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MADRAS

INSTRUCTIONS TO AUTHORS

Two numbers of the Journal are published every year, one in July and one in December and contributions for publication should be sent to the Editor not later than the 1st of April and the 1st of September respectively.

Contributors are requested to be clear and concise. Manuscripts should not exceed 8,000 words and should be in a final form for the press. Each paper should start with a short summary which should be an abstract of the whole paper, complete and clear in itself, and not over 3 per cent. of the length of the paper. The introduction and reviews of literature should be restricted to closely pertinent papers.

The manuscript should be typewritten on one side of the paper only, with wide margins and be double spaced throughout including titles, footnotes, *literature citations* and legends. Symbols, formulae and equations must be written clearly and with great care. Scientific names of genera and species are printed in italics and should be underlined in the typescript. Too many tables, graphs, etc. should be avoided. Each table should be typed on a separate sheet with its proper position marked in the text in pencil.

Literature citations: All references to literature cited in the text should be presented together at the end of the paper in alphabetical order of authors' names. Each reference should be given in a standard form as follows: (1) name(s), followed by initial(s), of author(s); (2) year of publication in brackets; (3) full title of paper; (4) title of journal, abbreviated according to *World List of Scientific Periodicals*, 1934, and underlined; (5) volume number in Arabic numerals, underlined with two lines to indicate bold type; (6) page numbers without the prefix, p. When books are mentioned in the references, the order should be: name of author(s), initial(s), year in brackets, title of the book, which should be underlined, volume number, edition, page, followed by place of publication and name of publisher. Where a reference has not been seen in original, it should be indicated by an asterisk and the name of the abstracting journal or other source should be mentioned in brackets. If the title is in a language other than English, the diacretic signs, etc., should be precisely given as in the original.

Examples:

Text: (Patel, 1948); but, e.g., 'Patel (1948) showed that . . . .'. For two authors, write as, e.g., Khanna & Sharma (1947), using the ampersand (&). If there are more than two authors, all names should be given when cited for the first time and thereafter the first name only, adding *et al.*

References:

Raman, C. V. (1949) The theory of the Christiansen experiment. *Proc. Indian Acad. Sci.*, A, 29: 381-90.

Sahni, B. (1936a) Wegener's theory of continental drift in the light of Palaeobotanical evidence. *J. Indian bot. Soc.*, 15: 31-32.

Sahni, B. (1936b) The Karewas of Kashmir. *Curr. Sci.*, 5: 10-16.

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Communications should be addressed to Professor T. S. Sadasivan, Editor, Journal of the Madras University (Sect. B), University Botany Laboratory, Madras-5, India.

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CONTENTS

J. Madras Univ., B. XXII, No. 2, pages 163-182, 1952

THE FUNGI OF INDIA — A SECOND SUPPLEMENT *

BY

K. RAMAKRISHNAN & C. V. SUBRAMANIAN
(*University Botany Laboratory, Madras*)

(Accepted for publication, 2nd May, 1952)

LIST OF HOSTS AND SUBSTRATA

Abutilon indicum G. Don
Puccinia abutili
Acacia arabica Willd
Ravenelia acaciae-arabicae
Septoria mortolensis
Acacia concinna DC.
Ravenelia acaciae-concinnae
Acacia leucophloea Willd
Hapalophragmiopsis ponderosa
Acacia suma Willd
Ravenelia acaciae-sumae
Achras sapota L.
Pestalotia sapotae
Polyporus gilvus *forma* lichnoides
Achyranthes aspera L.
Cercospora achyranthes
Cercopora achyranthina
Physalospora achyranthis
Septoria achyranthis
Aconitum laeve Royle
Uromyces lycoctoni
Acorus calamus L.
Uromyces acori
Actinodaphne hookeri Meissn
Phyllachora actinodaphnes
Adina cordifolia Hk. f.
Cercospora adinae
Adinandra javanica Choisy
Polyporus gilvus *forma* lichnoides
Aecidium pavettae Berk.
Tuberculina persicina
Aecidium sp.
Tuberculina persicina
Aeschynomene indica L.
Physoderma aeschynomenis
Aegle marmelos Corr.
Fusarium semitectum *v.* majus
Aesculus indica Colebrook ex Wall.
Valsa ceratophora
Agapanthus umbellatus L. Herit
Mycosphaerella agapanthi
Alangium begoniifolium Baill.
Dictyonella alangii
Albizzia amara Boiv.
Ravenelia albizziae-amarae
Albizzia lebbeck Benth.
Colletotrichum compactum
Helminthosporium albizzicolum
Albizzia odoratissima Benth.
Microstroma albizziae
Alchemilla indica Gardn.
Trachyspora alchemillae
Trachyspora intrusa
Alchemilla vulgaris W.
see *A. indica*
Aleyrodes sp. (insect).
Aegerita webberi
Aschersonia raciborskii
Alisma reniforme Don
Burrillia narasimhanii
Alloteropsis cimicina Stapf
Ramulispora alloteropsidis
Althaea rosea Cav.
Phyllosticta althaeina
Amaranthus blitum Linn.
Peronospora amaranthi
Amaryllis sp.
Aecidium crini
Amomum sp.
Uredo amomi
Amorphophallus campanulatus Bl.
Pellicularia rolfsii
Ampelocissus latifolia (Roxb.) Planch
Catenulopsora vitis
Amphicarpaea edgeworthii Benth.
Synchytrium aecidioides
Amphilophis ischaemum L.
Ustilago amphilophidis

* The first part of this paper: "List of Fungi" was published in *J. Madras Univ.* B, XXII: 1-65, 1952.

Amphilophis pertusa Stapf.
Sphacelotheca tenuis
Amygdalus persica L.
Tranzschelia punctata
Ananas sativus Schult
Wallrothiella bromeliae
Aneilema nudiflorum R. Br.
Ustilaginoidea burkilli
Anemone sp.
Synchytrium anemones
Anethum graveolens L.
Cercosporella anethi
Aneura sp.
Cladochytrium aneurae
Olpidiopsis ricciae
Anisomeles indica O. Kze.
Cercospora teucrii
Anisomeles ovata v. *mollissima*
see *A. indica*
Annona squamosa L.
Cercospora anonae
Pleosphaeropsis anonae
Anogeissus latifolia Wall.
Fomes caryophylli
Kellermannia malabarica
Anthistiria arundinacea L.
Sphacelotheca bursa
Anthistiria ciliata L. f.
see *Themeda quadrivalvis*
Anthistiria sp.
Sphacelotheca bursa
Anthocephalus cadamba Roxb.
Gloeosporium anthocephali
Apium graveolens L.
Septoria apii-graveolentis
Apluda aristata L.
Sphacelotheca apludae
Apluda varia Hack var *aristata* Hack
see *Apluda aristata*
Aquilegia vulgaris L.
Puccina melasmiodies
Aquilegia vulgaris L. var *alpina* H. & T.
Puccinia melasmioides
Arachis hypogea Willd.
Pellicularia rolfsii
Araucaria sp.
Pestalotia micheneri
Areca catechu L.
Coniothyrium arecae
Argyreia cymosa Sweet
Trochodium sampathense
Aristida depressa Retz.
Puccinia bottomleyae
Aristida sp.
Sphacelotheca aristidae-cyananthae
Aristolochia indica L.
Cercospora bangalorensis
Artemesia vulgaris L.
Cercospora ferruginea
Phakopsora artemesiae
Arthraxon lancifolius Hochst.
Bremia graminicola *var.* indica
Artocarpus integrifolia L.
Gloesporium artocarpi
Pestalotia elasticola
Artocarpus lakoocha Roxb.
Phaeochorella artocarpi
Arundinaria falcata Nees
Rosellinia bonaerensis
Arundinaria wightiana Nees
Ustilago shiraiana
Arundinella sp.
Sphacelotheca arundinellae
Arundo donax L.
Collectotrichum falcatum *var.* arundinis
Asparagus sp.
Puccinia phyllocladiae
Asplenium nidus L.
Cercospora asplenii
Asteracantha longifolia Nees
Doassansia hygrophilae
Astragalus maddenianus Benth.
Uromyces lapponicus
Atlantia monophylla Corr.
Plowrightia atlantiae
Atmosphere
Aspergillus amstelodami
Aspergillus oryzae
Aspergillus rugulosus
Aspergillus unguis
Atylosia sp.
Synchytrium atylosiae
Azalea indica L.
Exobasidium vaccinii
Azima tetracantha Lam.
Cercosporella azimae

"*Bamboo*"
Auricularia auricularis
Clathrus delicatus
Cyathus striatus

Dacryopinax spathularia
Polyporus gilvus *forma* lichnoides
Bambusa sp.
Dasturella bambusina
Meliola bambusicola
Bark
Cyathus montagnei
Dasyscyphella indica
Barleria cristata L.
Cercospora barlericola
Barleria sp.
Phyllosticta barleriae
Bassia bourdillonii Gamb.
Scopella echinulata
Bassia latifolia Roxb.
Scopella echinulata
Bauhinia purpurea L.
Phyllosticta bauhiniae
Polyporus gilvus *forma* gilvoides
Beilschmiedia roxburghiana Nees
Goplana indica
Bidens pilosa L.
Entyloma bidentis
Bischofia sp.
Phyllosticta bischofiae
Blepharis boerhaavifolia Pers.
Puccinia boerhaviafolia
Bombax malabaricum DC.
Cercospora bombacina
Borassus flabellifer L.
Sphaerodothis borassi
Borreria hispida K. Sch.
Synchytrium borreriae
Brachiaria distachya Stapf.
Melanotaenium brachiariae
Brachypodium sylvaticum Beauv.
Claviceps purpurea
Neovossia brachypodii
Puccinia baryi
Brassica campestris L. var *sarson* Prain
Tuburcinia brassicae
Brassica oleracea L.
Alternaria brassicicola
Breynia patens Rolfe
Ravenelia breyniae-patentis
Breynia rhamnoides M. Arg.
Masseeella breyniae
Bridelia retusa Spr.
Uredo malabarica
Bridelia roxburghiana Gehrm.
Stagonospora brideliae
Bridelia tomentosa Bl. var *chinensis*
Bubakia cingens
Bridelia sp.
Bubakia cingens
Bulbostylis barbata Kunth
Puccinia bulbostylidicola
Puccinia liberta
Sorosporium kuwanowanum

Cadaba indica Lam.
Microstroma cadabae
Cajanus cajan (L.) Millsp.
Diplodia cajani
Fusarium udum
Calamus rotang L.
Catacaumella calamicola
Sphaerodothis coimbatorica
Callicarpa lanata Lam.
Uredo callicarpae
Callistephus chinensis Bergmans
Fusarium othoceras *var* callistephi
Calotropis gigantea R. Br.
Cladosporium calotropidis
Canarium commune L.
Aecidium pulneyensis
Canarium sikkimense King
Phyllachora sikkimense
Canavalia ensiformis DC.
Cercospora canavaliae
Canna indica L.
Carpenterella cannae
Cannabis sativa L.
Cercospora cannabis
Cansjera rheedii Gmel.
Asterina cansjericola
Meliola cansjerae
Capparis aphylla Roth
Leptosphaeria capparidicola
Penzigia capparidis
Capparis heyneana Wall.
Phyllosticta capparidis-heyneanae
Capparis horrida L.f.
see *C. zeylanica*
Capparis sepiaria L.
Bulgariastrum tumefaciens
Cercospora capparidicola
Hariotula capparidis
Capparis zeylanica L.
Cercospora capparidis
Cardamine subumbellata Hook.
see *C. trichocarpa*

Cardamine trichocarpa Hochst
Cystopus intermediatus
Carduus nutans L.
Puccinia carduorum
Carex baccans Nees
Farysia americana
Farysia orientalis
Carex cardiolepsis Nees
Cintractia caricis
Carex condensata Nees
Farysia caricis-filicinae
Farysia pseudocyperi
Carex filicina Nees
Farysia americana
Carex haematostoma Nees
Cintractia disciformis
Carex incurva Lightf.
Cintractia leioderma
Carex nubigena D. Don
Puccinia caricis-nubigenae
Careya arborea Roxb.
Cercospora careyae
Carica papaya L.
Ascochyta caricae
Fusarium diversisporum
Phyllosticta caricae-papayae
Phyllosticta sulata
Carissa spinarum A. DC.
Phyllosticta carissae
Carissa sp.
Pestalotiopsis versicolor
Uredo carissae
Carthamus tinctorius L.
Alternaria carthami
Casearia tomentosa Roxb.
Cercospora caseariae
Cassia absus L.
Ravenelia berkeleyi
Cassia fistula L.
Phleospora cassiae
Cassia sumatrana Roxb.
Helicoceras oryzae
Castanea sp.
Valsa ceratophora
Catharinaea mülleri
Neottiella catharinaea
Cedrela toona Roxb.
Discella cedrelae
Celastrus paniculata Willd.
Uredo celastri
Celtis australis Linn.
Uncinulopsis polychaeta
Celtis tetrandra Roxb.
Exobasidium celtidis
Cephalandra sp.
Synchytrium trichosanthidis
Chasalia curviflora Thw.
Uredo chasaliae
Chenopodium album L.
Phyllosticta bacilliformis
"Chestnut"
Endothia parasitica
Chionachne koenigii Thw.
Ustilago polytocae
Ustilago polytocae-barbatae
Chloris barbata Sw.
Sphacelotheca chloridis
Chloris bournei Rang. and Tad.
Ustilago valentula
Chlorophytum attenuatum Bak.
Uromyces loculiformis
Chomelia asiatica O. Kze.
Puccinia spongiosa
Chrysanthemum cinerariafolium Vis.
Phytophthora cambivora
Chrysanthemum sp.
Cercospora chrysanthemi
Oidium chrysanthemi
Chrysopogon coerulens (Stend.) Watson
Sorosporium tumefaciens
Chrysopogon sp.
Sphacelotheca chrysopogonicola
Cicer arietinum L.
Fusarium orthoceras *var.* ciceri
Operculella padwickii
Cimcifuga foetida L.
Urocystis caricinoides
Cinchona ledgeriana Moens.
Pellicularia salmonicolor
Phytophthora cinnamomi
Pythium vexans
Cinchona officinalis Ak.
Pythium vexans
Cinchona sp.
Phytophthora cinnamomi
Cinchona succirubra Pav.
Phytophthora cinnamomi
Pythium vexans
Cinnamomum zeylanicum Bl.
Armatella cinnamomi

Cissampelos convolvulacea
see *C. pareira*
Cissampelos pareira L.
Meliola cissampelicola
Citrullus vulgaris Schrad.
Cercospora citrullina
Synchytrium trichosanthidis
Citrus aurantium L.
Pellicularia alba
Pellicularia salmonicolor
Penicillium fellutanum
Citrus grandis Hassk.
Pestalotia citri
Sphaceloma fawcettii
Citrus medica L.
Fusarium semitectum
Clausena willdenovii W. & A.
Cercospora clauseniae
Cleistanthus collinus Benth.
Fomes caryophylli
Clerodendron inerme Gaertn.
Puccinia erebia
Clerodendron infortunatum
Ascochyta infortunata
Cocculus hirsutus Diels
Nitschkia fuckelii
Cocculus villosus DC.
see *C. hirsutus*
Cocos nucifera L.
Diplodia epicocos
Lentinus decaisneanus
Pestalotiopsis palmarum
Polyporus gilvus *forma* gilvoides
Coelogyne sp.
Gloeosporium zonatum
Coffea sp.
Pellicularia salmonicolor
Coix lachryma-jobi L.
Puccinia operta
Ustilago lachrymae-jobi
Colchicum luteum Baker
Urocystis colchici-lutei
Colocasia antiquorum Schott
Choanephora trispora
Combretum ovalifolium Roxb.
Phyllosticta combreticola
Commelina sp.
Phakopsora tecta
'Conifers"
Polyporus circinatus
Convolvulus sp.
Hariotula convolvuli
Conyza sp.
Bremia ganglioniformis
Synchytrium vulgatum
Corchorus olitorius L.
Cercospora corchorica
Corchorus trilocularis L.
Cercospora corchorica
Corchorus sp.
Cercospora corchorica
Cordia obliqua Willd.
Physalospora cordiae
Cornus macrophylla Wall.
Fusarium biasolettianum
Cotoneaster integerrima Medik.
Gymnosporangium clavariaeforme
Cotoneaster nummularia F. & M.
Gymnosporangium clavariaeforme
"Cotton cordage"
Memnoniella echinata
Cousinia thomsoni C. B. Clarke
Puccinia cousiniae
Crataegus oxycantha L.
Gymnosporangium confusum
Crinum asiaticum L.
Aecidium crini
Crinum (?) asiaticum L.
Cercospora pancratii
Crinum sp.
Aecidium crini
Crotalaria juncea L.
Fusarium udum *var.* crotalariae
Crotalaria medicaginea Lam. v *neglecta* Baker.
Fusarium udum *var.* crotalariae
Crotalaria semperflorens Vent.
Synchytrium cortalariae
Croton oblongifolius Roxb.
Phyllachora gudalurensis
Croton sp.
Pleosphaeropsis crotonis
Cucumis melo L.
Fusarium equiseti
Cucurbita sp.
Phyllosticta cucurbitacearum
Cunninghamia sinensis
Pestalotiopsis funerea
Curcuma sp.
Sphaceloma curcumae
Cyathula tomentosa Moq.
Ascochyta cyathulae

Cycas circinalis L.
Arthrobotryum cycadicola
Sphaeropsis cycadis
Cymbopogon caesius Stapf
Sphacelotheca mutila
Cymbopogon citratus Stapf
Tolyposporium cymbopogonis
Cymbopogon coloratus Stapf
Sorosporium everhartii
Sphacelotheca cymbopogonis-colorati
Ustilago barberi
Cymbopogon flexuosus Wats.
Sphacelotheca cymbopogonis-colorati
Ustilago andropogonis-finitim
Cymbopogon parkeri Stapf
Sphacelotheca consueta
Cymbopogon pendulus Stapf
Sphacelotheca bengalensis
Cymbopogon polyneuros Stapf
Colletotrichum ciliatum
Cynodon dactylon Pers
Septoria cynodontis
Spegazzinia ornata
Cyperus alternifolius L.
Pythium intermedium
Cyperus compressus L.
Cintractia peribebuyensis
Cyperus eleusinoides Kunth
Pythium intermedium
Cyperus pangorei Rottb.
Cintractia peribebuyensis
Cyperus papyrus L.
Pythium intermedium
Cyperus rotundus L.
Cintractia peribebuyensis
Cyperus sp.
Cintractia peribebuyensis
Cintractia peribebuyensis *var.* major
Cystopteris fragilis (L.) Bernh.
Hyalopsora polypodii

Dactylis glomerata L.
Entyloma dactylidis
Dactyloctenium aegyptium Beauv.
Tilletia eleusines
Ustilago sparsa
Dactyloctenium scindicum Boiss.
Ustilago sydowiana
Dahlia coccinia Desf.
Entyloma dahliae
Dahlia variabilis Desf.
Entyloma dahliae
Dahlia sp.
Entyloma dahliae
Verticillium dahliae
Dalbergia paniculata Roxb.
Maravalia pterocarpi
Dalbergia sissoo Roxb.
Polyporus gilvus *forma* lichnoides
Dalbergia volubilis Roxb.
Cercospora dalbergicola
Datura fastuosa L.
Verticillium dahliae
Daucus carota L.
Cercospora apii *var.* carotae
"Dead plants"
Myrothecium roridum
"Dead roots"
Marasmiellus ramealis
Delphinium sp.
Pellicularia rolfsii
Dendrocalamus strictus Nees
Dasturella divina
Dendrocalamus sp.
Dasturella divina
Derris benthami Thw.
Hapalophragmium mysorense
Derris eualata Bedd.
Hapalophragmium anamalaiensis
Derris scandens Benth
Guignardia nilagirica
Dianthus caryophyllus L.
Heterosporium echinulatum
Septoria dianthi
Dianthus sp.
Pellicularia rolfsii
Septoria dianthi
Dichanthium annulatum Stapf
Cylindrosporium dichanthi
Sphacelotheca annulata
Sphacelotheca sahayi
Dichanthium caricosum A. Camus
Sphacelotheca dichanthicola
Dichapetalum gelonioides Engl.
Asterina dichapetali
Meliola dichapetali
Dicliptera cuneata Nees
Puccinia tweediana
Dicliptera sp.
Synchytrium lepidagathidis

Digitaria longiflora Pers.
Ustilago longiflora
Digitaria marginata Link.
Puccinia oahuensis
Septoria graminum
Dimeria ornithopoda Trin.
Phyllachora indica
Dinebra retroflexa Panz.
Sphacelotheca dinebrae
Dioscorea alata L. ?
Cercospora carbonacea
Dioscorea sp.
Phyllosticta dioscoreae
Diospyros melanoxylon Roxb.
Cercospora kaki
Diospyros montana Roxb.
Nitschkia fuckelii
Patellaria atrata
Diospyros tupru B. -Ham.
see *D. melanoxylon*
Dolichos lablab L.
Oidiopsis macrospora
Draba altaica Bunge
Puccinia drabae
Dunbaria ferruginea W. & A.
Synchytrium dolichi
"Dung"
Ascobolus glaber
Humaria pulcherrima
Poronia leporina

Echinochloa colona Link
Ustilago crus-galli
Echinochloa frumentacea Link.
Ustilago crus-galli
Eichornia crassipes Solms.
Fusarium equiseti
Elaeagnus conferta Roxb.
Asterina elaeagni
Meliola elaeagni
Elaeagnus latifolia L.
see *E. conferta*
Elaeocarpus munroi Mast
Catacauma elaeocarpi
Elaeocarpus oblongus Gaertn.
Catacauma elaeocarpi
Elephantopus scaber L.
Angiopsora elephantopodis
Elettaria cardamomum Matt.
Catacauma elettariae
Chlamydomyces palmarum
Pythium vexans
Uredo elettariae
Eleusine coracana Gaertn.
Curvularia lunata
Melanopsichium eleusinis
Pellicularia rolfsii
Eleusine flagellifera Nees
Massarina graminicola
Embelia ribes Burm.
Physalospora anamalaiensis
Pseudopeziza indica
Epichloe cinerea B. & Br.
Phyllosticta epichloes
Eragrostis nigra Nees
Puccinia eragrostidis
Eragrostis pilosa Beauv.
Helminthosporium ravenelii
Eremurus himalaicus Baker
Puccinia eremuri
Erianthus fulvus Nees
Puccinia erianthi
Eriobotrya japonica Lindl.
Pestalotia longi-aristata
Eriophorum comosum Wall.
Arthrinium sporophleum
Eritrichum rupestris Bunge
Erysiphe horridula
Erythrina suberosa Roxb.
Helminthosporium erythrinae
Erythrina sp.
Septoria erythrinae
Eucalyptus ficifolia F. Muell.
Cercospora eucalypti
Eucalyptus globulus Labill.
Pestalotiopsis funerea
Eugenia sp.
Meliola ranganathii
Eulalia argentea Borngn.
see *E. tristachya*
Eulalia tristachya O. Ktz.
Sorosporium crypticum
Euphorbia dracunculoides Ham.
Ustilago euphorbiae
Euphorbia hirta L.
Oidium cyparissiae
Euphorbia hispida Boiss.
Uromyces proeminens
Euphorbia pilosa L.
Uromyces haussknechtii
Euphorbia pilulifera L.
see *E. hirta*

Euphorbia pulcherrima Willd.
Cercospora petila
Eurya japonica Thunb.
Phyllachora cymbispora
Evolvulus alsinoides L.
Cystopus evolvuli
Puccinia bellurensis
Exacum wightianum Arn.
Mycosphaerella exaci

Feronia elephantum Corr.
Septogloeum feroniae
Ficus bengalensis L.
Auricularia polytricha
Ficus carica L.
Cylindrocladium scoparium
Ficus elastica Roxb.
Pestalotia elasticola
Phakopsora fici-elasticae
Phyllosticta roberti
Ficus faveolatus Wall.
Catacauma himalayanum
Ficus religiosa L.
Fusariella concinna
Ficus sp.
Asterina mysorensis
Cercospora kallarensis
Cronartium fici
Meliola bangalorensis
Meliola ficicola
Meliola ovatipoda
Pleosphaeropsis fici
Scopella fici
Fimbriaria sp.
Olpidiopsis ricciae
Fimbristylis annua R. & S. var. *diphylla* Kuk.
Cintractia axicola
Fimbristylis complanata Link.
Cintractia fimbristylidicola
Fimbristylis dichotoma Vahl
Cintractia axicola
Fimbristylis diphylla Vahl.
Cintractia axicola
Fimbristylis monostachya Hassk.
Thecaphora mauritiana
Fimbristylis quinquangularis Kunth
Cintractia axicola
Fimbristylis tenera R. & S.
Cintractia axicola

Flacourtia ramontchi Sher.
Catenulopsora flacourtiae
Flacourtia sapida Roxb.
see *F. ramontchi*
Flacourtia sepiaria Roxb.
Catenulopsora flacourtiae
Flemmingia sp.
Pestalotia albo-maculans
Fluggea leucopyros Willd.
Masseella narasimhani
Fragaria indica L.
Septoria geranii

Garcinia mangostana L.
Asterina garciniae
Gardenia latifolia Ait.
Hemileia gardeniae-thumbergiae
Gardneria sp.
Meliola gardneriae
Geranium collinum Steph.
Puccinia leveillei
Geranium pratense L.
Puccinia leveillei
Geranium rectum Trautv.
Puccinia leveillei
Geranium sp.
Puccinia leveillei
Geum alatum Wall.
Synchytrium gei
Gleicheina linearis Bedd.
Mycosphaerella gleicheniae
Globba bulbifera Roxb.
Taphrina linearis
Globba marantina W.
see G. *bulbifera*
Glochidion neilgherrense W.
Bubakia indica
Glycine javanica L.
Cercospora sojina
Glycine max (L.) Merr.
Uromyces sojae
Glycosmis cochinchinensis Pierre
Phyllachora glycosmidis
Gordonia obtusa Wall.
Exobasidium nilagiricum
Gossypium herbaceum L.
Verticillium dahliae
Gossypium sp.
Pestalotia gossypii

"Gramineae"
Lacellina libyca
"Grasshopper"
Empusa grylli
Grevillea robusta A. Cunn.
Pestalotia banksiana
Grewia asiatica L.
Polyporus gilvus *forma* gilvoides
Grewia betulaefolia Juss.
Catenulopsora grewiae
Grewia populifola Vahl.
see *G. betulaefolia*
Grewia rotundifolia Juss.
Pericladium tiliacearum
Grewia tiliaefolia Vahl.
Pericladium tiliacearum
Phyllosticta sedgewickii
Grewia villosa Willd.
Pericladium grewiae
Endophyllum heliotropii
Gueldenstaedtia (n. sp.?)
Uromyces kondoi
Gymnema sp.
Hemileia mysorensis
Gypsophila cerastioides D. Don.
Septoria gypsophilae *var.* macrospora

Hackelochloa granularis O. Ktz.
Sphacelotheca erythraensis
Hedera helix L.
Aecidium hederae
Hedyotis stylosa Br.
see *Oldenlandia stylosa*
Heliotropium indicum L.
Hemarthria compressa R. Br.
Sphacelotheca rottboelliae
Hemileia canthii B. & Br.
Olpidium uredinis
Heptapleurum venulosum Seem
Mundkurella heptapleuri
Nyssopsora thwaitesii
Heptapleurum sp.
Nyssopsora thwaitesii
Heracleum candicans Wall.
Aecidium stewartianum
Heracleum thomsoni var *glabrior* C. B. Clarke
Puccinia heracleicola
Heracleum sp.
Clyindrosporium hamatum
Heterophragma roxburghii DC.
Phragmidiella heterophragmae
Heteropogon contortus Beauv.
Sorosporium heteropogonicola
Sphacelotheca monilifera
Sphacelotheca zilligii
Heterostemma tanjorense W. & A.
Physalospora heterostemmae
Hevea brasiliensis M. Arg.
Colletotrichum ficus
Oidium heveae
Pellicularia salmonicolor
Heynea trijuga Roxb.
Meliola heyneae
Hibiscus cannabinus L.
Cercospora hibiscina
Phyllosticta hibiscina
Hibiscus esculentus L.
Pythium indicum
Verticillium dahliae
Holarrhena antidysenterica Wall.
Cercospora holarrhenae
Meliola holarrhenae
Holboellia latifolia Wall.
Puccinia holboelliae-latifoliae
Hoya wighti Hk. f.
Phyllosticta butleri
Hoya sp.
Phyllosticta butleri
Hydrocotyle javanica Thunb.
Septoria hydrocotyles
Hygrophila sp.
Doassansia hygrophilae
Hyoscyamus niger L.
Asoochyta kashmiriana

Ichnocarpus frutescens R. Br.
Acervulopsora ichnocarpi
Meliola ichnocarpi
Ilex wightiana Wall.
Sclerotiopsis indica
Imperata cylindrica Beauv.
Ustilago imperatae
Indigofera pulchella Roxb.
Cercospora pulchella
"Insect" (dead)
Allomyces arbusculus
Ischaemum ciliare var. *wallichii*
Phakopsora incompleta
Ischaemum rugosum Salisb.
Sorosporium ischaemi

Ischaemum spathiflorum Hk. f.
Sphacelotheca tonglinensis
Ischaemum sp.
Sphacelotheca tonglinensis
Iseilema laxum Hack
Sclerospora iseilematis
Sorosporium iseilematis
Sphacelotheca inayati
Sphacelotheca iseilematis
Ixora parviflora Vahl.
Cercospora ixorae

Jambosa laeta Bl.
Plowrightia indica
Jasminum brevilobum A. DC.
Chaconia butleri
Hysterostoma brevilobi
Jasminum flexile Vahl
Puccinia jasminicola
Jasminum malabaricum W.
Cercospora jasminicola
Jasminum pubescens Willd
Puccinia exhauriens
Jasminum rigidum Zenk.
Asterina erysiphoides
Cercospora jasminicola
Jasminum ritchiei Cl.
Hemileia jasmini
Jasminum sambac Ait.
Cercospora jasminicola
Jasminum sp.
Cercospora jasminicola
Puccinia exhauriens
Juniperus macropoda Bois.
Gymnosporangium confusum
Justicia betonica L.
Chrysocelis indica
Justicia procumbens L.
Synchytrium lepidagathidis
Justicia sp.
Puccinia shiraiana
Synchytrium lepidagathidis
"jute fibre"
Chaetomium chartarum

Kirganelia reticulata Baill.
Phakopsora kirganeliae
Ravenelia kirganeliae
Kobresia capillifolia C. B. Clarke
Cintractia elynae
Kobresia laxa Boeck.
Cintractia kobresiae
Koeleria cristata Pers.
Tilletia koeleriae
Kordyana celebensis Gäumann
Monotrichum commelinae
Kordyana indica Gäumann.
Monotrichum commelinae
Kydia calycina Roxb.
Meliola kydiae-calycinae
Puccinia anodae

Lactuca decipiens C. B. Clarke
Puccinia prenanthes-purpureae
Lactuca dissecta D. Don.
Bremia ganglioniformis
Lactuca runcinata DC.
Corbulopsora cumminsii
Lactuca scariola L.
Bremia ganglioniformis
Lactuca sp.
Bremia ganglioniformis
Lagenaria vulgaris Ser.
Synchytrium lagenariae
Lagerstroemia parviflora Roxb.
Pestalotiopsis guepini
Lagotis glauca Gaertn.
Puccinia acrophila
Lasiosiphon eriocephalus Dcne.
Irenopsis mysorensis
Lathyrus sativus L.
Fusarium orthoceras *var.* lathyri
Launaea asplenifolia Hook.
Synchytrium vulgatum
Lavatera kashmiriana Camb.
Endophyllum tuberculatum
Lawsonia alba Lam.
Pestalotia lawsoniae
"leaves"
Neogibbera aterrima
Stilbophoma microspora
Leea macrophylla Roxb.
Amazonia leeae
Meliola bakeri
Leea sp.
Meliola bakeri
Pestalotia menezesiana
Leersia hexandra Sw.
Tolyposporium globuligerum
Lepidagathis cristata Wall.
Synchytrium lepidagathidis

Lepidagathis sp.
Synchytrium lepidagathidis
Lettsomia elliptica W.
Cercospora lettsomiae
Trochodium sampathense
Leucas ciliata Benth.
Cercosporella leucadis
Leucas linifolia Spr.
Puccinia leucadis
Leucas stelligera Wall.
Cercosporella leucadis
Leucas vestita Benth.
Cercospora vestita
Limnanthemum indicum Thw.
Physoderma limnanthemi
Linum usitatissimum L.
Oidiopsis lini
Oidium lini
Litsea sp.
Kernella lauricola
Livistona mauritiana Wall.
Stemphylium ilicis
Lobelia trigona Roxb.
Melampsora mundkuri
Lonicera asperifolia H. & T.
Puccinia longirostris
Loranthus longiflorus Desv.
Puccinia luculenta
Loranthus sp.
Uromyces nilagiricus
Lychnis inflata Wall.
Puccinia behenis
Lycopersicon esculentum Mill.
Verticillium dahliae

Macrosiphon solanifolii? (aphid)
Empusa aphidis
Madhuca latifolia Macbridge
Fomes caryophylli
Maerua arenaria Hk. f. & T.
Nitschkia fuckelii
Mallotus albus M. Arg.
Helotium malloti
Irenina malloti
"Man"
Tritirachium viannai
Mangifera indica L.
Aspergillus variecolor
Asterolibertia mangiferae
Fracchiaea heterogenia
Penicillium fellutanum
Pestalotiopsis mangiferae
Pestalotiopsis virgatula
Polyporus gilvus *forma* gilvoides
Manisuris granularis L. f.
see *Hackelochloa granularis*
Manisuris sp.
Sphacelotheca erythraeneis
Mappia foetida Miers
Cylindrosporium mappiae
Marchantia sp.
Olpidiopsis ricciae
Marsdenia volubilis T. Cooke
Aecidium marsdeniae
Medicago sativa L.
Pellicularia rolfsii
Melothria mucronata Cogn.
Mycosphaerella melothriae
Puccinia melothriicola
Memecylon sp.(?) *umbellatum* Burm. f.
Aecidium memyceli
Mezoneurum cucullatum W. & A.
Elsinoe mezoneuri
Mimosa pudica L.
Ramularia mimosae
Mimusops elengi L.
Scopella aulica
Scopella mimusops
Mimusops hexandra Roxb.
Scopella gentilis
Mnesithea laevis Kunth
Sphacelotheca mnesitheae
Mollugo nudicaulis Lam.
Cystopus molluginicola
Monochoria vaginalis Presl.
Burrillia ajrekari
Morina longifolia Wall.
Ustilago morinae
Moringa pterigosperma Gaertn.
Polyporus gilvus *forma* lichnoides
Moringa sp.
Phyllosticta moringicola
Morus alba L.
Cercospora moricola
Massaria mori
Patellaria atrata
Phyllosticta morifolia
"Moss"
Bovistella lycoperdioides
Lycoperdon trachysporum
Mundulea suberosa Benth.
Ravenelia stictica

Murraya koenigii Spr.
Cylindrosporium koenigii
Musa paradisiaca L.
Helminthosporium torulosum
Phyllosticta gastonis
Musa sapientum L.
see *M. paradisiaca*
Myroxylon toluiferum L.
Phyllosticta myroxyli

Neolitsea zeylanica Merr.
Armatella litseae
Astomella neolitseae
Xenostele indica
Nephelium litchi Camb.
Absidia blakesleeana
Aspergillus phoenicis
Aspergillus pseudo-nidulans
Helminthosporium atro-olivaceum
Mucor silvaticus
Penicillium decumbens
Penicillium rugulosum
Pestalotia pauciseta
Syncephalastrum racemosum
Nerium oleander L.
Cercospora nerii-indici
Sphaceloma oleandri
Neyraudia arundinacea Henr.
Ustilago neyraudiae
Nicotiana tabacum L.
Verticillium dahliae
Nothopegia sp.
Uraecium nothopegiae
Notothylas sp.
Olpidiopsis ricciae
Nyctanthes arbortristis L.
Synchytrium nyctanthidis
Nymphaea stellata Willd
Doassansiopsis nymphaeae

Ocimum adscendens Willd.
Puccinia leiocarpum
Ocimum gratissimum L.
Puccinia thomasiana
Odina wodier Roxb.
Polyporus gilvus *forma* gilvoides
Oedogonium sp.
Chytridium olla
Olax wightiana Wall.
Asterina olacicola
Oldenlandia articularis Gamb.
Maravalia ascotela
Oldenlandia stylosa O. Kze.
Maravalia ascotela
Olea dioica Roxb.
Stephanotheca oleae
Ophiorrhiza brunonis W. & A.
Uredo ophiorhizae
Ophiuros corymbosus Gaertn. f.
see *O. exaltatus*
Ophiuros exaltatus O. Ktz.
Sphacelotheca cornuta
Oplismenus compositus Beauv.
Claviceps viridis
Tilletia vittata
"*Orange*"
Sporocybe hybrida
Oropetium thomaeum Trim.
Helminthosporium ravenelii
Orthosiphon glabratus Benth.
Uromyces orthosiphonis
Oryza sativa L.
Balansia oryzae
Curvularia lunata
Neovossia horrida
Trichoconis padwickii
Oryzopsis munroi Stapf.
Urocystis oryzopsidis
Oryzopsis lateralis Stapf.
Ustilago hypodites
Osyris arborea Wall.
Meliola osyridicola
Sphaceloma osyridis
Osyris wightiana Wall.
see *O. arborea*

Panax fruticosa L.
Cercospora panacis
Pancratium sp.
Aecidium crini
Pandanus fascicularis Lam.
see *Pandanus tectorius*
Pandanus tectorius Soland.
Phyllosticta pandanicola
Panicum frumentaceum Roxb.
Curvularia lunata
Panicum javanicum Hk. f.
see *Urochloa panicoides*
Panicum miliaceum L.
Sphacelotheca destruems

Panicum trypheron Schult.
Tilletia narayanaraoana
Panicum sp.
Tilletia vittata
Papaver sp.
Entyloma fuscum
"*Papilionaceae*"
Guignardia nilagirica
Paramignya sp.
Aecidium paramignyae
Cercospora paramignyae
Parthenocissus neilgherriensis Planch.
Uredo neilgherriensis
Paspalum scrobiculatum L.
Claviceps paspali
Pavetta indica L.
Hysterostoma pavettae
Pelargonium sp.
Pythium vexans
Pennisetum ciliare Link.
Sorosporium penniseti
Pennisetum flaccidum Griseb.
Sphacelotheca stewartii
Pennisetum orientale Rich.
Tilletia pennisetina
Pennisetum typhoides Stapf. & Hubb.
Curvularia penniseti
Fusarium poae
Tilletia ajrekari
Tolyposporium senegalense
Peristrophe sp.
Synchytrium lepidagathidis
Perotis indica O. Ktz.
Tilletia ahmadiana
Perotis latifolia Ait.
see *P. indica*
Petroselinum crispum (Mill) Nym.
Septoria petroselini
Phaseolus mungo L.
Synchytrium ajrekari
Synchytrium phaseoli
Phaseolus vulgaris L.
Pythium paroecandrum
Phoebe paniculata Nees.
Kernella lauricola
Scolecosporium phoebei
Phoebe wightii Meissn.
Kernella lauricola
Phoenix sp.
Uleodothis coonoorensis
Phlox sp.
Septoria phlogis
Phyllanthus polyphyllus Willd.
Ravenelia phyllanthi
Phyllanthus reticulatus Poir.
see *Kirganelia reticulata*
Physalis minima L.
Cercospora physalidis
Physalis sp.
Verticillium dahliae
Picris hieracioides L.
Puccinia picridis
Pinus excelsa Wall.
Coleosporium barclayense
Melampsora oblonga
Pinus insularis L.
Cronartium quercuum
Piper betle L.
Oidium piperis
Pellicularia rolfsii
Pythium vexans
Synchytrium piperi
Piper longum L.
Cercospora piperata
Chlamydomyces palmarum
Pythium vexans
Piper nigrum L.
Pestalotia piperis
Plagiochasma sp.
Olpidiopsis ricciae
Plectranthus coetsa Buch-Ham.
Aecidium plectranthicola
Plectronia didyma Kurz
Achorella plectroniae
Poa annua L.
Entyloma irregulare
Poa sp.
Urocystis poae
Photinia notoniana W. & A.
Pseudophacidium photiniae
Polygonum alatum Buch-Ham.
see *P. punctatum*
Polygonum alpinum All.
Puccinia monticola
Polygonum amplexicalue D. Don
Ustilago dehiscens
Polygonum chinense L.
Ustilago tumeformis
Polygonum glabrum L.
Melanopsichium pennsylvanicum

Polygonum punctatum Buch-Ham.
Ustilago nepalensis
Polygonum recumbens Royle
Septoria polygonorum
Polygonum rumicifolium Royle
Ustilago ahmadiana
Polygonum tortuosum D. Don
Puccinia monticola
Polygonum viviparum L.
Puccinia pistortae
Polygonum sp.
Ustilago cordai
Ustilago reticulata
Polytoca barbata Stapf.
see *Chionachne koenigii*
Pompilus sp. (caterpiller)
Cordyceps sphecocephala
Pongamia glabra Went.
Haploravenelia hobsoni
Populus ciliata Wall.
Taphrina populina
Porella sp.
Leptosphaeria porellae
Potamogeton sp.
Doassansiopsis martianoffiana
Potentilla atro-sanguinea Lodd.
Coleroa potentillae
Pothos scandens L.
Irenina pothodis
Pouzolzia bennettiana W.
Cercospora mysorensis
Prangos pabularia Lindl.
Puccinia libani
Puccinia plicata
Premna tomentosa Willd.
Crossopsora premnae-tomentosae
Prinsepia utilis Royle
Mycosphaerella prinsepiae
Prosopis spicigera L.
Botrysosphaeria prosopidis
Patellaria atrata
Psidium guajava L.
Alternaria chartarum
Aspergillus phoenicis
Helminthosporium atro-olivaceum
Monilia sitophila
Penicillium decumbens
Pleosphaeropsis psidii
Syncephalastrum racemosum
Psoralaea corylifolia L.
Phyllosticta psoraleae

Pteridium aquilinum (L.) Kuhn
Uredinopsis macrosperma
Pterocarpus marsupium Roxb.
Maravalia pterocarpi
Pterolobium indicum A. Rich.
Physalospora pterolobi
Pterotheca falconeri Hook.
Puccinia ahmadiana
Puccinia cynodontis Lacroix
Darluca genistalis
Pueraria hirsuta Kurz
Synchytrium puerariae
Pueraria sp.
Synchytrium puerariae
Punica granatum L.
Schizoxylon insigne
Tryblidaria azarae
Pyrus communis L.
Aspergillus japonicus
Penicillium atramentosum
Pyrus lanata Don
Gymnosporangium confusum
Pyrus malus L.
Cercospora mali
Coniothyrium olivaceum
Linospora ochracea
Monochaetia mali
Pythium vexans

Quercus dilatata Lindl.
Polyporus obtusus
Quercus griffithsii Hook. f.
Cronartium quercuum
Quercus incana Roxb.
Pestalotiopsis clavispora
Sphaerotheca lanestris
Quercus semicarpifolia Sm.
Polyporus obtusus
Quercus sp.
Discosia himalayensis

Randia brandisii Gamb.
Dasturella divina
Randia candolleana W. & A.
Dasturella divina
Randia dumetorum Lam.
Dasturella divina
Randia uliginosa DC.
Hemileia thomasii
Ranaunculus hirtellus Royle
Aecidium ranunculacearum

Rauwolfia serpentina Benth.
Mycosphaerella rauwolfiae
Rhamnus wightii W. & A.
Phyllachora rhamni
Rheum webbianum Royle
Ustilago stewarti
Rhododendron campanulatum D. Don
Discosia himalayaensis
Pestalotia macrotricha
? Rhus sp.
Pileolaria indica
Rhynchelytrum roseum Stapf.
Claviceps paspali
Claviceps pusilla
Puccinia tricholaenae
Rhynchosia minima DC.
Uromyces dolicholi
Rhynchospora sp.
Puccinia rhynchosporae
Ribes nigrum L.
Puccinia ribesii-caricis
Riccia himalayensis St.
Phaeosphaerella ricciae
Riccia sp.
Olpidiopsis ricciae
Ricinus communis L.
Botryotinia ricini
Phyllosticta bosensis
Rivea hypocrateriformis Choisy
Trochodium ajrekari
Robinia pseudo-acacia L.
Diplodia profusa
Endothiella robiniae
Rosa moschata Herrm.
Monochaetia depazeoides
Rosa sp.
Cryptostictis caudata
Pestalotia suffocata
Rotala aquatica Lour.
Macrophoma rotalae
Rottboellia exaltata L.f.
Ustilago flagellata
Rubia cordifolia L.
Pseudopeziza rubiae
Rubus lasiocarpus Sm.
see *R. niveus*
Rubus niveus Thunb.
Chlamydomyces palmarum
Phragomotelium mysorensis
Rumex hastatus D. Don.
Septoria acetosae

Rumex nepalensis Spr.
Ramularia decipiens
Rumex orientalis Bernh. ex Schult.
Ramularia decipiens
Rumex sp.
Ustilago parlatorei

Saccharum arundinaceum Retz.
Ustilago courtoisi
Saccharum barberi Jeswit
Ustilago scitaminea *var.* sacchari-barberi
Saccharum ciliare Anderss.
Sphacelotheca sacchari.
Saccharum munja Roxb.
Lacellina libyca
Arrhenia cuculata
Patellaria atrata
Polyporus pusillus
Poronia kurziana
Sorosporium indicum
Sphacelotheca schweinfurthiana
Saccharum officinarum L.
Puccinia sacchari
Ustilago scitaminea *v.* sacchari-barberi
Ustilago scitaminea *v.* sacchari-officinarum
Saccharum spontaneum L.
Lacellina libyca
Ustilago scitaminea *v.* sacchari-barberi
Saccharum sp.
Sphacelotheca erianthi
Sphacelotheca pulverulenta
Saccolepis indica Chase
Sphacelotheca saccolepidis
Sagittaria sp.
Doassansia opaca
Salacia sp.
Chaetothyrium mysorensis
Dimeriella salaciae
Salix hastata L.
Melampsora larici-epitea
Salix oxycarpa Anders ?
Melampsora larici-epitea
Salix tetrasperma Roxb.
Rhytisma salicinum
Salvadora oleoides Dcne.
Mucronella aggregata
Nitschkia fuckelii
Thyridaria incrustans

Valsaria salvadorina
Santalum album L.
Ascochyta santali
Sphaceloma santali
Sapindus emarginatus Vahl.
Cercospora sapindi-emarginati
Saponaria sp.
Pythium indicum
Sarcococca pruniformis Lindl.
Stictis radiata
Satyrium nepalense Don.
Coleosporium satyrii
Saussurea candolleana Wall.
Aecidium saussureae
"Scale insects"
Nectria diploa
Uredinella spinulosa
Schrebera swietenioides Roxb.
Cercospora schreberae
Schuteria vestita W. & A.
Uredo schuteriae
Scirpus articulatus L.
Entyloma scirpicola
Scirpus sp.
Entyloma mysorense
Scleria lithosperma Sw. var. *roxburghii* Thw.
Cintractia scleriae-lithospermae
Scutia myrtina Kurz.
Elsinoe bitancourtiana
Septogloeum scutiae
Selaginella chrysocaulos Spring
Melanopsamma ranjanii
Selinum papyraceum C. B. Clarke
Puccinia ligustici
Senecio alatus Wall.
Coleosporium barclayense
Senecio rufinervis DC.
Coleosporium barclayense
Sesamum indicum L.
Synchytrium sesamicola
Sesbania grandiflora Pers.
Pellicularia rolfsii
Setaria italica Beauv.
Curvularia lunata
Shorea robusta Gaertn.
Fomes caryophylli
Polyporus gilvus *forma* gilvoides
Polyporus gilvus *forma* lichnoides
Shorea talura Roxb.
Cercospora shoreae
Silene latifolia (Mill.) Britt. & Rendle
Puccinia behenis
Sisymbrium irio L.
Peronospora sisymbrii-officinalis
Skimmia laureola Sieb. & Zucc. ex Walp.
Pseudopeziza skimmiae
Smithea bigemina Dalz.
Parodiella smithiae
Soil
Allomyces anomalus
Allomyces arbusculus
Allomyces javanicus
Allomyces javanicus *var.* javanicus
Allomyces javanicus *var.* marcrogynus
Curvularia lunata
Fusarium avenaceum
Fusarium chlamydosporum
Fusarium equiseti
Fusarium javanicum
Fusarium poae
Fusarium scirpi
Fusarium scirpi *var.* acuminatum
Fusarium solani *var.* martii
Fusarium solani *var.* minus
Fusarium solani *var.* striatum
Memnoniella echinata
Trichoderma viride
"Soil"
Battarraea stevenii
Bovista concinna
Calvatia coelata
Clavaria angulispora
Clavaria compressa
Clavaria laeticolor
Clavaria pistillaris
Clavaria pulchra
Coltricia schweinitzii
Cyathus colensoi
Disciseda cervina
Disciseda pedicellata
Geaster mammosus
Geaster triplex
Geastrum clelandii
Geastrum minus
Geastrum simulans
Geoglossum velutipes
Helvella ephippium
Helvella fusca

Humaria pallidisetosa
Hydnellum zonatum *forma* vespertilio
Itajahya rosea
Ithyphallus rubicundus
Lachnocladium brasiliense
Lachnocladium ornatipes
Lamprospora constellatis
Lepiotophyllum rhacodes *v.* puellaris
Leucoagaricus excoriatus
Lycoperdon depressum
Lycoperdon mundkuri
Lycoperdon polymophum
Lycoperdon umbrinum
Lycoperdon wrightii
Macrolepiota procera
Melanogaster ambiguus
Mitrula agharkarii
Mycenastrum corium
Myriostoma coliforme
Octaviania iongiana
Panellus rupicola
Phallus celebicus
Phellorinia inquinans
Phellorinia strobilina
Poronia kurziana
Psathyrella disseminata
Pseudolycoperdon pusillum
Queletia laceratum
Rhizopogon roseolus
Rhizopogon rubescens
Schizostoma mundkuri
Simblum sphaerocephalum
Termitomyces microcarpus
Tylostoma albiceps
Tylostoma albocretaceum
Tylostoma amnicola
Tylostoma balanoides
Tylostoma cineraceum
Tylostoma evanescens
Tylostoma hygrophilum
Tylostoma macalpinianum
Tylostoma membranaceum
Tylostoma operculatum
Tylostoma parvissimum
Tylostoma psilophilum
Tylostoma puncticulosum
Tylostoma pygmaeum
Tylostoma sedimenticola
Tylostoma squamosum
Tylostoma subsquamosum
Tylostoma verrucosum
Tylostoma vulgare
Tylostoma xerophilum
Solanum giganteum Jacq.
Puccinia solani-giganteae
Solanum melongena L.
Ascochyta melongenae
Verticillium dahliae
Solanum tuberosum L.
Fusarium solani *var.* minus
Ozonium texanum *var.* parasiticum
Pellicularia rolfsii
Phytophthora himalayensis
Verticillium dahliae
Sonchus oleraceus L.
Bremia ganglioniformis
Sophora glauca Lesch.
Cercospora sophorae
Sorghum purpureo-sericeum Schweif and Aschers.
Tolyposporium ehrenbergi *var.* grandiglobum
Sorghum vulgare Pers.
Curvularia lunata
Fusarium brachygibbosum
Sphacelotheca reiliana
Titaeospora andropogonis
Spinacia oleracea L.
Alternaria spinaciae
Cladosporium macrocarpum
Colletotrichum spinaciae
Fusarium spinaciae
Heterosporium variabile
Peronospora spinaciae
Spirogyra sp.
Aphanomyces apophysii
Entophlyctis bulligera
Lagenidium entophytum
Pythium catenulatum
Sporobolus indicus R. Br.
Uromyces wellingtonica
Sporobolus pallidus Boiss.
Massarina graminicola
Sporobolus tremulus Kunth
Ustilago sporoboli-tremuli
Stereospermum suaevolens DC.
Mehtamyces stereospermi
Melampsora stereospermi
Synchytrium stereospermi
Stereospermum tetragonum DC.
Melampsora stereospermi

Stipa sibirica Lamk.
Urocystis stipae
Swertia sp.
Leptosphaeria swertiae
Septoria swertiae
Swietenia mahagoni Jacq.
Polyporus gilvus *forma* lichnoides
Symplocos foliosa W.
Camarotella symploci
Symplocos spicata Roxb.
Ascomycetella symploci
Syzigium cumini (L.) Skeds.
Fomes caryophylli
Syzigium montanum Gamb.
Diplodia longipedicellata

Tabernaemontana sp.
Meliola tabernaemontanicola
Tectona grandis L.
Auricularia polytricha
Cercospora tectonae
Chaconia tectonae
Hypomyces haematococcus
Terminalia bellerica Roxb.
Aecidium terminaliae
Terminalia paniculata Roth.
Uredo terminaliae-paniculatae
Thea sinensis L.
Auricularia auricularis
Calonectria theae
Candelospora theae
Corticium dealbans
Glomerella major
Irpex destruens
Irpex subvinosus
Nectria subquarternata
Pellicularia salmonicolor
Pestalotiopsis theae
Polyporus interruptus
Polyporus mesotalpae
Themeda quadrivalvis O. Ktz.
Sphacelotheca bursa
Themeda triandra Forsk.
Sphacelotheca vryburgi
Uromyces triandrae
Thespesia populnea Cav.
Cercosporella thespesiae
Septoria thespesiae
Thevetia neriifolia Juss.
Pleosphaeropsis thevetiae
Thunbergia grandiflora Roxb.
Bombardia hyalina
Tinospora cordifolia Miers.
Cercospora tinosporae
Toddalia aculeata Pers. var. *gracilis*
see *T. asiatica* v. *gracilis*
Toddalia aculeata v. *floribunda*
see *T. asiatica* v. *floribunda*
Toddalia asiatica Lamk.
Gymnopuccinia pulneyensis
Toddalia asiatica Lamk. v. *floribunda* Gamb.
Didymopsorella toddaliae
Meliola toddaliae *var.* toddaliae-asiaticae
Meliola toddalicola *var.* indica
Toddalia asiatica Lamk. v. *gracilis*
Didymopsorella toddaliae
Tragus biflorus Schult.
Ustilago punjabensis
Tricholepis elongata DC.
Puccinia tricholepidis
Trichosanthes dioica Roxb.
Blastotrichum chowdhuryii
Synchytrium trichosanthidis
Trifolium resupinatum L.
Peronospora trifolii-repentis
Physoderma trifolii
Triticum vulgare Host.
Neovossia indica
Tilletia foetida
Urocystis tritici
Triumfetta pilosa Roth
Cercospora pilosa
Triumfetta rhomboidea Jacq.
Cercosporella triumfettae
Tylophora asthmatica W. & A.
Cercospora tylophorae
Tylophora mollisima W.
Arthuria tylophorae
Tylophora tenuis Bl.
Arthuria tylophorae

Uredo amomi Petch
Eudarluca indica
Urochloa panicoides Beauv.
Cercospora fusimaculans
Urochloa reptans Stapf.
Sorosporium digitariae
Urtica dioica L.
Septoria urticae

Urtica parviflora Roxb.
Puccinia caricis *var.* himalayensis
Vaccinium leschnaultii W.
Achorella vaccinii
Exobasidium triseptatum
Vaccinium neilgherrense W.
Exobasidium vaccinii
Vernonia bourneana W. W. Sm.
Angiopsora vernoniae
Vernonia monosis Cl.
Puccinia vernoniae-monosis
Vernonia sp.
Cercospora consimilis
Veronica agrestis L.
Sorosphaera veronicae
Viburnum erubescens Wall.
Puccinia linkii
Viburnum hebanthum W. & A.
Phaeophacidium viburni
Vicia sativa L.
Peronospora viciae-sativae
Vigna catjang Valp.
Cercospora canescens
Vigna unguiculata (L.) Walp.
Myrothecium roridum
Vitis adnata Wall
Catenulopsora vitis
Vitis semicordata Roxb.
Phakopsora ampelopsidis
Vitis trifolia Law.
Catenulopsora vitis
Vitis vinifera L.
Pestalotia menezesiana
Pythium debaryanum *var.* viticolum
Volutarella divaricata Benth
Puccinia volutarellae

Wagatea spicata Dalz.
Cerotelium wagateae
Helminthosporium wagateae
Waltheria indica L.
Cercospora waltheriae
Water
Allomyces arbusculus
Hamidia indica
Isoachlya anisospora *var.* indica
Pythium carolinianum
Pythium periplocum *var.* coimbatorensis
Wedelia urticaefolia DC.
Uromyces piauhyensis
Uromyces wedeliae-biflorae
Wood
Auricularia auricularis
Auricularia polytricha
Auricularia fusco-succinea
Auricularia tenuis
Calocera cornea
Calocera striata
Clavicorona pyxidata
Coltricia acupunctata
Coprinus micaceous
Coriolus sinulosus
Dacryomitra glossoides
Dacryopinax spathularia
Daedalea stereoides
Daedalea subferruginea
Daldinia concentrica
Fomes scruposus
Fomitopsis ochroleuca
Ganoderma annulare
Glonium lineare
Hypocrea citrina
Lenzites tenuis
Lenzites unicolor
Polyporus circinatus
Polyporus dictyopus
Polyporus gilvus *forma* gilvoides
Polyporus gilvus *forma* lichnoides
Polypous personatus
Polyporus radiatus
Polystictus grammocephalus
Psathyrella disseminata
Pythium myriotilum
Sirobasidium indicum
Stereogloeocystidium spadiceum
Stereogloeocystidium vibrans
Strobilomyces kalimpongensis
Truncospora ochroleuca
Wrightia tinctoria R. Br.
Cercospora wrightiae
Hemileia wrightae
Wrightia tomentosa R. & S.
Hemileia wrightiae

Zea mays L.
Curvularia lunata
Ustilago maydis
Zingiber officinale Rosc.
Phyllosticta zingiberi

Pythium vexans
Zizania latifolia (Griseb.) Turz.
Melanopsichium esculentum
Zizyphus jujuba Lam.
Alternaria chartarum
Aspergillus luchuensis
Aspergillus nanus
Aspergillus parasiticus
Helminthosporium atro-olivaceum
Heterosporium interseminatum
Patellaria atrata
Penicillium decumbens
Penicillium rugulosum
Stemphyliomma valparadisiacum
Syncephalastrum racemosum
Zizyphus numularia W. & A.
Cercospora zizyphi
Zizyphus oenoploea Mill.
Catenulopsora zizyphi
Cercospora zizyphi
Zibyphus rugosa Lam.
Meliola zizyphi

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A PRELIMINARY STUDY ON SOME INTER-VARIETAL CROSSES AND HYBRID VIGOUR IN *HIBISCUS ESCULENTUS* L.*

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ABSTRACT

Six varieties and seven intervarietal crosses of "bhendi", Hibiscus *esculentus*, were studied in some detail. The varieties differed from one another in many respects. The immediate effect of crossing on the height, nature of leaf lobing and petal spot, earliness in flowering, fruit and yield of fruit per plant was determined and the various observations made are detailed in the text.

The hybrid plants were intermediate between the parental ones in height, and they flowered as early as or earlier than the early flowering parent. The crosses produced fruits which were either intermediate between the parental ones in size or slightly longer. In general, they produced more fruit per plant than the parents and increase in total yield was obtained in five crosses over both the parents, the improvement ranging from 5·4 to 14·5 per cent. over the better parent and 3·6 to 59·3 per cent. over the poorer parent. No improvement over both the parents was registered in one case.

The earliness in flowering and increase in number and yield of fruit per plant obtained in some of the crosses at least indicate the importance of using hybrid vigour in the improvement of commercial varieties of this vegetable.

Hybrid vigour in plants is indeed a double attraction (Whaley, 1944), affording as it does (i) ideal opportunities for the study of certain features of developmental genetics, and (ii) a possible method of improving crop plants. There is increasing indication that the systematic exploitation of this vigour offers unique possibilities in many commercial crops and that its practical application is of considerable value to agriculture and horticulture alike (Ashton, 1946). This paper deals with seven intervarietal crosses of the "bhendi", *Hibiscus esculentus*. The data

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presented herein were obtained from a few small scale exploratory trials, nevertheless they provide some information of practical interest.

Materials and Methods

Materials:

Fifty-eight seed samples were obtained from various sources in the country and out of the twenty-eight pure breeding ones representing sixteen distinct varieties (Venkataramani, 1949) the following six were chosen for a detailed study: "P. 13", "Mullu", "Pal", "Long Green W. V.", "Long Green R_8 P_5" and "Podugu". The original seed material was sown at one time, the second and subsequent sowings were made with seed selected from the previous crop. All these sowings were made at the University Botany Laboratory, Madras during the years 1945-1948 on compact areas forming fresh sites for each sowing. The raising of the crop and its maintenance throughout the course of the study conformed to recognized cultural practices.

Methods:

(i) *Comparison of varieties and hybrids*: The comparison of the six varieties was based on single plant selections. The experimental material consisted of ten plants (replicates) in each variety, the layout being of a randomised block design. In the case of the hybrids, they were compared with their respective parents, all the data being based on six plants (replicates) each of the hybrid and its parents. The results on the time taken to flower, length of fruit, number of fruits and total yield per plant were analysed statistically. All these data for comparison were mainly gathered from the crops raised during the summer months, as certain earlier studies indicated that optimum growth and yield were only obtained during that period (Venkataramani, 1945).

(ii) *Inter-varietal Crosses:* (a) *Emasculation:* For emasculation it was desirable to choose flower buds that had reached their maximum size, i.e., a day prior to anthesis. The size of the flower bud at this stage appeared to be a definite varietal character (Fig. 9) and in the case of the varieties under study it varied as follows: 4.8, 3.6, 3.3, 3.0, 3.0 and 2.7 cm. for the varieties "Long Green W. V.", "Long Green R_8 P_5", "Podugu", "P. 13", "Mullu" and "Pal" respectively (Venkataramani, 1949). It was, therefore, possible to spot out the flower bud at the right stage of development.

TABLE 1. *showing the characters of six "bhendi" varieties*

Particulars	P. 13	Pal	Mullu	L. Green W. V.	L. Green R_8 P_5	Podugu	Critical difference $P = 0{\cdot}05$
†Height in cm.	138·3	125·0	68·6	87·5	132·4	87·5	
Stem colour and hairiness	Green red and smooth	Green red and slightly hairy	Red and hairy	Dark green and smooth	Green red and hairy	Green red and smooth	
Leaf lobing	Deep	Shallow	Shallow	Shallow	Shallow	Deep	
Petal spot	Inside	Both sides	Both sides	Inside	Both sides	Both sides	
§Time of flowering in days	30 (29·6)	41 (40·6)	40 (39·7)	44 (43·5)	40 (39·7)	35 (34·9)	1·4
Fruit colour and spines	Light Green and spineless	White and spineless	Red and spiny	Light Green and spineless	Dark green and spiny	Light Green and spineless	
*Fruit length in cm.	9·3	7·3	8·4	12·1	11·4	15·4	0·3
No. of fruits per plant	20 (20·1)	16 (15·6)	20 (20·3)	12 (12·0)	15 (15·0)	15 (14·8)	1·2
*Weight of one fruit in g.	13·2	19·8	15·0	19·0	22·9	28·2	
Yield per plant in g.	264·0	321·6	297·0	221·8	343·9	422·0	11·5

* At the "vegetable stage", *i.e.*, on the seventh day after flowering.
† Distance between the cotyledonary node and the terminal bud when the plant ceased to flower.
§ The number of days taken to flower from the date of sowing the seed.

Two methods of emasculation were tried. The first (Fig. 6d) was in all essentials the same as that followed by Miller and Wilson (1937). Although this method was quite successful, it sometimes caused appreciable loss of flowers as the stylar column and the ovary were injured while slitting open the staminal tube. This defect was eliminated in the second method by removing the anthers only, leaving the staminal tube as it were protecting the enclosed delicate style and ovary (Fig. 6c). To avoid the bursting of the anthers a sharp scalpel was run from the top to the bottom of the staminal tube removing the anther lobes. Emasculation was generally done late in the evening and the treated flowers were bagged with thin muslin or paper bags which were tied securely to the pedicels. Early next morning the stigmatic lobes of the emasculated flowers were dusted with pollen obtained from bagged flowers of the staminate parents. The flowers thus treated were once again bagged to prevent any chance contamination from foreign pollen. The bag was removed after two or three days by which time the stigma had withered.

(b) *Crosses made:* The following crosses were studied:

♀	♂
(i) "Mullu"	× "Long Green W. V."
(ii) "P. 13."	× "Mullu"
(iii) "P. 13."	× "Pal"
(iv) "Long Green R_8 P_5"	× "Long Green W. V."
(v) "Podugu"	× "Long Green R_8 P_5"
(vi) "Mullu"	× "Long Green R_8 P_5", and
(vii) "Pal"	× "Podugu".

Experimental

1. *Comparison of six varieties:*

Table 1 presents the details of observations made on six varieties which varied from each other in many respects.

(a) *Plant height:* The average height of the plant in the different varieties ranged from 68·6 to 138·3 cm. The variety "P. 13" was the tallest, while the variety "Mullu" attained the minimum height.

(b) *Stem colour:* Three grades of colour were observed, viz., pure green, pure red or purple, and admixture of red and green.

(c) *Leaf lobing:* The leaf was deeply lobed in two varieties, while in the remaining four the lobing was shallow (Fig. 8).

TABLE 2 *showing the characters of the varieties "Mullu" and "Long Green W.V." and their hybrid.*

Particulars	A Mullu	B Long Green W.V.	C Mullu × Long Green W.V.	C.D. P = 0·05	Remarks
Height in cm.	68·6	87·5	81·4		
Stem colour and hairiness	Red and hairy	Dark green and smooth	Green with Red and hairy		
Leaf lobing	Shallow	Shallow	Shallow		
Petal spot	Both sides	Inside only	Both sides		
Time of flowering in days	40 (39·5)	44 (43·6)	40 (39·6)	2·4	$\overline{A\ C\ B}$
Fruit colour and spines	Red and spiny	Light green and smooth	Green with reddish tinge		
Fruit length in cm.	8·3	12·1	10·4	0·4	B C A
No. of fruits per plant	20 (19·8)	12 (11·6)	18 (17·8)	1·7	A C B
Weight of one fruit in g.	14·8	18·4	18·7		
Yield per plant in g.	295·3	220·8	338·1	9·6	C A B

TABLE 3 *showing the characters of the varieties "P. 13" and "Mullu" and their hybrid.*

Particulars	A P. 13	B Mullu	C P. 13 × Mullu	C.D. P = 0·05	Remarks
Height in cm. ..	138·3	68·6	120·0		
Stem colour and hairiness ..	Green red and smooth	Red and hairy	Green red and hairy		
Leaf lobing ..	Deep	Shallow	Deep		
Petal spot ..	Inside only	Both sides	Both sides		
Time of flowering in days ..	31 (30·8)	41 (40·5)	31 (31·0)	2·3	A C B
Fruit colour and spines ..	Light green and smooth	Red and spiny	Light green with reddish tinge and spiny		
Fruit length in cm. ..	8·9	8·2	9·2	0·4	$\overline{C\ A}\ B$
No. of fruits per plant ..	20 (20·0)	19 (19·3)	24 (24·0)	1·9	$C\ \overline{A\ B}$
Weight of one fruit in g. ..	12·7	15·3	10·9		
Yield per plant in g. ..	254·5	291·8	263·7	4·7	B C A

(d) *Petal spot:* In four of the varieties the petal spot was found on both sides and in the other two, only on the inside of the petal (Fig. 7).

(e) *Fruit:* The fruits of the different varieties were either light green, dark green, white or red in colour. In two varieties they were spiny. In length they ranged from 7·3 to 15·4 cm., those of "Pal" and "Podugu" being the shortest and the longest respectively. From the point of view of the weight of the individual fruit the variety "Podugu" showed the maximum weight of 28·2 g., while the minimum of 13·2 g. was recorded in "P. 13". The varieties "P. 13" and "Mullu" produced a maximum of 20 fruits per plant, while a minimum of 12 was recorded in the variety "Long Green W. V." In total yield, the variety "Podugu" topped the list with an average of 422·0 g. of fruit per plant.

2. *Intervarietal Crosses:*

(i) *Hybrid I.* "Mullu" ♀ X "Long Green W. V." ♂.

Table 2 presents the details of observations made on this hybrid.

The hybrid was intermediate in height; the dark green colour of the vegetative parts was a recessive character. The hybrid flowered as early as the early flowering parent and the fruit was intermediate in size (Fig. 4), green with a reddish tinge. In yield, the hybrid showed an increase of 14·5 per cent. over the better parent and 53·1 per cent. over the poorer parent, but the number of fruit produced per plant was intermediate between the parental numbers.

(ii) *Hybrid II.* "P 13" ♀ X "Mullu" ♂.

The hybrid and its parents are compared in Table 3.

The hybrid plant was intermediate in height, the stem being of the same colour as that of the parent "P. 13". The deep lobing of the leaf appeared to be a dominant character; the petal spot was prominent on both sides of the petal base. The hybrid flowered as early as the early flowering parent and the fruit was as long as that of the variety "P. 13" (Fig. 10), light green with a slight reddish tinge. The spiny character of the plant "Mullu" was to an extent observable in both the vegetative parts and the fruit of the hybrid. In the number of fruit produced per plant, the hybrid showed a significant increase over that of the parents, but in total yield per plant on weight basis a decrease of 9·6 per cent. over the better

parent and an increase of only 3·6 per cent. over the poorer parent were recorded.

(iii) *Hybrid III.* "P. 13" ♀ X "Pal" ♂.

Table 4 presents the details of this hybrid.

In this case also the hybrid plants were intermediate in height. The deep lobing of the leaf appeared to be a dominant feature and so also the presence of the petal spot on both sides of the petal. The hybrid flowered as early as the early flowering parent. The hybrid fruit was intermediate in length between those of the parents (Fig. 11). In yield, an increase was found both in the number of fruit per plant and on total weight, with an increase of 10·8 and 36·1 per cent. over the better and the poorer parents respectively.

(iv) *Hybrid IV.* "Long Green R_8P_5" ♀ × "Long Green W. V." ♂.

This hybrid is compared with its parents in Table 5.

In height this hybrid too was intermediate between the parents. Although on an average it flowered earlier than the early parent by three days, the differences were not found to be significant. The dark green colour of the variety "Long Green R_8P_5" seemed to be dominant over the light green colouration of "Long Green W. V." The hybrid fruit was longer than that of either parent (Fig. 1), and in yield an increase of 5·4 and 59·3 per cent. over the better and the poorer parents respectively was obtained. This hybrid had inherited the spiny character of the variety "Long Green R_8P_5".

(v) *Hybrid V.* "Podugu" ♀ × "Long Green R_8P_5" ♂.

Table 6 compares this hybrid with its parents.

The hybrid plant was intermediate in height, the deep lobing character of the leaf was dominant over the shallow lobing one, and the dark green colour of the fruit was dominant over the light green colour. The hybrid plant flowered as early as the early flowering parent and its fruit was as long as that of the parent "Podugu" (Fig. 2). In yield, it produced a larger number of fruits than those of either parent, but on the total weight basis a decrease of 17·2 per cent. over the better parent was noticed, while the difference between the yields of the hybrid and the poorer parent was not significant.

TABLE 4 *showing the details of the varieties "P. 13" and "Pal" and their hybrid.*

Particulars	A P. 13	B Pal	C P. 13 × Pal	C. D. P = 0·05	Remarks
Height in cm.	138·3	125·0	134·5		
Stem colour and hairiness	Green red and smooth	Green red and slightly hairy	Green red and smooth		
Leaf lobing	Deep	Shallow	Deep		
Petal spot	Inside only	Both sides	Both sides		
Time of flowering in days	30 (30·1)	41 (40·5)	31 (30·5)	2·6	$\overline{A\ C}$ B
Fruit colour and spines	Light green and smooth	White and smooth	Light green and smooth		
Fruit length in cm.	9·1	7·5	8·2	0·2	A C B
No. of fruits per plant	20 (20·3)	17 (16·5)	21 (21·0)	2·8	$\overline{C\ A}$ B
Weight of one fruit in g.	13·0	18·8	16·8		
Yield per plant in g.	260·1	319·5	354·0	11·2	C B A

TABLE 5 *showing the characters of the varieties "Long Green R_8P_5" and "Long Green W.V." and their hybrid.*

Particulars	A Long green R_8P_5	B Long green W.V.	C $R_8P_5 \times$ W.V.	C.D. P = 0·05	Remarks
Height in cm. ..	132·4	87·5	129·6		
Stem colour and hairiness ..	Green Red and hairy	Pure green and smooth	Green Red and hairy		
Leaf lobing ..	Shallow	Shallow	Shallow		
Fetal spot ..	Both sides	Inside only	Both sides		
Time of flowering in days ..	41 (40·5)	43 (42·6)	38 (38·0)	2·9	$\overline{C\ A\ B}$
Fruit colour and spines ..	Dark green and spiny	Light green and spineless	Dark green and spiny		
Fruit length in cm. ..	10·8	11·9	13·2	0·5	C B A
No. of fruits per plant ..	15 (14·8)	11 (11·3)	16 (16·3)	2·2	$\overline{C\ A\ B}$
Weight of one fruit in g. ..	22·8	20·6	22·6		
Yield per plant in g. ..	343·1	227·1	361·8	9·5	C A B

(vi) *Hybrid VI.* "Mullu" ♀ × "Long Green R_8P_5" ♂.

The details of the plant characters of the hybrid and its parents are given in Table 7:

In this hybrid the green-red colouration of the stem was dominant over the pure red. The cross was intermediate in height and earliness of flowering was not observed. In length, the hybrid fruit was intermediate between the parental ones (Fig. 5). An increase in yield of 12·8 and 27·9 per cent. over the better and the poorer parents was obtained.

(vii) *Hybrid VII.* "Pal" ♀ × "Podugu" ♂.

Table 8 presents the different characters of the hybrid in comparison with those of its parents.

In height the hybrid plant was intermediate between the parents, the leaf was deeply lobed as in the staminate parent, and the hybrid flowered 3 days earlier than the early flowering parent. The light green colour of the fruit was dominant over the pure white colour. In fruit length, the hybrid fruit was intermediate between the parental fruits (Fig. 3), and an increase in the number of fruits produced per plant was observed. An increase in total yield of 5·4 and 37·8 per cent. over the better and the poorer parents respectively was obtained.

From a study of these seven inter-varietal crosses it was observed that:

(1) the hybrid plant was intermediate in height,

(2) the deep lobing of the leaf was dominant over the shallow lobing character,

(3) the dark green colouration of the plant parts appeared to be dominant over the light green colouration, whereas the green colouration in general was recessive to the green-red colouration of the vegetative parts,

(4) the hybrids flowered either as early as or earlier than the early flowering parent,

(5) the hybrid fruit was either intermediate in size or longer than the parental ones,

(6) the number of fruits produced per plant by the hybrid was either more than those of the parents or intermediate between the parental ones,

TABLE 6 *showing the details of the varieties "Podugu" and "Long Green $R_8 P_5$" and their hybrid.*

Particulars		A Podugu	B Long green $R_8 P_5$	C Podugu × L. G. $R_8 P_5$	C. D. P = 0·05	Remarks
Height in cm.	..	87·5	132·4	126·0		
Stem colour and hairiness	..	Green Red and smooth	Green Red and hairy	Green Red and hairy		
Leaf lobing	..	Deep	Shallow	Deep		
Petal spot	..	Both sides	Both sides	Both sides		
Time of flowering in days	..	35 (34·8)	40 (40·1)	33 (32·5)	2·6	$\overline{C\ A}$ B
Fruit colour and spines	..	Light green and spineless	Dark green and spiny	Dark green and slightly spiny		
Fruit length in cm.	..	14·9	11·1	15·2	0·3	$\overline{C\ A}$ B
No. of fruits per plant	..	15 (14·5)	15 (14·6)	18 (17·6)	2·2	C $\overline{B\ A}$
Weight of one fruit in g.	..	28·1	22·8	19·4		
Yield per plant in g.	..	422·0	341·5	349·1	10·4	A $\overline{C\ B}$

TABLE 7 *showing the details of the varieties "Mullu" and "Long Green $R_8 P_5$" and their hybrid.*

Particulars		A Mullu	B L. Green $R_8 P_5$	C Mullu × L. Green $R_8 P_5$	C. D. P = 0·05	Remarks
Height in cm.	..	68·6	132·4	124·5		
Stem colour and hairiness	..	Red and hairy	Green Red and hairy	Green Red and hairy		
Leaf lobing	..	Shallow	Shallow	Shallow		
Petal spot	..	Both sides	Both sides	Both sides		
Time of flowering in days	..	40	40	39	..	$\overline{C\ A\ B}$
Fruit colour and spines	..	Red and spiny	Dark green and spiny	Dark green and spiny		
Fruit length in cm.	..	8·3	11·1	9·9	0·5	B C A
No. of fruits per plant	..	20 (19·8)	15 (15·0)	17 (17·3)	1·4	A C B
Weight of one fruit in g.	..	14·8	22·3	22·2		
Yield per plant in g.	..	295·6	335·3	378·3	10·6	C B A

TABLE 8 *showing the details of the varieties "Pal" and "Podugu" and their hybrid.*

Particulars	A Pal	B Podugu	C Pal × Podugu	C.D. P = 0·05	Remarks
Height in cm.	125·0	87·5	118·6		
Stem colour and hairiness	Green Red and slightly hairy	Green Red and smooth	Green Red and smooth		
Leaf lobing	Shallow	Deep	Deep		
Petal spot	Both sides	Both sides	Both sides		
Time of flowering in days	41 (40·5)	35 (35·3)	32 (32·3)	1·9	C B A
Fruit colour and spines	White and smooth	Light green and smooth	Light green and smooth		
Fruit length in cm.	7·4	15·0	10·2	0·4	B C A
No. of fruits per plant	16 (15·6)	15 (14·5)	18 (17·8)	1·6	C A B
Weight of one fruit in g.	20·3	28·2	24·8		
Yield per plant in g.	324·3	424·0	447·0	19·6	C B A

(7) an increase in yield over both the parents was obtained in five out of the seven crosses and over the poorer parent in one cross, while one did not register any improvement, and

(8) in general, hybrids between widely differing varieties showed a greater extent of vigour than those between varieties without much marked difference in their characters.

Discussion

An attempt was made to determine the effect of crossing on certain plant characters and the possibilities of exploiting hybrid vigour for increasing yields in the "bhendi", *Hibiscus esculentus*. In all the seven F_1 crosses, the height of the hybrid plant was intermediate between that of the parents, an observation in agreement with that of Miller and Wilson (1937). In an interspecific hybrid between *Hibiscus esculentus* and *H. Manihot*, Chizaki (1934) too found the cross to be intermediate between the parents. Singh, Chakravorti and Kapoor (1938), however, observed the cross between *Hibiscus ficulneus* and *H. esculentus* to be taller than the parental strains. Miller and Wilson (1937) also observed that strains producing fruit free of spines in the early part of the season produced spines later in the season and that this factor had prevented any conclusion on the mode of inheritance of this character. Such a feature was not, however, met with in the present study and the fruit of the spineless varieties remained spineless throughout. Spines occurred in the cross, though not to the same extent as in the spiny parent.

Two characters deserve mention: (i) earliness in flowering, and (ii) increase in yield. The hybrids flowered as early as or earlier than the early flowering parent and improvement was noted in the number and weight of fruit produced per plant. An increase in yield over both the parents was obtained in five out of the seven crosses and over the poorer parent alone in one cross. A marked decrease over the better parent was recorded only in one instance. Vijayaraghavan and Achyutha Wariar (1946) too observed evidence of hybrid vigour in regard to the number, size and weight of fruits in some F_1 varietal crosses of this vegetable. Increased yields and earliness of flowering have also been recorded in the brinjal, *Solanum melongena*, (Kakizaki, 1931: Daskaloff, 1941; Venkataramani, 1946; and Pal and Singh, 1949), and in several other vegetables too (Barrons, 1943; Deshpande, 1933; Hutchins, 1938; Nicolaisen, 1934; Subbiah Pillai, 1934; and others).

Although there are possibilities of increasing the yields of many vegetable crops by means of hybrid varieties, the practical utilization of this most promising line of improvement is partially limited by the wide variation in the extent of improvement between the F_1 progeny of different parental combinations and partly by the failure of some crosses to register any improvement over the parental varieties. The possibility of decreased yield through such intervarietal crossing though confined to only a single instance in the present study is sufficient to warrant the necessity for a detailed investigation with the object of determining the right parental combinations. The variation of vigour exhibited by different combinations of varieties has been observed in other vegetables too, and different degrees of hybrid vigour have been recorded depending on the morphological features and genetic diversity of the varieties crossed (Kakizaki, 1931; Keppler, 1941; Larson, 1941; Powers, 1945 and others). It is also known that the manifestation of hybrid vigour is to some extent influenced by the environment (Pal and Ramanujam, 1944; Currence, Larson and Virta, 1944), and this aspect needs further attention in large scale production of hybrid type vegetables. The data presented in this communication, though based on information secured from a limited number of plants, are suggestive of the potentialities. These preliminary observations on the influence of crossing on the performance of the first generation hybrid plants, it is hoped, will provide the necessary background for bringing about effective improvement through the use of hybrid vigour in this vegetable crop.

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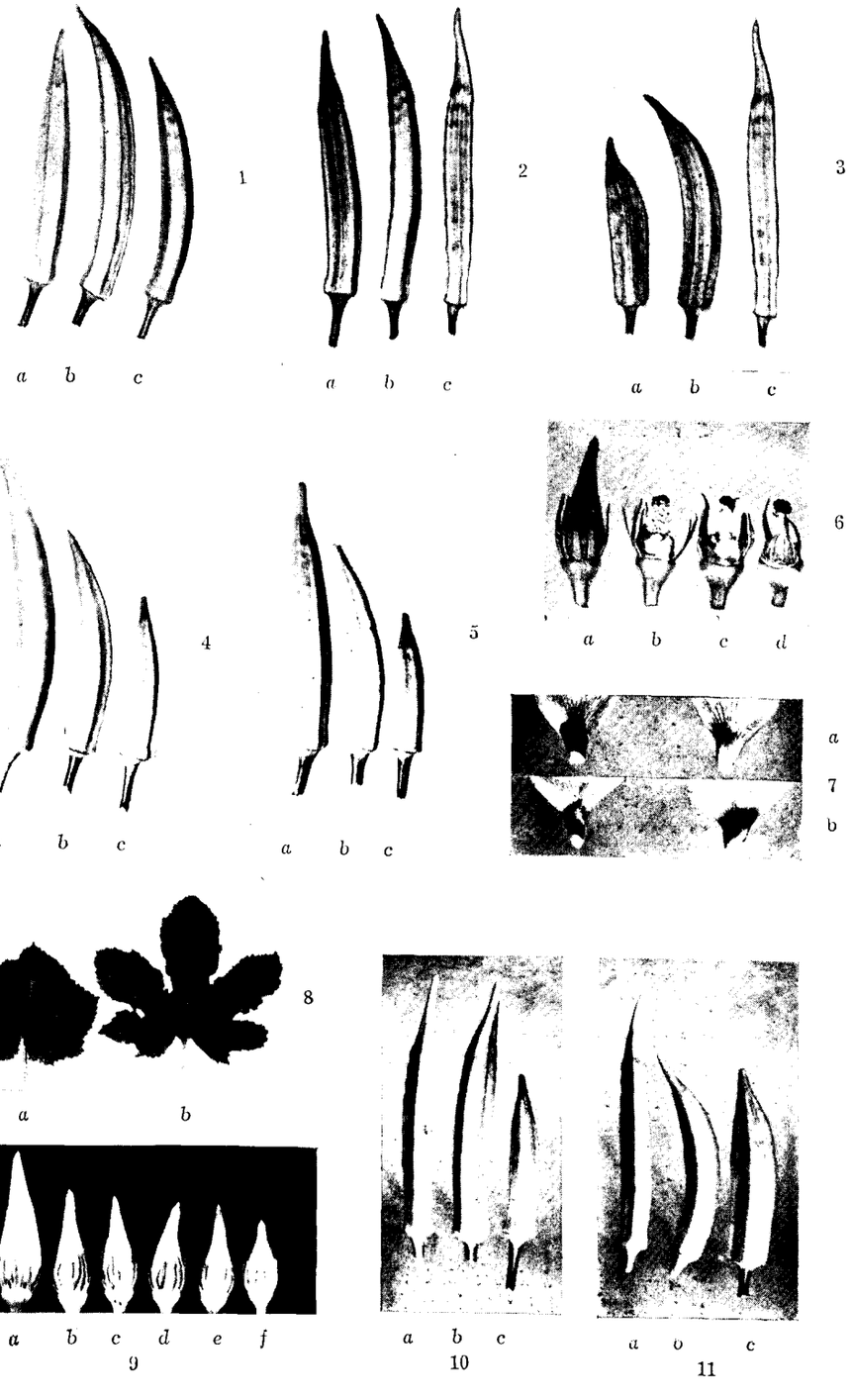
EXPLANATION OF PLATE I

Figs. 1 to 5, 10 and 11 show fruits of the hybrids in comparison with those of their respective parents. *Fig.* 1—(a) Long Green R_8P_5, (b) Long Green R_8P_5 × Long Green W. V., (c) Long Green W. V. *Fig.* 2—(a) Long Green R_8P_5, (b) Podugu × Long Green R_8P_5, (c) Podugu. *Fig.* 3—(a) Pal, (b) Pal × Podugu, (c) Podugu. *Fig.* 4—(a) Long Green W. V., (b) Mullu × Long Green W. V., (c) Mullu. *Fig.* 5—(a) Long Green R_8P_5, (b) Mullu × Long Green R_8P_5, (c) Mullu. *Fig.* 10—(a) P. 13, (b) P. 13 × Mullu, (c) Mullu. *Fig.* 11—(a) P. 13, (b) P. 13 × Pal, (c) Pal. *Fig.* 6 shows flower buds before and after emasculation. Note the staminal tube covering the style and ovary in (c). *Fig.* 7 shows the presence of the petal spot on (a) the inside of the petal base only, and (b) on both sides. *Fig.* 8 shows the two types of leaf lobing—(a) shallow and (b) deep. *Fig.* 9 shows flower buds at full maturity in the six varieties: (a) Long Green W. V., (b) Long Green R_8P_5, (c) Podugu, (d) P. 13, (e) Mullu, and (f) Pal.



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A NOTE ON THE DETERMINATION OF REDUCING SUGARS

BY

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Abstract

A volumetric procedure for determining reducing sugars which finds application in biological work is outlined. The effect of some of the common substances used in the preparation of synthetic nutrient media on the oxidation of sugars by alkaline ferricyanide has been studied.

In connection with a physiologic study of soil-fungi in pure cultures a need for a suitable analytical procedure for rapid determination of reducing sugars in substrate was felt.

In recent years, the procedure of clarification of alkaline ferricyanide by the reducing sugars of Hassid (1936, 1937), modified and extended by Forsee (1938) for photoelectric colorimetric determinations has been resorted to. Forsee's technique like Hoffman's (1937) is that when a solution of alkaline ferricyanide is heated with reducing sugars the intensity of yellow colour becomes diminished which permits a colorimetric estimation. This procedure modified by Morell (1941) represents a three-fold increase in the concentration range.

In the volumetric procedure of Hagedorn and Jensen (1923) and its macro-modification by Hanes (1929) the titrations were conducted on the unreduced residual ferricyanide solution by the iodometric method. Further, it was found that the method of Hagedorn and Jensen was superior to that of Folin and Wu (1919, 1920) in the estimation of blood sugar (Reid, 1950). Experimental evidence of Forsee (1938) and Hassid (1936, 1937) prove conclusively the validity of the ferricyanide method when compared with alkaline copper salts method.

Following Lane and Eynon (1923) who used methylene blue as an internal indicator in determining reducing sugars by the alkaline copper salts method, Coles (1933) evolved a volumetric

procedure whereby a one per cent solution of alkaline ferricyanide was titrated against reducing sugar solution using methylene blue as an internal indicator.

The method outlined below is an extension of Cole's procedure and gives accurate results down to 0·01 per cent reducing sugars in solution and has been used as a routine analytical method in the University Botany Laboratory and Madras Christian College Chemical Laboratory for the past three years.

Reagents: All chemicals used were Analar grade.

1% solution of Potassium ferricyanide in distilled water.

1% solution of Methylene blue in distilled water.

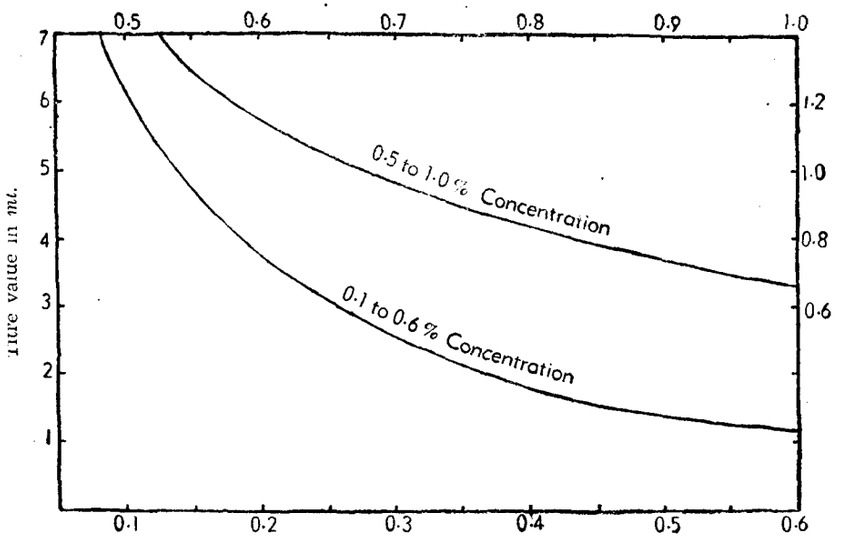
8N Hydrochloric acid (Standardized against standard alkali)

2·5N Sodium hydroxide (Standardized against standard acid)

Sucrose: This was maintained in a moisture free chamber at 45°C. for 48 hrs. prior to weighing out.

Hydrolysis of sucrose was carried out for 20 minutes on a water bath at 70°C. by the addition of 4 ml. of 8N hydrochloric acid to 70 ml. of solution containing the required amount of sugar and finally diluting to 100 ml. For concentrations ranging from 5·0% — 0·2%, 1·0% — 0.1%, and 0·1% — 0·01% sugar, 10, 5 and 1 ml. of one per cent solution of ferricyanide was used respectively for oxidation.

Procedure: The requisite amount of ferricyanide solution was pipetted out into a 100 ml. conical Pyrex flask followed by 10 ml. of alkali and 10 ml. of distilled water. The flame of the burner was so adjusted that the contents of the flask started boiling in 90 seconds and maintained there throughout the course of titration, small Pyrex glass heads being added to prevent local heating and consequent bumping. A micro-pipette reading to 0·02 ml. whose tip was held at the mouth of the flask enabled to wash down traces of sugar solution at the tip by the steam issuing out of the flask. A drop of methylene blue added when the yellow colour of the contents of the flask was notably reduced by the sugar solution decolourised at the end point. The whole titration was finished in three minutes as recommended by Coles. Titre values obtained plotted against sugar concentrations gave standard curves (Text-fig. 1.).



These curves were utilized to determine the sugar content of test solutions by straight away reading off the concentration for the titre value obtained during analyses.

Validity of the method: Since almost all fungal culture solutions contain nitrates, nitrites, phosphates, sulphates, urea, peptone and ammonium salts, the estimation of sugars was carried out in the presence of these substances and the results are tabulated in Tables I and II.

TABLE I. *Showing the percentage recovery of sugar from solutions containing 5% of chemical compounds*

Sugar in gm. %	Percentage recovery in the presence of chemicals used				
	KNO_3	KNO_2	Urea	NH_3 0·89 Sp. grty.	Peptone *
5·0	100	100	100	100	100
2·5	100	100	100	100	100
1.25	96	100	100	100	100
0·625	98	100	98	98	100
0·3	100	98	98	98	100
0·1	98	98	98	98	98
0·05	98	98	98	98	98
0·02	98	100	100	100	98

* at 1% concentration.

TABLE II. *Showing the percentage recovery of sugar from solutions containing 1% of ammonium salts*

Sugar in gm. %	Percentage Recovery					
	Phosphate	Sulphate	Acetate	Oxalate	Tartrate	Citrate
5	100	100	100	100	100	100
2·5	100	100	100	100	100	100
0·625	100	100	100	100	100	100
0·05	98	98	98	98	100	98

The foregoing tables indicate the utility of the method over a wide range in the presence of the chemicals usually found in synthetic nutrient media for fungi. Further, it is gathered from the tables that organic substances such as urea, peptone, acetates, tartrates, oxalates and citrates do not interfere with the exclusive oxidation of sugars by alkaline ferricyanide.

Discussion: The presence of organic substances like citrates, oxalates, acetates, tartrates, urea and peptone, and reducing substances like nitrites in the basal fungal nutrient solution does not appear to impair the accuracy of the method. The sharp end point obtained with the methylene blue as an indicator in this investigation is an improvement over the starch indicator in the iodometric method of Hagedorn and Jensen; especially because the starch adsorbs iodine to a certain extent as is always observed in such titrations.

Although Ray and Sen (1912) indicated that ammonia is oxidised to gassous nitrogen by alkaline ferricyanide, no such observations were recorded in the present study. If only ammonia were oxidized by alkaline ferricyanide percentage recovery values in Tables I and II would have been higher. It may be that the time of contact of ammonia with alkaline ferricyanide was so short that no oxidation of ammonia to nitrogen occurred. (Since ammonia was rapidly expelled from the flask by the boiling alkaline ferricyanide). This observation was further corraborated by Suryaraman (1951) who indicated that the process of oxidation of ammonia to nitrogen was very slow. The incapacity of alkaline ferricyanide to oxidize potassium nitrite was also confirmed by Suryaraman.

The time limit of three minutes is fixed to avoid excessive concentration of the contents of the flask and moreover to avoid excentric titre values as was pointed out by Coles. The empirical nature of the method, like most other methods necessitates special attention to be given to the time limit and temperature of the solution in the flask so as to avoid exaggerated results: the colour of methylene blue reappears on cooling of the liquid in the flask.

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FUNGI ISOLATED AND RECORDED FROM INDIAN SOILS

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INTRODUCTION

The importance of studies on soil mycofloras is now widely recognised. The fungus floras of soils have been investigated in some detail by many workers all over the world, and at least part of this work has been summarised by Gilman (J. C. Gilman: *A Manual of Soil Fungi,* The Collegiate Press, Iowa, 1945, 392 pp.). Unfortunately, however, the *Manual* is not exhaustive, and many Indian records have been omitted. Butler & Bisby **(10)** listed in "The Fungi of India" all the fungi reported from India up to 1931 and included a host index but no substratum index. Mundkur **(15)** published a supplementary list in 1938, but did not give a host or substratum index. Mundkur's list has been supplemented recently by the publication of a list by Ramakrishnan & Subramanian **(18**; the host and substratum index appears in this issue, pp. 163-82). There is, however, no consolidated list of fungi, recorded from Indian soils, available for those who need such a list. Such a list would be useful to soil mycologists in particular, and it was therefore thought that the preparation of a list would be worthwhile. The present list is the result. Much of the information presented here lay scattered in the three lists of Indian fungi already mentioned, and in most such cases the particular list or lists alone have been quoted for each species recorded, in order to avoid an extensive, and probably superfluous, bibliography. Indeed, the object in view has been to merely present a consolidated list since most of the literature could be gathered from the three lists quoted. Nevertheless, the information gathered from the three lists has been supplemented by records not mentioned in these lists and, in such cases, the relevant papers have been quoted.

The species have been listed alphabetically under genera. The genera, in turn, have been alphabetically arranged under the four classes: Phycomycetes, Ascomycetes, Basidiomycetes (Hymenomycetes and Gasteromycetes, separately) and the Fungi Imperfecti. The species listed include not only those isolated from Indian soils and brought into artificial culture but also those found growing and producing their fructifications directly in or on soils. The latter are usually excluded from lists of soil fungi, but they have been deliberately included here since, in my opinion, no picture of the soil mycoflora would be complete without them. An analysis of the species *isolated from* soils and those *recorded on or in* soils is given in the following table.

Class	No. of genera	No. of spp. isolated from soils	No. of spp. recorded on or in soils	Total No. of spp.
Phycomycetes	.. 8	20	None	20
Ascomycetes	.. 19	4	33	37
Basidiomycetes				
Hymenomycetes	.. 60	None	181	181
Gasteromycetes	.. 36	None	104	104
Fungi Imperfecti	.. 18	67	1	68
Total	141	91	319	410

It will be seen that all species belonging to the Phycomycetes and perhaps also the Fungi Imperfecti have been obtained only as isolations in artificial culture, although it should be admitted that no special attempt had been made to study their occurrence and growth directly in the soil. The majority of the Ascomycetes and all the Basidiomycetes listed, on the other hand, have only been obtained directly from natural soils where they were found to produce their fructifications. The only species of the Fungi Imperfecti recorded directly from soil is *Mylitta lapidescens* Horaninow, but this is a doubtful record. Amongst the Ascomycetes listed, the species which have been isolated from soils and brought into artificial culture are *Chaetomium bostrychodes* Zopf, *Neocosmospora vasinfecta* E. F. Smith, *Pseudogymnoascus roseus* Raillo and, probably, *Pseudosaccharomyces indicus* Kloecker.

Of the 410 species herein listed, 14 are doubtful records.

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I am grateful to Professor T. S. Sadasivan for several discussions on soil fungi and for having critically read the manuscript.

LIST OF FUNGI

PHYCOMYCETES

Absidia heterospora Ling-Young, isolated from Allahabad soils (17: 120).
Actinomucor corymbosus (Harz) Naumov (= *Mucor glomerula* Lendner fide Naumov), isolated from soil, Madras (10: 8).
Allomyces anomalus Emerson, isolated from soil, Pusa, Darbhanga, Bihar, (18: 5).
A. arbusculus Butler, isolated from soil, Bihar (10: 2; 18: 5).
A. javanicus Kniep, isolated from soil, Pusa, Darbhanga, Bihar (18: 6).
A. javanicus Kniep v. **javanicus** Emerson, isolated from soil, India (18: 6).
A. javanicus Kniep v. **macrogynus** Emerson, isolated from soil, India (18: 6).

Cunninghamella bertholletiae Stadel, isolated from Allahabad soils (17: 120).
C. echinulata Thaxter, isolated from soil, Pusa (15: 10); from Allahabad soils (17: 120).
C. elegans Lendner, isolated from soils, Pusa (10: 8).
C. verticillata Paine, isolated from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29).

Mucor circinelloides van Tiegh., isolated from tobacco field soil, Vedasandur, Madras State (23: 109).
M. hiemalis Wehmer, isolated from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29).
M. plumbeus Bonorden, isolated from soil, Madras (10: 8).
M. racemosus Fres., isolated from soil, Madras (10: 8); from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29).

Pythium gracile Schenk; saprophytic in soil, Calcutta (9: 71).
P. proliferum de Bary, saprophytic on vegetable debris in soil, Calcutta, Dehra Dun (9: 78).

Rhizopus arrhizus Fischer, isolated from alkaline soil, Pusa; neutral soil, Simla; acid soil, Ramgarh (13: 582); from Pusa soils (15: 11).
R. nigricans Ehrenberg, isolated from soils, Madras State (10: 9; 23: 109).
R. nigricans Ehrenberg v. **minutus** Chaudhuri, isolated from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29).
R. oryzae Went & Prinzen Geerlings, isolated from tobacco field soil, Vedasandur, Madras State (23: 109).

Syncephalastrum racemosum Cohn, isolated from Allahabad soils (17: 120).

ASCOMYCETES

Ascobolus gollani P. Henn., on manured ground, under trees, Botanic Garden, Saharanpur (10: 10).
A. magnificus Dodge, on the ground, (locality ?) (12: 87).
Carnostroma thyrsus (Berk.) Lloyd, ? on the ground, Narsinghpur District, Madhya Pradesh (10: 18).

Chaetomium bostrychodes Zopf, isolated from black cotton soil, Udamalpet, Madras State (23: 109).

Geoglossum ? alveolatum Durand, on the ground, Simla (10: 11).
G. hirsutum Pers., on bare earth, India (10: 11).
G. velutipes Peck, on the ground in an oak forest, Murree (18: 21).

Helvella crispa (Scop.) Fr., on the ground, the Punjab; Achibal, Kashmir; Simla (10: 11).
H. ephippium Lév., on the ground, Murree (18: 23).
H. fusca Gill., on the ground, Murree (18: 23).
Humaria pallidisetosa Cash, on the ground, Rohtak, E. Punjab (18: 24).

Lamprospora constellatis (B. & Br.) Seaver, on the ground, Rohtak, E. Punjab (18: 25).
Leotia lubrica Pers., on clay banks, Sinchul, Sikkim, 8600 ft. (10: 11); on the ground in an oak forest, Murree (7: 11).

Mitrula agharkarii Bannerji, on soil, Senchal Range, Darjeeling (8000 ft.) Sikkim Himalayas (18: 28).
M. rosea Lloyd, on bare earth, India (10: 12).
Morchella bohemica Krombholz, on the ground, Kashmir (10: 12).
M. conica Pers., on the ground, Dehra Dun (10: 12).
M. conica Pers. v. **acuminata** Kickx, Siwalik Hills (10: 12).
M. deliciosa Fr., on the ground, Kashmir; Amritsar; Kumaon (10: 12).
M. esculenta (L.) Pers., on the ground, Ranikhet, Kumaon, Himalayas; Kashmir (10: 12).
M. gigaspora Cooke, on the ground, Kashmir (10: 12).

Neocosmospora vasinfecta E. F. Smith, isolated from Allahabad soils (17: 120).

Ombrophila indica Syd., on the ground, Dehra Dun (10: 12).
Otidea darjeelensis (Berk.) Sacc., on the ground, Darjeeling (10: 12).

Peziza aurantia Pers., on earth, Sikkim; on clay banks, Darjeeling (10: 12).
P. badia Pers., on the ground, (locality ?), (12: 87).
Poronia arenaria Syd. & Butler, on sand dunes near *Casuarina* trees, Chatrapur, Ganjam (10: 36; 6: 14).
P. kurziana (Curr.)Lloyd, on brick-laid paths where fire had been burnt, rainy season, Botanic Garden Calcutta (6: 141; 18: 37; as *Kretzschmaria kurziana* (Curr.) Sacc. in 10: 25).
P. polyporoides P. Henn., on the ground, Botanic Garden, Saharanpur (10: 36).
Pseudogymnoascus roseus Raillo, isolated from Allahabad soils (17: 120).
Pseudosaccharomyces indicus Kloecker, soil, Himalayas (10: 9).

Tuber indicum Cooke & Massee, in the earth, Mussorie (10: 14).

Xylaria delitschii Auersw., on the ground, apparently on rotten fruits, Botanic Garden, Saharanpur (10: 41).
X. emerici Berk. in Herb., ? on the ground, Nilgiris (10: 41).
X. gomphus Fr., in an underground cellar, Botanic Garden, Saharanpur (10: 41).

X. nigripes (Klotsch) Sacc., on the ground, India; Belgaum; Botanic Garden, Saharanpur; on brick-laid paths, Botanic Garden, Calcutta; rooting in the soil, Sikkim, 5000 ft.; on the ground, Dehra Dun (U.P.), Koppa (Mysore), Pusa (Bihar), Jullundur (Punjab), Dhulia (Bombay), and elsewhere (10: 42).

X. sanchezii Lloyd, *on the ground, India* (10: 43).

BASIDIOMYCETES

Hymenomycetes

Agaricus arvensis Schaeff., *in meadows and grassy places, Calcutta* (8: 42).
A. burkillii (Mass.) Sacc. & Trott., on the ground, Calcutta (10: 84; 8: 42).
A. campester L., on the ground, Pengi, N. W. Himalaya (10: 84); on humus soil in open field, Calcutta (8: 42).
A. comosus (P. Henn.) Sacc. & D. Sacc., on the ground, Botanic Garden, Saharanpur (10: 84).
A. ? cretaceus Fr., on the ground, Botanic Garden, Saharanpur (10: 84).
A. ? elvensis (B. & Br.) Sacc., on the ground, Botanic Garden, Saharanpur (10: 85).
A. exaltatus Berk., on clay and earthy banks, Darjeeling (10: 84).
A. fulviceps Berk., on the ground, Sikkim (10: 85).
A. latipes Berk., on the ground, Nunklow, Khasi Hills (10: 85).
A. rimosus (P. Henn.) Sacc. & Sacc., on the ground, Botanic Garden, Saharanpur (10: 85).
A. silvaticus Schaeff., on earth, Darjeeling, 7500 ft. (10: 85).
A. squalidus Massee, on humus soil in an open field, Calcutta (8: 42).
A. woodrowii Massee, on the ground, Poona (10: 85).
Amanitopsis berkeleyi (Hooker f.) Sacc., on the ground, Darjeeling, 7500 ft. (10: 85).
A. eriophora (Berk.) Sacc., on the ground, Darjeeling, 7500 ft. (10: 85).
A. regalis (Berk.) Sacc., on the ground, Jalapahar, Darjeeling, 7500 ft. (10: 85).

Bolbitius grandiusculus Cooke & Massee, on the ground, Poona (10: 86).
Boletus areolatus Berk., *in open pastures, Kala Pani, Khasi Hills, 5500 ft.* (10: 86).
B. delphinus Berk., on exposed ground, Darjeeling, 7500 ft. (10: 86).
B. emodensis Berk., on the ground, Darjeeling, 7500 ft. (10: 86).
B. flavipes Berk., on the ground, Myrong, Khasi Hills (10: 86).
B. furfuraceus Berk., on clay banks, Moflong, Khasi Hills, 5500 ft. (10: 87).
B. pusillus Berk., on the ground, Moflong, Khasi Hills (10: 87).
B. scrobiculatus Berk., on soil in open places, Moflong, Khasi Hills (10: 87).
B. verrucarius Berk., on the ground, Sikkim (10: 87).

Calocera dilatata Mont., on the ground, edge of hill forest, Madura (10: 87).
C. sphaerobasis Berk., on the ground, apparently springing from a twig, Darjeeling, 7500 ft. (10: 87).
Cantharellus cibarius Fr., on the ground under *Pinus longifolia*, Arnigadh, Mussoorie (10: 87).
C. infundibuliformis Fr., on the ground, Myrong, Khasi Hills (10: 87).

Cladoderris mussooriensis (P. Henn.) Sacc., on the ground, Arnigadh, Mussoorie (10: 87).
Clavaria gollani P. Henn., *on the ground, Saharanpur* (10: 88; 11: 263).
C. jacquemontii Lév., on the ground, Kashmir (10: 88; 11: 263).
C. laeticolor Berk. & Curt., on ground among fallen leaves, Calcutta (18: 14; 8: 41).
C. pistillaris L., on the ground, Murree (18: 14).
Clavulina ornatipes (Peck) Corner (Syn: *Lachnocladium ornatipes* (Peck) Burt), among decaying leaves by the side of a pond, Calcutta (18: 25; 8: 41; 11: 333).
Clavulinopsis fusiformis (Fr.) Corner (Syn.: *Clavaria compressa* Schw.), on humus, Calcutta (8: 41; 18: 14; 11: 367).
C. pulchra (Peck) Corner (Basinym: *Clavaria pulchra* Peck), on earth among decaying leaves, Calcutta (8: 41; 18: 14; 11: 384).
Clitocybe incongrua Berk., on the ground, Jallapahar, Darjeeling, 7500 ft. (10: 88).
C. laccata (Scop.) Sacc., on the ground, Arnigadh, Mussoorie, 5500 ft. (10: 88).
C. pumila Massee, *about ants' nests under a wall, Calcutta* (10: 88).
Collybia albuminosa (Berk.) Petch, growing from termites' nests, India (10: 88).
C. ambusta Fr., on burnt ground, Calcutta (10: 88).
C. dryophila (Bull.) Fr. v. **caespitis** Berk., amongst grass and moss, Lachen, Himalaya, 14000-16000 ft. (10: 88).
C. macra Berk., on the ground in pine woods, Sikkim, 11000 ft. (10: 88).
C. mimica W.G.Sm., in grassy fields, Calcutta (10: 88).
C. napipes Hooker f. in Berk., on the ground, Darjeeling, 7500 ft. (10: 88).
C. podagrosa Berk., on clay banks, Sinchul, Himalaya, 8000 ft. (10: 89).
C. raphanipes Berk., on the ground, Jallapahar, Darjeeling, 7000 ft. (10: 89).
C. ustipes Berk., on the ground, Darjeeling, 8000 ft. (10: 89).
Coltricia schweinitzii (Fr.) Cunningham, on the ground, Botanic Garden, Saharanpur (18: 15; 10: 119).
Coprinus comatus Fr., on grassy earth, Darjeeling (10: 89); on lawns, Calcutta (8: 42).
C. fimbriatus Berk., and Br., on humus soil, *Calcutta* (8: 42).
C. hookeri Berk., in grassy places, Jallapahar, 7500 ft. (10: 89).
C. ? spraguei Berk. and Curt., on the ground, Botanic Garden, Saharanpur (10: 89).
C. vellereus Berk., on earth, Darjeeling (10: 89).
Craterellus cornucopioides (L.) Fr., on ground, Bengal (15: 25).
Crepidotus alveolus (Lasch) Fr., on the ground, Botanic Garden, Saharanpur (10: 91).

Deconia atro-rufa Schaeff., on the ground, Botanic Garden, Saharanpur (10 92).

Eccilia blandfordii P. Henn., on the ground, Kalsia; Botanic Garden, Saharanpur (10: 92).
E. griseo-rubella (Lasch) Sacc., a form on the ground, Botanic Garden, Saharanpur (10: 92).

Galera burkillii Massee, on the ground, Sureil, near Darjeeling (10: 97).
G. lateritia Fr., on the ground, Botanic Garden, Saharanpur (10: 97).

G. tenera (Schaeff.) Fr. on the ground, Jallapahar and Darjeeling (**10**: 97).
G. zeylanica Petch, on the ground in grass, Hooghly, Bengal (**10**: 97).

Hydnellum zonatum (Batsch) Karst. forma **vespertilio** (Berk.) Coker and Beers, on the ground, Nunklow, Khasi Hills (**18**: 24; **10**: 102).
Hydnum repandum L., on the earth, Arnigadh, Mussoorie (**10**: 101).
H. zonatum Batsch, on the ground, Nunklow, Khasi Hills (**10**: 102).
Hygrophorus pomona Berk., on clay banks, Moflong, Khasi Hills (**10**: 102).
Hypholoma appendiculatum (Bull.) Sacc., on the ground, Botanic Garden, Saharanpur (**10**: 103).
H. atrichum Berk., on soil impregnated with charcoal, Darjeeling (**10**: 103).
H. castanophyllum Berk., on the ground, Jallapahar, Darjeeling (**10**: 103).
H. condensum Berk., on the ground, Darjeeling (**10**: 103).
H. hemisodes Berk., on earth banks, Darjeeling (**10**: 103).
H. velutinum (Pers.) Fr., on earthy banks, Darjeeling (**10**: 103).

Inocybe echinata (Roth) Cooke, on the ground, Botanic Garden, Saharanpur (**10**: 103).
I. holophlebia Berk., on the ground, Masulipatam (**10**: 103).

Lachnocladium brasiliense Lév., on earth and decaying leaves, Calcutta (**18**: 25; **8**: 41).
Lactarius stramineus Berk., on the ground, Pomrang, Khasi Hills (**10**: 104).
Lentinus alopecinus Fr., recorded as apparently on the ground, India (**10**: 104).
Lepiota altissima Massee, in open pastures near Poona (**10**: 107).
L. anax Berk., on clay banks and amongst grass, Nunklow, Khasi Hills, (**10**: 107).
L. beckleri Berk., on the ground, Poona (**10**: 107).
L. cepaestipes Sowerby, on the ground, India; Poona (**10**: 107); Calcutta (**8**: 43).
L. cepaestipes Sowerby v. **lutea** With., on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. clypeolaria (Bull.) Fr., a form on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. cristata (Alb. and Schw.) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. erminea Fr., in grassy places, Calcutta (**10**: 108).
L. favophylla Massee, in grassy places, Calcutta (**8**: 43).
L. ? hispida (Lasch) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. holosericea Fr., on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. implana Berk., on dry, stony hills, Moflong, Khasi Hills (**10**: 108).
L. longicaudata P. Henn., on the ground, Kalsia; Botanic Garden, Saharanpur (**10**: 108).
L. mallens Berk., on the ground, Masulipatam (**10**: 108).
L. mammosa P. Henn., on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. mastoidea Fr., on ground, Calcutta (**8**: 43).
L. meleagris (Sowerby) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 108)).
L. microspora Massee, on the ground, Narcondam, Andaman Islands, (**10**: 108).
L. montosa Berk,. on the ground, Sikkim (**10**: 108).

L. punicea Massee, on ground, Calcutta (**8**: 44).
L. seminuda (Lasch) Juel, on the ground, Botanic Garden, Saharanpur (**10**: 108).
L. sericea Massee, in a plant pot and amongst grass, Calcutta (**10**: 109).
L. sistrata Fr., on the ground, Botanic Garden, Saharanpur (**10**: 109).
Lepiotophyllum rhacodes (Vittad.) Locquin v. **puellaris** (Fr.) Locquin, on the ground, Kalsia Hills (**18**: 25; **10**: 108).
Leucoagaricus excoriatus (Schaeff. ex Fr.) Singer, in hot valleys on the bare earth, Darjeeling, Punjab, Poona; on the ground, Botanic Garden, Saharanpur (**18**: 25; **10**: 108).

Macrolepiota procera (Scop. ex. Fr.) Singer, on the ground under *Ficus carica*, Saharanpur (**18**: 26; **10**: 108); on ground in open pastures (**8**: 43).
Marasmius erythropus Fr., on the ground, Darjeeling (**10**: 109).
M. iridescens Berk., on mossy banks, Sinchul, Sikkim Himalaya, 8000 ft. (**10**: 109).
M. urens Fr., on the ground, Arnigadh, Mussoorie (**10**: 110).
Mycena conocephala P. Henn., on the ground, Botanic Garden, Saharanpur (**10**: 111).
M. ? plicosa Fr., on the ground, Botanic Garden, Saharanpur (**10**: 111).
M. prasia Berk., on the ground, top of Tonglo, Sikkim, 10000ft. (**10**: 111).

Naucoria ? conspersa (Pers.) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 112).
N. fusispora P. Henn., on the ground, Arnigadh, Mussoorie (**10**: 112).
N. pediades Fr., on the ground, Botanic Garden, Saharanpur (**10**: 112).
N. scrupea Berk., on moist earth, Darjeeling, 7500 ft. (**10**: 112).

Omphalia calycinoides P. Henn., on the ground, Botanic Garden, Saharanpur (**10**: 112).
O. oedipus Massee, on the ground at the base of a wall, Calcutta (**10**: 112).
O. ranunculina Berk., on turf, etc., Lachen, Sikkim, 14000-16000 ft. (**10**: 112).
O. rogersi Massee, on the ground, Narcondam, Andaman Islands (**10**: 112).
O. ? rustica Fr., on the ground, Botanic Garden, Saharanpur (**10**: 112).

Panaeolus campanulatus (L.) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 113).
Panus monticola Berk., on the ground, probably attached to wood, Tonglo, Sikkim (**10**: 113).
Paxillus pinguis Hooker f., on earth and mossy banks ,Darjeeling, 7500 ft. (**10**: 113).
P. sulphureus Berk., on the ground, Darjeeling, 7500 ft. (**10**: 113).
Pholiota granuloso-verrucosa P. Henn., on the ground, Botanic Garden, Saharanpur (**10**: 113).
P. indica Massee, on the ground, Poona (**10**: 113).
P. praecox (Pers.) Fr., on the ground, Botanic Garden, Saharanpur (**10**: 113).
Pleurotus flabellatus Berk. & Br., on the ground, Hooghly District, Bengal (**10**: 114).
P. subpalmatus Fr., on the ground, perhaps on roots, Arnigadh, Mussoorie (**10**: 114).
Pluteus cuspidatus Berk., on the ground, Khasi Hills (**10**: 114).

Polyporus arcularius (Batsch) Fr. on the ground, Barkuda Island, Orissa (**10:** 115).
P. campbelli Berk., on the ground, Poona (**10:** 115).
P. chocolatus Bose, on the ground, Coimbatore, Madras State (**10:** 115).
P. friabilis Bose, on the ground, Bengal and Orissa (**10:** 116).
P. luteo-umbrinus Romell, on the ground, probably attached to buried wood or roots, Baroda (**10:** 117).
P. nodipes Berk., on the ground, Khasi Hills (**10:** 117).
P. saharanpurensis P. Henn., on the ground, near tree roots, Botanic Garden, Saharanpur (**10:** 118).
P. vallatus Berk., on the ground, Khasi Hills (**10:** 120).
Polystictus oblectans Berk., on the ground, Sikkim, 7500 ft.; Churra, Moflong and Nunklow, Khasi Hills; Siwalik Range (**10:** 123).
P. sacer Fr., on the ground, growing from sclerotia, Assam (**10:** 125).
Poria arenaria Klotsch, on sandy soil, India (**10:** 126).
Psathyra calvescens Berk., on mossy earth, Darjeeling, 7500 ft. (**10:** 127).
P. nana Massee, on the ground, Poona (**10:** 127).
P. obtusata Fr., on the ground, Botanic Garden, Saharanpur (**10:** 127).
Psathyrella discolor Berk., on the ground, Darjeeling, 7500 ft. (**10:** 127).
P. disseminata (Pers.) Fr., on ground, Calcutta (**18:** 37; **8:** 44).
P. gracilis Fr., on the ground, Kursar in the Nubra Valley, Kashmir; Botanic Garden, Saharanpur (**10:** 127).
P.? hydrophora (Bull.) Sacc., on the ground, Botanic Garden, Saharanpur (**10:** 127).
P. prona Fr., on the ground, Botanic Garden, Saharanpur (**10:** 127).
Psilocybe caespiticia Berk., on clay banks, Darjeeling, 7500 ft. (**10:** 127).
P. tristis P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 127).
Pterula himalayensis (Massee) Lloyd, on the ground in a pine forest, Phallaloong Ridge, Sikkim, 10000 ft. (**10:** 127). But see **11:** 434.
P. penicillata Lloyd, on humus in woods, India (**11:** 520).

Ramaria zippelii (Lév.) Corner, on the ground, in the forest, Khasi Hills (**11:** 634; as *Lachnocladium hookeri* Berk. in **10:** 104).
Russula cinnabarina Hooker f., on clay banks, Darjeeling, 7500 ft. (**10:** 128).
R. emetica Fr., Khasi Hills and on clay banks, Darjeeling (**10:** 128).
R. furcata Fr., on clay banks, Sinchul, Sikkim Himalaya, 8500 ft. (**10:** 128).
R. lepida Fr., on clay banks, Darjeeling, 8000 ft. (**10:** 128); on the ground in pine forest, Kodaikanal (*Proc. Indian Acad. Sci.*, **36:** 94).
R. sanguinea (Bull.) Fr. on the ground, Arnigadh, Mussoorie (**10:** 128).

Scytinopogon angulisporus (Pat.) Corner (Basinym: *Clavaria angulispora* Pat.), on humus, Calcutta (**18:** 14; **8:** 41; **11:** 648).
Stereum malabarense Lloyd?, apparently on the ground, Malabar (**10:** 129).
S. petalodes Berk., on ground near dead wood, Ballygung, Howrah, Burdwan (**15:** 29).
Strobilomyces montosus Berk., on the ground, Jallapahar, Darjeeling, 7500 ft. (**10:** 130).
Stropharia aurivella Massee, among grass, Calcutta maidan (**10:** 130).
S.? crocopepla Berk. & Br., on the ground, Kalsia (**10:** 130).
S. gollani P. Henn., on shady ground, Saharanpur (**10:** 130).
S. mephistopheles Cooke, on the ground, Belgaum (**10:** 130).
S. psathyroidea P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 130).

S. pygmaea P. Henn., on the ground, Saharanpur (**10:** 130).
S. semiglobata (Batsch) Quel., on the ground, Myrong, Khasi Hills, 6000 ft. (**10:** 130).

Termitomyces microcarpus (Berk. & Br.) Heim, growing from old termite nests or from the soil, Hooghly District and elsewhere in Bengal (**18:** 47; **10:** 93).
Thelephora? aurantiaca Pers., on the ground, Botanic Garden, Saharanpur (**10:** 130).
T. palmata (Scop.) Fr., on the ground, Nunklow, Khasi Hills (**10:** 130),
Tricholoma subpulverulentum (Pers.) Fr., on the ground, near Sassar in Kashmir, 16000 ft. (**10:** 132).
Tubaria asperata P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 133).
T. furfuracea (Pers.) W.G.Sm., on the ground, Botanic Garden, Saharanpur (**10:** 133).
T. saharanpurensis P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 133).

Ulocolla foliacea (Pers.) Bref., on mossy and rocky wet places, Tonglo, Sikkim, 10000 ft. (**10:** 133).

Volvaria liliputiana P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 133).
V. media (Schum.) Fr., on the ground, Botanic Garden, Saharanpur (**10:** 133).
V. woodrowiana Massee, on the ground, Poona (**10:** 133).

Gasteromycetes

Aseroe arachnoidea Fischer, on soil, Mysore (**15:** 30; **16:** 251).
Astraeus hygrometricus (Pers.) Morgan, on the ground, Simla, Saharanpur, Arnigadh, Mussoorie (**10:** 134); solitary on the ground, Dalhousie-Chamba Road; Khanag, Kulu Hills; Mussoorie (**4:** 178); on the ground, Dehra Dun (**10:** 135 as *Geaster lilacinus* Massee).

Battarraea levispora Massee, on the ground, Poona (**10:** 134).
B. stevenii (Libosch.) Fr., solitary on the ground with volva hidden by the soil, Rohtak, E. Punjab (**18:** 8).
Bovista argentea Berk., on the ground, Madras (**10:** 134).
B. concinna Ahmad, solitary or gregarious on vegetable debris under trees of *Taxus baccata*, Upper Topu, Murree, 6000 ft. (**18:** 9).
B. plumbea Pers., on soil, Sonamarg, Kashmir, 9000 ft. (**18:** 9; **4:** 179).
Bovistella bovistoides (Cooke & Massee) Lloyd, on the ground, amongst moss, Nilgiris (**10:** 134).
B. henningsii Lloyd, on the ground, Arnigadh, Mussoorie (**18:** 9; **10:** 134 as *Bovista plumbea* Pers.)
B. lycoperdioides (Cooke) Lloyd, amongst moss, Nila Valley, Garhwal, Himalaya, 12000 ft. (**10:** 138 as *Scleroderma cookei* de Toni); amongst moss, Sonamarg, Kashmir, 9000 ft. (**18:** 9).
B. trachyspora Lloyd, evidently in moss, Respanna Valley, Mussoorie (**10:** 134).

Calvatia gardneri Berk., on the ground, Shillong, Khasi Hills; Bengal (**10: 134**).
C. coelata (Bull.) Morgan, on the ground, Babet Pass, 18000 ft., Bashahr State (Himachal Pradesh) (**18: 10**).
C. lilacina (Berk. & Mont.) Lloyd, solitary on sandy soil, Gurdaspur, E. Punjab (**3: 137**).
C. saccata (Fr.) Lloyd, on soil, Baramula, Kashmir (**5: 283**); on the ground, Arnigadh, Mussoorie (**10:** 137 as *Lycoperdon saccatum* Vahl).
Cauloglossum elatum Fr., on the ground, India (**10:** 134).
Clathrella delicata (Berk. & Br.) Fischer, on soil, Mysore (**15: 30**).
Clathrus cancellatus Tournef., on the ground, Myrong, Khasi Hills, Sikkim (**10:** 134).
Cyathus colensoi Berk., on the ground, in a forest with thick undergrowth, Simla, 7000 ft. (**18: 16**).
C. limbatus Tul., in a flower pot, Botanic Garden, Calcutta (**10:** 135).
C. microsporus Tul., on the ground, Wahjain and Shillong, Khasi Hills (**10:** 135).
C. poeppigii Tul., on the ground, Botanic Garden, Saharanpur (**10:** 135; **5: 292**).
C. stercoreus (Schw.) de Toni, on dung cakes, Chamba (**5: 292**).

Dictyophora indusiata (Ventenat) Pers., on the ground, Khandala, Bombay; North Bengal (**10:** 135).
D. irpicina Pat., on soil, Panchgani, Bombay (**15:** 30); Rohtak, E. Punjab (**3: 141**).
Disciseda cervina (Berk.) Cunningham, hypogeous in sandy soil. (**18: 18**).
D. pedicellata (Morgan) Hollos, hypogeal, in rich humus under thick growth of *Acacia arabica* on the sides of a pond, Rohtak, E. Punjab (**18: 18**).

Geaster fimbriatus Fr., on the ground, ? Punjab (**10:** 135).
G. langeniformis Vittad., on the ground, Arnigadh, Mussoorie (**10:** 135).
G. mammosus Fr., solitary on the ground, Jalori Pass, 10000 ft. (**18: 21**).
G. plicatus Berk., on the ground, Madras (**10:** 135).
G. triplex Jungh., solitary on the ground, Khanag, Kulu Hills, Chamba (**18: 21**).
Glastrum clelandü (Lloyd) Cunningham (Syn.: *Geaster clelandii* Lloyd), solitary on the ground, Jalori Pass, 1000 ft. (**18: 21**).
G. minus (Pers.) Cunningham, solitary on the ground, epigeous, Gurdaspur, E. Punjab (**18: 21**).
G. simulans (Lloyd) Cunningham, solitary on the ground, Rotang Pass, 16000 ft. (**18: 21**).
Gyrophragmium delilei Mont., on the ground, Sonamarg, Kashmir, (**5: 292**).

Itajahya rosea (Delile) Fischer, common in Punjab plains and also at Rohtak, E. Punjab; solitary or in groups on decaying vegetable debris under trees of *Salvadora oleoides* and *Capparis aphylla*. (**18: 24**).
Ithyphallus aurantiacus (Mont.) Fischer, on the ground, Pondicherry, Masulipatam, "plains of India" (**10:** 135).

Lanopila bicolor (Lév.) Pat., on the ground, Bombay (**10:** 136).
Lycoperdon alveolatum Lév., on the ground, Nilgiris (**10:** 136).
L. berkeleyi de Toni, on the ground, Khasi Hills (**10:** 136).
L. depressum Bonorden, solitary or gregarious on rotten manure heaps, Gurdaspur, E. Punjab (**18: 26**).

L. elongatum Berk., on mossy ground, Darjeeling, 7500 ft. (**10:** 136); Arnigadh, Mussoorie, 5500 ft. (**5: 285**).
L. emodense Berk., on the ground, Sikkim, 15000 ft. (**10:** 136).
L. hiemale Bulliard, on the ground, Darjeeling, 7000 ft. (**10:** 136); solitary on the ground, Chamba (**5: 287**).
L. ? marginatum Vittad., on the ground, Botanic Garden, Saharanpur (**10:** 136; **5: 287**).
L. mundkuri Ahmad, on the ground, Khanag, Kulu, 8000 ft. (**18: 26**).
L. nigrum Lloyd, solitary on the ground rich in humus, Mussoorie (**5: 289**).
L. perlatum Pers., on the ground, among moss, Mussoorie, Dalhousie (**5: 285**); on the ground, paths, clay banks, Jallapahar, Darjeeling, 7000-8000 ft.; Sikkim Himalaya, 7000-8000 ft. (**10:** 136 as *L. gemmatum* Batsch).
L. piriforme (Schaeff.) Pers., on the ground, Naggen, Kulu, 5500 ft.; Sonamarg, Kashmir, 9000 ft. (**5: 283**).
L. polymorphm Vitt., on the ground, rich in humus, solitary or in groups, Mussoorie, Sonamarg, Kashmir (**18: 26**).
L. sericellum Berk., on the ground, Darjeeling, 7000 ft. (**10:** 137).
L. umbrinum Pers., solitary on the ground, Khanag, Kulu (**18: 26**).
L. wrightii Berk. & Curt., in grassy places, Mussoorie, 7000 ft. (**18: 26**).
L. xanthospermum Berk., on the ground, Moflong, Khasi Hills (**10:** 137).

Melanogaster ambiguus (Vitt.) Tul., growing in groups, a few inches below the ground, Dalhousie, Chamba Road (**18: 27**).
M. durissimus Cooke, a few inches below the surface of the ground, near Chakrata, Himalaya (**10:** 137).
Mitremyces junghunii Schlecht. & Muell. on the ground, Tonglo, Sinchul, and Chola, Sikkim, 6000-9000 ft. (**10:** 137).
Mycenastrum corium (Guers.) Desv., solitary or in groups in the ground, Ani, 3000 ft., Kulu Hills; Chamba-Dalhousie Road (**18: 29**).
Mycophanus gardneri (Berk) Petch, on soil, Mysore (**15: 30**).
Myriostoma coliforme (Dicks. ex Pers.) Corda, on the ground, Chandra Valley, Himalayas (**18: 29**).

Octaviana longiana Ahmad, on the ground, amongst grass, Rohtak, E. Punjab (**18: 30**).

Phallus celebicus P. Henn., on the ground, Punjab plains (**18: 33**).
Phellorinia inquinans Berk., on soil, Said Circle, Hyderabad Forest Division; Rohtak, E. Punjab (**18: 33**).
Podaxon calyptratus Fr., on the ground, Punjab; on sandy soil, Chatrapur, Ganjam (**10:** 137); solitary on sandy soil, Rohtak, E. Punjab (**3: 140**).
P. emerici Berk. in Herb., on the ground, Masulipatam (**10:** 137).
P. gollani P. Henn., on the ground, Botanic Garden, Saharanpur (**10:** 137).
P. pistillaris (L.) Fr., on the ground, India: Nadiad, Bombay; Madras; Punjab (**10:** 137); solitary on sandy soils, Rohtak, E. Punjab (**1: 48**).
Pseudolycoperdon pusillum (Batsch) Valenovsky, on the ground, Dehra Dun (**10:** 137; **18: 37**); solitary on sandy soil, Gurdaspur, E. Punjab (**2: 170**; **5: 288**).

Queletia laceratum (Ehrenb.) Ahmad, on soil, the Punjab plains (**18: 40**).

Rhizopogon roseolus (Corda) Hollos, on the ground, Murree; Changla gali (18: 41).

R. rubescens Tul., on soil, epigeous, Dalhousie (18: 41).

Schizostoma mundkuri (Ahmad) Long & Stouffer, solitary in sandy soil, Rohtak, E. Punjab (18: 41).

Scleroderma aurantium Pers., on the ground, Arnigadh, Mussoorie (10: 138; 5: 291).

S. bovista Fr., on the ground, Sikkim; Arnigadh, Mussoorie; Dalhousie (10: 138; 5: 289).

S. dictyosporum Pat., on the ground, Dehra Dun (10: 138; 5: 290).

S. geaster Fr., on clay banks, Nunklow, Khasi Hills, 4000-5000 ft.; Shillong (10: 138).

S. verrucosum (Bull.) Pers., on the ground, Arnigadh, Mussoorie; Dehra Dun; Dalhousie (10: 138; 5: 290).

Simblum periphragmoides Klotsch, on soil, Sibpur, Calcutta; coffee estates, Mysore (16: 252).

S. sphaerocephalum Schlecht., solitary or in groups, very common in grassy plots, Rohtak, E. Punjab (18: 42).

Sphaerobolus stellatus Tode, on dead moss, Botanic Garden, Saharanpur (10: 138); common on old manure heaps, Gurdaspur, E. Punjab; on dung cakes, Chamba (2: 172; 5: 291).

Tylostoma albiceps Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. albocretaceum Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. amnicola Long & Ahmad, on soil, Pusa, Bihar; Dehra Dun (18: 49).

T. balanoides Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. cineraceum Long, on soil, India (18: 49).

T. evanescens Long & Ahmad, on soil, Rohtak, E. Punjab; Delhi (18: 49).

T. hygrophilum Long & Ahmad, on soil, Bihar (18: 49).

T. mac-alpinianum Lloyd, solitary or in groups in grass, Gurdaspur, E. Punjab (18: 49).

T. membranaceum Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. mussooriense P. Henn., on the ground, Arnigadh, Mussoorie (10: 138; 4: 175).

T. operculatum Long & Ahmad, on soil, Jaggatpur, Gurdaspur, E. Punjab (18: 49).

T. parvissimum Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. psilophilum Long & Ahmad, on soil, Jaggatpur, Gurdaspur, E. Punjab (18: 49).

T. puncticulosum Long & Ahmad, on soil, Jaggatpur, E. Punjab (18: 49).

T. pygmaeum Lloyd, solitary on sandy soil, Gurdaspur, E. Punjab (18: 49).

T. sedimenticola Long & Ahmad, on soil, Gurdaspur, E. Punjab (18: 49).

T. squamosum Pers., solitary in sandy soil, Gurdaspur, E. Punjab (18: 49).

T. subsquamosum Long & Ahmad, on soil, Jaggatpur, Gurdaspur, E. Punjab; Dehra Dun (18: 49).

T. verrucosum Morg., solitary on the ground, Gurdaspur, E. Punjab (18: 49).

T. volvulatum Borsch, on sandy wastes, round Rohtak, E. Punjab (3: 141).

T. vulgare Long & Ahmad, on soil, Rohtak, E. Punjab (18: 49).

T. wightii Berk., on the ground, Madras (10: 138).

T. xerophilum Long, on soil, Madhya Pradesh (18: 49).

FUNGI IMPERFECTI

Alternaria humicola Oud., isolated from paddy field soil, Chinsurah, Calcutta (20: 29).

Aspergillus alliaceus Thom & Church, isolated from Allahabad soils (17: 120).

A. candidus Link, isolated from soil, Madras (10: 139); from paddy field soil, Chinsurah, Calcutta (20: 29).

A. chevalieri (Mang.) Thom & Church, isolated from Pusa soils (15: 31; 13: 582).

A. flavipes (B. & S.) Thom & Church, isolated from alkaline soils, Pusa (13: 582); from paddy field soil, Chinsurah, Calcutta (20: 29).

A. flavus Link, isolated from soil, Madras (10: 140); from alkaline soil, Pusa; acid soil, Darjeeling (13: 582); from paddy field soil, Chinsurah, Calcutta (20: 29); from Allahabad soils (17: 120).

A. fumigatus Fres., isolated from soil, Pusa and Madras (10: 140); from acid soils, Mungpoo, Chaubattia, Kulu (13: 582); from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29); from Allahabad soils (17: 120).

A. luchuensis Inui, isolated from paddy field soil, Chinsurah, Calcutta (20: 29).

A. nidulans (Eidam) Winter, isolated from soil, Madras (10: 140); from alkaline soils, Pusa, from acid soils, Darjeeling (13: 581); from Allahabad soils, (17: 120).

A. niger van Tiegh., isolated from soils, Pusa & Madras. (10: 140); from alkaline soils, Pusa, acid soil, Darjeeling (13: 582); from paddy field soil, Chinsurah, Calcutta (14: 115; 20: 29); from Allahabad soils (17: 120).

A. ochraceus Wilh., isolated from soils, Pusa (13: 582; 15: 31); from Allahabad soils (17: 120).

A. proliferans G. Smith, isolated from Allahabad soils (17: 120).

A. repens (Corda) de Bary, isolated from soil, Madras (10: 140); from Allahabad soils (17: 120).

A. sulphureus (Fres.) Thom & Church, isolated from paddy field soil, Chinsurah, Calcutta (14: 115).

A. sydowi (B. & S.) Thom & Church, isolated from alkaline soil, Pusa (13: 582); from paddy field soil, Chinsurah, Calcutta (14: 115); from Allahabad soils (17: 120).

A. tamarii Kita, isolated from soil, India (10: 140); from alkaline soil, Pusa (13: 582).

A. terreus Thom, isolated from alkaline soils, Pusa (13: 582); from paddy field soil, Chinsurah, Calcutta (20: 29); from black cotton soil, Udamalpet (23: 109).

A. ustus (Bain.) Thom & Church, isolated from soil, Pusa (15: 31); from alkaline soil, Pusa and acid soil, Darjeeling (13: 582); from black cotton soil, Udamalpet (23: 109).

A. variecolor (B. & Br.) Thom & Raper, isolated from black cotton soil, Udamalpet, by author.

A. wentii Wehmer, isolated from Allahabad soils (17: 120).

Botrytis cinerea Pers., isolated from soil, Madras (10: 141).

Cephalosporium acremonium Corda, isolated from soil, Madras (10: 141).

Cladosporium herbarum Link, isolated from alkaline soil, Pusa (13: 584); from paddy field soil, Chinsurah, Calcutta (20: 29).

Curvularia lunata (Wakker) Boedijn, isolated from alkaline soil, Pusa and acid soil, Kulu (**13**: 584); from Allahabad soils (**17**: 120); from black cotton soil, Udamalpet (**23**: 109).

Fusarium avenaceum (Fr.) Sacc., isolated from black cotton soil, Udamalpet (**18**: 20; **21**: 561).
F. chlamydosporum Wr. & Rg., isolated from black cotton soil, Udamalpet (**18**: 20; **21**: 561).
F. cuimorum (W. G. Sm.) Sacc., isolated from black cotton soil, Udamalpet (**21**: 561).
F. dimerum Penzig, isolated from paddy field soil, Chinsurah, Calcutta (**14**: 115).
F. equiseti (Corda) Sacc., isolated from black cotton soil, Udamalpet (**18**: 20; **21**: 561).
F. javanicum Koord., isolated from black cotton soil, Udamalpet (**18**: 20; **21**: 561).
F. javanicum Koord. v. **radicicola** Wr., isolated from black cotton soil, Udamalpet (**21**: 561).
F. orthoceras App. & Wr., isolated from paddy field soil, Chinsurah, Calcutta (**14**: 115; **20**: 29).
F. oxysporum Schlecht, isolated from paddy field soil, Chinsurah, Calcutta **14**: 115; **20**: 29); from black cotton soil, Udamalpet (**21**: 561).
F. poae (Peck) Wr., isolated from black cotton soil, Udamalpet (**18**: 20; **21**: 561).
F. scirpi Lamb. & Fautr., isolated from black cotton soil, Udamalpet (**18**: 21; **21**: 561).
F. scirpi Lamb. & Fautr. v. **acuminatum** (Ell. & Ev.) Wr., isoalted from black cotton soil, Udamalpet (**18**: 21; **21**: 561).
F. scirpi Lamb. & Fautr., v. **caudatum** Wr., isolated from black cotton soil, Udamalpet (**22**).
F. solani (Mart.) App. & Wr., isolated from paddy field soil, Chinsurah, Calcutta (**14**: 115; **20**: 29); from black cotton soil, Udamalpet (**21**: 561).
F. solani (Mart.) App. & Wr. v. **martii** (App. & Wr.) Wr., isolated from black cotton soil, Udamalpet (**18**: 21; **21**: 561).
F. solani (Mart.) App. & Wr. v. **minus** Wr., isolated from black cotton soil, Udamalpet (**18**: 21; **21**: 561).
F. solani (Mart.) App. & Wr. v. **striatum** (Sherb.) Wr., isolated from black cotton soil, Udamalpet (**18**: 21; **21**: 561).
F. vasinfectum Atk., isolated from black cotton soil, Udamalpet (**21**: 561).

Helminthosporium sativum P. K. & B., isolated from alkaline soil, Pusa (**13**: 584).
H. tetramera McKinney, isolated from alkaline soil, Pusa (**13**: 584 without authority).

Macrophomina phaseoli (Maubl.) Ashby, isolated from black cotton soil Udamalpet (**23**: 109).
Memnoniella echinata (Riv.) Galloway, isolated from soil, Vandalur, Madras State (**18**: 28).
Mylitta ? lapidescens Horaninow, on the ground, Nilgiris (**10**: 148).

Oospora lactis (Fers.) Sacc., isolated fom soil, Madras (**10**: 148).

Paecilomyces varioti Bainier, isolated from Allahabad soils (**17**: 120).
Penicillium decumbens Thom, isolated from paddy field soil, Chinsurah, Calcutta (**20**: 29).
P. digitatum Sacc., isolated from soil, Madras (**10**: 148).
P. fellutanum Biourge, isolated from Allahabad soils (**17**: 120).
P. glabrum (Wehmer) Westling, isolated from soil, Madras (**10**: 148).
P. glaucum Link, isolated from soil, Madras (**10**: 148); from paddy field soil, Chinsurah, Calcutta, (**20**: 29).
P. javanicum v. Beijma, isolated from soil sent to Raper & Thom by Mundkur from Delhi (**19**: 138).
P. lilacinum Thom, isolated from paddy field soil, Chinsurah, Calcutta (**20**: 29).
P. luteum Zukal, isolated from Allahabad soils (**17**: 120).
P. oxalicum Currie & Thom, isolated from soil, Madras (**10**: 148).
P. pinophyllum Hedgcock, isolated from paddy field soil, Chinsurah, Calcutta (**20**: 29).
P. terrestre Jensen, isolated from paddy field soil, Chinsurah, Calcutta (**14**: 115).
P. vermiculatum Dangeard, isolated from soil, India (**19**: 582).
P. viride-varians Chaudhuri & Sachar, isolated from paddy field soil, Chinsurah, Calcutta (**20**: 29).
P. wortmanni Kloecker, on humus, Himalayas (**10**: 149).

Sporotrichum roseum Link, isolated from soil, Madras (**10**: 150).
Stysanus stemonitis (Pers.) Corda, isolated from Pusa soils (**15**: 36).

Trichoderma album Preuss, isolated from soil, Madras (**10**: 150).
T. viride Pers. ex Fr., isolated from soil, Pusa (**15**: 37); from acid soils, Mungpoo, Manali (**13**: 583); from black cotton soil, Udamalpet (**23**: 109). See also **18**: 48.

Verticillium glaucum Bonord., isolated from soil, Madras (**10**: 151).

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GLYCERIDE COMPOSITION OF THE SEED FAT OF *CERBERA ODOLLAM GAERTN.*

Family: Apocynaceae

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ABSTRACT

The seeds of *Cerbera Odollam* contain 62·1% of a pale yellow oil. The component acids are, Stearic 10·8%, Palmitic 32.0%, Oleic 38·8%, and Linoleic acid 18·4% by weight. The molecular proportion of the acids are Stearic 10·3, Palmitic 34·1., Oleic 37·6, and Linoleic 18·0 per cent. The distribution of Glycerides in the sample on investigation by the tentative Oxidation method was found to be as follows: GS_3 Traces, GS_2U 51·1, GSU_2 31·0 and GU_3 17·9 per cent by molecules.

INTRODUCTION

Cerbera Odollam Gaertn. (Malayalam: *Odalam*, Tamil: *Udalai*, Bengali: *Dabur*, Marathi: *Sukanu*) is a small dicotyledonous tree growing in profusion on the banks of canals and salt swamps of the coasts of South-east Asian countries. The ripe fruit of the tree contains either one or two seeds which contain chemical constituents of pharmacological importance. The bark of the tree has purgative properties, while the nut is narcotic and poisonous. The green fruit is often used to kill dogs and the kernels of the fruit containing an irritant poison, when taken internally, produce vomitting and purging soon followed by collapse and death. Emetic and purgative properties are attributed to the milky acrid sap which fills the whole plant including the leaves. The fruit is used as a cure for hydrophobia. Kirtikar and Basu (1933) state that the plant is used medically in the Philippine islands and the Malay-Archipelago. The work of several investigators on the poisonous chemical constituents of the seed (Greshoff, 1890; Matubara, 1939; Chen and Steldt, 1942; and Poti and Moudgill, 1952) has led to the identification of three distinct cardiac poisons, "Cerberin",

"Odollin" and "Odollotoxin", which have a digitalis-like action. Poti and Moudgill (1952) quote the results of the experiments carried out with 'Cerberin' at the Tropical School of medicine, Calcutta, thus, "One to two milligrams of 'Cerberin', given intravenously to a cat first stimulate and then paralyse the nerve endings and also the intestinal movements. There is a marked and maintained increase of blood pressure. Mycrocardiographic experiments showed that the drug definitely slowed the rate of the heart beat, but increased the force of contraction of both the auricles and the ventricles".

The first report of the chemical examination of the oil by Ghanekar and Ayyar (1927) revealed the following characteristic features. The seeds yielded a pale yellow coloured, non-drying oil in a 43·1 % yield by weight on the seeds, by the extraction of the ripe, dried seeds with petroleum ether b.p. 60-80°. The extracted oil had the following constants:

Specific Gravity	.. { 15° / 15° }	0·9144
Refractive index	.. { 60° / D }	1·4578
Acid value	..	0·35
Saponification value	..	191·1
Unsaponifiable matter	..	0·8 percent
Acetyl value	..	0·0
Iodine value	..	73·8
Polenske value	..	inappreciable
Reichert-Polenske value	..	"
Hehner value	..	94·8

The mixed fatty acids had an Iodine value of 77, titre 34°, and molecular weight 277·5. The composition of the mixed fatty acids has been investigated in detail, employing preliminary separation into solid and liquid acids by means of Lead salts according to Twitchell's procedure, and subsequent fractionation of the Methyl esters from the two groups of acids. Thus saturated acids formed 41·2% and unsaturated acids 58·8% calculated on mixed fatty acids. The component acids are Linoleic 16·4% Oleic 42%, Myristic 0·4%, Palmitic 30%, Stearic 9·9% and Lignoceric acid 0·9%. The unsaponifiable matter formed 0·8% of the oil and contained 32·2% of a sterol, probably sitosterol.

Later, Kafuku, Hata, and Fujikawa (1934) studied the oil and reported the presence of a colourless oil in the seeds in a 64·0% yield, with 2% ash and 2% water. The constants of the oil were as follows:

d 30/4	..	0·9010.
n 30/D	..	1·4632.
Acid No.	..	0·74.
Sap. No.	..	199·15.
Iodine No.	..	66·28.
Unsaponifiables	..	0·13%.

The mixed acids had a neutralization value 200·92, average molecular weight 265·98; Iodine No. 68·11. They also reported that the oil is one of the best non-drying oils.

More recently, Kafuku and Hata (1936) analysed the oil for component fatty acids by the usual procedure and report the presence of Myristic, Palmitic and Oleic acids, as component acids in the oil.

The latest examination of the oil by Steldt and Chen (1943) revealed the presence of a yellow-brown coloured oil from the seeds in a 62% yield, by extracting the dried, ripe seeds with ether. The oil was optically inactive.

Specific Gravity	..	d 30°	0·9031.
Refractive index	..	30°	1·4599.
Solidification point	..		27·8°
Melting point	..		29·30°
Acid value	..		75·9
Hehner value.	Insoluble acids as butyric 0·71%. / Insoluble acids and unsaponifiables 90·0%.		

The component acids were Palmitic, Stearic and Oleic acids.

A survey of the literature reveals that no work has been done on the Glyceride composition of the fixed oil, and the present work relates to the same.

The oil was examined for the glyceride composition by the method of Kartha and Menon (1943, 1945). The saturated acid content was determined according to the method of Hilditch and Priestman (1931), which is a modification of Bertram's (1927) Oxidation procedure.

Experimental

The seeds used in this investigation were obtained from the Chepauk area in Madras and were fully ripe. On extraction of the dried, ground seeds with light petroleum (45° — 65°), a pale

yellow coloured oil was obtained in a 62·1% yield calculated on the weight of the seeds having the following constants.

Specific Gravity	..	28° / 28°	0·9684.
Refractive index		30°	1·4640.
Acid value	..		1·7
Saponification value	..		188·9
Unsaponifiable matter	..		0·74%
Iodine value (Hanus)	..		65·7
Reichert — Meissel value	..		1·7
Acetyl value	..		0·0
Hehner value	..		95·2

Neutral oil for oxidation purposes was prepared in the following manner. The oil was stirred with a 2-5% soln. of sodium carbonate for about three hours. Then it was warmed on the waterbath. The soap formed was removed, the oil washed with hot water to remove alkali, dried with anhydrous magnesium sulphate, and filtered. The filtered oil was a clear, pale yellow coloured liquid.

Oxidation of the oil :—

5·1187 grams of the neutral oil was weighed into a 500 c. c. round bottomed flask provided with a reflux condenser and dissolved in 200 c. c. of dry acetone. 12 c.c. of Glacial acetic acid was added to the acetone soln. Small quantities of well powdered potassium permanganate were added and the round bottomed flask shaken vigorously after each addition of permanganate. After the addition of some 16 grams of permanganate, 6 c.c. of Glacial acetic acid was added and for every further 16 grams of permanganate used a subsequent 6 c.c. of acetic acid was added. This keeps the medium acidic all through and prevents the accumulation of any carbonate, and eliminates the possibility of hydrolysis at any time. The oxidation was first carried out at room temperature, and then on the steam bath till the oxidation was complete. This can be observed by the pink colour in the flask due to excess of permanganate. The acetone was distilled off on the water bath, and the last traces of acetone were removed at the pump.

The mixture of Manganese-di-oxide and oxidation products was not removed from the flask. 300 c.c. of distilled water was added to the flask, the mixture shaken up with warming and small quantities of sodium bisulphite and dilute sulphuric acid (30%)

were added alternatively, with vigorous shaking after each addition, till the whole of the Manganese-di-oxide had dissolved and the fatty matter had separated as a clear layer. The flask was cooled and the contents transferred into a 500 c.c. separating funnel and exhaustively extracted, first with 100 c.c. and then with four successive 50 c.c. portions of ether. The ethereal layer was washed with distilled water, until it was free of mineral acids. The washings were extracted with 100 c.c. ether and ether combined with the original ether bulk.

The ether extract was then thoroughly shaken with 50 c.c. of 5% ice cold Sodium-bicarbonate solution. When the two layers separated clearly the lower layer was drawn off. The ethereal layer was washed with 50 c.c. distilled water, and the washing added to the Sodium bicarbonate washing. The extraction of ether with Sodium bicarbonate Soln. followed by washing with an equal volume of distilled water was continued with three more portions of 30 c.c. each of the Sodium bicarbonate solution, and distilled water. The washings were collected together and extracted with 50 c.c. of ether, and the ether added to the bulk of the ethereal solution.

The ether extract, after washing with bicarbonate soln. to remove free acidic products, contains a mixture of GS_3 (tri-saturated glycerides), GS_2A, GSA_2 and GA_3 (Azelaoglycerides). A preliminary oxidation of 4·9123 grams of oil gave only 0·0007 gram of trisaturated glycerides showing thereby that the fully saturated glycerides are nearly absent. Therefore the ether extract contains a mixture of GS_2A, GSA_2 and GA_3 together with negligible amounts of trisaturated glycerides. The ether extract was dried with anhydrous magnesium sulphate and transferred quantitatively to a tared, clean and dry flask. Ether was distilled off and the residue of mixture of glycerides heated to constant weight. The mixture of glycerides weighed 2·7259 grams. This was saponified with alcoholic potassium hydroxide and the alkali used for the saponification corresponded to 30·8 c.c. of 0·5006 N hydrochloric acid. Hence saponification value is 316·7.

The liquid after finding out the saponification value was warmed on the water bath to remove alcohol. The preliminary bicarbonate and aqueous washings were collected together, acidified and ether extracted. The ether was distilled off and the residue was mixed with the liquid left behind after determining the saponification value. The glycerides were subjected to a thorough saponification by refluxing with 100 c.c. of 2 N alcoholic potassium

hydroxide for three hours. Alcohol was distilled off on the water bath and the solution diluted with 150 c.c. of hot distilled water. The fatty acids were liberated by acidifying with dilute sulphuric acid. The fatty acids were extracted to completion with ether, the ether washed free of mineral acid, washings extracted with 50 c.c. of ether, and ether combined with the other ether bulk. The ethereal soln. was dried with anhydrous magnesium sulphate and ether distilled off.

The residual acid was subjected to Bertram separation. The saturated acids obtained from Bertram procedure weighed 2·084 grams. It showed *no Iodine* absorption showing thereby that it was fully saturated and no unoxidised portion of oil was contained in it. 2·084 grams of saturated acids required 15·87 c.c. of 0·5000 N alcoholic potash for neutralisation. Hence acid value is 213·2. This corresponds to a mean molecular weight of 263·1.

Calculation

Determination of saturated acid content :—

For purposes of calculation C_{16} and lower acids have been taken as Palmitic acid and C_{18} and higher acids as Stearic acid.

2·084 grams of saturated acids of Iodine value 0·00 is given by 5·1187 grams of oil, corresponding to 40·7% on the weight of the oil. The saturated acids have a mean molecular weight of 263·1. To arrive at the proportion of C_{16} and C_{18} saturated acids, the difference between the mean molecular weight of the mixed saturated acids and the molecular weight of Palmitic acid has to be taken.

Thus, molecular weight of Stearic acid 284.
molecular weight of Palmitic acid 256.

and the mean molecular weight of saturated acids found experimentally is 263·1.

Difference between the mean molecular weight of the saturated acids and that of Palmitic acid comes to 263·1−256=7·1. The difference between the molecular weights of Stearic and Palmitic acids is 284−256=28. The total percentage of saturated acids in the oil is

$$\frac{2\cdot084}{5\cdot1187}\times 100 = 40\cdot7$$

The percentage of C_{18} acid is therefore

$$\frac{40\cdot7\times 7\cdot1}{28} = 10\cdot3, \text{ and of } C_{16} \text{ acid } 30\cdot4.$$

This corresponds to weight on oil, and to convert it into weight of fatty acids, it has to be multiplied by $\frac{100}{95\cdot2}$

since 95·2 is the Hehner value, and on converting into weight percent of fatty acids, the values for palmitic and Stearic are as follows.

Total saturated acids. $\frac{100}{95\cdot2}\times 40\cdot7 = 42\cdot8\%$

Palmitic acid $\frac{100}{95\cdot2}\times 30\cdot4 = 32\cdot0\%$

and Stearic acid 10·8%.

Calculation of unsaturated acid content :—

The oil was tested for the presence of Linolenic acid by the hexabromide derivative, and the test was found to be negative. Hence the oil can be taken to be free from Linolenic acid.

The percentage of saturated acids in the oil is 40·7 and that of saturated acids in combination as glycerides is

$$\frac{40\cdot7\times(263\cdot1\times 3+38)}{(263\cdot1\times 3)} = 42\cdot7$$

Therefore percentage of unsaturated acids as Glycerides is

$100 - 42\cdot7 = 57\cdot3.$

The Iodine value of the oil is 65·7 and this is due to the unsaturated glycerides alone. The iodine value of the unsaturated glycerides is

$$\frac{65\cdot7}{100-42\cdot7}\times 100 = \frac{65\cdot7}{57\cdot3}\times 100 = 114\cdot7$$

The Iodine value of Triolein is 86·2 and of trilinolein is 173·6. Hence the percentage of Trilinolein, when the Iodine value is 114·7 comes to

$$\frac{114\cdot7-86\cdot2\times 57\cdot3}{173\cdot6-86\cdot2} = \frac{28\cdot5\times 57\cdot3}{87\cdot4} = 18\cdot7$$

That of Triolein is $57 \cdot 3 - 18 \cdot 7 = 38 \cdot 6$.

These figures indicate that approximately one part of Linoleic acid to two parts of oleic acid exist in combination giving a mean molecular weight of 281·3.

Hehner value of the oil is 95·2 and the percentage of saturated acids is 40·7

Hence the percentage of unsaturated acids is $95 \cdot 2 - 40 \cdot 7 = 54 \cdot 5$. Consequently the percentage of oleic acid will be

$$\frac{282 \times 3 \times 38 \cdot 6}{282 \times 3 + 38} = 36 \cdot 9$$

Similarly that of Linoleic acid will be 17·6.

It would be profitable at this stage to compare the calculated figures with the experimental results obtained by previous workers (Ghanekar et al) and since the figures in the literature are based on total acids, whereas these figures are based on oil, and have first to be converted into those corresponding to total acids. This can be accomplished by making use of the Hehner value 95·2, i.e. multiplying the percentages obtained on the basis of the oil by the fraction $\frac{100}{95 \cdot 2}$

Fatty acid	Weight percentage of acids.	
	Present investigation	Ghanekar & Ayyar
Stearic acid ..	10·8	9·9
Palmitic acid ..	32·0	30·0
Oleic acid ..	38·8	42·0
Linoleic acid ..	18·4	16·4

The above mentioned workers (Ghanekar et al) have in addition reported traces of Myristic acid, and Lignoceric acid.

The above composition obtained in the present investigation corresponds to Stearic 10·3, Palmitic 34·1, Oleic 37·6 and Linoleic 18·0 by molecules.

Calculation of Glyceride composition.

The molecular percentages of saturated and unsaturated acids are in the ratio 44·4 to 55·6. The glyceride composition can now be calculated.

The saponification value for GS_2A is

$$\frac{4 \times 56 \cdot 1 \times 1000}{38 + (263 \cdot 1 \times 2) + 188} = \frac{4 \times 56 \cdot 1 \times 1000}{752 \cdot 2} = 298 \cdot 4$$

and the saponification value for GSA_2 is

$$\frac{5 \times 56 \cdot 1 \times 1000}{38 + 263 \cdot 1 + (188 \times 2)} = \frac{5 \times 56 \cdot 1 \times 1000}{677 \cdot 1} = 414 \cdot 3$$

The above figures are based on the observation that the ratio of the saturated acids is the same in the two types.

From the result of the preliminary oxidation the fully saturated glycerides i.e. the triglycerides can be taken to be absent.

5·1187 grams of oil yielded 2·726 grams of the mixture of the two azelao-glycerides, and the trisaturated Glycerides if any. Since the latter has been found to be negligible the saponification value of 316·7 is due to the mixture of GSA_2 and GS_2A alone.

The weight of GS_2A in the mixture of GS_2A and GSA_2

$$= 2 \cdot 726 \times \frac{(414 \cdot 3 - 316 \cdot 7)}{(414 \cdot 3 - 298 \cdot 4)} = 2 \cdot 295 \text{ grams.}$$

The weight of GS_2U corresponding to this is

$$\frac{2 \cdot 295 \times [(263 \cdot 1 \times 2) + 282 + 38]}{(263 \cdot 1 \times 2) + 188 + 38} = 2 \cdot 582 \text{ grams.}$$

The percentage by weight of GS_2U will be

$$= \frac{2 \cdot 582 \times 100}{5 \cdot 199} = 50 \cdot 44$$

Conversion into moles percent :—
Weight of saturated acids in 50·44% of GS_2U

$$= \frac{50 \cdot 44 \times (263 \cdot 1 \times 2)}{846 \cdot 2} = 31 \cdot 36\%.$$

Weight of unsaturated acids in 50·44% of GS_2U

$$\frac{50\cdot44 \times 281\cdot3}{846\cdot2} = 16\cdot77\%.$$

Saturated acids in 100 grams of fat = 40·7%.

Unsaturated acids = 95·2 − 40·7 = 54·5%

(95·2 is the Hehner value)

Of the 40·7% saturated acids 31·36% have been used up for GS_2A. Similarly of the 54·5% unsaturated acids. 16·77% have been used up for GS_2U.

Hence the remaining acid mixture contains (40·7—31·36)% saturated acids and (54·5 — 16·77)% unsaturated acids.

i.e. 9·34% saturated acids

37·73% unsaturated acids.

Acid value of the remaining mixture of acids

$$9\cdot34 \times 213\cdot2 + 37\cdot73 \times 199\cdot5 = 47\cdot07 \times X.$$

$$\text{Therefore } X = \frac{(9\cdot34 \times 213\cdot2) + (37\cdot73 \times 199\cdot5)}{47\cdot07} = 202\cdot2$$

corresponding to a mean molecular weight of 277·4.

The remaining part of the fat is composed of acids of mean molecular weight 277·4.

Hence mean molecular weight of the remaining part of the fat other than $GS_2U = 277\cdot4 \times 3 + 38$

$= 832\cdot2 + 38 = 870\cdot2$

GS_2U percentage by moles will be

$$\frac{50\cdot44}{846\cdot2} :: \frac{49\cdot56}{870\cdot2} = 51\cdot1.$$

The molecular percentage of saturated acids has been found to be 44·4, that of GS_2U 51·1 and $GS_3 = 0$.

Hence the molecular percentage of GSU_2

$$= [(44\cdot4 - 0\cdot0) - (51\cdot1 \times 2/3)] \times 3 = 31.$$

Thus the specimen of oil contains GS_3 traces, GS_2U 51·1% and GSU_2 31·0% by molecules. The GU_3 therefore comes to 17·9% by molecules.

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APPLICATION OF THE VARIATE—DIFFERENCE METHOD TO ANALYSIS OF TWO TIME-SERIES

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ABSTRACT

In this paper different tests are obtained for determining the degree common to the polynomial trends of the two time-series and they have been illustrated numerically. An extension to several time-series is also considered.

1. INTRODUCTION

The variate-difference method is a statistical technique of isolating random components from time-series. It is applicable to a series which has a trend component represented by a polynomial and a random component but which has no seasonal or periodic components. A time-series will be free of such components if the time intervals are long enough to cover a year or a period. Various authors, Yule (1921), Tintner (1940) and Johnson (1948) have discussed the variate-difference method and have given tests for determining the order of difference required for eliminating the trend components from a time-series.

Tintner's test consists in differencing the series $u_1, u_2, \ldots u_n$ (assuming its setup as $u_t = f_t + z_t$; $t = 1, 2, \ldots n, \ldots$ (1) where f_t is the trend component given by polynomial in t of degree $(k-1)$ and z'_ts are independent random variables distributed normally with mean zero and variance σ^2) k-times whose expected values are given to be zero and the variance as

$$\varepsilon(\triangle^k u_t)^2 = 2kc_k\sigma^2 \quad .. \quad (2)$$

$$\varepsilon(\triangle^{k+1} u_t)^2 = (2k+2)\,c_{k+1}\,\sigma^2 \quad .. \quad (3)$$

He selected the terms from the k^{th} differences

$$\triangle^k u_t : t = r,\ r+(2k+3),\ r+2(2k+3), \ldots, r+(m-1)(2k+3)$$

and from the $(k+1)^{th}$ differences

$$\triangle^{k+1} u_t : t = r+k+1,\ r+k+1+(2k+3), \ldots, r+k+1+(m-1)(2k+3) \quad .. \quad (4)$$

where r is an integer lying between 1 and $(k+1)$, to secure independence and considered the ratio

$$\frac{\sum_s (\triangle^k u_t)^2/2kc_k}{\sum_{s'} (\triangle^{k+1} u_t)^2/(2k+2)\,c_{k+1}} \quad .. \quad (5)$$

as an F with the degrees of freedom $v_1 = m$ and $v_2 = m$ where $m = \left(\frac{n}{2k+3}\right)$ This variance ratio provides a criterion for testing the hypothesis that the polynomial of the trend component is of degree $(k-1)$.

Johnson modified Tintner's test, as the latter involves a small fraction of the series, by proposing alternative selection thus:

$$\text{for } \triangle^k u_t \text{ and } \triangle^{k+1} u_t : t = r,\ r+(k+2),\ r+2(k+2), \ldots, r+(l-1)(k+2) \quad .. \quad (6)$$

r lying between 1 and $(k+2)$. He constructed the test criterion

$$L = \frac{T_{k,k}\,T_{k+1,k+1} - T^2_{k,k+1}}{(2k+1)\left[T_{k,k} - \frac{1}{2}\frac{k+1}{2k+1}T_{k+1,k+1} + T_{k,k+1}\right]^2}$$

in which $T_{p,q} = \sum_s \triangle^p u_t \triangle^q u_t$: S being the set of l values of t in (6) and has shown from the distribution of L that there is significance if $\log_{10} L$ is less than $\frac{2\log_{10}\alpha}{l-1}$, α being the level chosen. By applying the test successively, the least value of k for which it is nonsignificant is obtained.

In this paper the variate-difference method is applied to the analysis of two time-series in which firstly the random components of one are uncorrelated with those of the other and secondly when they are correlated. Taking a selection of terms of the difference series similar to those made either by Tintner

or Johnson in the case of a single series, different tests are obtained for determining the degree common to the polynomial trends of the two series. These methods have been illustrated numerically. An extension to several time series considered as samples from a population is also discussed. Application of some of these methods to the case of a single series is briefly indicated.

2. *Time Series with Uncorrelated Random Elements*

We consider here two time-series having polynomial trends of the same order and nearly of the same type, that is when the polynomials are of the same degree in t and the coefficients of corresponding terms not very unequal. The series will therefore be correlated. Such a situation is common when we are dealing with the series of prices of closely allied commodities like steel and iron or ghee and vanaspati or with volumes of production of similar articles like cotton shirting and cotton or sugar and gur. We assume that each series is free from seasonal components. The random components in each series are due to random influences which have no systematic relation to time and so are mutually independent but there may or may not be correlation between the random components of the two series. In Section 2 the uncorrelated case will be considered.

2·1 *Analysis of Trends of Two Series*

Suppose $u_1, u_2, \ldots \ldots u_n$

and $v_1, v_2, \ldots \ldots v_n$

are two time-series at equal intervals $t = 1, 2, 3 \ldots . n$.

$$\text{Let} \begin{bmatrix} u_t = f_t + z_t \\ v_t = \Phi_t + \zeta_t \end{bmatrix} \quad .. \quad (7)$$

where f_t and Φ_t are the trend components and z_t and ζ_t are independent random variables normally distributed with mean zero and standard deviations σ and σ'.

Further $\mathrm{E}(z_t\zeta_t) = 0$. Let f_t and Φ_t be two polynomials in t of the same degree k (not $k-1$), so that

$\triangle^k f_t = a$; $\triangle^k \Phi_t = a'$, a, a' being some constants

and $\triangle^{k+1} f_t = 0$; $\triangle^{k+1}\Phi_t = 0$.

Hence $\mathrm{E}(\triangle^k u_t) = \mathrm{E}(a + \triangle^k z_t) = a$; similarly $\mathrm{E}(\triangle^k v_t) = a'$.

Also $\mathrm{E}(\triangle^{k+1}u_t) = \mathrm{E}(\triangle^{k+1}v_t) = 0$.

Further $Var\ (\triangle^k u_t) = \mathrm{E}(\triangle^k u_t - a)^2 =$
$\mathrm{E}(\triangle^k z_t)^2 = 2kc_k\,\sigma^2 = \sigma^2{}_k$ (say)

Similarly $Var\ (\triangle^{k+1}u_t) = (2k+2)\ c_{k+1}\sigma^2 = \sigma^2{}_{k+1}$,

$Var\ (\triangle^k v_t) = 2kc_k\,\sigma'^2 = \sigma'^2{}_k$,

$Var\ (\triangle^{k+1}v_t) = (2k+2)\,c_{k+1}\,\sigma'^2 = \sigma'^2{}_{k+1}$. .. (8)

We also have cor $(\triangle^k u_t, \triangle^k v_t)$

$= \mathrm{cor}\ (a + \triangle^k z_t, a' + \triangle^k\zeta_t) = \mathrm{cor}\ (\triangle^k z_t, \triangle^k\zeta_t) = 0.$

since z_t and ζ_t are uncorrelated. Denoting the cor $(\triangle^k u_t\ \triangle^k v_t)$ by p_k we shall consider the hypothesis H_1, that $p_k = 0$ and obtain a test for it.

By choosing $\triangle^k u_t$, $\triangle^k v_t$ as in (6) or as below so as to have more terms,

$t = r,\ r+k+1,\ r+2\ (k+1), \qquad r+(v-1)\ (k+1), \ldots$ (9)

r lying between 1 and $(k+1)$, we find an expression for the sample correlation coefficient

$$r_k = \frac{\sum_s (\triangle^k u_t - \overline{\triangle^k u_t})\ (\triangle^k v_t - \overline{\triangle^k v_t})}{\sqrt{\sum_s (\triangle^k u_t - \overline{\triangle^k u_t})^2 \times \sum_s (\triangle^k v_t - \overline{\triangle^k v_t})^2}} \qquad (10)$$

the summation being over the set S in (9) and the bars over the $\triangle$'s indicating means over the t's We apply the test for significance of r_k by calculating

$$t = \frac{r_k}{\sqrt{1 - r_k^2}}\sqrt{v-2}\,; \quad .. \quad (11)$$

the number of terms in S and referring it to the t-— scale with $v-2$ degrees of freedom.

In this procedure we assume that the correlation between the original u and v series is only due to the correlation between the trend component which are polynomials of the k^{th} degree. Hence when the trend is reduced to a constant by differencing k times, we should not have any appreciable correlation left between the k^{th} difference series. By taking successively $k = 1, 2, 3, \ldots .$ we

test for significance of r_k at a chosen significance level, say 5% and we accept that value of k for which r_k is first found to be non-significant Clearly for all larger values of k, there will be non-significance Then we infer that a trend line of the k^{th} degree will fit both the series.

It has to be noted that the original series should not be too short. This is a general requirement whenever the variate-difference method is used. After knowing the degree of the polynomical, the actual fitting, that is the determination of the coefficients in them is done by the usual method of least squares applied to the two original series.

Even when the trend components in the two series are not of the same order, the method described above is applicable. The value of k obtained by successive testing will be the maximum of the degrees of the polynomials and so will give the line of the lowest degree which fits both the series best.

Illustration 1

We shall now apply the above method to two series (u_t) and (v_t) constructed from the relations

$$u_t = 20 + 2\cdot5t + \cdot01t^2 + \varepsilon t,$$
$$v_t = 30 + 2t \quad + \cdot02t^2 + \varepsilon'_t \text{ for } t = 1 \text{ to } 48.$$

The random elements ε_t, ε'_t are taken from the table of random Samples from a Normal population (Mahalamobis, 1934) and multiplied by 10. The constructed series and the first three difference series are shown in Tables I-a and I-b.

Taking first $k = 1$, the correlation coefficient r_1 between the first difference terms selected according to scheme (9), viz. the terms with t= 1, 3, 5, ... 47 is calculated by formula (10) and is found to be $r_1 = \cdot5179$. Here $v = 24$ and hence the corresponding value of t in (11) is 2·791. For 22 degrees of freedom, the 5% point of t is 2·074. Thus the calculated value of t is greater than the 5 % limit and so it is inferred that the non-random elements have not been reduced to constants in the first differences.

Next taking $k = 2$ and selecting the terms $t = 1, 4 \ldots 46$ of the second difference series of u_t and v_t, r_2 is calculated and found to be $r_2 = \cdot4928$; v being 16, t is 2·119. This is less than 2·145, the 5% point of t for 14 degrees of freedom and hence it is not signifi-

TABLE Ia

t	u_t	$\Delta^1 u_t$	$\Delta^2 u_t$	$\Delta^3 u_t$
1	16·85	+ 8·47	− 13·52	+ 9·66
2	25·32	− 5 05	− 3·86	+ 32·08
3	20·27	− 8·91	+ 28·26	− 45·98
4	11·36	+ 19·35	− 17·72	+ 8·84
5	30·71	+ 1·63	− 8·88	+ 31·12
6	32·34	− 7·25	+ 22·24	− 26·37
7	25·09	+ 14·99	− 4·13	− 10·98
8	40·08	+ 10·86	− 15·11	+ 40·29
9	50·94	− 4·25	+ 25·18	− 64·17
10	46·69	+ 20·93	− 38·99	+ 52·95
11	67·62	− 18·06	+ 13·96	− 9·01
12	49·56	− 4·10	+ 4·95	+ 17·06
13	45·46	+ 0·85	+ 21·01	− 25·81
14	49·31	+ 21·86	− 4·80	− 42·70
15	68·17	+ 17·06	− 47·50	+ 84·56
16	85·23	− 30·44	+ 37·06	− 49·42
17	54·79	+ 6·62	− 12·36	+ 42·69
18	61·41	− 5·74	+ 30·33	− 66·67
19	55·67	+ 24·59	− 36·34	+ 67·62
20	70·26	− 11·75	+ 31·28	− 57·79
21	58·51	+ 19·53	− 26·51	+ 45·73
22	78·04	− 6·98	+ 19·22	− 34·32
23	71·06	+ 12·24	− 15·10	+ 42·05
24	83·30	− 2·86	+ 26·95	− 73·74
25	80·44	+ 24·09	− 46·79	+109·30
26	104·53	− 22·70	+ 62·51	−114·94
27	81·83	+ 39·81	− 52·43	+ 67·96
28	121·64	− 12·62	+ 15·53	− 35·19
29	109·02	+ 2·91	− 19·66	+ 31·49
30	111·93	− 16·75	+ 11·83	+ 13·83
31	95·18	− 4·92	+ 25·66	− 34·45
32	90·26	+ 20·74	− 8·79	− 9·59
33	111·00	+ 11·95	− 18·38	+ 24·62
34	122·95	− 6·43	+ 6·24	− 1·09
35	116·52	− 0·19	+ 5·15	− 9·16
36	116·33	+ 4·96	− 4·01	+ 21·89
37	121·29	+ 0·95	+ 17·88	− 33·75
38	122·24	+ 18·83	− 15·87	+ 3·19
39	141·07	+ 2·96	− 12·68	+ 26·97
40	144·03	− 9·72	+ 14·29	− 10·39
41	134·31	+ 4·57	+ 3·90	− 8·91
42	138·88	+ 8·47	− 5·01	+ 6·81
43	147·35	+ 3·46	+ 1·80	− 5·10
44	150·81	+ 5·26	− 3·30	+ 7·47
45	156·07	+ 1,96	+ 4·17	− 13·30
46	158·03	+ 6·13	− 9·13	− ..
47	164·16	− 3·00	− ..	− ..
48	161·16	− ..		

TABLE Ib

t	v_t	$\Delta^1 v_t$	$\Delta^2 v_t$	$\Delta^3 v_t$
1	42·70	+ 2·35	− 10·53	− 7·14
2	45·05	− 8·18	− 17·67	+ 65·99
3	36·87	− 25·85	+ 48·32	− 62·30
4	11·02	+ 22·47	− 13·98	+ 5·65
5	33·49	+ 8·49	− 8·33	+ 7·27
6	41·98	+ 0·16	− 1·06	+ 28·28
7	42·14	− 0·90	+ 27·22	− 66·21
8	41·24	+ 26·32	− 38·99	+ 64·71
9	67·56	− 12·67	+ 25·72	− 60·34
10	54·89	+ 13·05	− 34·62	+ 61·90
11	67·14	− 21·57	+ 27·28	− 31·78
12	46·37	+ 5·71	− 4·50	+ 17·48
13	52·08	+ 1·21	+ 12·93	− 14·90
14	53·29	+ 14·14	− 1·97	− 38·42
15	67·43	+ 12·17	− 40·39	+ 86·75
16	79·60	− 28·22	+ 40·36	− 64·47
17	51·38	+ 18·14	− 18·11	+ 32·57
18	69·52	+ 0·03	+ 14·46	− 33·48
19	69·55	+ 14·49	− 19·02	+ 50·32
20	84·04	− 4·53	+ 31·30	− 65·82
21	79·51	+ 26·77	− 34·52	+ 20·28
22	106·28	− 7·75	− 14·24	+ 52·92
23	98·53	− 21·99	+ 38·68	− 53·85
24	76·54	+ 16·69	− 15·17	+ 14·27
25	93·23	+ 1·52	− 0·90	+ 10·45
26	94·75	+ 0·62	+ 9·55	− 3·04
27	95·37	+ 10·17	+ 6·51	− 19·41
28	105·54	+ 16·68	− 12·90	− 15·66
29	122·22	+ 3·78	− 28·56	+ 45·78
30	126·00	− 24·78	+ 17·22	+ 5·66
31	101·22	− 7·56	+ 22·88	− 2·01
32	93·66	+ 15·32	+ 20·87	− 79·71
33	108·98	+ 36·19	− 58·84	+ 78·64
34	145·17	− 22·65	+ 19·80	− 6·75
35	122·52	− 2·85	+ 13·05	− 12·20
36	119·67	+ 10·20	+ 0·85	− 12·21
37	129·87	+ 11·05	− 11·36	+ 22·65
38	148·92	− 0·31	+ 11·29	− 21·80
39	140·61	+ 10·98	− 10·51	− 8·83
40	151·59	+ 0·47	− 19·34	+ 68·17
41	152·06	− 18·87	+ 48·83	− 81·04
42	133·19	+ 29·96	− 32·21	+ 24·10
43	163·15	− 2·25	− 8·11	+ 32·13
44	160·90	− 10·36	+ 24·02	− 11·50
45	150·54	+ 13·66	+ 12·52	− 63·22
46	164·20	+ 26·18	− 50·70	− ..
47	190·38	− 24·52	..	..
48	165·86	..		

cant. Thus we infer from the test that the non-random components have been reduced to constants in the second differences. Hence the common degree of the polynomials that fit the two series is 2, which is known to be true from their construction. It follows from this test that the trend components are significantly eliminated in the third order difference series.

We may proceed to the third order differences and show that the correlation co-efficient continues to be non-significant. We find that $r_3 = 0{\cdot}510$, $v = 12$ and the corresponding $t = 1{\cdot}875$, which is less than $2{\cdot}228$, the 5% point for t for 10 degrees of freedom.

2·2 *A Single Series Considered as Two Series*

If a given series (u_t) $t = 1, 2, 3, \ldots . n$ admits of a trend component and a random component as in (1) we can construct two series out of it by taking the alternative elements thus:

$$u_1, u_3, u_5, u_7, \ldots\ldots\ldots\ldots$$
$$u_2, u_4, u_6, u_8, \ldots\ldots\ldots\ldots \quad .. \quad (11)$$

Since the random components in the two series are uncorrelated, we can apply the method of sec. 2·1 to find the degree of the polynomial in the trend of each of sub-series. This will be the degree of the polynomial trend in the given series, $u_1, u_2, u_3 \ldots\ldots\ldots$

The numerical procedure is quite simple. The successive differences of each of the subseries in (11) are determined and from the differences of the same order select suitable terms according to the scheme (9). Evaluating r_k in (10), we test for its non-significance for successive values of k.

Illustration II

We shall now apply this method to the series of American wheat flour prices for the years 1890-1937 which is analysed by Tintner (1940) and Johnson (1948). Two series u'_t, v'_t are constructed from the original series by taking alternative elements and the difference series are formed. These are shown in Table II (a) & (b) —

To apply the test of Sec. 2·1 to the two series u'_t and v'_t, take first $k = 1$, the correlation co-efficient r_1 is calculated by formula (10) and is found to be $r_1 = \cdot 613$. Here $v = 11$ and the corresponding value of t is $2{\cdot}332$. For 9 degrees of freedom, the 5% point of t is $2{\cdot}262$. Thus the calculated value of t is greater than the 5%

TABLE IIa

ANNUAL AMERICAN WHEAT-FLOUR PRICES

(The Series in Tintner's Book 'The Variate-Difference Method' P. 35 is divided into Two Series u'_t—, v'_t— taking alternative terms)

The u— Series

t	u'_t	$\triangle^1 u'_t$	$\triangle^2 u'_t$	$\triangle^3 u'_t$
1	5·185	− 0·839	+ 0·087	+ 0·866
2	4·346	− 0·752	+ 0·953	− 0·220
3	3·594	+ 0·201	+ 0·733	− 2·554
4	3·795	+ 0·934	− 1·821	+ 2·674
5	4·729	− 0·887	+ 0·853	+ 0·751
6	3·842	− 0·034	+ 1·604	− 4·276
7	3·808	+ 1·570	− 2·672	+ 4·916
8	5·378	− 1·102	+ 2·244	− 3·309
9	4·276	+ 1·142	− 1·065	+ 0·764
10	5·418	+ 0·077	− 0·301	+ 0·350
11	5·495	− 0·224	+ 0·649	+ 2·294
12	5·271	− 0·175	+ 2·243	− 1·575
13	5·096	+ 2·168	+ 0·768	− 1·229
14	7·264	+ 2·936	− 0·461	− 7·407
15	10·200	+ 2·475	− 7·868	+13·170
16	12·675	− 5·393	+ 5·302	− 3·976
17	7·282	− 0·091	+ 1·326	− 3·782
18	7·191	+ 1·235	− 2·456	+ 2·098
19	8·426	− 1·221	− 0·358	+ 0·507
20	7·205	− 1·579	+ 0·149	+ 3·858
21	5·626	− 1·430	+ 4·007	− 6·521
22	4·196	+ 2·577	− 2·514	− ..
23	6·773	+ 0·063	− ..	
24	6·836	− ..		

limit and so it is inferred that the non-random elements have not been reduced to constants in the first differences.

Next taking $k = 2$, we find $r_2 = \cdot 057$ and v being 7, the corresponding $t = \cdot 0127$ which is less than the 5% limit for $t = 2 \cdot 571$. Thus we can infer that the non-random elements have been reduced to constants in the second difference, that is, they have been eliminated in the third difference. This is the conclusion arrived at by Johnson by his method described in the introduction. The degree of the polynomial trend of the original series is therefore 2.

TABLE IIb

The v— Series

t	v'_t	$\triangle^1 v'_t$	$\triangle^2 v'_t$	$\triangle^3 v'_t$
1	5·305	− 1·299	+ 0·936	+ 0·375
2	4·006	− 0·363	+ 1·311	− 3·076
3	3·643	+ 0·948	− 1·765	+ 2·618
4	4·591	− 0·817	+ 0·853	− 0·369
5	3·774	+ 0·036	+ 0·484	+ 0·088
6	3·810	+ 0·520	+ 0·572	− 2·211
7	4·330	+ 1·092	− 1·639	+ 3·067
8	5·422	− 0·547	+ 1·428	− 2·987
9	4·875	+ 0·881	− 1·559	+ 1·703
10	5·756	− 0·678	+ 0·144	+ 2·509
11	5·078	− 0·534	+ 2·653	− 0·038
12	4·544	+ 2·119	+ 2·615	− 6·748
13	6·663	+ 4·734	− 4·133	− 0·140
14	11·397	+ 0·601	− 4·273	+ 6·004
15	11·998	− 3·672	+ 1·731	+ 2·653
16	8·326	− 1·941	+ 4·384	− 9·222
17	6·385	+ 2·443	− 4·838	+ 5·886
18	8·828	− 1·395	+ 0·748	− 2·309
19	7·433	− 0·647	− 1·561	+ 4·874
20	6·786	− 2·208	+ 3·313	− 2·425
21	4·578	+ 1·105	+ 0·888	− 3·841
22	5·683	+ 1·993	− 2·953	− ..
23	7·676	− 0·960	− ..	
24	6·716	− ..		

2·3 *Several Series*

In a study of changes of a certain factor with time, we may have several time-series and for statistical analysis they could be considered as samples from an unknown population. For instance there will be different series of observations relating to the price of a commodity or index of cost of living at different places in a region. From these series we would like to obtain the secular trend for the whole region. We assume that the random components within each series and between the series are all independent and that they are normally distributed with mean zero. This means that their values do not depend on time or the place of observation.

The method of Sec. 2·1 could be applied to these series. Suppose there are j series of the same length. Taking the k^{th} differen-

ces of each of those series and choosing from them terms according to the scheme (9), we have the subseries

$$\triangle^k u^{(1)}_r,\ \triangle^k u^{(1)}_{r+k+1}, \ldots\ldots \triangle^k u^{(1)}_{r+(v-1)(k+1)}$$

$$\triangle^k u^{(2)}_r,\ \triangle^k u^{(2)}_{r+k+1}, \ldots\ldots \triangle^k u^{(2)}_{r+(v-1)(k+1)}$$

$$\triangle^k u^{(j)}_r,\ \triangle^k u^{(j)}_{r+k+1}, \ldots\ldots \triangle^k u^{(j)}_{r(v-1)(k+1)}$$

Under the hypothesis that the degree of the polynomial trend in the population is k, the correlation between each pair of these subseries is zero, that is,

$$p^{(12)} = p^{(23)} = p^{(13)} = \ldots = 0.$$

To test this hypothesis, we may test the significance of each p separately by the t-test as in Sec. 2·1. The values of k for which non-significance is first attained are found. The maximum of these values is then the degree of the polynomial that fits the trends of all the j subseries.

Alternatively, the average of the jc_2 correlation co-efficients may be taken and tested for significance and the best k obtained.

3. *Time-Series with Correlated Random Components*

3·1 *Formulation of the hypothesis when the order of the polynomial trend is the same for the two series :—*

We consider in this section two time-series having different polynomial trends but of the same order. The random components in each of the two series are mutually independent but the two series of random components are correlated. It may be noted that the random components corresponding to a time t are correlated. In economic statistics such a situation arises when the same type of random influences affects both the series, as for instance with the wages of agricultural labour and of industrial labour. As in Sec. 2 we assume that each series is free from seasonal components.

Suppose (u_t) and (v_t), $t = 1, 2, 3, \ldots . n$ are two time-series, having the set-up's

$$u_t = f_t + z_t,$$
$$v_t = \Phi_t + \zeta_t,$$

where f_t and Φ_t are the trend components and z_t, ζ_t are random components. Suppose z_t, ζ_t are normally distributed with mean zero and standard deviations σ, σ' respectively and the correlation co-efficient between z_t, and ζ_t is p. Let f_t and Φ_t be two polynomials in t of the same degree, k, so that

$$\triangle^k f_t = a\ ;\ \triangle^k \Phi_t = a^1\ ;\ \triangle^{k+1} f_t = 0\ ;\ \triangle^{k+1}\Phi_t = 0.$$

then $\mathrm{E}(\triangle^k u_t) = a$

$\mathrm{E}(\triangle^k v_t) = a'$; a, a' being some constants

and as in (8)

$$\mathrm{E}(\triangle^{k+1} u_t) = 0,\quad \mathrm{E}(\triangle^{k+1} v_t) = 0$$

$$Var\,(\triangle^k u_t) = 2kc_k\sigma^2 = \sigma_k^2\ ;$$

$$Var\,(\triangle^{k+1} u_t) = (2k+2)\,c_{k+1}\,\sigma^2 = \sigma^2_{k+1}\ ;$$

$$Var\ (\triangle^k v_t) = 2kc_k\sigma'^2 = \sigma'^2_k\ ;$$

$$Var\ (\triangle^{k+1} v_t) = (2k+2)\,c_{k+1}\,\sigma'^2 = \sigma'^2_{k+1}.$$

Further

$$\mathrm{cor}\ (\triangle^k u_t\ \triangle^k v_t) = \mathrm{cor}\ \{(a + \triangle^k z_t)\ (a' + \triangle^k \zeta_t) = p_k\ (\text{say})\}$$

$$\mathrm{cor}\ (\triangle^{k+1} u_t\ \triangle^{k+1} v_t) = \mathrm{cor}\ (\triangle^{k+1} z_t\ \triangle^{k+1}\zeta_t) = p_{k+1} \quad \ldots\ (12)$$

Now

$$p_k = \frac{\mathrm{E}[(\triangle^k u_t - a)\ (\triangle^k v_t - a')]}{\sigma_k \sigma'_k} = \frac{\mathrm{E}[\triangle^k z_t\ \triangle^k \zeta_t]}{\sigma_k \sigma'_k}$$

$$= \frac{2kc_k \mathrm{E}(z_t\zeta_t)}{\sigma_k\sigma'_k} = \frac{2kc_k\, p\sigma\sigma'}{\sqrt{2kc_k}\sigma\sqrt{2kc_k}\sigma'} = p$$

Also $p_{k+1} = \dfrac{\mathrm{E}(\triangle^{k+1} u_t \cdot \triangle^{k+1} v_t)}{\sigma_{k+1}\cdot\sigma'_{k+1}}$

$$= \frac{(2k+2)\,c_{k+1}}{\sqrt{(2k+2)\,c_{k+1}\ (2k+2)\,c_{k+1}}}\ \frac{\mathrm{E}(z_t\zeta_t)}{\sigma\cdot\sigma'}$$

$$= p.$$

Thus $p_k = p_{k+1} = p$, $\quad \ldots\ (13)$

which means that the correlation between a pair of difference series of the same order which is not less than k is zero.

The hypothesis, that the common order of the polynomial trends is k, is equivalent to the hypothesis

$$H_2 : \quad p_k = p_{k+1} \qquad .. \quad (14)$$

It is also equivalent to the hypothesis

$$H_3 : \frac{\sigma^2_k}{\sigma^2_{k+1}} = \frac{\sigma'^2_k}{\sigma'^2_{k+1}} = \frac{2kc_k}{(2k+2)c_{k+1}} \qquad .. \quad (15)$$

It will be seen from the relation

$$\frac{p_{k+1}}{p_k} = \frac{\sigma_k \sigma'_k}{\sigma_{k+1}\sigma'_{k+1}} \times \frac{(2k+2)c_{k+1}}{2kc_k}$$

that if H_3 is true, H_2 is also true, but not vice versa. We shall obtain the tests of H_2 and H_3 in the following sections.

3·2. *A Test of the hypothesis H_2 similar to Tintner's Test:*

By choosing elements of the k^{th} and $(k+1)^{th}$ difference series of u_t and v_t according to the scheme given in (4), Tintner finds the correlation co-efficients r_k, r_{k+1} for the two selections and applies the tests for significance of the difference between r_k and r_{k+1}. Since in this method of selection the chosen sets of $\Delta^k u_t$ and $\Delta^{k+1}u_t$ are independent and similarly the sets of $\Delta^k v_t$ and $\Delta^{k+1}v_t$ are independent, we have here two independent bivariate normal samples. Hence using Fisher's z — transformation.

$$z_k = \frac{1}{2}\log_e \frac{1+r_k}{1-r_k}$$

$$\text{and } z_{k+1} = \frac{1}{2}\log_e \frac{1+r_{k+1}}{1-r_{k+1}}$$

the difference $z_k - z_{k+1}$ is under H_2, normally distributed with mean zero and variance $\frac{2}{m-3}$, m being the number of terms selected for each difference series. The procedure thus consists in calculating $z_k - z_{k+1}$ and testing for its significance successively for $k = 1, 2, 3, \ldots$. The least value of k for which we get non-significance at 5% level will give the corresponding degree k of the polynomials that fit both the u and v series.

Tintner in his book has considered this hypothesis in a slightly different form namely that the trend components are eliminated in the $(k+1)^{th}$ differences, so that $p_{k+1} = p_{k+2}$. Calculating the values of r_{k+1} and r_{k+2} by the formula

$$r_p = \frac{\Sigma \Delta^p u_t \cdot \Delta^p v_t}{\sqrt{\Sigma(\Delta^p u_t)^2 \cdot \Sigma(\Delta^p v_t)^2}}; \quad p = k+1,\ k+2,$$

he tests the significance of the difference between r_{k+1} and r_{k+2}. In the above approach we tested the hypothesis $p_k = p_{k+1}$ by calculating r_k and r_{k+1} by formula (10) in which the deviations from the means are taken into account and tested the significance of the difference. Both the methods would give the same $(k+1)$, the order of the difference series in which the trends are eliminated. But in the present method, the conclusion is reached one stage earlier than in Tintner's method and so the labour involved would be much less.

3·3. *An Alternative Test of the Hypothesis H_2:*

In the method of Sec. 3·2 only a small fraction of the k^{th} and $(k+1)^{th}$ difference series could be used resulting in a great loss of information. Hence an alternative test is proposed in this section using the method of selection (6) employed by Johnson for the test with one series. We choose elements from the four series

$$\Delta^k u_t,\ \Delta^{k+1}u_t,\ \Delta^k v_t,\ \Delta^{k+1}v_t$$

for which $t = r,\ r+(k+2),\ r+2(k+2),\ldots,\ r+(l-1)(k+2)$, r being an integer between 1 and $(k+2)$. In this case the difference series $\Delta^k u_t$, $\Delta^{k+1}u_t$ are not independent and so also are the series $\Delta^k v_t$, $\Delta^{k+1}v_t$ not independent.

Let us first derive the serial correlation coefficient between $\Delta^k u_t$ and $\Delta^{k+1}u_t$. Since

$$\Delta^k u_t = a + \Delta^k z_t \text{ and } \Delta^{k+1}u_t = \Delta^{k+1}z_t,$$

therefore cor $(\Delta^k u_t \cdot \Delta^{k+1}u_t) =$ cor $(\Delta^k z_t \cdot \Delta^{k+1}z_t)$.

Now $\Delta^k z_t = c_0 z_{t+k} - c_1 z_{t+k-1} + \ldots + (-1)^k c_k z_t$

$$\Delta^{k+1}z_t = c'_0 z_{t+k+1} - c'_1 z_{t+k} + \ldots + (-1)^{k+1} c'_{k+1} z_t$$

Where $c_i = kc_i$ and $c'_i = (k+1)c_i$

So $\triangle^k z_t \cdot \triangle^{k+1} z_t = -(c_o c'_1 z^2_{t+k} + c_1 c'_2 z^2_{t+k+1} + (-1)^{2k} c_k \cdot c'_{k+1} z^2_t)$

$+ (c_o c^1{}_o z_{t+k} z_{t+k+1} + \text{similar product term})$

Hence $E(\triangle^k u_t \triangle^{k+1} u_t) = -E(z^2_t)[c_o c'_1 + c_1 c'_2 + \ldots + c_k \cdot c'_{k+1}]$ the expectation of the other products being zero since

$$E(z_r z_s) = 0 \text{ for } r \neq s$$

Hence

$$\text{Cor } (\triangle^k u_t \triangle^{k+1} u_t) = \frac{-\sigma^2[c_o c'_1 + c_1 c'_2 + \ldots + c_k \cdot c'_{k+1}]}{\sigma_k \cdot \sigma_{k+1}} \quad (16)$$

Substituting in (16) the values of σ_k, σ_{k+1} in terms of σ from (8), we find that

$$\text{Cor } (\triangle^k u_t \cdot \triangle^{k+1} u_t) = \frac{-(c_o c'_1 + c_1 c'_2 + \ldots + c_k \cdot c'_{k+1})}{\sqrt{2k c_k} \times (2k+2) c_{k+1}} \quad (17)$$

The expression in brackets in the numerator is the co-efficient of x^k in the expression $(1+x)^{2k+1}$ and so is equal to $2k+1 c_k$. Hence (17) simplifies to

$$\text{Cor } (\triangle^k u_t \triangle^{k+1} u_t) = -\sqrt{\frac{2k+1}{2(k+1)}}$$ It can similarly be shown

that $\text{Cor } (\triangle^k v_t \triangle^{k+1} v_t) = -\sqrt{\frac{2k+1}{2(k+1)}}$

Let us denote this common correlation by p'. Thus

$$p' = -\sqrt{\frac{2k+1}{2(k+1)}} \quad .. \quad (18)$$

Modifying the notation of (12) we shall write

$p_{k,k} = \text{Cor } (\triangle^k u_t \cdot \triangle^k v_t)$

$p_{k+1,k+1} = \text{Cor } (\triangle^{k+1} u_t \cdot \triangle^{k+1} v_t)$

$p_{k,k+1} = \text{Cor } (\triangle^k u_t \cdot \triangle^{k+1} v_t)$

and $p_{k+1,k} = \text{Cor } (\triangle^{k+1} u_t \cdot \triangle^k v_t)$

It was shown in Sec. 3·1 (equation (13) that if the polynomial trends are of the common order k, then with this notation, $p_{k,k} = p_{k+1,k+1} = p$ (unknown)

$$\text{Also } p_{k+1,k} = \frac{E\{(\triangle^{k+1} u_t)(\triangle^k v_t - a')\}}{\sigma_{k+1} \cdot \sigma'_k} = \frac{E(\triangle^{k+1} z_t \triangle^k \zeta_t)}{\sigma_{k+1} \cdot \sigma'_k}$$

$$= \frac{-(2k+1) c_{k+1} E(z_t \zeta_t)}{\sqrt{2k c_k} \cdot \sqrt{(2k+2) c_{k+1}} \cdot \sigma\sigma^1} = -p\sqrt{\frac{2k+1}{2(k+1)}} = pp'$$

from (18).

Similarly $p_{k,k+1} = pp'$. Hence the hypothesis H_2 in (14) specifies

$$p_{k,k} = p_{k+1,k+1} = \frac{p_{k+1,k}}{p'} = \frac{p_{k,k+1}}{p'} = p \text{ (unknown)} \quad .. \quad (19)$$

Introduce new variables ξ_1, η_1 & ξ_2, η_2 by transformation

$$\xi_1 = \frac{\triangle^k u_t}{\sigma_k} - p'\frac{\triangle^{k+1} u_t}{\sigma_{k+1}}; \quad \xi_2 = \sqrt{1-p'^2}\frac{\triangle^{k+1} u_t}{\sigma_{k+1}}$$

$$\eta_1 = \sqrt{1-p'^2}\frac{\triangle^k v_t}{\sigma'_k}; \quad \eta_2 = \frac{\triangle^{k+1} v_t}{\sigma'_{k+1}} - p'\frac{\triangle^k v_t}{\sigma'_k} \quad .. \quad (20)$$

where p' is the correlation between the k^{th} and $(k+1)^{\text{th}}$ difference series of u as well as of v. Then

$$E(\xi_1) = \frac{1}{\sigma_k} E(\triangle^k u_t) - \frac{p'}{\sigma_{k+1}} E(\triangle^{k+1} u_t) = 0 \text{ by (8)}$$

Similarly $E(\xi_2) = E(\eta_1) = E(\eta_2) = 0$

$$\text{Var } (\xi_1) = E\left[\left(\frac{\triangle^k u_t}{\sigma_k} - p'\frac{\triangle^{k+1} u_t}{\sigma_{k+1}}\right)^2\right] = (1-p'^2)$$

$$\text{Similarly Var } (\xi_2) = \text{Var } (\eta_1) = \text{Var } (\eta_2) = (1-p'^2) \quad .. \quad (21)$$

Also cov $(\xi_1 \xi_2) = E(\xi_1 \xi_2)$

$$= \sqrt{1-p'^2}\frac{E(\triangle^k u_t \triangle^{k+1} u_t)}{\sigma_k \sigma_{k+1}} - p'\sqrt{1-p'^2}\frac{E(\triangle^{k+1}u_t)^2}{\sigma^2_{k+1}} \quad .. \quad (22)$$

$$= p'\sqrt{1-p'^2} - p'\sqrt{1-p'^2} = 0$$

and similarly Cov $(\eta_1 \eta_2) = 0$.

Hence ξ_1, ξ_2 are uncorrelated normal variables having mean zero and variance $(1-p'^2)$ and so also are η_1 η_2.

Let us obtain the correlations between ξ_1, η_1 and between ξ_2, η_2. Denote

$$\text{Cor } (\xi_1 \eta_1) = R_1 \quad .. \quad (23)$$

$$\text{Cor } (\xi_2 \eta_2) = R_2$$

$$\left[\left(\frac{\triangle^k u_t}{\sigma_k} - p'\frac{\triangle^{k+1}u_t}{\sigma_{k+1}}\right)\left(\sqrt{1-p'^2}\frac{\triangle^k v_t}{\sigma'_k}\right)\right]$$

Then $R_1 = E$

$$\sqrt{\text{Var } \xi_1 \text{ var } \eta_1}$$

$$= \frac{\sqrt{1-p'^2}\,p_{k,k} - p'\sqrt{1-p'^2}p_{k+1,k}}{1-p'^2}$$

Again

$$R_2 = E \frac{\left[\left(\sqrt{1-p'^2}\frac{\triangle^{k+1}u_t}{\sigma_{k+1}}\right)\left(\frac{\triangle^{k+1}v_t}{\sigma'_{k+1}} - p'\frac{\triangle^k v_t}{\sigma'_k}\right)\right]}{\sqrt{\text{Var } \xi_2 \,.\, \text{Var } \eta_2}}$$

$$= \frac{\sqrt{1-p'^2}\,p_{k+1,k+1} - p'\sqrt{1-p'^2}\,p_{k+1,k}}{(1-p'^2)}$$

Thus

$$R_1 = \frac{p_{k,k} - p'p_{k+1,k}}{\sqrt{1-p'^2}}$$

$$R_2 = \frac{p_{k+1,k+1} - p'p_{k+1,}}{\sqrt{1-p'^2}}$$

Using the relations in (19) we find that the expressions for R_1 and R_2 in (24) become identical. Hence the hypothesis H_2 equivalent to $R_1 = R_2$.

To test this hypothesis we calculate the sample values of $p_{k,k}$; $p_{k+1,k+1}$; $p_{k+1,k}$ from the selected series, of the k^{th} and $(k+1)^{\text{th}}$ differences of u and v series, using formulae similar to (10). Putting in these sample values denoted by r's in the expression (24) and substituting the value of p' from (18) we have the expressions for sample R_1 and R_2 in the form

$$r_1 = \sqrt{2k+2}\,r_{k,k} + \sqrt{2k+1}\,r_{k+1,k}$$

$$r_2 = \sqrt{2k+2}\,r_{k+1,k+1} + \sqrt{2k+1}\,r_{k+1,k}. \quad .. \quad (25)$$

Now r_1, r_2 are independent since the pairs (ξ_1, η_1) and (ξ_2, η_2) are independent. Transforming them into Fisher's z_1, z_2, the test reduces to testing the significance of the difference of two independent normal variables z_1 and z_2 with means zero and variance $\frac{1}{l-3}$ where l is the number of elements chosen in the k^{th} and $(k+1)^{\text{th}}$ difference series. The procedure thus consists in calculating $(z_1 - z_2)$ and testing for its significance successively for $k = 1, 2, 3, \ldots$. The least value of k for which we get non-significance at say, 5% level, will give the corresponding degree k of the polynomials that fit both the series u_t and v_t.

Illustration III

Let us apply the above test to the two constructed series u_t and v_t given in Table III (a) & (b) below. These two series are constructed from the relations

$$u_t = 20 + 3t + 0{\cdot}1t^2 + \varepsilon_t$$
$$v_t = 30 + 2t + 0{\cdot}2t^2 + \varepsilon'_t$$

The ε'_ts are random elements taken from the Table of Random Samples from a Normal population (Mahalanobis 1934) and multiplied by 10. Another set of random elements is taken from these tables and the series of ε'_t is formed from them by arranging the random elements so that there would be high positive correlation between this series and the series of ε_t. This is secured by making some large positive values in ε'_t correspond to large positive values in ε_t and also some large negative values correspond in the two series.

TABLE IIIa

t	u_t	$\Delta^1 u_t$	$\Delta^2 u_t$	$\Delta^3 u_t$
1	22·98	+ 2·65	+ 2·31	− 31·56
2	25·63	+ 4·96	− 29·25	+ 77·73
3	30·59	− 24·29	+ 48·48	− 62·30
4	6·30	+ 24·19	− 13·82	+ 5·65
5	30·49	+ 10·37	− 8·17	− 14·04
6	40·86	+ 2·20	+ 5·87	+ 7·97
7	43·06	+ 8·07	+ 13·84	− 46·90
8	51·13	+ 21·91	− 32·06	+ 57·94
9	73·04	− 10·15	+ 25·88	− 60·34
10	62·89	+ 15·73	− 34·46	+ 61·90
11	78·62	− 18·73	+ 27·44	− 31·78
12	59·89	+ 8·71	− 4·34	+ 17·43
13	68·60	+ 4·37	+ 13·09	− 14·90
14	72·97	+ 17·46	− 1·81	− 38·42
15	90·43	+ 15·65	− 40·23	+ 86·75
16	106·08	− 24·58	+ 46·52	− 64·47
17	81·50	+ 21·94	− 17·95	+ 32·57
18	103·44	+ 3·99	+ 14·62	− 33·48
19	107·43	+ 18·61	− 18·86	+ 50·32
20	126·04	− ·25	+ 31·46	− 65·82
21	125·79	+ 31·21	− 34·36	+ 20·28
22	157·00	− 3·15	− 14·08	+ 45·15
23	153·85	− 17·23	+ 31·07	− 20·80
24	136·62	+ 14·84	+ 10·27	− 41·26
25	151·46	− 25·11	− 30·99	+ 52·44
26	176·57	− 5·88	+ 21·45	− 14·78
27	170·69	+ 15·57	+ 6·67	− 19·41
28	186·26	+ 22·24	− 12·74	− 15·66
29	208·50	+ 9·50	− 28·40	+ 45·78
30	218·00	− 18·90	+ 17·38	+ 5·68
31	199·10	− 1·52	+ 23·04	− 2·01
32	197·58	+ 21·52	+ 21·03	− 79·71
33	219·10	+ 42·55	− 58·68	+ 78·64
34	261·65	− 16·13	+ 19·96	− 6·75
35	245·52	+ 3·83	+ 12·21	− 28·20
36	249·35	+ 17·04	− 14·99	+ 35·79
37	266·39	+ 2·05	+ 20·80	− 25·35
38	268·44	+ 22·85	− 4·55	− 5·80
39	291·29	+ 18·30	− 10·35	− 8·83
40	309·59	+ 7·95	− 19·18	+ 68·17
41	317·54	− 11·23	+ 48·99	− 81·04
42	306·31	+ 37·76	− 32·05	+ 40·10
43	344·07	+ 5·71	+ 8·05	− 5·07
44	349·78	+ 13·76	+ 2·98	+ 4·10
45	363·54	+ 16·74	+ 7·08	− 46·82
46	380·28	+ 23·82	− 39·74	..
47	404·10	− 15·92	..	
48	388·18	..		

TABLE IIIb

t	v_t	$\Delta^1 v_t$	$\Delta^2 v_t$	$\Delta^3 v_t$
1	26·49	+ 8·09	− 13·44	+ 9·36
2	34·38	− 4·35	− 4·08	+ 32·62
3	30·03	− 8·43	+ 28·54	− 45·98
4	21·60	+ 20·11	− 17·44	+ 8·84
5	41·71	+ 2·67	− 8·60	+ 31·12
6	44·38	− 5·93	+ 22·52	− 26·27
7	38·45	+ 16·59	− 3·85	− 10·98
8	55·04	+ 12·74	− 14·83	+ 40·29
9	67·78	− 2·09	+ 25·46	− 64·17
10	65·69	+ 23·37	− 38·71	+ 52·95
11	89·06	− 15·34	+ 14·24	− 9·01
12	73·72	− 1·10	+ 5·23	+ 16·06
13	72·62	+ 4·13	+ 21·29	− 25·74
14	76·75	+ 25·42	− 4·45	− 42·84
15	102·17	+ 20·97	− 47·29	+ 84·63
16	123·07	− 26·32	+ 37·34	− 49·42
17	96·75	+ 11·02	− 12·08	+ 32·69
18	107·77	− 1·06	+ 20·61	− 46·67
19	106·71	+ 19·55	− 26·06	+ 57·62
20	126·26	− 6·51	+ 31·56	− 57·59
21	119·75	+ 25·05	− 26·23	+ 45·73
22	144·80	− 1·10	+ 19·50	− 34·32
23	143·62	+ 18·32	− 14·82	+ 42·05
24	161·94	+ 3·50	+ 27·23	− 74·54
25	165·44	+ 30·78	− 47·81	+111·70
26	196·17	− 16·58	+ 64·39	−117·34
27	179·59	+ 47·81	− 52·95	+ 68·76
28	227·40	− 5·14	+ 15·81	− 35·19
29	222·26	+ 10·67	− 19·38	+ 31·49
30	232·93	− 8·71	+ 12·11	+ 13·83
31	224·22	+ 3·40	+ 25·94	− 34·45
32	227·62	+ 29·34	− 8·51	− 9·59
33	256·96	+ 20·83	− 18·10	+ 24·62
34	277·79	+ 2·73	+ 6·52	− 1·09
35	280·52	+ 9·25	+ 5·43	− 9·16
36	289·77	+ 14·68	− 3·73	+ 21·89
37	304·45	+ 10·95	+ 18·16	− 33·75
38	315·40	+ 29·11	− 15·59	+ 3·19
39	344·51	− 13·52	− 12·40	+ 27·06
40	358·03	+ 1·12	+ 14·66	− 10·66
41	359·15	+ 15·78	+ 4·00	− 8·55
42	374·93	+ 19·78	− 4·55	+ 6·45
43	394·71	+ 15·23	+ 1·90	− 4·83
44	409·94	+ 17·13	− 2·93	+ 7·38
45	427·07	+ 14·20	+ 4·45	− 13·30
46	441·27	− 18·65	− 8·85	..
47	459·92	− 9·80	..	
48	469·72	..		

Taking the first differences i.e., $k = 1$ and selecting the terms according to the scheme (6), viz., $t = 1, 4, 7, \ldots 46$ we find $r_{11} = \cdot 7861$; $r_{22} = \cdot 4407$; and $r_{21} = -\cdot 524$. Substituting in (25), we have

$r_1 = \cdot 6646$ and $r_2 = -\cdot 0262$. The corresponding values of z_1 and z_2 are given by $z_1 = \cdot 8013$ $z_2 = -\cdot 026$, so that $(z_1 - z_2) = \cdot 8273$. The number of terms selected being $l = 16$, the standard error of $(z_1 - z_2)$ is $\sqrt{2/13} = \cdot 3921$. Hence $(z_1 - z_2)$ exceeds twice its standard error. So we infer that in the first differences the non-random elements have not been reduced to constants.

Taking next $k = 2$ and selecting the terms $t = 1, 5, 9 \ldots \cdot 45$ we obtain

$r_{22} = \cdot 7533$; $r_{33} = \cdot 6810$; $r_{32} = -\cdot 7381$, whence $r_1 = \cdot 1944$, and $r_2 = \cdot 0174$. Then $z_1 = \cdot 1968$, $z_2 = \cdot 0170$ so that $(z_1 - z_2) = \cdot 179$. Here l is 12 and so the standard error is $\sqrt{2/9} = \cdot 4713$. The difference is less than its standard error. Hence it is not significant. It is therefore inferred that the non-random elements are reduced to constants in the second differences. Hence the degree of the polynomial trends of the two series u_t and v_t is 2 which is in fact true. If we proceed one step further and take $k = 3$, we will find that the difference between r_1 and r_2 will also be non-significant.

3·4. *Test of the Hypothesis* H_3:

In the test of the hypothesis H_2 described in Sec. 3·2, the terms of the k^{th} and $(k+1)^{th}$ difference series are so chosen as to be independent. With the same selection (namely $t = r$, $r + (2k+3)$, $\ldots . r + (m-1)(2k+3)$ from the k^{th} differences of u_t and $t = r + k + 1$, $r + k + 1 + 2k + 3$, $\ldots . r + k + 1 + (m-1)(2k+3)$ from the $(k+1)^{th}$ differece of u_t, where r is an integer lying between 1 and $(k+1)$ we shall test the slightly more general hypothesis H_3 in (15).

$$\frac{\sigma_k}{\sqrt{2kc_k}} = \frac{\sigma_{k+1}}{\sqrt{(2k+2)c_{k+1}}} = \sigma \text{ (unknown)}$$

$$\frac{\sigma'_k}{\sqrt{2kc_k}} = \frac{\sigma'_{k+1}}{\sqrt{(2k+2)c_{k+1}}} = \sigma' \text{ (unknown)}$$

As shown in Sec. 3·1, this gives $p_{k,k} = p_{k+1,\,k+1}$. Further owing to the nature of the selections $p_{k,\,k+1} = p_{k+1,\,k} = 0$.

Hence under H_3,

$$c_1\sigma_k = c_2\sigma_{k+1}$$

$$c_1\sigma'_k = c_2\sigma'_{k+1}$$

$$\text{and } p_{k,k} = p_{k+1,\,k+1} \qquad \ldots \quad (26)$$

where c_1 and c_2 stand for the fraction $\frac{1}{\sqrt{2kc_k}}$ and $\frac{1}{\sqrt{(2k+2)c_{k+1}}}$.

For convenience let us write

$$x_1 = c_1 \triangle^k u_t\,; \qquad x_2 = c_2 \triangle^{k+1} u_t,$$

$$y_1 = c_1 \triangle^k v_t\,; \qquad y_2 = c_2 \triangle^{k+1} v_t$$

and $p_1 = p_{k,k}$, $p_2 = p_{k+1,\,k+1}$

H_3 then, specifies $\sigma_{x_1} = \sigma_{x_2}$; $\sigma_{y_1} = \sigma_{y_2}$ and $p_1 = p_2$.

We consider (x_1, y_1) and (x_2, y_2) as pairs of variates in two normal bivariate populations with means (c_1a, c_1a') and $(0, 0)$, variance $(\sigma^2_{x_1}\, \sigma^2_{y_1})$ and $(\sigma^2_{x_2}\, \sigma^2_{y_2})$ and the correlations p_1 and p_2. Suppose the observations are $(x_{i\alpha} \cdot y_{i\alpha})$; $\alpha = 1, 2, \ldots m$; $i = 1, 2$.

From (8), it is seen that

$$E(x_1) = c_1a\,; \quad E(y_1) = c_1a',$$

and $E(x_2) = 0$; $E(y_2) = 0$.

So the likelihood function is

$$P = \left(\frac{1}{(2\pi)^2\sigma_{x_1}\sigma_{y_1}\sigma_{x_2}\sigma_{y_2}\sqrt{1-p_1^2}\sqrt{1-p_2^2}}\right)^m e^{-\theta} \text{ where}$$

$$\theta = \frac{m}{2}\left[\frac{1}{1-p_1^2}\sum_{\alpha=1}^{m}\left(\frac{(x_{1\alpha}-c_1a)^2}{\sigma^2_{x_1}} + \frac{(y_{1\alpha}-c_1a^1)^2}{\sigma^2_{y_2}} - \frac{2p_1(x_{1\alpha}-c_1a)(y_{1\alpha}-c_1a^1)}{\sigma_{x_1}\sigma_{y_1}}\right)\right.$$

$$\left. + \frac{1}{1-p_2^2}\sum_{\alpha=1}^{m}\left(\frac{x^2_{2\alpha}}{\sigma^2_{x_2}} + \frac{y^2_{2\alpha}}{\sigma^2_{y_2}} - \frac{2p_2x_{2\alpha}y_{2\alpha}}{\sigma_{x_2}\cdot\sigma_{y_2}}\right)\right] \qquad \ldots \quad (27)$$

The likelihood ratio criterion for testing the hypothesis H_3 is

$$\lambda = \frac{P\omega \max}{P\Omega \max}$$

where Ω is the class of all admissible sets of populations and ω is the subclass of Ω for which

$$\sigma_{x_1} = \sigma_{x_2} = \sigma_x \text{ (unknown)}, \quad \sigma_{y_1} = \sigma_{y_2} = \sigma_y \text{ (unknown)}$$
$$\text{and } \rho_1 = \rho_2 = \rho \text{ (unknown)} \qquad .. \quad (27\text{-a})$$

Maximising log P *for variations* of all admissible parameters we obtain

$$\sigma^2_{x_1} = S^2_{x_1} = \frac{1}{m}\sum_{a=1}^{m}(x_{1a} - \bar{x}_1)^2; \; \sigma^2_{y_1} = S^2_{y_1} = \frac{1}{m}\sum_{a=1}^{m}(y_{1a} - \bar{y}_1)^2$$

$$\sigma^2_{x_2} = S^2_{x_2} = \frac{1}{m}\sum_{a=1}^{m} x^2_{2a}; \quad \sigma^2_{y_2} = S^2_{y_2} = \frac{1}{m}\sum_{a=1}^{m}(y^2_{2a}),$$

$$\sigma_{x_1}\sigma_{y_1}\rho_1 = S_{x_1}S_{y_1}r_1 = \frac{1}{m}\sum_{a=1}^{m}(x_{1a} - \bar{x}_1)(y_{1a} - \bar{y}_1),$$

$$\sigma_{x_2}\sigma_{y_2}\rho_2 = S_{x_2}S_{y_2}r_2 = \frac{1}{m}\sum_{a=1}^{m} x_{2a}y_{2a}. \qquad .. \quad (28)$$

Substituting these estimates in (27) we get

$$P_{\Omega\max} = \prod_{i=1}^{2}\pi\left(\frac{1}{2\pi S_{x_i}S_{y_i}\sqrt{1-r^2_i}}\right)^m e^{-m}$$

To obtain we put in the conditions of 27(a) in P of (27) and maximise it. We find that

$$\sigma^2_x = \sum_{i=1}^{2}\frac{S^2_{x_i}}{2}; \; \sigma^2_y = \sum_{i=1}^{2}\frac{S^2_{y_i}}{2}$$

$\sigma_x\sigma_y\rho = \frac{1}{2}\sum_{i=1}^{2} S_{x_i}S_{y_i}r_i$, the same S's and r's

having the same expressions as in (28).

So $P\omega \max =$

$$\left[\frac{4}{4\pi^2\left\{\sum_{i=1}^{2}S^2_{x_i}\sum_{i=1}^{2}S^2_{y_i} - \left(\sum_{i=1}^{2}S_{x_i}S_{y_i}r_i\right)^2\right\}}\right]^m e^{-m}$$

Hence $\lambda = \left[\dfrac{4S_{x_1}S_{y_1}S_{x_2}S_{y_2}\sqrt{1-r^2_1}\sqrt{1-r^2_2}}{\sum_{i=1}^{2}S^2_{x_i}\sum_{i=1}^{2}S^2_{y_i} - \left(\sum_{i=1}^{2}S_{x_i}S_{y_i}r_i\right)^2}\right]^m$

So $L_1 = \lambda^{2/m} = \left[\dfrac{16\,S^2_{x_1}S^2_{y_1}(1-r^2_1)\,S^2_{x_2}S^2_{y_2}(1-r^2_2)}{\sum_{i=1}^{2}S^2_{x_i}\sum_{i=1}^{2}S^2_{y_i} - \left(\sum_{i=1}^{2}S_{x_i}S_{y_i}r_i\right)^2}\right]^2$ (29)

To return to the difference series, we express $S^2_{x_1}$, $S^2_{y_1}$ etc., in (28), in terms of the terms $\Delta^k u_t$, $\Delta^k v_t$ etc., and the constants

c_1 and c_2 are $\dfrac{1}{\sqrt{2kc_k}}$ and $\dfrac{1}{\sqrt{(2k+2)c_{k+1}}}$.

Thus we have

$$S^2_{x_1} = c^2_1\frac{1}{m}\Sigma(\Delta^k u_t - \overline{\Delta^k u})^2,$$

$$S^2_{y_1} = c^2_1\frac{1}{m}\Sigma(\Delta^k v_t - \overline{\Delta^k v})^2$$

$$S^2_{x_2} = c^2_2\frac{1}{m}\Sigma(\Delta^{k+1}u_t)^2$$

$$S^2_{y_2} = c^2_2\frac{1}{m}\Sigma(\Delta^{k+1}v_t)^2 \qquad .. \quad (30)$$

$$S^2_{x1}S^2_{y1}r^2_1 = c^2_1\frac{1}{m}\Sigma(\Delta^k u_t - \overline{\Delta^k u})\;(\Delta^k v_t - \overline{\Delta^k v}),$$

$$S^2_{x_2}S^2_{y_2}r^2_2 = c^2_2\frac{1}{m}\Sigma\,\Delta^{k+1}u_t\,\Delta^{k+1}v_t,$$

when the summations are over the m chosen values of t.

The distribution of L_1, (Nair, 1938) is given as

$$df(L_1) = \frac{\Gamma(2n-3)}{\Gamma^2(n-2)\,2^{2n-6}} L_1^{2n-3} \log\frac{1+\sqrt{1-L_1^2}}{L_1} dL_1$$

Hence the probability of obtaining as large a value as an observed l_1 is given by

$$P(l_1 \leq L_1) = \int_0^{l_1} df(L_1)$$

$$\frac{\Gamma(2n-3)}{\Gamma(n-1)\ \Gamma(n-2)\,2^{2n-5}}$$

$$\left[(l_1^2)^{2n-2} \log \frac{1+\sqrt{1-l_1^2}}{l_1} + \tfrac{1}{2}\int_0^{l_1^2} y^{n-3}(1-y)^{-\frac{1}{2}}\,dy\right]$$

The procedure consists in evaluating L_1 in (29) using the expressions in (30) for $k = 1\ 2\ 3 \ldots$ and see if the probability of getting L_1 or values smaller than L_1 is less than or more than ·05. The k for which we first get a probability greater than ·05 is taken as the degree of the polynomial which fits the trend of both the u and v series best. The value of k derived by this method of testing H_3 is not likely to differ from that of the previous methods dealing with H_2.

We may generalise the above method to the problem of finding a common k for several time-series, in which both the trend elements are correlated and so also are the random-elements. The test is the same as the test for the equality of the variance covariance matrix in two multi-variate normal populations (the variates being the k^{th} and $(k+1)^{th}$ differences multiplied by c_1 and c_2), given that — the means of the variates in one population (the k^{th} differences) are all equal to an unknown quantity and that those of the other (the $(k+1)^{th}$) are all zero.

3·5. *Several Series:*

In Sec. 1 we have mentioned Johnson's method of finding the order of the difference series in which the trend In a single series is eliminated. We can employ a different method of testing that

the variances of the k^{th} and $(k+1)^{th}$ difference series are in a constant ratio, the hypothesis being that the trend component is eliminated in the $(k+1)^{th}$ difference series.

Denoting $x_1 = c_1 \triangle^k u_t$; $x_2 = c_2 \triangle^{k+1} u_t$

where $c_1 = \dfrac{1}{\sqrt{2kc_k}}$ $c_2 = \dfrac{1}{\sqrt{(2k+2)\,c_{k+1}}}$ we have to test that the variance of x_1 does not differ significantly from the variance of x_2. Since x_1 and x_2 are correlated, we shall consider the variates $x_1 + x_2$ and $x_1 - x_2$ and test for the significance of the correlation between them. Suppose r is the correlation coefficient between $(c_1\triangle^k u_t + c_2\triangle^{k+1}u_t)$ and $(c_1 \triangle^k u_t - c_2 \triangle^{k+1}u_t)$ calculated from the chosen values according to the scheme:

$$\triangle^k u_t,\ \triangle^{k+1}u_t : t = i,\ i+k+1,\ i+2(k+1), \ldots . i+(v-1)(k+1),$$

i lying between 1 and $k+1$, the value of $t = \dfrac{r}{\sqrt{1-r^2}}\sqrt{v-2}$ is referred to the t — probability scale with $v-2$ degrees of freedom. Applying the test successively for $k = 1, 2, 3 \ldots .$, the value of k for which non-significance is first established is the degree of the polynomial trend and thus we can infer that in differences of this order, the trend is reduced to a constant while in the next it is eliminated. It will be noted that in this method the known correlation (p') between the $\triangle^k u_t$ and $\triangle^{k+1}u_t$ is not employed in the test procedure.

If there are several time-series of the same length which may be regarded as samples, but in which the random elements are not uncorrelated, we may employ the above method to each series and take the maximum of the values of the k. In practice the k obtained for each series will be one of two consecutive integers and the larger of the two is then chosen as the degree of the polynomial trend in the population.

If, however, the random elements of one series are uncorrelated with those of another an overall test could be framed. Take the selected v pairs for each of the j series thus

u series: $(c_1 \triangle^k u_t + c_2 \triangle^{k+1}u_t,\ \ c_1 \triangle^k u_t - c_2 \triangle^{k+1}u_t)$

v series: $(c_1 \triangle^k v_t + c_2 \triangle^{k+1}v_t,\ \ c_1 \triangle^k v_t - c_2 \triangle^{k+1}v_t)$

and pooling them we have vj pairs. Then we calculate the correlation between them as between two series of vj elements each and test for its significance. This procedure is justified only on the hypothesis that the trend in each series is defined by the same

polynomial so that the means of the terms of the k^{th} differences are the same for all the series.

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THE RESPIRATORY MECHANISM OF *BALANUS TINTINNABULUM* L.

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ABSTRACT

The opercular valves and their muscles aiding respiratory movements are studied. The muscles responsible for the rhythmic upward and downward movements of the opercular valves as well as the opening and closing mechanism are described.

The contraction of the lateral depressor muscle which takes half a second results in the separation of the opercular valves of one side from those of its pair at the occludent margin and opening the entrance to the mantle cavity which is kept in this position for two seconds.

By the co-ordinated contraction of the lateral, rostral and tergal depressor muscles which takes half a second the opercular valves are pulled downwards with the mantle entrance kept open and sea water is ejected out through the orifice.

By the relaxation of all these three muscles the opercular valves revert to its previous position which takes a second and a half.

The closing of the entrance to the mantle chamber is by the contraction of the adductor scutorum muscle.

INTRODUCTION

Though the action of M. adductor scutorum in drawing the opercular valves close together during respiratory movements of the Cirripedes was stressed even as early as 1854 by Darwin, it was Cannon (1948, P. 90) who pointed out that the mantle cavity so closed is opened through the muscular contraction of the oblique fibres of the peduncle, forcing the blood into the capitular region and into the walls of the mantle cavity and thus causing the valves to become erect and move apart.

The respiratory mechanism of the sessile Cirripedes cannot be explained thus. In the sessile cirripedes the mantle cavity can

open to the exterior by a cleft bounded on either side by a tergal plate as well as a scutal plate. These two valves on each side of the opening are immovably interlocked. The bases of all the four valves are attached to the inside of the cup-like shell by means of an elastic membrane. This opercular membrane permits vertical movements of the valves within the shell. The lower edges of the valves are also attached by three pairs of muscles (i) the lateral depressor muscles, (ii) the rostral depressor muscles and (iii) the tergal depressor muscles, to the bottom of the shell. When the lateral depressor muscle contracts the opercular valve move downwards. In this movement the valves knock against the cirri and are pushed apart, opening the entrance to the mantle cavity. The raising and lowering of the opercular valves with the mantle entrance kept open is effected by the co-ordinated contraction and relaxation of the lateral, rostral and tergal depressor muscles. The closure of the mantle opening is effected by the M. adductor scutorum, which runs between the scuta of opposite sides as in the pedunculate Cirripedes. Thus in the sessile Cirripedes, the opening of the valves, their rhythmic upward and downward movements as well as their closing is effected by active muscular action directly.

The respiratory organs in the sessile cirripedes are a pair of arc shaped branchaiae on either side of the prosoma, inside the mantle chamber. The mantle surface also is believed to be capable of respiratory interchange. (Darwin, 1854). Water inside the mantle cavity is expelled, whenever the valves are pulled towards the base and the mantle chamber opens to the exterior. Fresh oxygenated sea water is sucked in when the valves return to their original position through the relaxation of the muscles at the base of the valves. The mantle chamber is subjected to more feeble and less regular ventilations, whenever the creature feeds by the pushing out and drawing in of the cirri. During such sporadic bouts of feeding the regular muscular respiratory movements are suspended and are resumed later.

II. *Material and Methods :*

Balanus tintinnabulum Linne abundant on the rocks of the southwestern side of the Madras harbour provided the material for the present investigations. Large sized specimens measuring between 45 mm. to 50 mm. were removed carefully without causing injury. Such dislodged specimens were brought to the laboratory in large jars of fresh sea-water. Daily renewal of sea water in the

laboratory ensured a healthy condition of the animals for several weeks.

The muscles involved in the movement of the opercular valves were studied by removing the rostral and carinal plates without causing much damage to the base of the shell, the opercular valves and the animal proper. Graphical records of the opening and closing and raising and lowering of the opercular valves were made on a smoked drum by the method suggested by Fox and Johnson (1934). By means of dentist's cement one end of a very fine silk thread was glued to the apical tip of the scutum of a large barnacle left in a jar of fresh sea-water. The other end of the silk thread was tied to the end of a long light aluminium lever which was supported on a fixed knife edge. The lever was counter-poised by suitable weights and the thread was kept stretched.. The downward movement of the opercular valves pulled the thread down and the tip of the lever went up while the upward movement moved the opposite way. The movements were thus exaggerated. The inflow and outflow of water was studied by dropping carmine particles in the current of water set up by the animal during its respiratory movement and by closely following their course.

III. *The muscles connected with the opercular valves :*

(1) *The adductor scutorum muscle* :— is a single, short, strong and straight, transversely running, muscle which connects both the scuta with one another at a special pit on the underside of each valve near the upper end of the tergal margin. It is a very powerful muscle, ranging in length from 7 to 8 mm., in the contracted condition. It consists of about 250 separate fasiculi, each measuring 1·5 mm.,, in diameter and arranged parallel to one another.

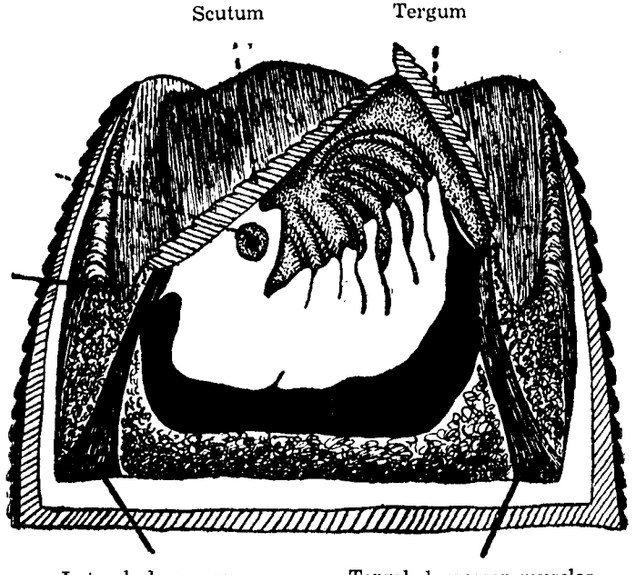
(2) *The lateral depressor muscles* :—are paired and each muscle is broad at its base and at the peripheral margin of the basis more towards the lateral compartment and converges to the lateral depressor pit situated at the basitergal corner of the scutum. It measures a length of 32-35 mm., in the relaxed condition and is provided with about 170 separate fasiculi, each 1 mm. in diameter and arranged parallel to one another.

(3) *The Rostral depressor muscles* : —are also paired and each takes origin at the basis near the rostral plate and converges to a small cavity at the rostral end formed by the over-folding of the occludent margin of the scutum. It resembles the lateral depressor in structure.

(4) *The Tergal depressor muscles* :—are paired but confluent uniting to form a single large bundle which starts at the base of the carinal plate and runs to a point at the basi-carinal corner of the tergum where there are crests.

The opercular valves surrounded by the elastic opercular membrane are attached on the inner surface by these muscles and rest upon the body fluid which is subjected to internal pressure during voluntary or reflex movement.

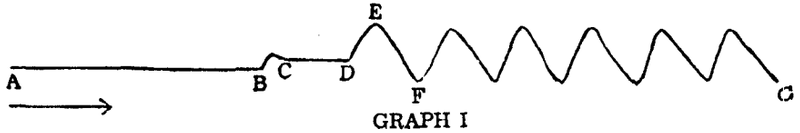
FIGURE I



Balanus tintinnabulum showing the location of the opercular valves and muscles

IV. *The Mechanism of movement :*

When there are no breathing movements, the scuta are held together tight by the powerful adductor scutorum muscle in its contracted condition. In this condition, the lateral, the rostral and the tergal depressor muscles are all relaxed. This state is represented by AB in Graph I.



GRAPH I

The barnacle can remain in this stage (i.e.) at respiratory rest for long periods. At the end of this period, the lateral depressor muscle alone contracts with the rostral and tergal depressor muscles in the relaxed position resulting in a force at the basitergal corner of the scutum pulling the opercular valves of either side downwards and during this process the inner surface of either scuta strike against the cirri, the opercular valves of either side rotate round an axis connecting the rostral and carinal edges of the shell

Diagramatic representation of the scuta and terga with their muscles, to explain the opening of the valves.

FIGURE II—Closed Position

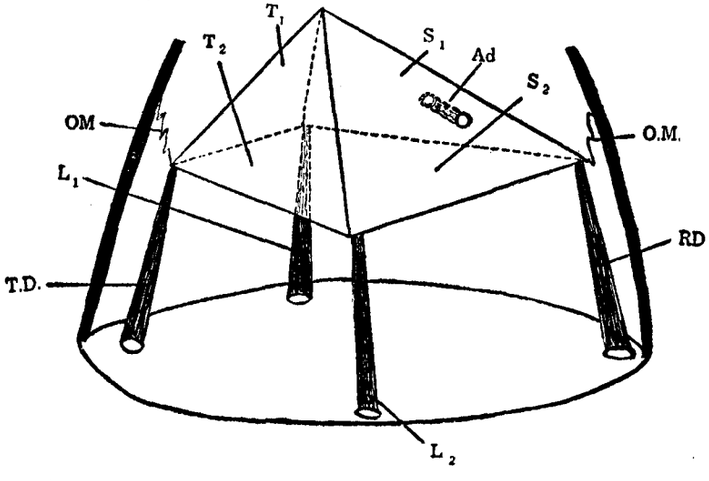
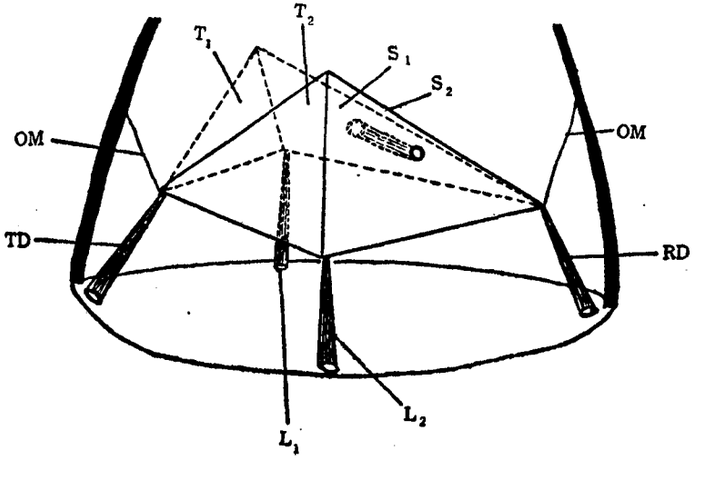


FIGURE III—Open position.



S_1—Scutum of one side

S_2—Scutum of the other side

T_1—Tergum of one side

T_2—Tergum of the other side

OM—Opercular membrane

RD—Rostral depressor muscles

TD—Tergal depressor muscles

L_1—Lateral depressor muscles of one side

L_2—Lateral depressor muscles of the other side

Ad—Adductor Scutorum muscle other side

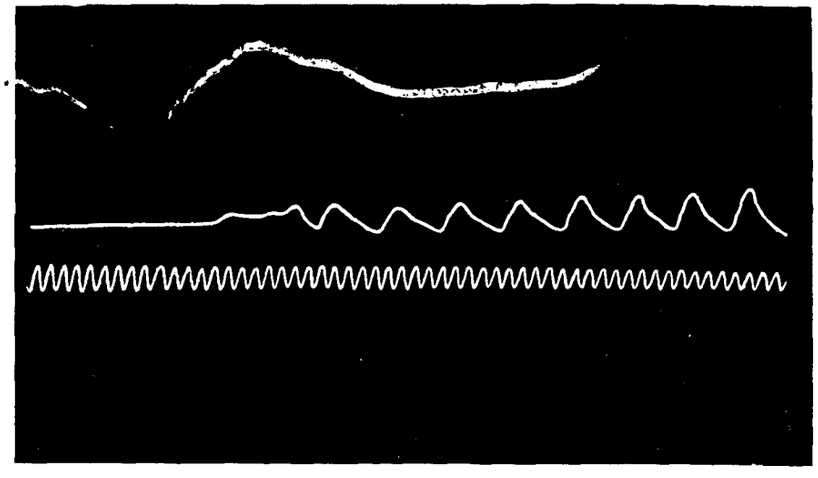
and the scutum and tergum of one side move away from those of the other side at the occludent margin, opening the entrance to the mantle cavity. The opening of the orifice at the entrance to the mantle cavity by the contraction of the lateral depressor muscle is represented by the slight elevation from B to C in the graph. This takes half a second. (Graph 1 and Photograph 1). The opercular valves are kept in this position for about two seconds represented in the graph by the line CD. Now, at this point D, the lateral depressor, the tergal depressor and the rostral depressor muscles contract resulting in the downward movement of the opercular valves with the mantle entrance kept open and the space within the mantle cavity is reduced and sea water inside the mantle-cavity is forcibily ejected out through the orifice. The co-ordinated contraction of the lateral, the rostral and the tergal depressor muscles and the consequent downward movements of the opercular valves is represented in the graph by the line D to E. This takes half a second.

At the point E the lateral, the rostral and the tergal depressor muscles relax and the opercular valves go upwards due to the pulling upwards of the elastic opercular membrane and reverts to the previous position occupied at D. This upward movement of the scuta and terga result in the enlargement of the space within the mantle-cavity and sea-water rushes in through the orifice. This is represented from E to F in the graph. This takes a second and a half. Now once again the lateral, the rostral and tergal depressor muscles contract and then relax and a series of upward and downward movements which are regular and uniform (F to G in graph) takes place. This rhythmic upward and downward movement of the opercular valves is interrupted during feeding when the cirri are thrust out in a sweeping motion. When the barnacle is irritated or it needs respiratory rest the lateral, the rostral and the tergal depressor muscles are all relaxed, and the adductor scutorum muscle contracts and the scuta are brought together thus closing the orifice completely.

V. *Remarks:*

Though respiratory movements are regular and uniform when they take place yet they are frequently interrupted by periods of pause, or spells of feeding movements of indefinite duration. Sometimes respiratory movements will go on uninterupted for 7 to 8 minutes, at others longer periods of continuous feeding will intervene. It must be remembered that feeding also implies fresh seawater entering the mantle-cavity and leaving it, aiding respiratory

PHOTOGRAPH I



I *a* — A Photograph of the Respiratory movements of the barnacle *Balanus tintinnabulum tintinnabulum* recorded on a smoked drum.
I *b* — ½ second time tracing.

exchange of grasses. The periods of pause, always ranged between 1 to 4 minutes but never exceeded 15 minutes in any of the numerous observations made. During this period, it is probable that the limited amount of oxygen in the water contained in the mantle chamber, was sufficient for the restricted needs of the resting animal. Broch (1927) observes that the opercular movements involving contractions of the body are responsible for aiding circulation especially in the large blood sinuses. This is very probable during periods of active ventilation and vigorous feeding when a large number of muscles are brought into play though it is difficult to say whether circulation is slackened or assisted during periods of rest.

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PLANT TUMOURS VERSUS ANIMAL TUMOURS

BY

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Researches in the last five decades in the twin fields of plant and animal tumours has led to the accumulation of a very vast literature and it is beyond the scope of this article to attempt the ambitious task of reviewing this literature to any full extent. Indeed, what is attempted in the following pages is just an assessment of the progress made in the study of plant tumours or 'crown galls' and integrating and comparing our present knowledge of this phenomenon with our knowledge of animal tumours. No effort is therefore made in giving a detailed bibliography. A key to the literature in this field would be readily available to the reader from the excellent review by White (1951) and other sources (Gaumann 1950; Mohanty 1949; Oberling 1944; Greenstein 1947; White 1948; Smith, Brown and Townsend 1911; Riker 1942). And in dealing with plant tumours the stress is laid mostly on crown galls induced by *Bacterium tumefaciens*.

Bacterium Tumefaciens and Primary Tumours Induced in Plants

Bacterium tumefaciens, Smith and Towns (*Phytomonas tumefaciens*) is well-known as a wound parasite of plants, which uses the wound as a gateway into the plant and as the site of pathogenic development. Plants of almost any sort are susceptible to infection by this agent. At the site of infection tumerous growths occur, characterised by rapid and disorganised growth by invasion of surrounding tissue and in some cases of metastasis. The disease process thereafter continues its course according to its own rules even after the pathogen has been eliminated. Following the wound infections of root collars or roots of all kinds of cultivated or wild plants, there arise spontaneously tuberous, strumrose or cauliflower like swellings which some times reach the size of a child's head.

Mode of Colonisation of the Host: Secondary Tumours and the Characteristics of Tumerous Tissue

Within limitations imposed by the structural peculiarities of plants and animals, the autonomous characteristics of the plant tumours very much resemble those of animal origin. Nevertheless, the metastases in plants must remain quite puzzling since plants lack a circulating and distributing system which animals have. Evidently, the metastases cannot have conceivably arisen from mechanical transport of tumour cells in a manner identical with that in animals. However, it is known that some bacteria and a few fungi are transported more or less mechanically by the sap flowing through the xylem. With Datura Tatula it has been noticed that even B. tumefaciens can be carried for a distance of nearly 120 c.m. during a few weeks time under favourable conditions. This might be one of the reasons for the frequent failure to eliminate infections of the crown gall disease in plants by pruning off of the diseased part, new tumours arising in many cases. In these cases the passive transport of the pathogen by specific proliferations of the host (cell strands), (Brown 1941) have been observed. Thus in the presence of a primary tumour secondary tumours may be formed some distance away in the host tissue, through portions of tissue in the xylem region starting to proliferate, forcing themselves forward between the vasular bundles by gliding growth. This method of internal infection by means of cellular strands carrying bacteria have evoked great interest and much discussion because it resembles in a way the formation of metastases in cases of human carcinoma.

All the above observations do not necessarily lead to the postulate that secondary tumours arising at considerable distances from the primary tumour will be infected in all cases with the pathogen. (White 1945; White and Brown 1942; Brown and White 1943). Indeed, there is considerable proof available indicating that in many cases the metastatic lesions are bacteria-free although still possessing the properties of unlimited growth in vivo and in culture (in vitro).

Tissues of bacteria-free crown galls cultured for many generations in vitro have been successfully implanted into the sunflower and artichoke. The retention, after many years, of the tumefacient property in the absence of the original inciting agent is evidence of the fundamental characteristic of the property. This property is characteristic also of plant tumours of genetic origin (White

1944). Thus tumours arising spontaneously, after tissue culture for five years could still induce tumours in even the resistant parent strain. In a sense, therefore, the pathogen (B. tumefaciens) is responsible only for the initial impetus; once the tumour reaction is under way the gall is converted into an independent biological entity possessing the power of autonomous growth.

Cancer cells in animals also provoke a continued vascular proliferation from the surrounding host tissue and this property may in part at least be resopnsible for their autonomous nature. The identity of the provoking substance is still unknown. Having thus eliminated the absolute necessity of live B. tumefaciens for induction of secondary tumours in plants or their transmission, the nature of the agent of their cause will remain to be revealed. Very likely, the causative agent may be one of the artefacts (metabolic products) of the tumourous tissue with the power of effecting both secondary and transplant tumours. It is known that glycosides, alkaloids, proteins and viruses can effect a passage through the plant. It is known that viruses are the result of a derangement of the nucleoprotein metabolism of the host cell brought about by a nucleoprotein; and a virus can easily be involved in such a mechanism. Or the agent may be a metabolite of the pathogen belonging to the class of radiomimetic compounds able to produce an alteration of the genetic material revealed by chromosome breakage and rearrangement in subsequent divisions.

Tissue Immunity Reactions and the Problems of Immunisation Against the Infection

On the basis of genetic constitution it is very difficult to explain why in aimals certain organs like spleen, heart, striated skeletal muscle and kidney are free both of primary as well as secondary growths, whereas a specific metabolic differentiation, for which there is still not much evidence, could easily explain such a phenomenon. In plants we know that crown, leaves, stems and roots are prone to attack and infection. But whether specific parts of the plant are immune to attack we do not know.

In animals it is very difficult to induce refractoriness to the innoculation from a graft from its own tumour. However, previous innoculation either of tumour cells or of normal homologous cells can immunise the animal towards transplants from other animals. Not all transplantable tumours can be immunised against in this way, many factors operating to condition such immunisation. In

the case of bacterial plant tumours corresponding studies are not available. In this field the laws concerning the mechanism of immunological response will remain to be studied.

We have, however, some evidence showing that repeated cuttings and infection might induce an increasing immunisation of the clone. Some workers were unsuccessful in building up a lasting immunity by alternate gall infection and subsequent vegetative propagation. Similarly, some investigations have led to no detection of any difference between the reaction type of healthy and pre-diseased clones of any agglutinins, precipitins or lysins in the tumours. In the case of tobacco, superinfected with B. tumefaciens after pre-innoculation of the leaves just below with the same, no protection or immunisation against infection was evident. Slight local immunisation and high susceptibility in fresh stock have been demonstrated in pelargoniums, while in the same plant very young tumours have been found to inhibit superinfection. It has also been noted that while new tumours may not be formed there may be evident hypersensitive reactions resembling that of anaphylactic shock. However, the positive observations cannot be disregarded and it may well be that a local or general modification of the host which renders it able to resist a new gall infection is possible only under special conditions-variety of stock, age, nutritional status, etc., being factors of importance.

Passive immunisation against tumour induction has been attempted with antibodies of both plant and animal origin. It has been found that rabbit serum agglutinative to B. tumefaciens protects the plant, and also has a healing effect on already existing tumours. Thus the interesting passive immunisation of plants by animal serum seems possible. On the other hand, results from using homologous antibodies of plant origin are more contradictory, especially in the case of graft scions and transplanted tissues. The probable existence of circulation of antibodies has also been proposed. This latter aspect needs more detailed investigation and further elaboration. Though in curly top disease of beet the protective effect travels from the stock to the scion, we have still to get positive evidence concerning the existence in plants of a protective action based on mobile antibodies and as to this property being inheritable by the scion from the parent stock.

The Analogy of Plant Tumours to Human-Animal Tumours

The supposed analogy of plant tumours (canker or crown galls) with malignant growths (carcinoma) in animals (Nobecourt 1937)

has caught the fancy of many workers and has also shaped the course of their investigations. These tumours, like malignant growths, with the power of metastasis and transferability cannot entirely be equated with animal tumours because the mechanism of metastasis in plants has necessarily to be different due to the different form of organisation of the plant with its rigid scaffolding of cellulose walls. Instead of the freely mobile cancer cells in the lymphatic system of the animals, we have here compact cell strands growing out from the primary loci. In the case of transplants the causative effect, as in animals, is likely to be different and the problems presented by them also as challenging.

In etiology also there are partial coincidences and divergences. The individual must possess an initial latent proneness to the disease. In plant tumours the agency is B. tumefaciens (or, as suggested, a cohabiting virus) (Black 1946), whereas for animals and man it is vegetative mutations, chemical stimuli, and in sarcoma, possibly, pathogenic viruses.

It is of note that the possibility of chemical stimulation is present both in plants and animals, though the point of attack on the cell or the responsive reactions of the organism may be different. The plant may respond nonspecifically with root or callus formation (Brown 1929) whereas the animal would respond specifically with cancer formation. While radiomimetic compounds of widely different types may elicit responses from plants, the aromatic hydracarbons, the azo dyes and dyes of the styryl quinone group are not as effective as compounds of a different type. These latter belong to the class of plant growth hormones (e.g. indolyl acetic acid) which while eliciting no response from the animal gives rise in plants to growths histologically identical to bacterial tumours (Brown and Gardner 1936; Havas 1937; Locke, Riker and Duggar 1938). Because, B. tumefaciens produces in culture growth substances, the mechanism of tumour formation has been explained on that basis. The work of Gautheret (1942, 1947, 1948) and his colleagues has made possible the culture of tumourous and other tissues in vitro and demonstrated that the autonomy of tumourous tissues might be due to a heightened capacity to synthesise some auxin as compared to normal tissues (1939) and, further, that a piece of tumourous tissue can, in fact, impart tumour properties to a bit of contiguous normal tissue (Camus and Gautheret 1948). While the effectiveness of bacterial extracts and tumour extracts in tumour induction may seem to support the above contention, the explanation is far too simple to be true. Possibly, other chemical

entities are as well responsible for the effect and the higher growth substance concentration observed in tumours (contrasted to normal in vitro cultures of the bacterium) may be the result of chemical stimulation of the growth substance production of the bacterium by the host. However, the pathogenic range of B. tumefaciens and indolylacetic acid do not coincide. Besides, other bacteria producing the same growth substance are ineffective in inducing plant tumours. While tumours thus seem to upset growth substance metabolism in plants, in animals we find disturbances in the enzyme components. There is also a report (Link and Eggers 1943-44) that crown gall tissue, at any moment, either contains more of enzymes than do normal tissues, or its enzymes are more active.

As in etiology, in histology also many similarities and slight differences exist.

In general, there is fundamental agreement between plant and animal tumours in the functionless development of the growths, in their atypical organisation (loss of polarity) (Bittmann 1925), in the lack of capacity for differentiation, in the insufficient vascularisation of the gall tissue, in the autonomous behaviour after transplantation as if they were themselves parasitic, and in the degenerative changes within the cells. However, as regards histology, in plant tumours the specific character of malignancy is absent, i.e. there is no destruction of neighbouring tissues by infiltration or expansion into them.

As in respect of pathology and histology, so in respect of physiological metabolism also there are possibly some similarities and some differences between animal tumours and plant tumours. But in plant pathology this aspect of the field has so far been very little explored. Observations of farreaching significance may be expected to be forthcoming in the future concerning the physiological metabolism and the cellular chemistry of normal and diseased plant tissue and of the infecting bacterium. Much work may be centred on the metabolism of protein and non-protein nitrogenous constituents, carbohydrates, lipids, enzymic components, vitamins, hormones and minerals, of water and other gross alterations in physiological reaction of the sap, patterns of respiration, etc. A determined effort should be made to correlate and integrate the patterns of organisation and meatbolism of the original infecting bacterium and the host plant and in getting the explanations for the disturbances induced once infection has set in.

When we are dealing with the phenomenon of tumorous growths we have our fingers right on the fundamental characteristics of living matter. The control of such growths is rather contingent on the discovery of biological and chemical principles inherent in living matter, which remain for the most part still unknown. The further studies on plant tumours may throw considerable light on the chemistry of such plant infection, its control or possible elimination, and its prophylaxis or therapy. Because most life still appears mysterious in its behaviour, further knowledge in this field may give some insight into medical problems even though these tumours are more analogues rather than causal homologues. The problem of plant tumours is undoubtedly of farreaching biological significance.

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THE POINCARÉ SPHERE AND STOKES PARAMETERS

BY

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ABSTRACT

The representation originally suggested by Poincaré can be extended so that any state of polarisation of a light beam (including partial polarisation) may be represented by a point inside a sphere of unit radius. Then the resolved components along suitable axes of the vector joining the centre to this point, multiplied by the intensity (I) of the beam, are the three Stokes parameters M,C,S. Various theorems on Stokes parameters, can be derived very simply, using this representation. It is shown that the mean degree of polarisation always decreases when two beams are superposed incoherently, being a constant only when the states of the polarised components of the two are the same. The Poincaré representation is used to discuss the theory of a monochromatic depolariser and more general conditions are derived than those indicated earlier by Billings.

1. *Introduction:*

The representation of the state of polarisation of a completely polarised beam of light is most conveniently made by using the Poincaré sphere. (Poincaré, 1892; Pockels, 1906; Ramachandran and Ramaseshan, 1952). All the possible states of complete polarisation, linear, circular or elliptic, can be represented by points on the surface of the Poincaré sphere and *vice versa*. However, the most general state of polarisation of a beam of light is a mixture of a fraction of unpolarised light, and a fraction of completely polarised light of arbitrary state of polarsation (Stokes, 1901). To represent such a beam, the most convenient method is to use the four so-called Stokes parameters. These have the important property that when two beams are incoherently superposed, the Stokes parameters of the two beams are additive and each parameter of the resulting beam is the sum of the corresponding parameters of the individual beams. In spite of the great simplicity arising from their application, these parameters appear to have been used only in a small number of investigations. (Soleillet, 1929; Perrin, 1942; Chandrasekhar, 1946, 47; Billings, 1951). An excellent account of Stokes parameters is to be found in the book "Radiative

Transfer" by S. Chandrasekhar (1949). Recently, Fano (1949) has considered the relation between Stokes parameters and the Poincaré sphere, but he had not carried it forward sufficiently. The present paper is concerned with

(a) The geometrical representation of a beam of light having an arbitrary state of (partial) polarisation by a point *inside* the Poincaré sphere, and

(b) The application of this representation to some problems in polarisation, e.g. the design of a depolariser. An interesting result is proved in this connection that on mixing two arbitrarily polarised beams incoherently the degree of polarisation always decreases, being constant only in the limit when the two beams have their polarised components of the same state.

2. *Geometrical Representation of Stokes Parameters* : †

The same notation will be used in connection with the Poincaré sphere, as was adopted by the author and Ramaseshan (1952) in an earlier paper *. Let OZ be the direction of propagation of the light beam and let OX, OY be two mutually perpendicular directions in the plane at right angles to OZ, such that OXYZ forms a right handed system of co-ordinates. Conventionally, we may take OX to be horizontal and OY vertical. If we take an elliptically polarised light beam of intensity I and if the major axis a of the ellipse makes an angle λ to the horizontal (measured counter-clockwise looking towards O in the direction ZO) and the axial ratio is given by

$$\pm \mid b/a \mid = \tan \omega, \; -\pi/4 \leqslant \omega \leqslant \pi/4$$

(where the + sign is taken for a left-rotating ellipse and vice-versa), then the four Stokes parameters (I,M,C,S) referred to the particular system of co-ordinates are defined by

$$\left.\begin{aligned} I &= I \\ M &= I \cos 2\omega \cos 2\lambda \\ C &= I \cos 2\omega \sin 2\lambda \\ S &= I \sin 2\omega \end{aligned}\right\} \qquad (1)$$

† Some of the results in this section have been mentioned by Fano (1949). However, the author believes that the best method of deriving the properties of Stokes parameters is from the Poincaré representation and they are therefore discussed here in some detail.

* This will be referred to by the Letter A. e. g. (A, Fig. 4).

If P is the point on the Poincaré sphere (of unit radius) which represents this ellipse, then 2λ and 2ω are respectively the longitude and latitude of P (see A, Fig. 1). Consequently, if we denote the vector OP by **P** and its components along OH, OA and OC by P_1, P_2, P_3 respectively, then we have

$$M = IP_1, \; C = IP_2, \; S = IP_3 \qquad (2)$$

As has been shown in A, the intensity transmitted by an analyser Q, when light of polarisation P falls on it is

$$I_t = I \cos^2 \frac{PQ}{2} = \frac{I}{2} (1 + \cos PQ) = \frac{I}{2} (1 + \mathbf{P}.\mathbf{Q}) \qquad (3)$$

where **Q** stands for the unit vector OQ.

Equation (3) can readily be generalised to partially polarised beams. Suppose that a light beam of intensity I consists of a fraction p of polarised light of state P and a fraction u of unpolarised light. The degree of polarisation would then be given by p. Since any analyser Q transmits half the intensity of the unpolarised part, we have now

$$I_t = \frac{I}{2} (1 - p) + \frac{Ip}{2} (1 + \mathbf{P}.\mathbf{Q})$$

$$= \frac{I}{2} (1 + p\,\mathbf{P}.\mathbf{Q}) \qquad (4)$$

If we put $\mathbf{p} = p\,\mathbf{P}$, (5)

where **p** is a vector in the same direction as **P**, but of length $p < 1$ then

$$I_t = \frac{I}{2} (1 + \mathbf{p}.\mathbf{Q}). \qquad (6)$$

This equation is of the same form as (3) and covers both the cases of completely and partially polarised light beams. Thus, the state of polarisation of any (partially polarised) light beam may be represented by a vector **p**, of magnitude p, in the Poincaré sphere. Its length gives the degree of polarisation, while its orientation (i.e. latitude and longitude) gives the state of the polarised part. While Poincaré conceived of representing all *completely* polarised states by points *on the surface* of a sphere, we now have a representation in which completely or partially polarised light can

be represented by a point in the *volume* contained by a sphere of unit radius, including its surface. Completely polarised light is still represented by points on the surface of the sphere, as before, while unpolarised light is represented by the centre ($p = O$). We shall call this representation, which is a generalisation of that due to Poincaré, as the Poincaré representation and the vector **p** as the Poincaré vector. The *state* of polarisation of unpolarised light can thus be defined by *three parameters*, namely the *three components* of the vector **p** along the three axes of the Poincaré space mentioned above. These together with the intensity I, give the four Stokes parameters for partially polarised light:

$$I = I,\ M = Ip_1,\ C = Ip_2,\ S = Ip_3 \qquad (7)$$

Equations (7) thus form the generalisations of Equations (2) for partially polarised light. The validity of this statement is shown by the fact that if $2\omega^1$, $2\lambda^1$, are the longitude and latitude of the point Q on the Poincaré sphere, then from Equation (6),

$$I_t = \tfrac{1}{2}\ (I + M \cos 2\omega^1 \cos 2\lambda^1 + C \cos 2\omega^1 \sin 2\lambda^1 + S \sin 2\omega^1), \qquad (8)$$

which is the formula for the intensity transmitted by a general eliptic analyser of light having the Stokes parameters I,M,C,S. (cf. Stokes, 1901; *Perrin*, 1942).

Equations (7) show the independence of the three parameters M,C,S, and one can readily prove, using this and Equation (6), the additivity law for the parameters, when a number of light beams are superposed *incoherently*. The intensities are then clearly additive and if the superscript (r) refers to the *r*th beam, we have

$$I_t = \Sigma I_t^{(r)} = \tfrac{1}{2}\ \Sigma I^{(r)}\ \ (1 + \mathbf{p}^{(r)}.\mathbf{Q})$$

$$= \frac{1}{2}\ [\Sigma I^{(r)} + \Sigma I^{(r)} p_1^{(r)} Q_1 + \ldots\ldots\ldots]$$

$$= \frac{1}{2}\ [\Sigma I^{(r)} + Q_1 \Sigma M^{(r)} + Q_2 \Sigma C^{(r)} + Q_3 \Sigma S^{(r)}]$$

But $I_t = \dfrac{1}{2}\ [I + Q_1 M + Q_2 C + Q_3 S]$

where I,M,C,S are the Stokes parameters of the resultant beam, so that

$$I = \Sigma I^{(r)},\ M = \Sigma M^{(r)},\ C = \Sigma C^{(r)},\ S = \Sigma S^{(r)}$$

Further, since $|p| = (p^2_1 + p^2_2 + p^2_3)^{1/2} \leqslant 1$, one obtains from (7) the well-known relation between the four Stokes parameters, namely

$$(M^2 + C^2 + S^2)^{1/2} \leqslant I \qquad (10)$$

3. *Addition of Polarised Beams:*

The additivity law (9) for Stokes parameters has a simple interpretation in the Poincaré representation. Suppose $p_1, p_2, \ldots \ldots p_n$ are the Poincaré vectors of n incoherent light beams, and let their intensities form the fractions $C_1, C_2, \ldots . C_n$ of the total intensity. Then, the Poincaré vector of the resultant beam is the vector

$$\mathbf{p} = \sum_{r=1}^{n} C_r \mathbf{p}_r \qquad (11)$$

This result, which is a direct consequence of Equation (9), appears trivial, but it has some interesting corollaries. Thus, it is clear from it that any polarised light beam can be resolved into the sum of two oppositely polarised beams in one and only one way (unless it is completely unpolarised). For, if **p** is the Poincaré vector representing the state of polarisation of the light beam, and if $\mathbf{P}_1$ and $\mathbf{P}_2$ are the Poincaré vectors (modulus unity) into which it is to be resolved, then $\mathbf{P}_1$, $\mathbf{P}_2$, **p** must be coplanar. Consequently, $\mathbf{P}_1 = -\mathbf{P}_2$ only if all the three vectors are parallel, which makes the resolution unique (if $p \neq O$). Also if C_1, and C_2 are the fractions of intensities of the two resolved beams, then

$$C_1P_1 + C_2P_2 = p \qquad \text{or } C_1 - C_2 = p$$

which, together with $C_1 + C_2 = 1$, gives

$$C_1 = (1 + p)/2,\ C_2 = (1 - p)/2. \qquad (12)$$

If one compares the above proof with the analytical proof due to Stokes, the great advantage of the Poincaré representation becomes obvious. Incidentally, equal intensities of any two oppositely polarised light beams, superposed incoherently, would lead to unpolarised light, as can be seen by putting $p = O$ in the above equation (12).

If the restriction that the two components are oppositely polarised is removed, then the resolution of an arbitrary state of polarisation (**p**) into two *completely* polarised states $\mathbf{P}_1$ and $\mathbf{P}_2$ is not unique. In fact, the only condition is that $\mathbf{P}_1$, $\mathbf{P}_2$, **p** should be coplanar. Thus, one has the interesting result that, while two

polarised beams combine to produce a partially polarised beam represented by a definite point, the resolution of the latter beam into two completely polarised beams is not at all unique.

Associated with this is another result, namely that the degree of polarisation of a combination of two beams is always equal to or less than the weighted mean of the degrees of polarisation of the two beams individually. This follows from the equation

$$\mathbf{p} = C_1\mathbf{p}_1 + C_2\mathbf{p}_2$$

so that

$$p \leqslant C_1 p_1 + C_2 p_2, \qquad (13)$$

the equality occurring when, and only when $\mathbf{p}_1$ and $\mathbf{p}_2$ are parallel. The above Equation (13) can also be put in the form

$$Ip \leqslant I_1 p_1 + I_2 p_2 \qquad .. \quad (14)$$

(where $I = I_1 + I_2$), which means that the intensity of the polarised component is always reduced when two partially polarised beams are mixed together.

The converse is also true, namely that it is possible to increase the mean degree of polarisation by splitting a beam into two. In fact, under ideal conditions, the two components can both be perfectly polarised, corresponding to the resolution into two oppositely polarised beams, as mentioned earlier. However, it appears that it is not possible to increase the degree of polarisation of a single beam without reducing its intensity.

4. *A. Direct Method of Measuring Stokes Parameters*

The method follows from Equation (6). Suppose we determine the intensity transmitted by the following analysers: a linear analyser set at angles (a) 0°, (b) 90° (c) 45° and (d) $-45°$ and (e) a left-circular analyser and (f) a right circular analyser. Let the measured intensities be respectively denoted by I_0, I_{90}, I_{45}, I_{-45}, I_+ and I_-. Then, from Equations (16) and (7), we have:

$$I_0 = \tfrac{1}{2}(I + M), \quad I_{90} = \tfrac{1}{2}(I - M)$$

$$I_{45} = \tfrac{1}{2}(I + C), \quad I_{-45} = \tfrac{1}{2}(I - C)$$

$$I_+ = 1/2(I + S), \quad I_- = 1/2(I - S),$$

so that

$$M = (I_0 - I_{90}), \quad C = (I_{45} - I_{45}), \quad S = (I_+ - I_-) \qquad .. \quad (15)$$

$$I = (I_0 + I_{90}) = (I_{45} + I_{45}) = (I_+ + I_-) \qquad .. \quad (16)$$

Thus, putting these various analysers in turn in the path of the beam and determining the intensities of the transmitted beam by a photometer, one can obtain straight-away the four Stokes parameters. Actually, only four of the six measurements are independent, but the others act as a check.

5. *Applications of the Poincaré Representation of Stokes Parameters*

(a) *Law of Transformation of Stokes Parameters:*

The law of transformation for a rotation of the axes of reference has been given by Chandrasekhar (1949), who chose for this purpose a four-vector having the components $[(I + M)/2, (I - M)/2, C, S]$ rather than (I, M, C, S). Although the former choice of four independent parameters is convenient in the applications discussed by Chandrasekhar, the original choice of Stokes is more useful in a large number of cases. The latter choice enables one to represent the *state* of the polarised component by a three-vector $\mathbf{p}$ whose three components are M/I, C/I and S/I. In fact, if the four-vector (I, M, C, S) were taken to represent the light beam, then so long as the degree of polarisation is unaltered, then the transformation leaves $I^2 - M^2 - C^2 - S^2$ invariant. Such a case arises during the propagation of light through a non-absorbing anisotropic medium, exhibiting birefringence, optical activity, or both and only the state of the polarised component is altered. However, since I itself is an invariant in such a case, the transformation is equally well represented by a three-dimensional rotation of the vector $\mathbf{p}$.

Suppose that an optically active plate giving a rotation ϱ is introduced in the path of the beam its effect is equivalent to rotating the sphere through an angle 2ϱ and the transformation matrix for the components of $\mathbf{p}$ is

$$R(\varrho) = \begin{pmatrix} \cos 2\varrho & -\sin 2\varrho & 0 \\ \sin 2\varrho & \cos 2\varrho & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad .. \quad (17)$$

where the three axes are respectively OH, OA and OC_l in the Poincaré space (see Ref. A). The effect of choosing new axes of reference in the plane at right angles to the direction of propagation, rotated with respect to the original one through an angle θ, is equivalent to interposing a crystal plate giving a rotation $-\theta$, and is thus given by the matrix $R(-\theta)$.

Similarly, introducing a relative phase retardation δ between the vertical and the horizontal direction is equivalent to rotating the Poincaré sphere through an angle δ about OH and the transformation matrix is then

$$L(\delta, 0) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\delta & -\sin\delta \\ 0 & \sin\delta & \cos\delta \end{pmatrix} \quad .. \quad (18)$$

If the relative retardation is between the directions $+45°$ and $-45°$, then the transformation matrix is

$$L(\delta, 45) = \begin{pmatrix} \cos\delta & 0 & \sin\delta \\ 0 & 1 & 0 \\ -\sin\delta & 0 & \cos\delta \end{pmatrix} \quad .. \quad (19)$$

More generally, if a crystal plate producing a phase retardation δ is introduced with its fast axis at an angle λ to the horizontal, the effect on the vector **p** is equivalent to rotating it in the Poincaré space through an angle δ about an axis inclined at 2λ to the direc- OH, so that the resulting matrix of transformation is

$$L(\delta, \lambda) = R^{-1}(2\lambda)\ L(\delta, 0)\ R(2\lambda) \quad .. \quad (20)$$

The analytical proofs of the above relations are involved, but they are straightforward if the Poincaré representation of Stokes parameters is used.

(b) *Application to the design of a depolariser*:

A monochromatic depolariser, a device by which any light beam is converted into an unpolarised beam, has been recently described by Billings (1952). Billings has made use of Stokes parameters in considering the theory of the instrument, but his arguments are in many places intuitive, and for the rest, require complicated formulae. As will be seen below, the use of the Poincaré representation of Stokes parameters leads to a large simplification of the derivation.

Suppose the state of polarisation of the beam is represented by a vector **p** in Poincare space. Our aim is to alter its state of polarisation in such a way that *on the average* it is unpolarised, i.e.

$$\int \mathbf{p}\, ds = 0, \quad .. \quad (21)$$

where **s** is some parameter. One can use for this purpose birefringent or optically active plates or crystal plates exhibiting both birefringence and optical activity. In every case, the effect on the vector **p** is to rotate it about some axis (say ROR') in Poincaré

space. It is obvious that rotation about one such axis alone is in general insufficient to make the degree of polarisation zero, for the mean value of **p** for an integral number of rotations will only be a vector **r**, which is the projection of **p** on RR'. However, if one rotates **r** about an axis at right angles to RR' (say TT'), then its mean value will become zero. Thus, in principle, one design of the depolariser would be an instrument which produces, in effect, rotations of multiples of 2π about two perpendicular axes in Poincaré space, the rotations being uncorrelated.

We may also investigate whether any correlated rotations are possible. Suppose we denote rotations about the axis RR' by the angle α, and those about TT' by β. Taking our axes of reference in the Poincaré space along OR, OT and the third mutually perpendicular direction, the matrices for the rotations through α and β are:

$$R(\alpha) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{pmatrix}$$

$$R(\beta) = \begin{pmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{pmatrix}$$

The effect of consecutive rotations of α about OR and β about T is

$$R(\beta)\ R(\alpha) = \begin{pmatrix} \cos\beta & \sin\beta\sin\alpha & \sin\beta\cos\alpha \\ 0 & \cos\alpha & -\sin\alpha \\ -\sin\beta & \cos\beta\sin\alpha & \cos\beta\cos\alpha \end{pmatrix}$$

Since we require that the mean value of the three components of an arbitrary vector **p** should be reduced to zero, the necessary and sufficient condition is that the mean value of all the components of the above matrix over the range of values occurring for α and β is zero. i.e. since α and β are correlated,

$$\int \begin{matrix}\sin\\ \cos\end{matrix} \alpha\, d\alpha = 0; \quad \int \begin{matrix}\sin\\ \cos\end{matrix} \beta\, d\alpha = 0; \quad \int \begin{matrix}\sin\\ \cos\end{matrix} \alpha \cdot \begin{matrix}\sin\\ \cos\end{matrix} \beta\, d\alpha = 0 \quad (22)$$

A solution of the first two equations is that $\beta = m\alpha$, where m is an integer, and the range of integration is 0 to 2π or a multiple thereof. The third equation may be put in the form

$$\int \left(\begin{matrix}\sin\\ \cos\end{matrix} (\alpha+\beta) \pm \begin{matrix}\sin\\ \cos\end{matrix} (\alpha-\beta) \right) d\alpha = 0 \quad (23)$$

When $\beta = m\alpha$, $\alpha+\beta = (m+1)\alpha$ and $(\alpha-\beta) = -(m-1)\alpha$.

Therefore, Equation (23) is obviously not satisfied if $m = \pm 1$. For any other integral value of m, the mean value over a cycle of α is zero. In fact, for any rational value of m, all the three equations in (22) are satisfied, provided a sufficient number of cycles of α is taken. The simplest case is when $m = 2$, and this is the one considered as a practical possibility by Billings.

As mentioned earlier, the crystal plates employed should produce effects equivalent to rotating about *any* two axes at right angles in the Poincaré space. The simplest combination is when one of them is about OH and the other about OA i.e. one crystal plate produces relative retardation between the vertical and horizontal directions, while the other produces relative retardation between the $+45°$ and $-45°$ directions. This case was pointed out by Billings, but he did not discuss the general case. In the practical instrument envisaged by Billings, the retardations would be produced by impressing electric fields varying linearly with time in a saw-tooth fashion at a fairly high frequency, so that several cycles occur within a measurable period of time. Thus, for ordinary observations, the transmitted beam would appear in effect to be unpolarised. He has also pointed out the various practical difficulties in realising such an instrument.

However, for many purposes, one may be satisfied with a beam, which is on the whole unpolarised, although variations in the state of polarisation may occur over its area. Here, the space average leads to zero degree of polarisation, just as the time average does in Billings's design. Such beams may be useful in studies on scattering of light or the Raman effect. A simple "depolariser" based on the above theory could be constructed for the purpose. It consists of two wedges of birefringent material, (the wedge tapering, say horizontally), one of which has its axes vertical and horizontal, while the other has its axes at $\pm 45°$. One of the wedges would have twice the angle as the other and the phase retardation may vary from zero to several multiples of 2π over the length of the wedge. The two wedges are placed one behind the other in the path of the light beam and the transmitted beam would then be completely unpolarised, irrespective of the state of polarisation of the incident beam. If it is desired to avoid refraction, each plate can be made as a combination of two opposite wedges with their axes crossed (as in the Babinet compensator).

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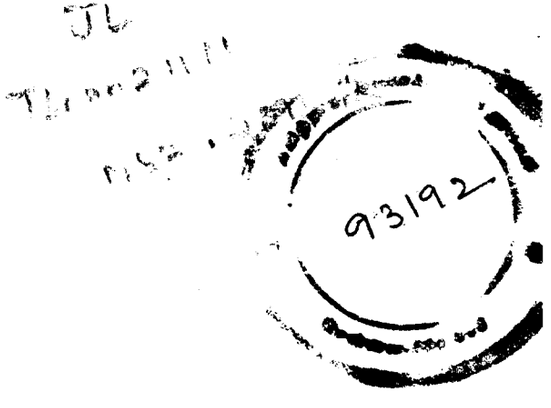

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