	24,071,320	5,380,342	Unfavourable.
1896-97 ...	20,579,727	5,363,289	
1897-98 ...	24,537,775	7,208,384	Favourable on the whole.
1898-99 ...	25,370,078	6,837,674	Not favourable on the whole.
1899-1900 ...	18,687,782	5,357,142	Unfavourable on the whole.
1900-01 ...	23,864,550	7,093,529	Not unfavourable on the whole.
1901-02 ...	23,446,161	6,090,524	Unfavourable on the whole.
1902-03 ...	23,395,277	7,971,446	Favourable on the whole.
1903-04 ...	28,413,743	9,641,145	Exceptionally good.
1904-05 ...	28,470,200	7,582,040	Not very favourable on the whole.
1905-06 ...	26,357,400	8,570,140	Favourable on the whole.
1906-07 ...	29,212,500	8,491,700	Favourable at first, but dull weather prevailed later.
1907-08 ...	22,661,900	6,136,400	Disappointing. Crop injured by deficient rain, cold winds, frosts.

Note.—The figures for 1907-08 are subject to revision.

The yield of Wheat per acre in India.[1]

Average yield (lbs. per acre) of wheat in each Province of British India and in Mysore revised with reference to Crop experiments made up to the year 1906-07.

Province.			Wheat.
Upper Burma, Unirrigated			575
Lower Burma ,,			...
Eastern Bengal and Assam			784
Bengal*			(*d*) 984
			(*e*) 861
			(*f*) 451
United Provinces ...		Irrigated	1,250
		Unirrigated	850
		Both	1,050
Ajmer-Merwara ..		Irrigated	...
		Unirrigated	...
		Both	...
Punjab ...		Irrigated	994
		Unirrigated	619
		Both	816
North-West Frontier		Irrigated	842
		Unirrigated	540
		Both	618
Sind ...		Irrigated	1,229
Bombay ...		Irrigated	1,250
		Unirrigated	510
		Both	575
Central Provinces ...		Irrigated / Unirrigated / Both	600
Madras ...		Irrigated	...
		Unirrigated	...
Coorg ...		Unirrigated	...
Mysore ...		Irrigated	...
		Unirrigated	...

Note.—The average yield of both irrigated and unirrigated land is ascertained by multiplying the yield of irrigated land by the irrigated area cropped, adding the yield of unirrigated land multiplied by the unirrigated area cropped, and dividing the sum of these products by the total area cropped.

1 *Agricultural Statistics of India for the years* 1902-03 to 1906-07, Calcutta, Vol. I., 1908, p. 400.
* The estimates for Bengal are the standards adopted provisionally by the Agricultural Department of the Province, which are partly based on the information collected in 1892. The results of the experiments for the period ending 1906-07, as recorded in Appendix B—iii, are not considered sufficiently reliable to justify a revision of provisional estimates.
(*d*) Bihar, (*e*) Bengal, (*f*) Chota Nagpur.

APPENDIX C.

The price of Wheat in India.[1]

Quinquennial averages of wheat. Seers per rupee.

	1861—65	1866—70	1871—75	1876—80	1881—85	1886—90	1891—95	1896-1900	1901—05
Upper Burma ...	.....	.....	.....	.....	.....	10'57	13'27	10'98	13'95
Lower Burma ...	...	11'85	12'12	14'27	14'8	10'65	10'94	9'73	12'14
Eastern Bengal and Assam ...	...	15'83	15'48	13'82	15'46	14'29	11'9	11	12'32
Bengal ...	...	15'7	16'65	15'24	16'69	15'44	13'27	11'69	12'89
Agra ...	...	17'33	18'94	18'18	19'8	16'15	14'91	12'62	14'57
Oudh ...	...	19'3	20'55	19'12	20'86	17'13	15'02	13'27	15'04
Rajputana ...	...	.....	15'45	14'33	16'68	14'1	14'14	10'98	12'91
Central India ...	...	.....	14'41	12'47	18'31	14'14	13'98	10'5	12'11
Punjab and N.-W. F. Province	...	24'72	22'52	18'57	22'04	17'52	17'64	13'44	16'08
Sind and Baluchistán ...	...	16'7	15'61	12'17	13'73	12 23	13'27	11'16	12'73
Bombay ...	...	11'91	13'32	9'82	14'72	12'76	12'5	9'67	11'11
Central Provinces ...	...	25'96	24'76	19'05	24'37	17'8	14'98	11'09	13'69
Berár ...	...	15'75	17'16	13'52	20'13	16'11	13'76	9'35	10'68
Nizám's Territories ...	...	13'45	13'86	10'46	16'84	13'98	11'75	8	8'45
Mysore ...	...	9'35	9'24	7'46	11'02	10'72	9'84	8'58	9'81
Coorg ...	...	7'81	8'4	6'22	8'79	9'36	8'29	6'75	6'66

1 *Prices and Wages in India*, Calcutta, 1906, p. 7.

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GLOSSARY OF VERNACULAR TERMS.

Abi	Land watered from tanks.
Abpáshi	A term applied to irrigated fields.
Arhar	Pigeon pea, *Cajanus indicus*.
Bakhar	A native cultivator used in the Central Provinces and in the Bundelkhand Districts.
Bájra	A millet, *Pennisetum typhoideum*.
Baluá	Sandy land.
Bandhia	Embanked fields.
Bángar	Land beyond the influence of inundation (Punjab). The uplands of the alluvial plain (United Provinces).
Bandhan	An embankment of masonry.
Bara	Lowlying soils.
Bárání	Dependent on rain.
Bari Káli	Deep black alluvial clay.
Bathú	A weed of wheats fields, *Chenopodium album*.
Bazar	A market.
Berí	A closely woven basket used for lifting water.
Besár	Medium soil which will grow wheat with irrigation.
Bhábar	The gravelly slope along the foot of the mountains.
Bharkila	Fields cut up by water channels.
Bharolá	An earthen jar for storing grain.
Bhatha	New alluvial soils on the banks of rivers.
Bhet	A tract inundated or moistened by the rise of the river.
Bhúr	Sandy land.
Bhúsa	Chaff.
Bigha	A unit of area applied to land; the size of a *bigha* varies in different parts of the country. In Bengal it is about 4/5 of an acre
Birrá	A mixed crop of wheat and gram.
Bund	An embankment made of earth.
Chahi	Land watered by wells.
Charsa	A leathern bag for lifting water.
Chhaj	A winnowing basket.
Chena	A millet, *Panicum miliaceum*.
Chhamb	Heavy clay soil.
Cholam	A millet, *Sorghum vulgare*.
Dákar	Heavy clay soil.
Deára	Alluvial land.
Desi	Local.
Desya	Land beyond the influence of inundation.
Dhankar	Heavy clay land.

Dhenkli . . . . . A bucket used for lifting water out of wells.
Dholi . . . . . A bamboo grain bin.
Dhongár . . . . . Highlying fields on a slope which are damaged by surface wash and too much drainage.
Doáb . . . . . The region between two rivers.
Doras . . . . . The fertile loam of the uplands.
Dorsa . . . . . Second class black soil containing sandy or limestone particles.
Dumat . . . . . The fertile loam of the uplands.
Gauhán . . . . . Highly manured land round a village.
Gehum, gehun . . . Wheat.
Gharú . . . . . An earthen jar.
Godhi . . . . . Wheat.
Godhumai . . . . . Wheat.
Godhumalu . . . . . Wheat.
Gohání . . . . . Fields which will grow wheat.
Goind . . . . . Highly manured land round a village.
Gorádu . . . . . Light sandy soil of great depth.
Gorát . . . . . Ligh sandy soil of great depth.
Gujai . . . . . A mixed crop of wheat and barley.
Hathia . . . . . The period between September 26th and October 10th.
Henga . . . . . A flat wooden beam used to consolidate the soil (Bihár).
Jandra . . . . . A wooden rake.
Játs . . . . . A race of cultivators living in the Upper Doab of the United Provinces.
Jhils . . . . . A pond or natural tank.
Jowár . . . . . A millet, *Sorghum vulgare*.
Kábar . . . . . First class black soil suitable for wheat (Central Provinces). Soil lighter in colour than black cotton soil (Bundelkhand).
Kachár . . . . . First class black soil (Central Provinces).
Kachhár . . . . . River lowlands submerged in the rains (United Provinces).
Kachchá . . . . . Temporary.
Kála . . . . . Black.
Káli . . . . . First class black soil.
Kallar . . . . . The efflorescence on the surface of alkali lands.
Kanhar . . . . . Black soil.
Káns . . . . . A weed, *Saccharum spontaneum*.
Kapli . . . . . Emmer.
Karab . . . . . A native cultivator used in Gujarat.
Karail . . . . . A strong black loam.
Kewal . . . . . A strong black loam (Bihár). A black clayey soil very retentive of moisture (Chota Nagpur).
Khádar, Khddir . . Land inundated or moistened by the rise of a river.
Khar . . . . . Marshy salt lands.
Kharif . . . . . The monsoon period.
Khurti . . . . . A pulse, *Dolichos biflorus*.
Khutti . . . . . A grain pit.

Kiari . . . . . An irrigation bed.
Kothi . . . . . An unbaked clay jar.
Lal . . . . . Red.
Mahajan . . . . . A merchant.
Máhjah . . . . . The higher parts of the Doáb.
Mahuá . . . . . A tree, *Bassia latifolia*.
Maira . . . . . Sandy soil.
Mál . . . . . Black moisture retaining soil.
Mamúli . . . . . Ordinary.
Manjhár . . . . . Fields between the highly manured land near the villages and the outlying fields. They are occasionally manured.
Már . . . . . First class black soil suitable for wheat (Central Provinces). Black soil suitable for wheat but more friable than that of the Central Provinces (Bundelkhand).
Mariár . . . . . First class black soil suitable for wheat (Central Provinces).
Masúr . . . . . Lentil, *Ervum lens*.
Matiyár . . . . . Heavy clay land.
Maund . . . . . The Indian standard of weight which is equivalent to 82·28 lbs.
Missa . . . . . Wheat and gram chaff mixed.
Morand . . . . . Loamy soil, lighter coloured than *már*.
Mot . . . . . A leathern bag used for lifting water.
Mota . . . . . An impervious layer of stiff clay.
Moti . . . . . Rich black friable soil.
Mund . . . . . Loamy soil, lighter coloured than *már*.
Murand . . . . . Loamy soil, lighter coloured than *már*.
Murum . . . . . Decayed trap rock.
Nagár . . . . . A heavy plough used in the Central Provinces and Bundelkhand.
Nahri . . . . . Land watered by canals.
Nala . . . . . A natural water course.
Nim . . . . . A tree, *Melia indica*.
Nyai . . . . . Richly manured land round the homestead.
Pálo . . . . . Outlying village lands which are little manured.
Parkhi . . . . . An instrument for sampling grain.
Parwá . . . . . Light soil reddish or yellowish in colour.
Patarua . . . . . Poor, light coloured loam.
Pathár . . . . . A heavy beam used to consolidate the soil (United Provinces).
Phala . . . . . A threshing frame.
Phio . . . . . A flat spade-like instrument used for winnowing.
Piazi . . . . . A weed, *Asphodelus fistulosus*.
Rabi . . . . . The cold-weather season.
Rákar . . . . . Very heavy clay soil (Punjab). Gravelly soil derived from *már* (United Provinces).
Ránkar . . . . . Poor, light coloured loam.
Rausli . . . . . Light loam (Punjab). Fertile loam of the uplands (Muzuffarnagar).
Regar . . . . . Black cotton soil.

Reh . . . . . The efflorescence found on alkali land.
Reti . . . . . Soil with windblown hillocks of sand.
Rohi . . . . . Well drained loam.
Safed . . . . . White.
Sailaba . . . . . Land inundated by the rise of a river.
Sál . . . . . A tree, *Shorea robusta*.
San . . . . . Sunn hemp, *Crotalaria juncea*.
Sane . . . . . Rich black clayey soil.
Sehwan . . . . . The earcockle disease of wheat.
Senji (white flowered) A leguminous weed found in wheatfields, *Melilotus alba*.
„ (yellow flowered) A leguminous weed found in wheatfields, *Melilotus indica*.
Siwái . . . . . The fertile loam of the uplands.
Sohága . . . . . A heavy beam used for consolidating the soil (Punjab).
Súp . . . . . A winnowing tray.
Tarai . . . . . The unhealthy forest tract at the foot of the Himálayas.
Tat . . . . . A country made mat.
Teora . . . . . A vetch, *Lathyrus sativus*.
Tibba . . . . . Soil which is almost pure sand.
Tifan . . . . . A native drill which sows three furrows at once.
Tikchana . . . . . A common weed of wheatfields, *Launea asplenifolia*.
Ujarhá . . . . . A term applied to fields in which the crop is liable to be damaged by wild beasts.
Uparhar . . . . . Outlying fields which are little manured.
Urd . . . . . The name applied to various pulses such as *Phaseolus radiatus* and *Phaseolus mungo*.
Usár . . . . . Alkali land.
Vakhar . . . . . A native cultivator used in the Deccan.
Vadának . . . . . Macaroni wheat.
Wadának . . . . . Macaroni wheat.
Yeri bhumi . . . . . The black soil country.
Zamindár . . . . . A landholder.