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SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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SCIENTIFIC REPORTS

OF THE

Agricultural Research Institute, Pusa

(Including the Report of the Imperial Cotton Specialist)

1917-18

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INTRODUCTION.

It seems unnecessary to repeat that this volume contains the reports of the various scientific workers at Pusa, written in their own words, and that for them each officer is solely and individually responsible. They stand or fall by the verdict on the value of their work passed by workers on the same subjects in the scientific world, and although the misinformed or intentionally vicious criticism to which they were subjected in a certain newspaper last year caused some annoyance, such criticism fortunately does not affect the true estimate of the work which is formed by the scientific world whose opinion is the only one that really counts.

With regard to the criticism in the article referred to, " that one searches in vain for a clue to the particular aims with which and the manner in which the activities of the ' Imperial scientific sections ' are co-ordinated and directed or what their labours all amount to in the end from the standpoint of Indian Agriculture as a whole," I need only remark that of this Provincial Departments of Agriculture are the best judges nor do I think that they will endorse the views of the newspaper critics.

The widespread distribution of the Pusa wheats, tobacco and other improved seeds : the solution of various important chemical and bacteriological problems of general application : the recommendations of mycological and entomological methods of control and prevention are appreciated throughout the provinces by whose verdict and that of other scientific workers of repute we are prepared to stand.

J. MACKENNA,

Director, Agricultural Research Institute, Pusa.

SIMLA,

10th Sept., 1918.

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Scientific Reports of the Agricultural Research Institute, Pusa

(Including the Report of the Imperial Cotton Specialist)

1917-18.

REPORT OF THE DIRECTOR.

(J. Mackenna, C.I.E., I.C.S.)

I. Charge and Staff.

Charge. I held charge of the office of the Agricultural Adviser to the Government of India and Director, Agricultural Research Institute, Pusa, throughout the year. From the 8th of October, 1917, I also acted as President of the Indian Cotton Committee in addition to my own duties. Mr. Wynne Sayer held the post of Assistant to the Agricultural Adviser during the year except for a month from the 3rd September, 1917, when he was on privilege leave.

Staff. Dr. W. H. Harrison was appointed Imperial Agricultural Chemist from the 11th November, 1917, in succession to the late Dr. J. H. Barnes.

Mr. F. M. Howlett, Imperial Pathological Entomologist, on return from leave, resumed charge of his duties on the 28th August, 1917.

Mr. G. S. Henderson, Officiating Imperial Agriculturist, was appointed a member of the Indian Cotton Committee, and acted as such in addition to his own duties. From 6th February, 1918, he was deputed to Mesopotamia to advise the General Officer Commanding as to the methods to be

adopted to ensure the development of local resources, and has now been appointed Controller (Agricultural Requirements, Mesopotamia) under the Munitions Board. Mr. Wynne Sayer, Assistant to the Agricultural Adviser, has been placed temporarily in charge of the work of the Imperial Agriculturist in addition to his own duties.

II. Work of the Institute.

Scientific Work. The more important enquiries of the year were the following :—

On the Pusa farm permanent manurial and rotational experiments form an important piece of work. But the most important work is the breeding of pedigree herds of cattle : (*i*) a pure-bred pedigree herd of Montgomery cattle and (*ii*) a cross-bred herd (Montgomery × Ayrshire). The results of crossing are so far very favourable. Alibi, the first crossbred heifer to complete her lactation period, has given over 7,000 lb. in a lactation period of 10 months—nearly double the quantity yielded by a good Montgomery cow. The Ayrshire-Montgomery cross bullocks have also proved good workers. Pusa is now able to supply good stock to cattle breeders and zamindars. A sale of surplus stock was held in March when the 53 head offered were very keenly bid for and realized very handsome prices. Another sale is to be held early in December.

The results of the cross-breeding work at Pusa are of very great importance in view of the known shortage of cattle in this country and their low milk yield.

In the Section of Chemistry the utility of Dyer's method of estimating the available plant food in highly calcareous soils is being investigated and the relationship of the gaseous products of decomposition to the paddy soils, particularly with reference to carbon dioxide and hydrogen, is being studied. The question whether or not the use of ammoniacal manures can be advantageously combined with green-manuring in the case of the paddy crop is also under examination. As regards sugarcane, investigations into the effect of storing canes by clamping and of windrowing are in hand. The importance of these investigations lies

in the fact that the adoption of these methods if found economical will tend to lengthen the working season for a sugar factory in the North-West Frontier Province.

In the Section of Botany the most important work is in connection with wheat both as regards seed distribution and wheat breeding. Another crop receiving attention is Java indigo. Besides the selection work on this crop, its root system and the effect thereon of any alteration in the soil conditions and also of cutting back to varying degrees are being investigated. The Howards are devoting much attention to the improvement of fodder production and fruit culture in Baluchistan as also the sun-drying of vegetables and the raising of the wheat crop on a minimum amount of water.

In the Mycological Section the "ufra" disease of rice claimed a very large amount of Dr. Butler's attention. Among other important diseases under study in this Section are the black band disease of jute, black thread disease of rubber, die-back of chillies and the *tikka* disease of groundnuts.

In the Section of Entomology the most important work of the year was in connection with the pests of sugarcane. The Entomological Department have been able to distinguish no less than 10 different forms which hitherto passed under the name of *Chilo simplex*. The question of alternative wild food plants of these borers is being investigated. Experiments to test the best methods of storing grain have shown that grain and pulses remain perfectly safe and in good condition when stored under a layer of sand. The enquiry regarding the occurrence within the Indian Empire of any insects which may be utilized as efficient checks on the growth of *Lantana*, a weed pest, is still in progress. Life-histories of various insects were studied and useful work in connection with bee, lac, and silkworms done during the year.

In the Section of Pathological Entomology some work has been done on cheap repellants to prevent Tabanidæ

attacking camels and so help to check the spread of surra among transport and other animals.

In the Bacteriological Section the following questions under soil biology are being studied:—conditions determining maximum nitrification in various types of Indian soils, the formation of bacterio-toxins in soils, nitrogen fixation, green-manuring and phosphate requirements of soil bacteria. The most important work, however, of the Section is in connection with the bacterial aspect of the fermentation taking place in the indigo steeping vats. Great variations are known to occur in the yield of different factories from plants grown under similar conditions of soil and climate and these can be correlated with the differences in the bacterial content of their water supply. The enquiry has shown that it is possible to avoid losses of indigo by altering the character of the bacterial fermentation in the steeping vat so as to secure more complete hydrolysis of the indican contained in the leaf. But, as the Imperial Agricultural Bacteriologist points out, some further work is necessary before it is possible to elaborate a routine method suitable for use in a factory without immediate scientific control.

Equally important is the work which Mr. Hutchinson is doing in connection with pebrine, a disease which has been largely responsible for the decline of the silk industry in India.

The work done by the Indigo Research Chemist, whose headquarters are at Pusa, has been published in the *Agricultural Journal of India* and in a series of Indigo Publications. No mention of that officer's work is therefore made here.

Training. A number of post-graduate students attended the Institute during the year and short courses were given in sericulture. Details are given in the Sectional Reports. The following is an abstract:—

	No. of Students
Agricultural Chemistry	3
Mycology	1
General Agriculture	2

Agricultural Bacteriology (including bacteriological technique in silkworm disease)	5
Entomology	2
Sericulture (short course)	9

Besides the regular students, Mr. B. N. Vakil, B.Sc., of St. Xavier's College, Bombay, worked in the Mycological Laboratory for a short period.

III. Publications.

During the year under report, 8 Memoirs, 11 Bulletins and 2 Indigo Publications (a special series started to embody the work of the recently created Indigo Section of the Institute) were issued.

Twelve publications were in the press at the end of the year.

During the year the proceedings of three conferences were published, *viz.*, the Board of Agriculture, the Second Entomological Meeting, and the First Mycological Meeting. An effort, which it is believed has been appreciated, has been made to make the form of the proceedings of these conferences more attractive.

The Report of the Proceedings of the Second Entomological Meeting held at Pusa in February, 1917, issued in an octavo volume of 340 pages, forms practically an abstract of our current knowledge of Indian crop-pests. There has been a satisfactory demand for it from the public.

It is gratifying to record that the public demand for the Bulletins of the Institute is increasing every year. A second edition of two bulletins had to be brought out during the year; the first edition of the bulletin on "New Agricultural Implements for India" ran out of stock within three months of its issue. There were also many applicants for the bulletin on Water Hyacinth—that serious pest in Bengal and Burma. This bulletin shows how a definite return can be obtained in the process of exterminating what was previously considered a useless and harmful weed-pest. A large number of copies of the three bulletins regarding

the diseases and feeding of camels issued during the year were supplied to the Army Department.

The *Agricultural Journal of India* in its new form is increasing in popularity among those interested in the agricultural, co-operative, veterinary and such like problems in this country. As in the previous two years, a Special Number of the Journal containing a selection of papers on agricultural and allied subjects read at the annual session of the Indian Science Congress, was published.

The grant for publications has remained at the figure of Rs. 29,000 previously sanctioned, but with the continuous rise in the price of paper and other materials it is becoming more and more difficult to keep the expenditure down within the sanctioned amount.

IV. General Administration.

Buildings and Works. During the year under report a bungalow for the Electrical Engineer was sanctioned by the Government of India and the work has been taken in hand. Sanction has also been received for the construction of quarters for the First Assistant to the Imperial Mycologist and also of quarters for the staff of the High English School at Pusa. The condition of the roads and drainage on the estate has been much improved during the year.

Library. In addition to the 1,320 bulletins, memoirs, reports, etc., received in exchange, about 375 new volumes were purchased for the library. The United States Department of Agriculture supplied during the year 30,200 printed subject cards of their bulletins, and these have been arranged according to their subjects. The preparation of a new catalogue of the books in the library is in hand.

Pusa School. The total number of pupils attending the Pusa High School on the 30th June, 1918, was 160, including one girl student, as against 198 last year on the same date.

General Health of the Station. The outbreak of a virulent epidemic of cholera in April, 1918, and the un-

healthy conditions which subsequently prevailed in the villages in the neighbourhood of Pusa contributed to an appreciable rise in the number of patients treated in the hospital and dispensary attached to the Institute. The number of out-patients rose to 20,638 from 11,956 and that of in-patients from 297 to 316. Pusa was the only place in the district where no indigenous case of cholera occurred. Great credit is due to the medical staff for the successful way in which they coped with the increased work. The general health of the station continued to be good during the year under report.

V. Accounts.

The total expenditure during the financial year 1917-18 was Rs. 5,81,723, as against Rs. 5,18,603, during the previous year. The details are given below :—

	Rs.
Office of the Agricultural Adviser to the Government of India and Director of the Institute	2,34,865
Chemical Section	30,783
Mycological Section	46,964
Entomological Section	46,100
Pathological Entomological Section	22,493
Bacteriological Section	30,858
Botanical Section	46,203
Agricultural Section	64,577
Indigo Research Section	58,880
Total	5,81,723

Out of the budget of this Department for 1917-18 a sum of Rs. 27,000 was placed at the disposal of the United Provinces Agricultural Department for expenditure in connection with the continuance of the appointment of Mr. W. Hulme as Sugar Engineer in that province.

A sum of Rs. 15,000 was paid as a grant-in-aid to the Indian Tea Association.

The principal items of expenditure under the annual grant of Rs. 10,000 placed at the disposal of the Agricul-

tural Adviser to the Government of India for special agricultural experiments were as follows :—

	Rs.
Experimental cotton cultivation by the Imperial Cotton Specialist	1,250
Grant-in-aid to the Dairy Education Association, Indian Branch, for the Quarterly Journal of Dairying	510
Fittings and apparatus for the field laboratory of the Imperial Agricultural Bacteriologist . .	1,999
Storage experiments by the Imperial Entomologist .	434
Purchase of silk yarn	454
Grant to the Fibre Expert, for purchase of flax seed	1,453
Pay of a Veterinary Assistant in connection with cattle breeding, a Fieldman for mosquito experiments, and an Assistant for pebrine work . .	1,903

The gross receipts during the year from the sale of farm produce, milk, publications of the Department and other articles amounted to Rs. 19,843 as against Rs. 17,878 in the previous year.

VI. Visitors.

Fifty-four gentlemen visited the Institute during the year under report. Among them were the following :—

The Hon'ble Mr. H. Le Mesurier, Member of the Executive Council, Bihar and Orissa; Sir Frank Sly, President of the Champaran Agrarian Committee; the Hon'ble Mr. H. J. Maynard, Financial Commissioner, Punjab; Dr. J. W. Gregory, Professor of Geology at the University of Glasgow and Member of the Calcutta University Commission; Colonel G. J. H. Bell, Inspector-General of Civil Hospitals, Bihar and Orissa; Lieutenant-Colonel Sir James Roberts, I.M.S., Mr. G. E. Fawcus, Director of Public Instruction, Bihar and Orissa; Professor H. Stanley Jevons, Allahabad University; the Reverend Father E. Blatter, Professor of Botany, St. Xavier's College, Bombay; and Mr. Frank B. Hill, a planter in British East Africa. Among the other visitors were officers of the various Provincial Departments of Agriculture, and

planters and zamindars of estates surrounding Pusa. A party of members of the Chanakya (Economic) Society of the Patna College, under Professor Sammadar, also visited the Institute during the year.

REPORT OF THE IMPERIAL AGRICULTURIST.

(Wynne Sayer, B.A. [in charge.])

Forenote.

Mr. G. S. Henderson was in charge of the post of Imperial Agriculturist till the 6th of February, when he was sent on special duty to Mesopotamia. On return he was put on special duty to purchase agricultural requirements for that country. From the 6th February, Mr. Sayer, Assistant to the Agricultural Adviser to the Government of India, took over charge in addition to his own duties.

From August Mr. Henderson toured extensively along with the Deputy Director, Dairy Farms, Southern Division, to get into touch with the extensive dairy organization which has been formed by the military authorities. From October till the end of January he was a member of the Indian Cotton Committee.

Mr. Henderson has now been made a member of the recently created Central Foodstuffs and Transport Board and appointed a Controller of the Munitions Board to deal with agricultural equipment for Mesopotamia.

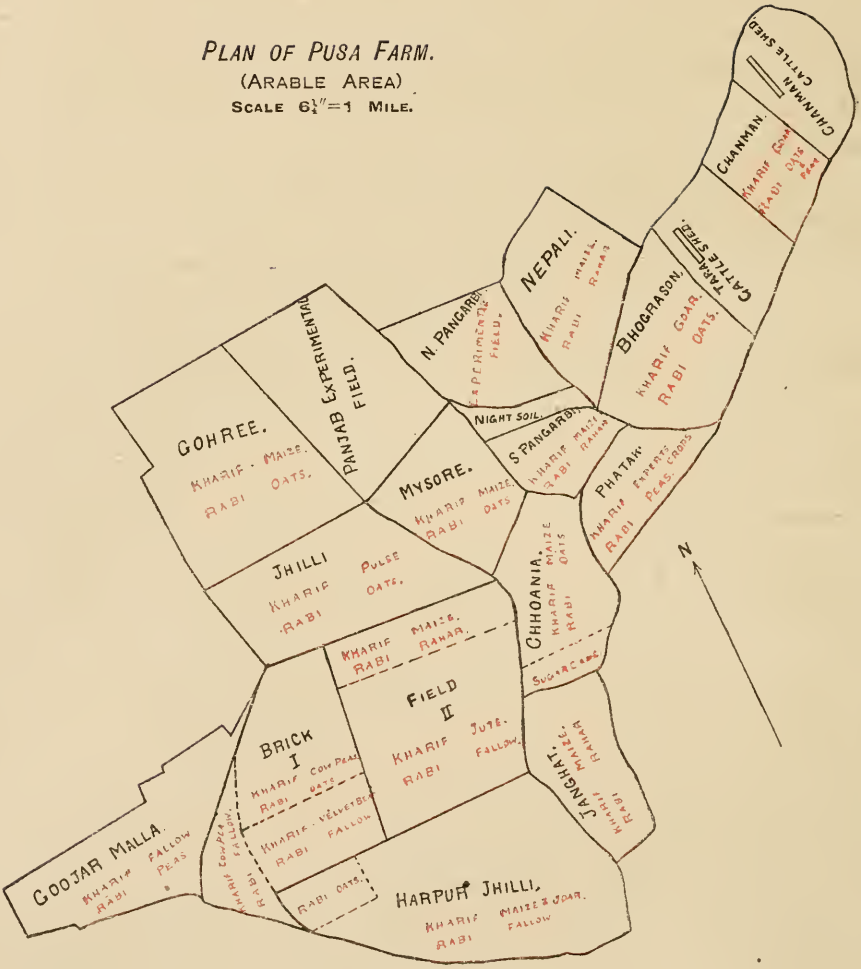
I. Charge and Staff.

Mr. Wynne Sayer was in charge of the Pusa farm from the 6th February, 1918, in addition to his own duties.

Mr. Imdad Husain Khan, Fieldman, left on 4th November, 1917, for Mesopotamia to work under the Military Department.

Training. Mr. S. N. De, a stipendiary from the Bengal Agricultural Department, joined on 9th August, 1917, for a course in agriculture but left on 21st January, 1918.

Mr. Kalyan Mal Banthia, a stipendiary sent by the Ajmer and Merwara Administration, was admitted to the general course in agriculture from 8th June, 1918.


PLAN OF PUSA FARM.
(ARABLE AREA)
SCALE 6½"=1 MILE.
CHAMMAN CATTLE SHED
CHAMMAN
KHARIF GOAR. DATS & PEAS
RABI
CATTLE SHED
BHOGRASON.
KHARIF GOAR.
RABI OATS.
TARAS
NEPALI.
KHARIF MAIZE. RAMAS
RABI
N. PANGARBI.
EXPERIMENTAL FIELD.
NIGHT SOIL
S. PANGARBI.
KHARIF MAIZE RAMAS
RABI
PHATAK
KHARIF EXPERTS CROPS
RABI PEAS.
PANJAB EXPERIMENTAL FIELD.
GOHREE.
KHARIF MAIZE.
RABI OATS.
MYSORE.
KHARIF MAIZE.
RABI OATS
JHILLI
KHARIF PULSE
RABI OATS.
CHHOANIA.
KHARIF MAIZE
RABI OATS
SUGARCANE
KHARIF MAIZE. RAMAS.
RABI
FIELD II
KHARIF JUTE.
RABI FALLOW.
JANGHAT.
KHARIF MAIZE. RAMAS
RABI
BRICK I
KHARIF COW PEAS
RABI OATS
KHARIF VELVET BE
RABI FALLOW
RABI OATS.
KHARIF COW PEAS
RABI OATS
GOOJAR MALLA.
KHARIF FALLOW
RABI PEAS
HARPUR JHILLI.
KHARIF MAIZE & JOAR.
RABI FALLOW
N

II. Pusa Farm.

The Season. The monsoon broke early in June and sowings were completed by the middle of that month. The total rainfall throughout the year (June, 1917 to May, 1918) was 45·54 inches as against 59·67 inches in the corresponding period of 1916-17, the normal rainfall being about 50 inches. The total failure of the cold weather rain made the oat crop a very short one and also affected the yield of peas adversely.

The arable portion of the farm is worked under the following rotation :—

	1st year	2nd year	3rd year
Kharif* . . .	Maize for silage and fodder	Maize for corn .	Pulse green crop
Rabi † . . .	Oats . . .	Arhar *(Cajanus indicus)*	Oats

The object of this rotation is to keep the land clean and in good heart while providing grain and fodder for the herds.

By soiling the cattle on the *kharif* pulses it is hoped to do the land even better than under the usual rotation. On the heavy low land portion of the farm this may prove impossible at times, but it is anticipated that it will produce a considerable improvement in the yields on the higher sandy lands in future years.

The cropping of the various fields of the arable area for the season under report is shown on the plan of the farm given here, and the yields were as follows :—

1st year rotation. *Kharif* maize cut green for silage or fodder (a dressing of farmyard manure at 10 tons per acre or 10 maunds oilcake per acre being given before sowing); four fields aggregating 135 acres down under this crop

* Crop sown in monsoon.
† Crop sown in winter.

averaged 200 maunds per acre; average income Rs. 50 per acre; working costs Rs. 20 per acre.

Rabi oats followed in the same four fields and averaged 12 maunds of grain and 25 maunds of straw throughout, bringing in Rs. 40 per acre with a working cost of Rs. 12 per acre.

The best yields were 231 maunds green maize per acre in Chandman and 13 maunds oats in Gonhri.

2nd year rotation. Maize and *arhar* sown together, no manure being applied; maize cut for corn in end of September and *arhar* left throughout *rabi* for grain; 4 fields totalling 80 acres averaged 23 maunds grain from maize and *arhar* combined, bringing in Rs. 70 per acre at a working cost of Rs. 14 per acre—figures covering both seasons.

3rd year rotation. Kharif pulse either fed standing or cut green for fodder or ploughed in; four fields totalling 118 acres stood under this crop which was followed by oats in *rabi* over 84 acres; the remaining 34 acres standing fallow for hot weather maize of 1918 which was sown in March. The oats got one maund of super per acre. The cost of the two seasons' crops was Rs. 30 per acre and the income Rs. 70 per acre. The best field Jhilli gave 18 maunds oats per acre.

Sugarcane and jute are the two crops grown which are exceptions to the above rotation. Sugarcane is taken in the first year and jute in the second. These crops are sown from middle of February up to middle of March on moisture conserved by repeated cultivation in the cold weather.

Sugarcane. A number of sugarcane varieties are grown on the farm without irrigation. These varieties for the most part come from Dr. Barber, the Sugarcane Expert. The main crop consists of Red and White Sathi, Purple Mauritius and few other thick canes. The canes were disposed of at 6 annas per maund. In the area sown during the past year the cost of cultivation was Rs. 65 per acre and income Rs. 144-13 per acre.

Jute was grown on 40 acres for seed by arrangement with the Fibre Expert to the Government of Bengal,

but this arrangement will have to be terminated over the main area of the farm as it is impossible to spare this land from fodder crops for the cattle. As jute is a useful crop for low ground which is liable to be flooded during the rains and consequently will not hold a *kharif* crop with any certainty, it will be sown next year in Gujarmalla field which is outside the protective bundh, and consequently has to be left fallow in *kharif* as far as the ordinary rotation is concerned.

Berseem. This seed was imported from Egypt, but it arrived almost too late for sowing. It was sown but the result was very disappointing. About 4 maunds was distributed to various planters who mostly reported that they received it too late to sow. It will be given a proper trial this year.

Experimental work. This work was continued in the two fields, Punjab and North Pangarbi, set apart for the purpose.

(*a*) The permanent manurial and rotational experiments were continued. A bad outbreak of wilt among the *arhar* on these plots considerably reduced yields for the year from some of these plots.

(*b*) The green-manuring experiments carried out in collaboration with the Imperial Agricultural Bacteriologist, were continued in the Punjab field on the newly tested plots. The results are given below :—

Particulars	Yield of oats (grain) per acre	Particulars	Yield of oats (grain) per acre
	Mds.		Mds.
3 times san hemp fermented with 3 cwt. superphosphate per acre.	24	3 times san hemp fermented without superphosphate.	18
6 times san hemp fermented with 3 cwt. superphosphate per acre.	32	6 times san hemp fermented without superphosphate.	19
San hemp ploughed in with 3 cwt. superphosphate per acre.	25	San hemp ploughed in without superphosphate.	15
Superphosphate alone 3 cwt. per acre without green manure.	14	No superphosphate and no green manure.	$12\frac{1}{2}$

These plots will all be cropped with maize in *kharif* to test the residual effect.

(*c*) Experiments in collaboration with the Imperial Mycologist for determining a method of dealing with die-back (wilt) in the chilli crop were started in the year under report and will be continued.

(*d*) Fourteen varieties of the more widely-known wheats were under trial. The average yield per acre from all varieties was 17 maunds. The best yields were :—

	Maunds
Lal of Jhelum	24
Muzaffernagar white	24
Pusa 12	22
Maroo Boojee (Sindhi)	18

These trials will be continued next year from carefully selected seed when Federation and other Australian wheats which have done well in India will be brought in.

(*e*) The experiments for testing yields of green fodder with yields of seed and comparative economic value of the common leguminous crops were continued. Florida Beggar weed, velvet and soy beans, *val* (*Dolichos Lablab*), *guar* (*Cyamopsis psoraloides*), *math* (*Phaseolus aconitifolius*) and *urid* (*Phaseolus radiatus*) being tried in *kharif*, while white and purple peas, *khesari* (*Lathyrus sativus*), *val* and gram varieties and *math* were sown in *rabi*. They will be continued next year.

(*f*) Experiments with Java and Sumatrana indigo were carried on in collaboration with the Indigo Research Chemist and the Imperial Agricultural Bacteriologist. These will be continued over a period of years and the results will be dealt with from time to time by the Indigo Research Chemist and the Imperial Agricultural Bacteriologist in their respective reports.

The testing of the remainder of the plots laid out in Punjab field continued. Crops for the various experts were grown in North Pangarbi and a set of experiments on *rahar* wilt in collaboration with the Imperial Mycologist

and the Fibre Expert to the Government of Bengal were laid down.

Buildings and Machinery. Two new pit silos have been dug. This type of silo has proved a great success and vastly superior to the brick tower type, as there is little or no wastage at top, bottom and sides, and the silage does not dry out as is the case in the brick silos owing to the impossibility of pressing them sufficiently tight from the top.

A new silage cutter, Climax, was purchased from Messrs. Shaw Wallace & Co., and was tried during the season; it has a feeder attached to it and the chopped stuff is carried up by a blast and blown through a pipe into the silo.

Five hundred and five maunds of cleaned oats were turned out by the 4′ 6″ Marshall Thresher in one day, which is a record, I think, for India.

Steam Plough Tackle. This tackle consisting of two single cylinder K Class Fowler engines and a disc plough, a gang plough, a disc harrow, a grubber, a zigzag harrow and a roller, worked for 121 days during the year, but the total cost of working this year was Rs. 6,098-8-3, as against Rs. 4,034 for 151 days of last year. The details are given below :—

STATEMENT A.

Showing cost for working and maintaining the tackle in 1916-17 and 1917-18.

Particulars	1916-17. No. of working days 151	1917-18. No. of working days 121
	Cost	Cost
	Rs. A. P.	Rs. A. P.
Labour	1,233 0 0	940 1 6
Coal	1,788 0 0	1,424 9 0
Oil	500 0 0	315 0 0
Miscellaneous stores, etc., and renewals	713 0 0	3,418 13 9
TOTAL	4,034 0 0	6,098 8 3

Statement B.

Showing the above cost divided into following operations per acre in the year 1916-17 and 1917-18.

Particulars	1916-17			1917-18		
	Total area cultivated in the year	Cost per acre	Best day's work	Total area cultivated in the year	Cost per acre	Best day's work
	Acres	Rs. A. P.	Acres.	Acres	Rs. A. P.	Acres
Ploughing .	267	4 6 2	7	170·5	9 3 2	7
Disc harrowing .	498	2 0 9	18	821·5	3 0 3	20
Grubbing .	1,080	1 7 4	25	616·0	4 5 7	26
Zigzag harrowing	41	0 14 9	27	11·0	2 2 6	...
Rolling . .	320	1 5 6	22	173·0	3 14 0	22
Total .	2,206	...	...	1,792·0	...	...

The enormous rise in the cost of spare parts and replacements owing to the war has resulted in a great increase in the general working cost per acre this year. This, however, is due to the absolutely abnormal conditions with regard to imports now prevailing, which have necessitated laying in a stock of spares sufficient to carry one over a considerable period, the possibility of being unable to procure spares in the future having to be carefully guarded against as we are now absolutely dependent on the tackle for cultivation, and the greatest objection to it is the fact that the breakdown of one engine alone is sufficient to render the *whole* tackle useless.

But with the renewals which have been made this year (including a set of new cables which will be good for another 3 years' work) the tackle is now to all intents and purposes as good as the day it started work.

Pusa is far from being a suitable place to test such tackle as several of the fields are too small for economic working, the number of stops and turns being out of all proportion to the area run over; nevertheless as is seen from the figures, the best day's work of the tackle steadily increases and the rapidity and thoroughness with which it deals with the work has greatly simplfied the *rabi* cultivation.

A new gang plough was tried during the year under report and worked excellently—burying its rubbish far more effectively than the disc plough formerly used.

III. Cattle Breeding.

The combined herds totalled 386 head in the year under report.

The Montgomery herd is divided into two portions used as follows :—

(*a*) For selective breeding for milk production.

(*b*) For crossing with the Ayrshire bulls.

The stock under (*a*) are divided into five groups each of which has a separate bull to prevent in-breeding. The stock under (*b*) consists of cows which are not sufficiently good milkers for inclusion under (*a*) and are therefore used for putting with the Ayrshire bulls for the cross-bred herd.

The Montgomery milch herd now contains 119 cows of which 42 have given over 4,000 lb. in a lactation period, 14 over 3,800 lb. and 24 over 3,000 lb.

A rigorous policy of selection for milk yield is being carried on and no cow is being kept on in the milch herd who does not show signs of coming up to the standard.

The best performances among the Montgomery cows during the season under report were as follows :—

	lb.	
Syria No. 182	5,935	Lactation period 10 months.
Joogni No. 142	5,464	
Akli No. 231	5,406	
Kabutri No. 236	4,738	
Roomali No. 140	4,711	

The Montgomery-Ayrshire cross-bred herd now stands at 61 head.

Two $2\frac{1}{2}$ year old bulls, by Lessnessock Wildfire off Montgomery cows, have been taken up for stud purposes.

Six of the heifers got by Mossgeil Titanic in 1915, have calved down and are now milking. They have grown into good type cows, in the majority of cases taking more after their sire than their dam. The photograph (Plate I, fig. 2) of one of them, Alibi, is given with this report and it should be compared with the photograph (Plate II) of Akli, one of the best type Montgomery cows in the herd, which is also given. They have got good, well set on bags, flat and carried well forward, in Ayrshire style—a distinct contrast to the Montgomery type. After calving they all came back to bull in one to three months and are all due to calve again in December, thus showing no sign of the Montgomery tendency to stand off for several months which forces us to maintain continually for long periods a large number of empty dry cows, and which is another obstacle to successful dairy farming with the indigenous cow.

In all six cases their calves were weaned at birth, and this has had absolutely no effect on their mothers' milk yield, which is one of the great improvements this cross effects. These calves which are by Carston Royal Scotch are all $\frac{3}{4}$-bred English, but appear at present similar in all respects to half-breds. Two out of the six unfortunately died but the remainder are doing well. It is proposed to start this year putting half-bred bulls across half-bred heifers, and it will be interesting to see whether the result of this cross will continue to allow of its calves being weaned at birth. It is absolutely essential that this character should be maintained, as with milk at 6—4 seers per rupee—which is a very low price for big towns—when the calf sucks continuously the result is that you rear a calf in the most expensive fashion possible, keeping it on milk during the whole lactation period of the cow and materially reducing your profit

Fig. 1. Cross-bred bull. (Montgomery cow × Ayrshire bull.)

Fig. 2. Cross-bred cow, Alibi No. 3. (Montgomery cow × Ayrshire bull).

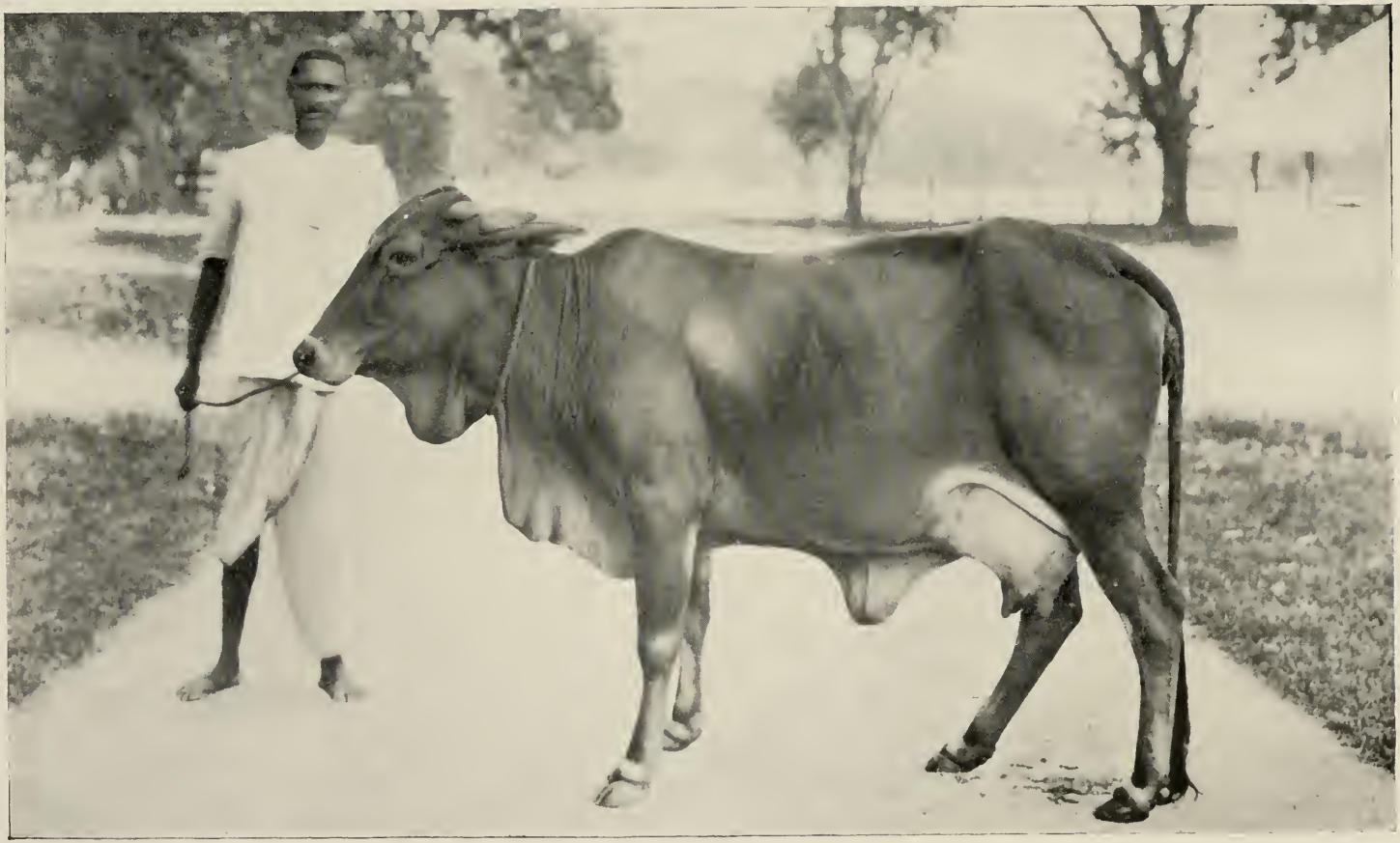


PLATE II.

One of the best type Montgomery cows—Akali.

thereby, but this is only one of the many points which must be tested in this cross-breeding work.

The first heifer, Alibi, to calve out of the above batch, has given over 7,000 lb. in a lactation period of 10 months. Two of the others are expected to reach over 6,000 lb. The lactation periods of the rest are not yet complete but the figures so far go to show that they will be well above the average.

The castrated stock of the Ayrshire-Montgomery cross have turned out exceedingly quick, strong workers and are proving equally useful for fast as well as heavy work, being very big and massive without being overtopped. The imported Ayrshire bulls, Lessnessock Wildfire and Carston Royal Scotch, kept very fit throughout the year and continue to increase in weight.

A sale of surplus stock was held on the 30th March, 1918, when 53 head—bulls, cows, heifers and calves—came under the hammer. They realized Rs. 5,600, averaging as below—

	Rs.
Bulls	203
Cows	90
Heifers	217
Montgomery bull calves	82
Cross-bred bull calves	93

The best prices were Rs. 300 for a bull, Rs. 230 for a cow, Rs. 340 for a heifer, Rs. 220 for a cross-bred bull and Rs. 175 for a Montgomery bull calf.

There was a large attendance and the bidding which was very keen, especially for the heifers and cows in calf, showed clearly that there is a strong demand for good class cattle in India; while the way in which the cross-bred bull calves were bid for was evidence of the value which they represent for rapidly improving the yield of milch herds.

As the herd is now increasing so rapidly that it has become impossible to accommodate the stock properly in the present buildings, an auction sale will be held at short intervals in future years, the next being in early December. People requiring cattle will do well to come down beforehand and inspect the stock, which will be on view for a month before the sale.

The feeding of the herd has as usual monopolized the output of the major portion of the cultivated area on the farm, and if the breeding up of the Montgomery herd in the five groups already established is to be properly done (and this means retaining all stock bred from these groups for thorough trial), while the collection of data regarding the transmission of characters in the cross-bred herd will also require careful selection and observation among a large number of animals, the arable portion of the farm will have to be entirely devoted to the work of producing fodder and grain for the herd, and the question of finding the land for growing crops such as jute, wheat and sugarcane, etc., on a field scale will have to be considered.

Disease. There was an outbreak of foot-and-mouth disease in 1917 which lasted some three months and resulted in 5 deaths, four of which were suckling calves of under two months old, while a number of young stock were considerably put back by the attack. There was one case of black-quarter in the beginning of May, 1918, which proved fatal, and in consequence all the calves in the herd—some 175 in number—were inoculated against this disease.

Inoculation. It is proposed to have all the young stock inoculated against rinderpest by the simultaneous method. This will enable the cross-bred bull calves sold at auction to go out into the district without risk and should greatly enhance their usefulness, while the ever present risk of having years of work on the cross-bred herd wiped out in one attack will be removed.

The capital value of the herd based on current prices now stands at Rs. 42,000, and the following figures give the

receipts and expenditure in connection with it for the year under review :—

Returns	Rs.	A.	P.	*Cost*	Rs.	A.	P.
Received for sale of milk	6,660	14	3	Budget for up-keep (all labour) . . .	3,900	0	0
7 Montgomery and cross-bred transferred to work cattle	540	0	0	3,695 mds. 7½ seers grain at Rs. 2-8 per md. .	9,237	15	6
53 head sold . . .	5,600	0	0	9,647 mds. 23 srs. silage at as. 6 per md. . .	3,617	13	6
Sheep and cast stock . .	104	6	0	5,412 mds. green fodder at as. 4 per md. . .	1,353	0	0
	12,905	4	3	3,973 mds. bhusa at as. 4 per md. . . .	993	4	0
					19,102	1	0

The net cost of upkeep and maintenance was Rs. 6,196-12-9.

Sheep Breeding. The sheep breeding experiments were continued during the year under report. As soon as conditions regarding importation improve two new Merino rams will have to be procured for the flock, as much in-breeding is now going on for want of fresh blood.

IV. Publications.

The demand for Bulletins on "Berseem" and "New Agricultural Implements for India" was so great that a second edition of these publications had to be brought out during the year.

A pamphlet was also issued to advertise the sale of surplus dairy stock and was widely distributed.

V. Programme for 1918-19.

Major.

1. Practical treatment of pedigree dairy herd of Indian cattle and pedigree dairy herd of cross Montgomery-Ayrshire cattle.

II. Practical treatment of 1,200 acre mixed farm, with particular attention to profitable modern machinery and the financial result of the work.

The bulk of the produce of the Pusa farm is used for the maintenance of the dairy herd. The rotation adopted aims at the up-keep of the fertility of the land along with supply of concentrated food and long fodder and a constant supply of the green fodder throughout the year. Included in the above is the study on a practical scale of :—

(*a*) Rotations.
(*b*) Crops for fodder, seed and silage.
(*c*) Implements and machinery.
(*d*) Technique of cultural operations.
(*e*) Types of farm buildings.

III. *Experimental work at Pusa.* After the preliminary testing of the new experimental area at Pusa, the following will be started and continued along with existing work :—

(*a*) Rotational experiments.
(*b*) Trial of new varieties of existing crops, especially leguminous fodder crops, American maizes, foreign oats, and wheat varieties.
(*c*) Manurial experiments, especially seasonal and quantitative tests with phosphates.
(*d*) Rotation and manurial experiments already started.
(*e*) Seasonal tests with Java and Sumatrana indigo.
(*f*) Fermented green-manuring experiments in collaboration with the Imperial Agricultural Bacteriologist.
(*g*) Trial of sugarcane varieties suitable for growth without irrigation. (Some of Dr. Barber's varieties are very promising.)

IV. *Demonstrations, exhibitions and cattle sales of* surplus dairy stock, etc., will be held from time to time as occasion offers.

Minor.

V. *Touring and advisory.* Visits will be paid to provincial agricultural centres. This should tend to co-ordination of agricultural work.

VI. *Berseem cultivation.* Experiments with this will be continued.

REPORT OF THE IMPERIAL AGRICULTURAL CHEMIST.

(W. H. Harrison, D.Sc.)

I. Administration.

The Section was in charge of Mr. W. A. Davis, B.Sc., A.C.G.I., F.C.S., Indigo Research Chemist, until November 10th, 1917, on which date I took over charge as Imperial Agricultural Chemist.

Mr. J. Sen, Supernumerary Agricultural Chemist, continued on special duty under the Government of the United Provinces in connection with the work at the Ghazipur Opium Factory.

II. Education.

Mr. N. N. Ghosh and Mr. S. C. Dutt joined this Section as private students, the former on July 10th and the latter on September 9th, 1917, and both have since taken up appointments as assistants. Mr. A. K. Mitra joined the Section as a stipendiary student of the Bihar and Orissa Government on June 1st, 1918.

III. Meteorology and Drain-gauges.

The usual meteorological records were maintained and the crops and drainage waters from the drain-gauges were examined in the usual manner. The waters and crops from the Cawnpore gauges were also analysed.

IV. General analytical work and assistance given to other Sections.

The following samples were analysed and reported upon during the year :—

Soils	150
Feeding stuffs	155
Manures	22
Waters	31
Miscellaneous	9
Total	367

Amongst the manures examined was a sample of guano from the Nicobar Islands which contained 8·5 per cent. nitrogen.

A number of soils were received for examination from the Settlement Officer, Gorakhpur, consisting of various types of *bhat* and *bangar* soils. The analyses disclosed the fact that *bhat* soils are characterized by a high carbonate of lime content and could be classed as marls, whereas the proportion of lime in the *bangar* soils was low and they would be classed as loams. The *bhat* soils had a uniformally low available phosphoric acid (P_2O_5) content, whereas that of the *bangar* soils was about normal, although the total phosphoric acid present in both types was not dissimilar.

The following assistance was rendered to other Sections :—

Mycological Section. Six samples of soil from apple orchard soils and 21 samples from selected plots growing jute were analysed. The loss of copper sulphate during the steeping of jute seeds was determined.

Botanical Section. One " usar " soil was examined.

Agricultural Section. Eighteen samples of manures and 48 of sugarcane and feeding stuffs were analysed and reported upon.

Indigo Research Section. Seventy-three soils were analysed, consisting of samples from indigo soils of Bihar and samples from the experimental indigo plots of the Imperial Agricultural Bacteriologist. Three samples of cement and one of petrol were also examined.

Imperial Cotton Specialist. Fifty-one samples of cotton seeds were examined for their feeding value.

V. Methods of Analysis.

Dyer's method of estimating the available plant food in soils, or one of its many modifications, is adopted by

agricultural chemists throughout the world as a means of evaluating the manurial requirements of soils, and undoubtedly has proved of great value, but whether or not the method can be applied uniformly to all soils is a question which, since its introduction, has exercised the minds of chemists, and in particular a considerable controversy has arisen regarding the values obtained for available phosphoric acid in highly calcareous soils.

A short time ago Mr. Sen published the results of a series of experiments carried out in this laboratory, which showed that the addition of increasing proportions of carbonate of lime to a non-calcareous soil, rich in available phosphate, had the effect of greatly decreasing the values obtained, and that the values obtained when the calcium carbonate content reached about 20 per cent. were of the same order as those obtained from Pusa soils. An increase in the proportion of calcium carbonate over this value did not materially affect the values obtained.

The greatest change in the order of the values obtained occurred at the point where the calcium carbonate content was sufficient to neutralize fully the citric acid of the solvent solution, and Mr. Sen concluded that the effect of the calcium carbonate in giving rise to low available phosphate values was due to the neutralization of the acid. In addition, as the values obtained continued to decrease after the point of neutrality was reached, he concluded that a certain amount of phosphoric acid was "absorbed."

These experiments have been repeated in greater detail, and no evidence has been obtained that absorption occurs to any appreciable extent, but, on the contrary, the values obtained from the various mixtures appear to be determined mainly by the composition of the liquid after its reaction with calcium carbonate. With increasing amounts of calcium carbonate the composition of the liquid gradually changes, and the phases may approximately be defined as follows:—(*a*) 1 per cent. citric acid solution, (*b*) a saturated solution of calcium citrate with decreasing amounts of acidity, (*c*) a saturated solution of calcium citrate and

carbon dioxide, (*d*) a somewhat indefinite phase consisting of saturated solutions of calcium citrate with increasing concentrations of calcium bicarbonate, and (*e*) a final phase of a saturated solution of calcium citrate and calcium bicarbonate. Extractions of the soil in the absence of calcium carbonate with solutions approximating in composition to the phases defined above yielded values commensurate with those obtained from the corresponding mixture of carbonate of lime and soil. *Consequently the application of Dyer's method to calcareous soils is in effect an extraction with a series of dissimilar solutions the composition of which mainly depends upon the calcium carbonate content*, and this being the case, the values obtained in the case of calcareous soils of varying lime content can bear no very definite relationship one with the other and much less with non-calcareous soils. In the case of non-calcareous soils the value of Dyer's method is entirely due to a rigorous correlation of the analytical data with the known manurial reaction of specific soils, but such rigorous correlation is almost entirely lacking in regard to highly calcareous soils. The interpretation to be placed on the values obtained is very indefinite, and so long as this condition obtains the method must remain of dubious value.

Incidentally during the course of this investigation, it was discovered that the presence of calcium carbonate seriously interfered with the estimation of citrate-soluble phosphoric acid by the standard method under standard conditions. This is caused by the phosphate present in the ammonium citrate solution reacting with the calcium carbonate to produce insoluble calcium phosphate.

VI. Soils and Soil Conditions.

(*a*) **Paddy Soils.** The study of the relationship of the gaseous products of decomposition to these soils has been continued, and particularly that of carbon dioxide and hydrogen. It has been shown that carbon dioxide when present alone can persist as such, but that in admixture with hydrogen, and under biological influences, a recom-

bination occurs, of such intensity that the absence of any large quantity of these gases from the atmosphere in paddy soils is accounted for. Incidentally distinct evidence has been obtained to show that marsh gas can be produced by a combination of these two gases under biological influences.

This phenomenon offers a reasonable explanation to account for the accumulation of nitrogen gas in these soils without the necessity of putting forward the theory of the presence of peculiar types of fermentation, and it also has a considerable bearing on the question of lime conservation. The important fact has also been obtained that this reaction between carbon dioxide and hydrogen is not peculiar to paddy soils, but that it can be induced in dry soils with the utmost ease when the conditions are approximately anaerobic in character.

This investigation is practically completed and the results are being prepared for publication.

(*b*) **"Bara" Soils.** At the instance of the late Dr. Barnes, a series of pot-culture experiments were instituted with the object of testing the growth which could be induced in these sterile soils by washing out the salts present with ordinary water. The water used in this instance was the ordinary well water of Pusa with the result that germination was practically entirely inhibited.

The washed soils were, therefore, subjected to a careful examination, and it became evident that the bicarbonate of lime in the water had brought about a reaction leading to the production of alkaline carbonate in the soil. The soil experimented with originally contained a comparatively small amount of alkaline carbonate and a considerable proportion of sulphates and chlorides, whereas, after the washing process, the sulphates and chlorides were reduced in amount but the carbonate content had considerably increased, so that the effect had been to change the original condition of *white alkali* into one of *black alkali.*

The danger of *black alkali* forming in calcareous soils has recently been the subject of investigation in America,

but no attention has hitherto been drawn to the danger of employing a water containing calcium bicarbonate in solution for the irrigation of lands showing *white alkali*, and consequently this question is being subjected to a close investigation.

(*c*) **Mode of action of superphosphate in calcareous soils.** The mode of action of superphosphate in calcareous soils is somewhat obscure, and it appeared desirable to obtain information regarding the combinations formed, the rapidity of their formation, and the consequent effective range of superphosphate applications. With this object in view a preliminary series of experiments have been carried out in relation to the reactions occurring between phosphates of lime and calcium carbonate under varying conditions. It has been found that superphosphate reacts very rapidly at ordinary temperature with calcium carbonate ($CaCO_3$), the product of the reaction being the comparatively insoluble dicalcicphosphate, and that the latter in turn slowly reacts with more $CaCO_3$ forming tricalcicphosphate. At higher temperatures the intermediate stage practically disappears and tricalcicphosphate is formed with great rapidity.

The reaction between solid dicalcicphosphate and calcium carbonate ($CaCO_3$) in the presence of water is very slow owing to the slight solubility of the former, but as dicalcicphosphate is very rapidly removed by $CaCO_3$ from a saturated aqueous solution and also from a saturated solution in 1 per cent. ammonium citrate the probability of its persisting in solution in the presence of calcium carbonate ($CaCO_3$) is very remote.

Applying these facts to calcareous soils it would appear that the range of action of superphosphate is limited owing to the rapid formation of the comparatively insoluble dicalcicphosphate and the formation in turn of the insoluble tricalcicphosphate from any dicalcicphosphate which becomes soluble. The final stage in which the phosphoric acid (P_2O_5) is in the form of tricalcicphosphate would be quickly reached, so that the fertility of these calcareous soils

becomes largely a question of the solubility of this substance in the soil solution. These deductions are of considerable interest, and experiments are being conducted to test their validity.

VII. Crops.

(*a*) **Paddy.** A series of experiments were instituted with the object of determining whether or not the investigations on paddy on which I had been engaged at Coimbatore could be carried on in a satisfactory manner at Pusa. As a result there appears to be no insuperable difficulty to be faced, and consequently work on this crop will constitute in the future one of the major subjects of investigation of this Section.

For this preliminary work the question selected for investigation was whether or not the use of ammoniacal manures could be advantageously combined with green-manuring. For this purpose two series of fifty pots each were laid down, filled with soil to which graduated increments of ammonium sulphate were added, and to half of the pots green leaf manure was added at the rate of 10,000 lb. per acre. Into each series a selected pure strain of paddy seedlings was transplanted, and I am greatly indebted to the kindness of Mr. F. R. Parnell, Government Economic Botanist, Madras, for supplying me with the seed. At the time of writing the crops have not reached maturity and no quantitative results are available, but the growth in the pots is well differentiated and will, in all probability, give rise to definite conclusions. One point, however, is very clear even at this stage. The reaction of the two strains of paddy to green-manuring is very dissimilar and leads to the conclusion that the uncertain reaction of green manures is not entirely associated with soil conditions, but that the strain of paddy employed is a factor to be considered. This is a question which will require close investigation.

(*b*) **Tobacco.** The First Assistant, Mr. J. N. Mukerji, has continued his experiments on the effect of different

manures on the yield, quality, and nicotine content of Indian tobaccos. As regards yield the best results were obtained from farmyard manure, closely followed by a combination of superphosphate and potassium nitrate, whereas neither of the latter manures had any appreciable effect when used alone. The leaf produced from the various plots was submitted to the Director of the Indian Leaf Tobacco Development Company, Dalsing-Sarai, for valuation, and in his opinion no definite relationship was apparent between the manurial treatment given and the quality of leaf produced. Similarly no definite relationship was discovered in regard to the nicotine content.

The relative effect of *topping* and *spiking* the plant was also investigated. The yield of plant was practically identical, but the topped plants gave a greater outturn of stalk than the spiked ones. On the other hand, the topped plants yielded a leaf of better texture and a higher nicotine content.

An investigation contrasting the effect of rack-curing and ground-curing on the composition of the leaf showed that there is a destruction of starch and sugar during the process, but that ground-curing causes a greater reduction of the starch content than does rack-curing and at the same time produces a leaf of higher nicotine content.

(*c*) **Sugarcane.** For several years the effect of storing canes by clamping has been under investigation in the North-West Frontier Province, and the conclusion arrived at was that no deterioration of the juice took place. This has been confirmed during the last cold season, and, in addition, the effect of windrowing cane as practised in Louisiana has been examined.

The analytical values obtained were as follows:—

—	Ashy Mauritius Cane		Local Pounda Cane		
	Before windrowing	After windrowing for four months	Before windrowing	After windrowing for four months	
				Sample 1	Sample 2
Average weight of cane lb.	2·88	2·31	2·39	2·12	2·00
Juice . . per cent	74·86	72·73	75·84	71·70	72·00
Sucrose . . „	9·86	12·01	9·57	13·25	12·41
Glucose . . „	2·08	2·46	2·38	2·74	2·83
Brix . (cor.) „	13·69	16·69	13·34	18·05	17·17
Co-efficient of purity „	72·00	71·96	71·70	73·41	72·27

The effect of windrowing at low temperatures for a period of four months has been very marked. The weight of the individual canes decreases considerably, and this is accompanied by a decrease in the percentage of juice, showing that there has been a drying-up of the canes. This in turn has led to a concentration of the juice, but the purity of the juice tends to increase rather than to decrease, so that windrowing will not lead to the introduction of increased difficulties in the production of sugar.

The question whether or not windrowing leads to a loss of sugar is more difficult of solution, but an attempt was made to determine this by carefully checked weighings of the canes and juice produced. As a result it would appear that there is an actual loss, though comparatively small, in the case of Ashy Mauritius canes, but that in the case of Local Pounda there is a marked increase. This fact is of great importance and requires confirmation before being accepted, but if confirmed it opens out a field for further investigation.

VIII. Programme of Work.

Major subjects.

1. Continuation of the investigations into the amount and nature of drainage water from fallow land and land bearing crops.

2. Pot-culture experiments with paddy to determine (*a*) the relationship between rate of drainage and crop production, (*b*) the direct manurial value of the nitrogen in green manures, (*c*) the value of green manures when used in conjunction with nitrogenous mineral manures other than nitrates, and (*d*) the behaviour of different strains of paddy to green-manuring.

3. An investigation into the conditions governing the formation of *black alkali* in soils irrigated by calcareous waters.

4. Continuation of previous work in connection with the factors governing the composition and quality of tobacco.

5. The study of the effect of windrowing sugarcane at low temperatures.

Minor subjects.

1. A study of the mode of action of phosphatic manures in calcareous soils.

2. Checking the accuracy of the methods of analysis used at Pusa and the examination of new methods of analysis.

IX. List of Publications.

W. A. Davis . . Report on Agricultural Chemistry, 1916-17, for the Board of Scientific Advice.

REPORT OF THE IMPERIAL ECONOMIC BOTANISTS.

(A. Howard, C.I.E., and Gabrielle L. C. Howard, M.A.)

I. Introduction.

The Imperial Economic Botanist held charge of the Section during the year ending June 30th, 1918, with the exception of one month from September 8th, 1917, which was spent on privilege leave in India. During this period the Second Assistant, Maulvi Abdur Rahman Khan, was in charge of current duties at Pusa.

The work of the staff continues to be satisfactory. The Second Assistant, Maulvi Abdur Rahman Khan, has made himself exceedingly useful in carrying out a number of improvements in the Botanical Area and also in the experimental work at Indore, Bhopal and Gwalior. Chowdhury Ram Dhan Singh, Third Assistant, has worked well in connection with the experiments on indigo and on sub-soil aeration at Pusa. The Fourth Assistant, Babu Kashi Ram, has done useful work in connection with the vegetable-drying experiments at Quetta and with the tobacco-breeding experiments at Pusa.

The inadequacy of the facilities available at Pusa for making the most of the results obtained is becoming more evident as the years pass. The area of well-drained, well-aerated, high-lying, light land suitable for the testing and seed production of many of the crops under investigation, is exceedingly small. In consequence, the material available in the shape of pure lines cannot be worked through fast enough and even when this has been done, we have insufficient room to meet the ever-increasing demands for seed. New centres of distribution of Pusa wheats are springing up every year but there is never sufficient botanically pure seed for starting the work. What is urgently required is a special Institute of Plant Industry, situated in a more

favourable locality, to which the work of the present Botanical Section at Pusa can be transferred.

For the first time since the war, the transport of seed from the farms in Bihar has been interrupted due to the railway restrictions now in force. At harvest time, it was only possible to send seed to distant parts of India by passenger train. Such a method is out of the question in the case of hundreds of maunds of seed. Several important indents from Central India, Kathiawar and Bengal for this reason could not be met. The Bengal North-Western Railway, however, were able to provide sufficient transport for the wheat produced and distribution had to be confined to Bihar and the United Provinces. These difficulties were represented to the Central Transport and Foodstuffs Board with the suggestion that facilities should be given to the Agricultural Department generally in the transport of seed of all improved varieties of food grains intended for sowing. This has been accepted and the Directors of Civil Supplies have been instructed to issue priority certificates in class 2 (*b*) for all consignments of improved varieties of seed for sowing purposes booked by or under the order of the Agricultural Department.

II. Investigations at Pusa.

1. Wheat.

Substantial progress has been made during the year in the wheat investigations at Pusa both as regards seed distribution and also in connection with wheat breeding. Two of the early series—Pusa 4 and Pusa 12—are establishing themselves rapidly over large areas of the country as a result of the efforts of the Agricultural Departments. The rate of replacement of the country wheats by these improved types is now a question of organization, of the supply of seed and of adequate funds.

Pusa 12. The United Provinces are a long way ahead in the replacement of the mixed country wheats by an improved grade which also satisfies the cultivator on the important question of yield.

In the Central Circle of this Province, Mr. B. C. Burt has continued the systematic introduction of Pusa 12 on the alluvial soils of the Doab and Oudh portions of his charge. In connection with the special steps taken in conjunction with the Irrigation Department to increase the area under wheat, the bulk of the available seed supply was concentrated mainly in the Districts of Etawah and Cawnpore where the demand for this variety was intense. The total quantity of seed issued during the year from stores controlled by Mr. Burt was 12,290 maunds of which the largest items were Etawah 3,840 maunds, Cawnpore 4,773 maunds and the Sitapur Court of Wards 1,100 maunds. This variety is now well established in these Districts and is spreading rapidly (apart from the efforts of the Department) on account of the increased yield (estimated from crop-cutting experiments to be three to four maunds per acre under ordinary cultivation) and the enhanced price which it fetches. There are now many villages in the Etawah District and some in the Cawnpore District where practically no other wheat is grown and special measures are being taken to maintain these as centres of purity where seed can be purchased (to supplement the supply from the seed farms) and from which this variety will also spread naturally to surrounding villages. In the Sitapur District, most excellent work has been done by the Special Manager of the Court of Wards' estates, Mr. Dunne, in the systematic introduction of this wheat The Katesar estate now possesses its own seed store and last year supplied over a thousand maunds of seed to a group of neighbouring villages. The store worked at a considerable profit and inspection of the crops in the villages showed that they were practically pure. For the current year, this estate has stored 1,363 maunds, material quantities have also been kept by individual cultivators and arrangements are in progress for special demonstration plots and for the maintenance of pure stocks of seed on the areas commanded by three tube wells with which this estate is now equipped. It has unfortunately proved impossible to form even an

approximate estimate of the extent to which this wheat is spreading naturally in the Central Circle apart from direct departmental supplies of seed. Evidence is available that such natural expansion is very considerable but it is impossible to gauge its extent without a special enquiry for which staff is not available. From time to time, examples have been met with of seed being taken very considerable distances by relations of successful growers and of very considerable areas thus arising in tracts that had not been reached by direct demonstration.

In Oudh, Mr. L. C. Sharma continues to make rapid progress in establishing this variety where last year the estimated area under Pusa 12 was one hundred thousand acres. One of the chief agencies employed in seed growing and demonstration are the local notables, the Taluqdars of Oudh, many of whom are maintaining excellent seed farms. In one case, one of these farms supplied last year 2,000 maunds of pure Pusa 12 seed to the Agricultural Department of Bihar and Orissa and 1,100 maunds to the Central Circle. These figures convey some idea of the scale on which these private seed farms are being conducted and the useful purpose they are serving in the agricultural development of the country.

In the Western Circle of the United Provinces, Pusa 12 is now widely grown and has yielded well in the Agra and Meerut Divisions. Although the greater part of the produce is held in reserve in the villages for sowing, the indents received by the Agricultural Department show no signs of diminution. It is estimated that next *rabi* from ten to twelve thousand acres will be sown with seed controlled by the Officiating Deputy Director, Rai Sahib Ganga Pershad. The growers find Pusa 12 to be rust resistant, an early ripener, with a straw strong enough to resist high winds, and a higher yielder than the country wheats. It also requires less irrigation water and, as its grain is large and fine looking, it attracts the buyer immediately it is exposed for sale and so fetches a better price. When stored, it resists weevils better than the softer *deshi*. The fact

that it is beardless and the ears are copper-coloured when ripe enables this variety to be rogued easily and so kept pure by the cultivators.

The substitution of the country wheats by Pusa 12 in the United Provinces, important as this is, is, however, only a part of the advantage that is possible as a result of this work. One of the characteristics of a really superior variety is its power to respond to improved cultivation. The future possibilities of the plains of India in wheat production will be evident from a consideration of the yields obtained on the large scale during the past season with this variety. In Oudh, the average yield of Pusa 12 on large areas at Chandapur in the Rai Bareli District and at Malihabad near Lucknow worked out at 30 maunds per acre. At the Kalianpur seed farm near Cawnpore, which a few years ago was very indifferent village land, an area of over 70 acres gave an average of 27 maunds to the acre. Some of the cultivators' fields in the Etawah District weighed out over 24 maunds to the acre. At the Sugar Experiment Station at Shahjahanpur, the record yield of 35 maunds to the acre over 18 acres was reached. These yields are now the rule in well managed seed farms in this Province and are the result of a proper grading of the land combined with good cultivation and good management.

In Bihar, the introduction of Pusa 12 has made satisfactory progress in the Patna and Bhagalpur Divisions where, however, the work is still hampered by a shortage of seed. The whole of the Pusa 12 grown last year on the Dholi and other estates in North Bihar was placed at the disposal of Mr. Milne for use in South Bihar as well as an additional 2,000 maunds from Oudh. Even with the local supplies, these amounts only satisfied a very small portion of the demand.

In the Punjab, the Director of Agriculture reports that Pusa 12 is exceedingly popular in the Hoshiarpur, Jullundur, Gurdaspur and Sialkot Districts on well lands. The criticism has been made on this wheat that it is being

encouraged in these Districts without sufficient tests having been made as to its suitability for them. Feeling the force of these criticisms, the Director of Agriculture recently made a tour through these Districts and was struck by the great and unanimous enthusiasm evinced for Pusa 12 by all the growers of it. They all assured him that they got at least 25 per cent. increased outturn from it and a premium of at least 2 annas per maund. One grower sold 500 maunds of it to a Lahore contractor, who required it for eating purposes in that city, at a premium of 4 annas per maund over ordinary wheat. A certain amount of this wheat is also being grown in the Ferozepore, Karnal, Hissar and Rohtak Districts. Everywhere it is exceedingly popular and increasing amounts are being stored for next season by growers.

In Sind, Mr. Main has commenced the trial of Pusa 12 in various parts of the Province and the work is being continued. Some promising results were obtained in the Upper Sind Frontier District on zamindars' fields and the conclusion in this tract is that Pusa 12 is an early ripener and a heavy yielder. The zamindars concerned have kept the whole of the produce for sowing next season.

In the Simla Hill tracts, Mr. Peake has successfully introduced Pusa 12 in three villages in Sirmoor where this variety has done well. The people are very much taken with the grain and a number of villages have undertaken to grow nothing but Pusa 12 next year. The Chief Secretary of the Sirmoor State, Sirdar Narain Singh, who has interested himself in this work, has introduced a book to record the quantity of Pusa 12 sown each year together with the acreage. Distribution of seed will be carried out village by village so as to prevent admixture.

Pusa 4. In many parts of India where a rapidly maturing, high quality wheat is required which will also respond to good cultivation, Pusa 4 is meeting a distinct want and is rapidly coming into favour.

In North Bihar, the fall in the price of indigo led last year to a great demand for seed of this variety from the

indigo planters a portion only of which could be met. Nearly all the last crop of seed produced on the Dholi estate, an exceptionally fine product, was used for setting up a number of these estates with a pure supply of seed.

In the United Provinces, Mr. Burt reports that this variety has been a most marked success in the Ken and Dhasan Canal areas in the Districts of Banda and Hamirpur. Last year, over five thousand maunds of Pusa 4 were issued and in addition a number of zamindars and cultivators sowed considerable areas from their own seed. A large proportion of the seed was distributed through the Canal Department. At the last harvest, this variety fetched a very substantial premium in the local markets often amounting to eight to ten annas a maund over country wheat, the keenest buyers being exporters to Bombay. For the coming year, a stock of 8,000 maunds of this wheat is being held for issue in Bundelkhand. This variety is also likely to prove useful on the alluvium in helping to solve the fodder problem. For the third year in succession at Kalianpur, excellent crops of Pusa 4 have been obtained after early fodder *juar* (*A. Sorghum*). The practice, if generally adopted, would go far to solve the fodder difficulty in canal irrigated tracts and would permit of a larger area being put under wheat.

In the Central India States, the results obtained with Pusa 4 led to a keen demand for seed but nothing could be done to assist matters due to the railway restrictions in force. A supply was arranged for the Gwalior State but transport could not be obtained.

In the North-West Frontier Province, the result of the trials of this variety by the ryots is that " Pusa 4 has gained the cultivators' favour and has been accepted by them, and it is confidently expected that the vareity will occupy the greater part of the 280,000 acres of irrigated wheat in the North-West Frontier Province within a very few years. Pusa 4 has been so well received by the people that the North-West Frontier Province Government have allotted a sum of Rs. 25,000 to purchase seed from those

growers who tested the variety last season and a further sum of Rs. 25,000 has been set aside to build grain stores at some of the Tehsils in the Province, primarily to store seed of Pusa 4 for sale to the cultivators."

At the Sydney Royal Agricultural Show of 1917, Pusa 4 and two other varieties (Pusa 107 and Pusa 110), grown by Mr. J. B. Roach at Gilgandra in New South Wales, gained 44 out of 45 points and were awarded the first prize in one of the classes. At the Food Products Exhibition at Calcutta in January of this year, an exhibit of Pusa 4 and Pusa 12 and of bread made from Pusa 4, grown in Bundelkhand, gained a special prize. This exhibit was arranged in collaboration with Mr. Burt, all the wheat exhibited being grown on the farms of the Central Circle. The samples were particularly well grown and attracted much attention. The bread was baked by the Great Eastern Hotel Company from flour prepared by Messrs. Shaw Wallace & Co. at the Hooghly Flour Mills.

Punjab 11. In addition to the wheats selected at Pusa, one of the types, Punjab 11, separated by us at Lyallpur from a local mixture in 1906 and handed over to the Punjab Agricultural Department in 1908, is being distributed in the Canal Colonies of the Punjab, the area last year amounting to no less than 100,000 acres. This type will in all probability be rapidly displaced by Pusa 12 when the zamindars in the Chenab Colony cease to overwater their wheat. At Mirpurkhas in Sind, Pusa 12 has given as much as 25 maunds to the acre on the preliminary irrigation only, a result which confirms the common experience with this wheat in the United Provinces that it does best if somewhat sparingly watered.

Wheat breeding. The work on wheat breeding at Pusa, referred to in previous reports, is now rapidly approaching the stage when variety trials can be carried out on a field scale. Two of the selections (Pusa 32 and Pusa 42) from a cross made at Cambridge in 1910 between Pusa 4 and one of the new English wheats were tried last year by Mr. Burt at Kalianpur to see how these wheats would behave under

canal irrigation. The new types were tried against Cawnpore 13 and Pusa 12 on large plots and the sowings were made in duplicate. The yields obtained were as follows :—

TABLE I.

Trials of new Pusa wheats at Kalianpur.

Variety	Yields in lb. per acre		Remarks
	Grain	Straw	
Cawnpore 13	2,180	4,628	
Pusa 32	2,010	3,700	
Pusa 12	2,578	4,486	
Pusa 42	2,390	4,250	
Cawnpore 13	2,130	4,552	
Pusa 32	1,880	3,922	
Pusa 12	2,204	4,070	Damaged by lodging and by rats.
Pusa 42	2,320	4,538	

Nos. 32 and 42 have since been discarded as this cross has yielded six more wheats which are much more promising. These will be tried on a field scale at Kalianpur in October next. Three other series of crosses—on Pusa 6—are now rapidly becoming fixed and this material is expected both to yield wheats of immediate utility as well as parents for further crosses. To obtain the full advantage of the breeding work in progress at Pusa and to bring it to a practical issue several years' work will still be needed.

The results to India of the Pusa work on wheat were referred to in the House of Commons on August 14th, 1917, by Lord Henry Cavendish Bentinck (*Parliamentary Debates*, vol. 97, no. 116, p. 1008) when advocating that more money should be spent on research in agricultural development. It was pointed out that research is the basis of all progress in agriculture whether at home, in India or

in Africa, and that the money value of a single successful introduction like Pusa 12 is out of all proportion to the cost of a Research Institute.

2. Indigo.

The investigations on this crop, referred to in previous reports, have been continued during the year and have been confined largely to Java indigo. As this crop, when grown for leaf, is in the ground for nearly a year, it must be remembered that it differs entirely from the ordinary cold weather and monsoon crops as it has to maintain itself under a very wide range as regards soil conditions. Sown in September or early October, the first portion of the growth period takes place under cold weather conditions. The crop then has to survive the hot season when dry west winds are to be expected after which the temperature of the surface soil rapidly rises. The plant then completes its first year's growth in the monsoon phase, during the latter portion of which the aeration of the soil is interfered with by the cessation of drainage due either to the rise of the rivers, the flooding of the country, the rise in the subsoil water level or to a combination of these causes. In interpreting the results obtained with this crop, therefore, it will always be necessary to bear in mind these facts. It is generally in the second half of the monsoon and after the first cut has been taken that growth slows down and the plant often becomes diseased.

Much time has been spent in the investigation of the root system of this crop and the effect thereon of any alteration in the soil conditions and also of cutting back to varying degrees. The roots of Java indigo are exceedingly sensitive to undecayed organic matter such as oil cake, fresh *san* hemp (*Crotalaria juncea*) weeds or partially decayed indigo, particularly when these substances are added to the soil at times when the aeration is poor. It is then possible to kill the crop outright by these means. When, however, the damage does not proceed so far, the root system is often profoundly affected, the total absorbing

surface is reduced and the young roots and nodules lose their freshness and become discoloured and unhealthy. The above-ground portion ceases to grow normally and the young branches are frequently attacked by *Psylla*. Similar results have been obtained in the August sown seed crop when the indigo has been sown in land foul with weeds which have been turned under a few weeks previous to sowing.

The effect of complete or partial cutting back on the root system of rapidly-growing Java indigo has yielded some interesting results. In the cultivation of indigo in Bihar it is the universal practice to cut the indigo back completely in June and to leave the stumps for a second crop. The time taken in forming new shoots varies with the season. In very wet weather, sprouting is delayed and the process is distinctly favoured by a break in the rains. It has frequently been observed at Pusa that if a few leaves are left at the first cut, the new growth is much more rapid. This year, the effect of complete cutting back and of hard pruning on the root system was examined. It was found that complete cutting back, while the plant is in active growth, kills the fine roots and nodules and that a new absorbing system has to be produced before new shoots form. This naturally takes time. Heavy pruning, on the other hand, leads to far less damage to the roots and nodules, which at once explains the rapidity with which such plants form new growth. This fact may easily prove of considerable practical advantage to the indigo industry. If the crop could be grown in double lines with interculture, it could be heavily pruned at the first cut and the second crop could be advanced by several weeks. A new system of growing Java indigo, based on these results, has been worked out at Pusa. The crop is sown in September (after a clean fallow) in double lines with a space between for mechanical interculture to keep down weeds and to aerate the soil. The lines are pruned as early as possible after the rains break and the second cut is taken as soon as possible afterwards. Whether it will be better to be

content with this second cut and then dig out the stumps or to prune a second time and try to obtain a third and final cut, is a matter which further experience will decide. The results already obtained show that under actual field conditions in the monsoon the pruned plant, grown in double lines, shoots much faster and much better than the completely cut back plant. Further, it is possible in this way to keep the land clean by bullock cultivation during the *rabi* season and the following hot weather and to reduce the labour spent in weeding. As is well known, one of the great drawbacks at the present time of Java indigo cultivation in Bihar is the difficulty and expense of keeping down weeds.

The effect on the growth of Java indigo of an alteration in the soil conditions by the addition thereto of inert aerating agents such as sand or broken bricks and tiles, was investigated by means of the modified system of pot culture described in a paper read at the Indian Science Congress at Lahore.[1] As an example of the kind of results obtained by this method, the following measurements in the case of Java indigo may be cited:—

TABLE II.

The effect on the growth of Java indigo of diluting Pusa soil with potsherds or sand.

Kind of soil	No. of plants measured	Average length in cm.	Percentage increase
Soil only	33	36·7	0
Soil 1/2 + sand 1/2	36	51·6	40
Soil 9/10 + potsherds 1/10 . . .	33	48·3	31
Soil 7/10 + potsherds 3/10 . . .	35	50·9	38

The results obtained by diluting Pusa soil have been strikingly confirmed during the year by Mr. Clouston who

[1] *The Agricultural Journal of India*, Special Indian Science Congress Number, 1918, p. 36.

grew the same type of Java indigo under similar climatic conditions at two centres—on the stiff black soils at Tharsa and on the open, porous *bhata* soils at Chandkhuri near Raipur. On the well-aerated, poor *bhata* soils, Java indigo grew with great rapidity and formed good and abundant seed. On the richer but badly aerated black soils at Tharsa, the growth was very poor. These results are illustrated in a paper by Messrs. Clouston and Padmanabha Aiyer read at the Lahore meeting of the Indian Science Congress. A more effective confirmation of our views on the effect of soil aeration and drainage on the growth of Java indigo could hardly be desired. All interested in the welfare of the Bihar indigo industry should carefully study Messrs. Clouston and Aiyer's paper which is published in the Special Indian Science Congress Number of the *Agricultural Journal of India* of 1918. It will be interesting to see what class of colour will be obtained on these *bhata* soils when the Chandkhuri crop is made into indigo.

The results obtained on the production of seed of Java indigo under Bihar conditions were applied on a large scale during the year and very fine samples were obtained, much better than anything imported from Java. The yield was affected by shortage of moisture at the end of the rains and also by the dry winds during the ripening period in February which led to a good deal of loss from the splitting of the pods. For the first time since the shortage of seed of this crop became acute, the supply has been such that the price per maund has fallen very considerably, a result which will probably reduce the quantity of seed grown outside Bihar. The Pusa experiments have proved that good crops of seed can be obtained in Bihar provided the land is well selected and sufficient care is taken in the manuring, cultivation and spacing of the plants. The best returns are obtained under conditions of garden rather than of field cultivation, and it might easily pay some of the estates to devote very special attention to the seed crop on a small area and also to keep in reserve a year's supply in case of floods or unfavourable seasons. The experiments

on this subject are being continued as it is expected to raise, under conditions of intensive culture, heavy yields of seed no matter what the season may be. There is little doubt that the sooner North Bihar becomes self-supporting as regards Java seed the better. As the crop is not uniform but consists of a mass of heterozygotes, differing widely in root development, it is not safe to rely on seed produced under quite different soil conditions. The result of growing seed outside Bihar might easily result in a gradual change of type which might prove quite unsuitable to the local soil conditions.

The work on the selection of Java indigo is proceeding as rapidly as circumstances permit. One of the early selections, Type 15, is being grown on the large scale on four estates. A number of others are being tested on a field scale and reserves of seed are being accumulated. Java indigo is practically self-sterile and almost all the seed is obtained by means of cross-fertilization following insect visits. These facts render selection work very difficult and the multiplication of promising types very slow as only one kind can be grown for seed each year in the Botanical Area. This difficulty has been met to some extent by facilities granted by the proprietors and manager of the Dholi estate. A small field has been lent in one of the villages of this estate for indigo seed purposes and at the present time two types can be multiplied each year.

3. Tobacco.

The demand for seed of Type 28, both for cigarette purposes and also for general cultivation, continues to increase. In addition to a large number of small indents from all parts of India, three definite schemes of seed distribution have now developed—in North Bihar, in Burma and in the Central Circle of the United Provinces. Seed sufficient for 4,000 acres of new cultivation was distributed during the year. It is impossible to say how much locally grown seed of this type was sown.

In the Tirhut Division of North Bihar, the distribution of seed has been undertaken by the Indian Leaf

Tobacco Development Company who give out the seed to any one who applies for it. There is no obligation on the part of any ryot taking this seed to sell the produce to the Company. Mr. Acree, the Manager of the Dalsing-Sarai Branch, reports (Letter, dated April 13th, 1918) that the advantages obtained by the growers of Pusa seed can be summed up as follows :—

(*a*) Nearly all the seeds germinate.

(*b*) When transplanted, the tobacco plants are nearly all the same size and are equally strong. In consequence, very little replacement is necessary in the fields and partly for this reason a larger yield per *bigha* is obtained.

(*c*) At harvest time, the whole field is ripe and ready to cut at once. As a rule, when the ryot uses his own seed, several varieties are found in each field which come to maturity at different times and so cause the harvesting period to extend over four to six weeks. When this tobacco is ready for sale, the ryot has three or four sorts to dispose of instead of one uniform lot.

(*d*) Type 28 has not only been found very good for cigarette purposes but the growers also find no difficulty in disposing of it to the Indian dealers.

These results are interesting as showing that even the conservative tobacco grower, if given time, is able to appreciate the advantages of growing a pure line (which combines yield and quality) in place of the ordinary mixed crop. At first, the Company had some difficulty in getting the work started and the growers were averse to trying the new kind. Now all this is changed and should the demand go on increasing at the present rate, the difficulty will be to provide sufficient seed.

In Burma, seed for 800 acres has been supplied to Mr. McKerral for distribution in two of the most important tobacco-growing Districts.

In the United Provinces, Mr. B. C. Burt is distributing Type 28 among the tobacco growers of the Farrukhabad District where it is doing well.

As the production of large quantities of seed, true to type, of any variety of tobacco at an experiment station at which plant breeding work is also in progress, is a difficult and expensive matter, it would help materially if all future indents for seed could be sent in each year before the end of November. Small quantities of seed of Type 28 will always be available but special arrangements will have to be made if the demand for seed increases

4. Fibres.

The isolation of the numerous unit species which make up the gametic constitution of the four varieties of *Hibiscus Sabdariffa*, described in the Botanical Series of the *Memoirs of the Department of Agriculture in India* (vol. IV, no. 2), was continued during the year. When this is complete, it will be possible to finish the work and to put forward a full explanation of the results hitherto obtained.

Favourable reports continue to be received of the behaviour of the improved type of *patwa* (*Hibiscus cannabinus*) known as Type 3. Only a very small portion of the seed required could be supplied and none of the samples of fibre asked for could be prepared. About two acres of this type are being grown for seed during the present year for starting seed distribution centres in South Bihar and in Orissa. The seed likely to be obtained will not suffice for purposes of seed distribution in these areas but it is hoped thereby to stock a few farms at which this type can be multiplied for local seed distribution. Unfortunately, no suitable high land could be spared for fibre purposes. Only a few of the highest and lightest plots of the Botanical Area at Pusa are suitable for growing *patwa* to advantage and as similar conditions are required for a number of other crops under investigation, progress must

continue to be very slow in establishing the fibre of this improved variety as an article of commerce.

5. Oil seeds and gram.

The work on these crops at Pusa, referred to in previous reports, was almost at a standstill during the year due to the lack of suitable land for the culture work. The linseed cultures had to be grown on two new plots in the old fruit area which proved to be too uneven for such purposes. These cultures will be repeated if possible during the coming year.

6. Root development.

In a paper read before the Botanical Section of the Indian Science Congress at Bangalore in 1917, an account was given of the results obtained in the study of the root systems of the varieties of agricultural crops. It was suggested that this aspect of variety trials has been neglected in the past and that a study of the root systems of a set of types throws a considerable amount of light on the results of field experiments. During the past year, the work has been continued and further results have been obtained.

One of the difficulties in these investigations is to remove the soil so as to lay bare the distribution of the entire root system, including the finer branches. In the case of leguminous crops, it is also necessary to expose the nodules without damage. The best method so far found for use in fine, silt-like, alluvial soils, like those at Pusa, is to remove the soil by means of a knapsack sprayer. By this means, two plants can be dealt with in an ordinary working day and all the fine ramifications down to the piliferous layer and the root cap can be traced without damage. With leguminous plants, great care is necessary if all the nodules are to be obtained attached to the roots.

In soil aeration experiments, where it is necessary to study root development in relation to the physical condition of the soil, some method of growing a large number of

separate cultures has to be devised. Ordinary field plots are out of the question, due to the permanent alteration in the physical texture of the soil that would be involved. The ordinary pots used for culture work are also unsuitable for such investigations, for the following reasons :—

(*a*) There is inadequate space for root development, unless the pots are very large and deep.

(*b*) The normal circulation of air and water, such as occurs in the soil, is impossible in a culture pot even when unglazed and even when a sunk pot is used.

(*c*) Artificial drainage has to be provided in pots, which in itself acts as an aerating agent.

(*d*) Culture pots frequently introduce the temperature factor.

(*e*) Such cultures have to be constantly watered, an operation consumptive of much time.

(*f*) It is almost impossible to explore in detail the root system of a plant grown in a culture pot.

These difficulties can be overcome by using very small plots in the place of culture pots. Pits from three to six feet square are dug to the depth of two and a half feet, the upper nine inches of soil being kept separate from the sub-soil. Various aerating agents are mixed with the soil, which is then replaced, care being taken to refill the pits a little at a time and to compress the earth to the required degree. If prepared a few weeks in advance and irrigated immediately, the contents of the plots resemble very nearly the conditions obtaining in field culture. The difficulties connected with the circulation of air and water are in this way removed and the temperature factor does not interfere with the results. In cases where the soil is mixed with large quantities of aerating agents, such as potsherds, broken bricks, sand, or powdered charcoal, it is advisable to spread from half to an inch of ordinary soil on the surface of the beds to prevent any undue heating or cooling due to the higher conductivity of the aerating materials. Control plots of undisturbed soil and also of soil which has

been dug out and then re-filled should be included in the series. Where both root development and yield of seed have to be determined, the plots should be in duplicate as the removal of specimens for root examination introduces a new aeration factor.

The differences in growth and root development obtained by this modified form of pot culture are very striking and the new method has yielded results of considerable interest both at Pusa and also at Quetta. Measurements of the length of growth, of the total weight of crop and of the seed can rapidly be obtained while very useful results as regards the conditions on which root development depends have been secured.

III. Investigations in the Native States.

1. Central India States.

A beginning has been made in extending the investigations started at Pusa to some of the Native States. At the request of Mr. B. Coventry, C.I.E., Agricultural Adviser in Central India, and with the concurrence of the Durbars concerned, variety trials with wheat and gram were carried out on three of the farms in Central India during the past *rabi* season. Results of considerable value were obtained and the trials are being continued and extended.

The soils of Central India are by no means uniform and the conditions, even on a black soil tract like the Malwa plateau, vary considerably. On the well-irrigated, garden lands of Malwa, on which till recently opium poppy was grown, it has been found that Pusa 4 does exceedingly well and produces heavy crops under well irrigation. Mr. Coventry reports on these trials as follows (Letter dated April 13th, 1918) :—

"Pusa 4 has again been a great success this year on the irrigated area. Dhar, for example, has got 25 maunds per acre, a record result for Central India. I have therefore very strongly urged the Durbars to take up the distribution of this wheat on as large a scale as possible.

"I should like to add that when I came to Central India I was told by every one that the cultivators had been brought to the verge of ruin by the cessation of poppy cultivation and that what was wanted was a crop to replace opium. A good yield of opium is 9 seers an acre, which at Rs. 7 gives Rs. 63. Pusa 4 with a yield of only 15 maunds at Rs. 5 gives Rs. 75. The cost of production of wheat too is lower than poppy, the former taking three waterings at most, while the latter takes seven. The cultivators too declare that this wheat pays them better than poppy and they prefer it."

On the old poppy lands, Pusa 4 has passed the experimental stage and seed distribution is now in progress under Mr. Coventry's direction.

On the *barani* wheat areas of the plateau, however, Pusa 4 and similar types while producing good samples of grain have not shown any superiority over the local macaroni wheats. The contrast between the manner of growth of Pusa 4 on irrigated and on dry land was so great that it seemed certain that some other factor besides moisture was operative. On irrigated well lands, Pusa 4 tillers well, throws up tall, strong straw with long ears and large fine grain even better than that obtained on the Gangetic alluvium. The crop seems entirely at home and there is no trace of rust. On the dry areas, however, even after late rains and with abundant sub-soil moisture the ears are small, the straw weak and the crop easily lodges. The variety is hardly recognizable when grown under these conditions. These differences were found to be of a botanical nature and to be associated with root development. On the poppy lands under irrigation, the secondary roots develop well and the crop maintains itself largely on this system. Under *barani* conditions, practically no secondary roots are produced and the plant has to do its best on the primary system. Macaroni wheats when grown on the *barani* areas behave in the same way and rarely produce secondary roots, but here the first root system as well as the first internode are much more strongly developed

than those of bread wheats like Pusa 4. This difference is fundamental and it is clear that for the dry area of the Malwa plateau improved macaroni wheats are required. On the other hand, when these macaroni wheats are irrigated they do not respond to the changed conditions as Pusa 4 does and the extra moisture is as it were largely thrown away on these types.

These differences in root development indicate not only the general policy to be followed in wheat improvement on the Malwa plateau but also throw light on the methods of irrigation to be adopted for wheat. As regards the policy for these areas, high quality, rapidly maturing bread wheats which respond to irrigation and to improved soil conditions are clearly required for the well-irrigated lands. Improved macaroni types are needed for the *barani* tracts. With regard to irrigation, the first watering on all well lands should be given just when the plant is ready to tiller so that the formation of the secondary root system is not delayed too long. The secondary roots must follow the descending moisture and when these are established growth will proceed rapidly and the crop will be assured. Fortunately with well irrigation, the timing of the first irrigation is a simple matter.

Where the soils of the Central Indian States, as in parts of Gwalior, resemble the alluvium of the plains, it was found that wheats like Pusa 12 and Pusa 4 are quite suitable given a supply of irrigation water.

As would be expected from the root system, the Pusa varieties of gram, when tried on the various soils of Central India, provided no surprises. Many of the types did exceedingly well and it is expected in a short time to decide which is the best in all respects and to begin seed distribution.

Although these Central Indian trials have only extended over a single season and the work has had to be carried out either on new farms or on farms in the making, the results are much greater than could have been expected and the experience gained has been well worth the time and

trouble involved. For facilitating the trials at Indore and Bhopal we are indebted to Mr. Coventry, while at Gwalior, Mr. Higginbottom, the Director of Agriculture, and his staff placed the resources of the new farm at our disposal.

2. Kapurthala State.

At the request of His Highness the Maharajah, a visit was paid to the Kapurthala State in the Punjab with the object of suggesting the best means of developing the agricultural resources of the State. The main territories of this State comprise three well defined areas—the sandy high-lying areas (*dona*) near the town of Kapurthala, the low-lying inundated areas (*bet*) near the river Beas and the *iláqua* of Phagwara (a portion of which is still in the original *dhak* forest) the agricultural conditions of which are similar to those of the adjoining Jullundur District. The Kapurthala State is the Eastern Punjab in miniature and the problems presented for solution apply in large measure to extensive areas of territory directly under British administration. The *dona* areas, given organic manure and water, can be made exceedingly fertile and here up-to-date large tube wells, provided with cheaply constructed permanent distributaries to prevent percolation, are a possible means of agricultural development. The low-lying *bet* lands present an interesting problem in drainage as well as for the distribution of varieties with a somewhat superficial root development. In Phagwara, the *dhak* areas provide an almost ideal surface for demonstrating the advantages of the realignment of holdings, the establishment of model villages and the provision of a complete system of surface drainage which at the same time will prevent erosion. A detailed report on these matters was submitted to His Highness who has decided, not only to start an Agricultural Department as soon as a suitable Director can be found, but to institute a State Development Fund for the smooth and rapid execution of any projects which are likely to improve his dominions.

IV. The Development of the Agriculture of Baluchistan.

The increase in the agricultural work carried out at the Fruit Experiment Station, Quetta, referred to in the last report continues. All the land available has now been taken up and no further expansion is possible with the means at present available. The extension of the vegetable-drying experiments has been rendered possible by means of a special grant of Rs. 1,500 from the Baluchistan Administration.

1. Soil aeration.

The decision of the Baluchistan Administration in 1911 to start a small experimental station near Quetta for the study of local questions has, in one direction, suggested far-reaching developments in Indian agriculture. In the Quetta valley, the texture of the soil is such that after surface flooding, ventilation is very easily impeded with disastrous results to the crops. The investigation of this matter led to the recognition of the importance of soil aeration as a factor in crop production and to the working out of an improved system of irrigation which, if adopted generally in India, would bring in every year an additional revenue of at least £5,000,000—enough to pay the interest on the war loan. Now that the investigation of the various aspects of soil aeration has reached a stage when the results can be summed up with advantage and their practical applications to Indian agriculture have become clear and definite, the present is a convenient opportunity for bringing together the various sides of this question and for emphasizing their importance in the future development of the country.

During the years 1912 to 1914, a number of observations and results had accumulated at Quetta which appeared to be most easily explained on the assumption that the stiff loess soils of the valley suffered from want of aeration and that in the removal of this factor lay the best line of advance. A similar explanation seemed to underlie numerous other

results and observations made in the plains of India and elsewhere. The available evidence in favour of this view was collected in 1914 and published in Pusa Bulletin 52 (*Soil ventilation*) in 1915. After this, further results rapidly accumulated which were dealt with in 1916 in Pusa Bulletin 61 (*Soil aeration in agriculture*). These two papers were very favourably reviewed in a large number of journals all over the world and many letters were received from correspondents dealing with the obvious explanation by the soil aeration factor of results hitherto obscure or but little understood. The publication of these views was the means of setting in motion a great deal of experimental work both in India and other countries. The connection between surface drainage, soil aeration and crop production and the increase in yield which follows the slightest improvement in surface drainage were dealt with in 1915 in Pusa Bulletin 53 (*Soil erosion and surface drainage*). Recently, more information has been obtained on this question which will be published when a convenient opportunity occurs.

During the past year, careful experiments have been conducted both at Pusa and at Quetta on the effect on the yield of the addition of inert materials such as potsherds and sand. In all cases, increased yields have been obtained both in the case of cereals and of leguminous crops. Some of the Pusa results are given in Table III.

TABLE III.

The effect of diluting Pusa soil with potsherds or sand.

1. Wheat, oats and tobacco.

Crop	Yield per acre of control plot	Yield per acre with one inch of pot-sherds	Increase per acre	Percentage increase
	m. s.	m. s.	m. s.	
Oats	24 17	28 36	4 19	18
Wheat	16 18	19 30	3 12	20
Tobacco . . .	21 0	23 3	2 3	10

2. Indigo.

Kind of soil	No. of plants measured	Average length in cm.	Percentage increase
Soil only	33	36·7	0
50% soil + 50% sand . . .	36	51·6	40
90% „ + 10% potsherds . . .	33	48·3	31
70% „ + 30% „ . . .	35	50·9	38

Similar results have been obtained on the large scale on the Dholi estate in Bihar where in 1918 the best yield of Pusa 12 was given by the plot to which one inch of broken tiles had been added to the soil. At Quetta, the crop experimented on was lucerne. The increase due to the use of the various aerating materials is given in Table IV.

TABLE IV.

The effect of diluting Quetta soil with inert aerating materials.

Kind of soil	No. of plants	Yield of fresh produce	Percentage increase
		lb. oz.	
Soil only	33	12 2	0
2/3 soil + 1/3 potsherds . . .	33	15 0	24
1/2 soil + 1/2 wind-blown sand . .	33	17 2	42

That such results are possible can only be explained in one way, namely, that the aeration of both soils is defective. The increased yield is due to the increase in oxidation which follows the improvement in the porosity of the soil.

The existence of the soil aeration factor furnishes the explanation of the low yields of poor quality which always follow over irrigation on silt-like soils. The texture of these soils deteriorates after being flooded with water. As

the soil dries under the hot sun, the surface bakes into a hard crust largely impermeable to air. That the crust is impermeable can be seen by immersing in water a portion of the hardened surface soil after irrigation. The air escapes sideways not through the surface skin. Each successive irrigation destroys the soil texture more and more and the surface crust becomes more and more impermeable to air. The effect of irrigation on alluvial soils, therefore, interferes with its ventilation. The process removes one limiting factor, the want of water, but it introduces another, namely, the need of aeration. That this is so will be clear from Table V which contains the result of a recent experiment at Quetta.

TABLE V.

The introduction of a new limiting factor after irrigation.

Number of waterings	Area in acres	Total weight of produce	Total weight of grain	Yield grain per acre	Percentage reduction
		lb.	m. s.	m. s.	
One	3·99	10,367	52 6	13 2	0
Three	2·65	6,620	25 15	9 23	26

Here the last two irrigations reduced the yield through the introduction of another limiting factor—the need of soil aeration. Similar results[1] were obtained at three stations in the Punjab in 1917. One irrigation gave nearly ten maunds of wheat to the acre, two gave a little over sixteen, while three reduced the yield appreciably. These results prove that successful irrigation involves the working out of a practical compromise between the two conflicting factors —water and air. The aim of the irrigator is not the mere application of water *but the provision of water in such a*

[1] A full account of the irrigation results obtained at Quetta and elsewhere will be found in *Quetta Bulletins* 4 and 7 and in a paper on soil aeration in the *Indian Forester* of May, 1918.

manner as to interfere as little as possible with the aeration of the soil.

Confirmatory evidence of the importance of soil aeration in agriculture has been abundant in the recent literature. Experiments are in progress on this subject in India and other countries and a large number of further papers are expected to appear during the next two or three years. The opportunity was taken of the 1918 meeting of the Indian Science Congress at Lahore to place on record a statement of the present position of the investigations on soil aeration. This was done in the form of a joint lecture (with Mr. R. S. Hole,[1] Forest Botanist at Dehra Dun) to the whole Congress on January 9th last immediately after the presidential address. Mr. R. G. Allan, Principal of the Nagpur Agricultural College, supplemented the lecture by an account of his results on sub-soil aeration on the black soils. The lecture has since been published in full in the May issue of the *Indian Forester* and in the July issue of the *Agricultural Journal of India*. In the Botanical Section of the Science Congress, other papers on soil aeration were read and discussed including one by Mr. Clouston, Officiating Director of Agriculture of the Central Provinces, and Mr. A. R. Padmanabha Aiyer, Officiating Agricultural Chemist, Central Provinces, on the results obtained on the poor laterite soils (*bhata*) at Chandkhuri near Raipur. Hitherto, these soils (of which there are millions of acres now lying practically waste or in jungle) have only borne occasional crops of inferior millets in the rains and have been considered useless for agricultural purposes. In reality, however, they possess in their porosity and good drainage, enormous potentialities which Mr. Clouston is now developing. The aeration of the *bhata* soils is perfect and with the addition of organic manure and irrigation water very fine crops of cotton, indigo, groundnuts, sugarcane and various fodders have been obtained. One feature of these crops is

[1] Mr. Hole's investigations on soil aeration deal with the importance of this factor in various forestry and ecological problems. His conclusions have been arrived at largely from physiological experiments and agree with our own on the importance of the soil aeration factor in plant growth.

their remarkable freedom from disease compared with those grown under similar conditions on the richer but poorly aerated black soils. Messrs. Clouston and Aiyer concluded their paper as follows :—

" We venture to say here that Mr. and Mrs. Howard of Pusa and Mr. Hole of Dehra Dun have done India a great service in focussing our attention on the importance of drainage and soil aeration as soil factors which count for even more in crop-production than manuring. The time may yet come when, with the extension of irrigation facilities, these laterite soils, which in the Central Provinces at least are at present considered to be below the margin of cultivation in most cases, will be treated as garden land of the best quality. Given water, all that is required for such soils is cultivation and manure. We can rely on the nitrifying organisms to do the rest."

2. The improvement of fodder production.

Progress continues to be made at Quetta in the study of the various factors involved in the growth of leguminous crops and also in the better preparation and utilization of the resulting fodder.

One of the factors concerned in the raising of these crops has been proved to be the aeration of the soil. That such a result was probable could be inferred from the following facts :—

(*a*) In both *shaftal* (*Trifolium resupinatum*) and lucerne cultivation, the edge effect is pronounced and the crop is always better on the small embankments separating the irrigation compartments (*kiari*) than in the *kiari* itself.

(*b*) In order to maintain a good stand of lucerne under Quetta conditions it is necessary to manure the land every winter with farmyard manure applied on the surface.

(*c*) The best crops of lucerne are obtained by leaving the mulch of manure undisturbed during the growth period as by this means the surface soil

remains open and a crust cannot form. Surface cultivation by mixing the mulch of manure with the soil allows a crust to form after irrigation and the yield is considerably reduced.

(*d*) The number of cuts obtained from a *shaftal* crop, other things being equal, depends on the presence of aerating materials in the soil.

The importance of soil aeration in the growing of these crops was confirmed during the year by the results of a series of aeration experiments with lucerne and *shaftal*. The origin of these experiments is a matter of some interest. In 1917, during a visit to the Mustung valley in the Kalat State, the great difference between the health and vigour of the wheat and other crops near Mustung compared with those in the Quetta valley was very marked. The difference appeared to be due to the admixture of the Mustung soil with fine wind-blown sand carried into the valley from the desert to the west. Samples of this wind-blown sand were obtained and cultures were started of mixtures of Quetta soil and various aerating agents including this desert sand. The results obtained were very striking. An admixture of 50 per cent. of the wind-blown sand to Quetta soil increased the yield of lucerne by 42 per cent. These experiments are being continued and will be published in due course. The improvement in the physical texture of the soil of the Mustung valley brought about by this wind-blown sand would also explain the reputation for quality this locality has achieved in such crops as wheat, tobacco and melons. The admixture with sand improves the aeration of the soil and this in turn influences the development of quality. One possible means of improving the Quetta soil would be by the admixture of finely ground ashes which are available in large quantities near the railway station. Some of this waste product is being ground up in a mortar mill and will be applied to the land this year. For vegetables and crops like lucerne, ground ashes might act as a very useful manure.

The trials of baled *shaftal* by the Army at Quetta, which were referred to in the last report, were duly completed and

the results were reported to Army Headquarters. Orders have since been received for carrying out a further set of tests on a larger scale and for this purpose about 1,000 maunds of baled clover have this year been supplied for the trials supervised by Brigadier-General Cook, R. G. A. This fodder was grown by the zamindars near Harnai and was purchased green for drying and baling. These operations were interfered with to some extent by the scarcity and dearness of agricultural labour which resulted from the temporary concentration of troops at Harnai and in the neighbourhood in connection with the Mari Field Force. Some of the fodder was supplied to the troops green, the rest was dried and made into bales for the tests at Quetta. These are now in progress and are proceeding satisfactorily. A suitable centre for the growth and baling of *shaftal*, lucerne and berseem on the large scale has been found at which it will be possible to erect and run a hydraulic press. Detailed suggestions as to future work are being drawn up at the request of the Army authorities.

At the suggestion of Brigadier-General Cook, R.G.A., and with the assistance of Major Hislop, experiments have been made at Quetta to determine whether or not these leguminous fodders could be baled close enough to meet Army transport requirements. The difficulty in baling *shaftal* and lucerne hay, under the dry conditions at Quetta, is to obtain a close bale without, at the same time, damaging the product. Both these fodders dry out so quickly and become so brittle that it is almost impossible to bale them without considerable loss of leaf—the most nutritious portion of the fodder.

These difficulties have now been overcome. If *shaftal* or lucerne hay is allowed to dry outright in small stacks, the brittle fodder can be got back into condition for close pressing by watering the heap on the outside by means of an ordinary watering can and by covering it up for 24 hours with a tarpaulin or a small tent. The moisture then penetrates the heap and brings the fodder into condition for handling and baling. The outside layers are often a little too damp,

but if these are allowed to dry in the sun for an hour or so, the extra moisture rapidly evaporates. The amount of water required is about 10 gallons for every 150 cubic feet of stacked fodder. To enable the moisture to spread evenly, heaps $14' \times 3{\cdot}5' \times 3'$ are quite suitable. Some judgment is required in baling the moistened fodder but a little practice will avoid any danger of pressing too damp. The best stage is when the fodder is just beginning to feel brittle.

The baling experiments were duly carried out on August 1st, 1917, by means of the Boomer press at the Supply Reserve Depôt, Quetta, with lucerne brought into condition by damping as indicated above. Two kinds of bales were made with the Boomer press—(1) with lucerne only and (2) with chaffed lucerne and *bhusa* in equal parts by weight mixed ready for feeding. The lucerne by itself was found to be the more easily compressed. The size of a maund bale of lucerne was $30'' \times 16'' \times 13''$ (equivalent to 97 cubic feet to the ton). The size of the mixed lucerne and *bhusa* bale was $31'' \times 17'' \times 13''$ (equivalent to 105 cubic feet to the ton). The press had not been used for some time and was a little out of adjustment or it would have been easy to compress to 90 cubic feet to the ton—the Army standard for pressed *bhusa*. There is no doubt therefore that these leguminous fodders can be compressed to the required degree.

As regards keeping qualities, there is every reason to believe that no danger need be apprehended from this source. Several bales, made on August 1st, 1917, were opened during the present year and the fodder in both the lucerne and mixed bales was found to be in perfect condition with no trace of sourness or mouldiness.

Now that all the difficulties in converting these leguminous fodders from the green state into compact bales of hay have been solved and many successful trials of the product have been carried out, it only remains to suggest the desirability of taking up similar work in localities such as the Punjab, the Western Districts of the United Provinces and Central India where some or all of these crops are easily raised. A stock of such concentrated fodder would be of

the greatest use in India for improving the feeding value and palatability of existing materials such as *bhusa, karbi* and dried grass both for ordinary stock, for oxen engaged in transport and also for dairy cows and buffaloes.

Lucerne behaves as a perennial both on the soils of the Peninsula and also on those of the alluvium wherever the drainage and soil aeration during the monsoon period are sufficient. When kept free from weeds, when well manured and supplied with sufficient moisture, large crops are obtained. Berseem does well during the cold season in localities like Sind and the Central Provinces where the temperature and soil conditions are suitable. *Shaftal* does best on the upland frontier valleys but it can also be grown to advantage in the Punjab. In some localities, all three of these crops can be grown and in this way a large number of cuts of fodder could be produced for making into hay.

3. The sun-drying of vegetables.

The preliminary work connected with the sun-drying of vegetables at Quetta, referred to in the last report, has aroused a considerable amount of interest throughout India and numerous requests for these products have been received. In order to discover the extent of the demand for sun-dried vegetables from the civil population, an exhibit of this material was arranged for at the All-India Food Products Exhibition at Calcutta in January of the present year. By this means we were enabled to get into touch with a number of possible consumers including some of the lines of steamers based on Calcutta. There is likely to be a demand for sun-dried vegetables from hotels and boarding houses, clubs, private individuals in Southern India, expeditions, passenger steamers, sailing ships, engineering parties engaged in railway construction, bridge building and on oil-fields, and also from the caravans on the trade routes in desert regions like Persia and Seistan. A number of samples have been tested by various people and very favourable reports have been received. The Calcutta exhibit, for which a special prize was awarded, was then transferred to Lahore

and shown at the Conversazione in connection with the meeting of the Indian Science Congress. This attracted many visitors and completely exhausted the first edition of Bulletin No. 8 in which the process of sun-drying is described in detail. A paper on this subject was read and discussed in the Botanical Section of the Science Congress.[1] The medical men present were keenly interested in this matter and as a result of the discussions we secured the co-operation of Colonel Sir Leonard Rogers, F.R.S., in the investigation of the anti-scorbutic and anti-berri berri properties of vegetables prepared in this manner. A number of samples have since been despatched to Calcutta for these experiments.

As the only way of finding the value of a new thing is to sell it, arrangements have been made to place sun-dried vegetables on the market. Suitable agencies have been arranged at Calcutta, Bombay and at Quetta and as soon as the coloured labels (which are being designed and printed by the Lucknow School of Arts and Crafts) arrive, half pound tins of these vegetables, in a compressed form, can be purchased by the public. The price charged will be below that of the Californian tinned product which is put up wet and which is very heavy and bulky to transport. Samples of dried vegetables, in brick form, will also be available this year for trial on the trade routes in Seistan and Persia.

The quality of sun-dried vegetables depends on the way in which the fresh product is grown. Most of the vegetables produced for the market at Quetta are not well cultivated and in almost all cases about half the irrigation water is wasted. The result is that the fresh material now available is not the best possible for sun-drying and the yield is somewhat low. The methods of vegetable growing in this locality appear to be capable of considerable improvement and arrangements have been made to grow a plot at the Fruit Experiment Station in 1919 and to work out the best methods applicable to local conditions. At the same time,

[1] "Sun-drying of vegetables." *The Agricultural Journal of India*, vol. XIII, pt. IV, 1918.

the cost of conversion on the large scale can be determined with the help of labour saving devices such as slicing and peeling machines which are being imported for the purpose. As far as can be seen at present, there is every prospect of a new and profitable industry being created in Baluchistan in the growing of vegetables for sun-drying.

For military purposes, the Army at Quetta is continuing the work started in 1917 and during the present year it is expected that a further quantity of sun-dried vegetables will be prepared for use on active service.

The demand for copies of Bulletin No. 8, in which the process of sun-drying was described, has been considerable. The first edition, printed in August 1917, became exhausted early in the present year and a second English edition was brought out in March 1918 as well as one in Urdu.

4. The improvement of fruit culture.

In the last report, reference was made to the results obtained in the raising of nursery stock for local distribution. These matters have since been described in detail in Bulletin No. 9, which was issued early in the present year. A considerable number of copies have also been sold and distributed in India.

The demand for fruit trees still continues very great and every year many small trees are purchased for planting which really ought to remain another year in the nurseries. It is hoped now to hold in reserve sufficient trees for a second year's growth for issue in the autumn of 1919. As all the details relating to the experiments on the propagation of fruit trees have been published, it would seem that the time has come for private enterprise to begin the supply of the large number of trees required every year in Baluchistan. The ideal arrangement in this matter would appear to be for Government to supply a reasonable number of trees every year, to maintain suitable varieties true to name, to provide budwood, to train *malis*, to undertake all the importation of new varieties and to carry out all experimental work in these matters. After this, private enterprise should supply any

further trees needed and should supplement the work of the experiment station. Unless some such principle is adopted and means are found of developing local agencies to take over portions of the work when it has passed the experimental stage, the burden of routine will become so great that no further investigations will be possible. Fortunately, a beginning has already been made in this direction and two private nurseries have been started at Quetta by retired Europeans. The work is not arduous and when carefully carried out should prove both interesting and remunerative. One of the surest means of increasing the income of a private garden at Quetta is by raising a number of young trees for sale every year. Similar work might also be taken up in the districts.

5. Fruit packing.

The sale of improved fruit boxes to the public, which up to 1916 had proceeded very satisfactorily, has latterly been greatly interfered with by the war. Although arrangements were made in 1916 for the delivery the next year of a large supply of cardboard boxes, punnets and crate wood, all the consignments were delayed and arrived at Quetta too late. The consignments of cardboard boxes and punnets from Great Britain happened to be shipped to India by the same vessel which struck a mine outside Bombay and only just reached port. In due course, both consignments arrived at Quetta at the end of the fruit season. The crate wood was arranged for in 1916 from two Indian factories but in each case delivery did not take place till the middle of 1918 due to the fact that both the saw mills were engaged in war work. At the time of writing, July 24th, 1918, the last of the consignments ordered in 1916 has arrived at Quetta and the various boxes and crates can now be put together. It was hoped that the box boards prepared in India from locally grown timber would be considerably cheaper than similar supplies from Norway, Great Britain and Japan but this expectation has not been realized. Indian boards have proved inferior to and considerably

dearer than imported material, while the railway freights now charged for full waggon loads are enormous. Till more normal conditions of supply and transport obtain and till importation from Norway and other countries is again practicable, it will scarcely be possible to collect any more fruit box material at Quetta. The supplies already in hand are expected to last till 1920 after which no more orders will be sent till after the war. This work is financed by means of Treasury advances and purchases and sales have to balance each other. The system therefore does not admit of the holding of large stocks of unsold materials and is quite unsuited to the trade conditions of the present time. As soon as the war is over and prices settle down, the supply of these boxes will be handed over to a local agency. The demand is now considerable and the suitability of the various boxes and crates has been thoroughly tested. Railway concessions have been arranged for and are now in working order. The whole question has passed the experimental stage and will be dealt with by the trade at the earliest opportunity.

V. Programme and Publications.

1. Programme of work for 1918-19.

Investigations will be continued on the following crops on the lines indicated in the annual reports and in the publications of the Section—wheat, tobacco, fibre plants, indigo, gram, oil seeds, fodder crops and fruit.

2. List of Publications.

The following papers were published during the year :—

1. The sun-drying of vegetables. *Bulletin* 8, *Fruit Experiment Station, Quetta.* First edition, August, 1917. Second edition, March, 1918. Abstract read at the Indian Science Congress, Lahore, 1918, and published in the *Agricultural Journal of India*, vol. XIII, pt. IV, 1918.
2. Tarkarion ka dhup men khushk karna. *Rasala no. 8*, August, 1917. (Urdu publication.)

3. Note on the baling of *shaftal* and lucerne hay. *Journal of Dairying and Dairy Farming in India*, vol. V, 1917, p. 61. Reprinted in the *Agricultural Journal of India*, vol. XIII, pt. IV, 1918.
4. The agricultural development of North-West India. *Journal of Dairying and Dairy Farming in India*, vol. V, 1917, p. 7.
5. The improvement of fruit culture in Baluchistan. *Bulletin 9, Fruit Experiment Station, Quetta*, February, 1918.
6. Recent investigations on soil aeration. A lecture with Mr. R. S. Hole, delivered to the Indian Science Congress, Lahore, 1918, and published in full in the *Indian Forester*, vol. XLIV, 1918, p. 107. Reprinted in the *Agricultural Journal of India*, July, 1918.
7. Report for 1916-17, on Economic Botany for the Board of Scientific Advice.
8. Some methods suitable for the study of root development. A paper read at the Indian Science Congress, Lahore, 1918, and published in the Special Science Congress Number of the *Agricultural Journal of India*, 1918.

REPORT OF THE IMPERIAL MYCOLOGIST.

(F. J. F. Shaw, D.Sc., A.R.C.S., F.L.S.)

I. Charge and Establishment.

Dr. Butler held charge of the Section throughout the year and I remained as Second Imperial Mycologist. On 8th July, 1918, Dr. Butler proceeded on deputation to the Federated Malay States and handed over charge of the office to me, hence I am writing this report. It is with deep regret that I have to record the death, on 1st March, 1918, of Munshi Inayet Khan, Third Assistant to the Imperial Mycologist. Munshi Inayet Khan was the oldest assistant in the Section and had been with Dr. Butler from its commencement; his record of service was, however, considerably longer as he served with Mr. Duthie in the Botanical Survey of India and held the Hazara (1888), Relief of Chitral (1895), Punjab Frontier (1897-98), and Tirah (1897-98) medals for plant collecting service on these expeditions. Of late years he held charge of the mycological herbarium at Pusa and the accurate knowledge of systematic botany, which he had acquired by many years of practical experience, was always of the greatest utility in the work of the laboratory; in this direction his loss is one which we can hardly hope to replace. Throughout his service he remained an example of loyalty and efficiency to all his fellows.

II. Training.

Lala Kripa Ram, L.Ag., Assistant to the Economic Botanist, Punjab, finished his course of training on 25th September, 1917. Mr. B. N. Vakil, a private student, worked in the Section from 19th November, 1917 to 29th June, 1918. Mr. M. Mitra joined the Section on 15th June, 1918.

III. Diseases of Plants.

The investigation and the demonstration of methods of control of plant diseases formed as usual the major part of

the work of the Section. Crop parasites were collected and identified and advice given to the officers of the Department and the general public as occasion required.

(1) Ufra of rice. Evidence was obtained both in pot cultures at Pusa and in a field experiment carried out in collaboration with the Bengal Department on Dacca farm that this disease can be sometimes conveyed by seed from an infected crop.

The laboratory work at Pusa during the past season was directed chiefly to a study of the conditions which enable or induce the parasitic eelworm (*Tylenchus angustus* Butl.) to leave the water of the paddy fields and ascend the plant to reach its susceptible portion near the apex of the shoot. In last year's report it was explained that atmospheric humidity immediately around the plant was the determining factor, the worm being unable to move out of water except at high humidities.

The exact measure of the humidity of the air on the surface of a plant is exceedingly difficult. It is, however, possible to grow paddy in enclosed chambers and measure the relative humidity of the air within the chamber. It is also possible to watch the movements of worms on glass slides kept in similar chambers. By these methods, using a Polymeter, it was found that the worms can move freely when kept on glass slides at a relative humidity of 95 (temperature 87° to 90° F.), but not at all at 90, the exact point being apparently near 93. On the living plant they can move at lower air humidities, certainly below 90 but not at 75, at the same temperature. If they can soon reach the inner folds of the shoot (which is only possible in young seedlings), they become less dependent on high air humidity than when they remain on the exposed surface, no doubt because the vapour of transpiration causes the confined air within the folds to reach a higher degree of saturation than that of the surface.

Temperature also influences movement but less regularly. For instance, worms when free in water are much

more sluggish at 73° than at 88° F. provided they have not fed recently, but active, well-nourished worms taken directly after feeding show little difference in motility at the two temperatures. At low temperatures there is ordinarily little tendency to ascend shoots projecting out of the water even when the air is approximating to saturation, but here again freshly fed worms seem somewhat more active than those that have been dried for some time.

Light is also a factory but the results so far obtained require further testing.

Starvation is a factor of great importance. In one experiment two batches of 20 worms were placed in drops of water on slides in a saturated atmosphere, one batch containing only worms that had not fed for 18 days, the other worms taken after they had had access to living young paddy shoots. In 24 hours all but 4 of the former batch had left the water and were wandering freely in the chamber, whereas in the other batch none had left the drop. Four days later only 1 was left in the first drop while 19 were still in the second.

Hence amongst the factors which control the wanderings of the worm in search of the food that it can only obtain from the living paddy plant, some, such as humidity, are absolute in that they impose conditions which rigidly limit the power to move, while others are relative in that they act through the instinctive or other vital processes of the worm and so influence its movements indirectly, and are more variable in their action.

In carrying out such enquiries progress is necessarily slow, since the period during which the work can be done is limited each year, and all the work has to be done under microscopic control, the worm being invisible to the naked eye.

As an indication of their practical application, it is sufficient to mention that in certain districts the earliest attacks take place on the *aus* paddy growing in close proximity to or even mixed with the main crop, and that as the

former ripens off about July it becomes unable to supply food to the worm : the latter must then rapidly fall into the starvation condition which will induce it to wander vigorously to the *aman* crop.

Some further progress has been made in defining the limits of the infected tract. No new outbreak outside previously known areas was reported during the year except a small extension towards Chittagong. Two fieldmen from Pusa examined the infected areas near Chittagong, in Faridpur, and in the Manikganj Subdivision of Dacca.

The following demonstrations were carried out by the Bengal Department of Agriculture under advice from Pusa.

Dacca District. (*i*) *Vikrampur.* About 58 acres were treated by burning the stubble and sown with either *aman* or *digha* paddy alone or with *aus* and *aman* mixed or with *aus* followed by jute. The *aus* paddy escaped, the *digha* was very slightly damaged, but about 12 acres of *aman* were attacked. The amount of loss was not reported.

(*ii*) *Nagari.* About 25 acres were treated as above. Ufra appeared in 3 acres only but the amount of damage was not reported.

(*iii*) *Pubail.* A small isolated block which has given little or no crop for several years was treated as before. The disease appeared in one part only. The yield was about seven-eighths of a normal crop for the first time for a number of years. Another larger area was similarly treated but the loss was about a quarter of the crop. It was not isolated from untreated infected paddy close by.

Faridpur District. About 10 acres were treated as above at Gopalganj. No disease appeared until late in the year. Further reports have not been received.

A detailed account of the present state of knowledge of the disease has been written by Dr. Butler and it is hoped will be published during the coming year.

(2) Black band disease of jute. During the rains of 1917 an area of about 40 acres of jute (*Corchorus capsu-*

laris) was grown on the Pusa farm as a seed crop for the Fibre Expert to the Government of Bengal. The variety grown was that called *kakya bombai* and about half the area was sown in March and the remainder in June. The early sown portion of the crop grew well, but about the beginning of August a number of plants appeared to be drying up, the leaves falling to the ground and the stems blackening. Inspection of the crop showed that this disease commenced with the formation of a black patch on the stem at a point from 1½—3 feet above the ground level. This black patch spreads rapidly forming a discoloured band round the stem about 4—12 inches long. At this stage the leaves of the plant droop and fall and the black band extends up and down the stem, until finally the diseased plant is left simply as a blackened stick.

Examination of the surface of a diseased stem showed the presence of large numbers of pycnidia of a fungus which proved to be identical with that known as *Diplodia Corchori* Syd. This fungus was first collected as a parasite of jute on Pusa farm in 1910, but until the present season there was no reason for suspecting it of being more than an occasional parasite. As, however, the crop ripened the disease increased until it was estimated that about 20 per cent. of the crop was infected. The fungus was obtained in pure culture and inoculations upon healthy plants succeeded in establishing the disease and proved the parasitism of the fungus.

Inspection of the jute seed crop in other parts of Bihar showed that the disease was in 1917 widespread and, as the Bihar seed crop was intended for seed distribution in the jute growing districts of Bengal, suggested the advisability of disinfecting this seed before sending it to Bengal. The fact, however, that an examination of old specimens of jute in the mycological herbarium at Pusa showed that this fungus had, during the past 10 years, been collected, but not identified nor suspected of parasitism, over a large area in Bengal, indicated that there was no danger of introducing

a fresh parasite to the jute growing districts. Nevertheless as the seed was being distributed very extensively by the Bengal Department of Agriculture, it was decided to disinfect it. The problem of disinfecting the jute seed resolved itself into discovering some method of treatment which would kill those spores of the fungus which became mixed with the seed during threshing without injuring the germination of the seed. Experiment showed that steeping for 10 minutes in a 2 per cent. solution of copper sulphate could be relied upon to inhibit the germination of the fungus spores without appreciably affecting that of the seed. The whole of the Bihar seed crop was therefore collected in Pusa and steeped in a 2 per cent. solution of copper sulphate for 10 minutes and the seed then carefully dried on a concrete threshing floor. The work was carried out during the first three weeks of January and the seed at once bagged and despatched to Dacca, a total of about 20 tons of seed was treated in this way.

Early in November the jute seed crop in Kamrup was inspected and found to be suffering from *Diplodia Corchori*. This seed was collected and treated at Dacca. A fact which was apparent both in Bihar and Kamrup was that the late sown crop was relatively immune from attack. All field observations suggest that in some way the incidence of the disease is dependent upon the host plant reaching a certain stage of maturity and size and thickness of stem. Field and laboratory experiments are being continued at Pusa with the object of elucidating the conditions which favour the spread of the disease and any further methods of control. Further observations and experiments on *Rhizoctonia* on jute and its relation to this new disease are also being made; this investigation is being carried out by Dr. Shaw.

(3) Root rot of the sal tree. The inoculations carried out at Dehra Dun on young sál trees have not yielded any results, and a further series of infections using pieces of fresh sporophores of *Polyporus Shoreæ*, is being arranged in collaboration with the Forest Botanist. The figures

obtained during the past year in the fungus observation plots at Rajabhatkhawa show a number of new attacks but a relatively low proportion of fresh deaths.

(4) Black thread disease of rubber. In Burma there is now hardly a plantation in bearing that is free from the effects of this disease. It is not confined to the tapping surface and the fruits as previously supposed, but it attacks leaves as well and causes an extensive defoliation. The infected trees do not readily recover from the effects of leaf-fall and consequently there is a great reduction in the yield of latex in the months of October, November and December when under normal conditions the trees are expected to yield their maximum, before natural wintering takes place.

The remedial measures previously recommended have been tested on a plantation scale in Burma and have been found to be successful. The removal of seeds and the free admission of light and air by thinning and pruning have proved effective in reducing both leaf-fall and black thread on the tapping surface; but on account of the high cost of systematically removing the seeds it is doubtful if this measure is commercially practicable. In the Federated Malay States a regular application of Izal on the tapping cut has proved effective in preventing and checking black thread, but on a plantation in Burma where this disinfectant and others, such as, Solignum and Brunolinum, were given an extensive trial they have not been found to do much good; the reason is that in Burma there is more likelihood of the disinfectant being washed off in the more frequent heavy showers of rain than in the Federated Malay States where the rainfall is not as high as in Burma and is not confined to four months of the year.

The extent of the damage done by black thread on different plantations in Burma is not the same. The varying amounts of rainfall in the different rubber growing districts do not seem to have any direct bearing on the extent of the disease on the tapping cut, and on the amount of

damage done; but they seem to be proportional to the depth of the tapping cut. On a certain plantation where the rainfall is only 100 inches but where the tapping is very fine and deep, black thread is present in an epidemic form; not only is the percentage of diseased trees very high but the actual damage done to the bark is very great. But on other plantations where the rainfall is 200 inches or more but where the tapping is rather light, black thread is considerably less and seldom causes open wounds. These observations have also been confirmed by inoculation experiments.

(5) Chillies. *Die-back of chilli.* Experiments in the treatment of die-back, a very serious disease of chillies in Bihar, caused by *Vermicularia Capsici* Syd., have been continued by Mr. Dastur in the year under review. It has been found that one per cent. Burgundy mixture sprayed soon after the flowers set and again a fortnight later, considerably checks the disease, both on the plants and the fruits. The percentage of the disease in fruits picked from the sprayed plot of last year up to the first week of December (after which time the disease is practically negligible in the fields) was 7·6, while that on fruits from the unsprayed control plots was over 33. Not only did the freshly picked fruits from the sprayed plot compare favourably, in regard to the percentage of disease, with those from the unsprayed plots, but they also stood drying better, the market value of the sprayed fruits being thereby increased.

Another measure that proved successful in completely checking the disease was sowing the crop a month later than usual on a field manured at the rate of 2 cwt. of superphosphate and 1 cwt. of soda nitrate. The manure was applied to increase the yield of the late sown crop which would otherwise be very poor.

These and other measures will be again tried during the coming chilli season at the end of which it is hoped to publish a detailed account of the study of the die-back disease.

Anthracnose of chilli. During the year under review Mr. Dastur has continued the study of *Colletotrichum*

nigrum and *Glœosporium piperatum* on chillies, and has found that these two fungi are identical and that they are the conidial forms of *Glomerella cingulata* (Stoneman) Spauld. and v. Schrenk which is considered to be synonymous with *Glomerella piperata* (Stoneman) Spauld. and v. Schrenk.

A second disease of chillies, causing blossom and twig rot, was discovered during the progress of the investigation on anthracnose. It did as much damage as the chilli die-back. This disease is due to a fungus which has been identified as *Choánephora cucurbitarum* (B. and Rav.) Thaxt. It has not been previously known to occur in India but in America it is a serious pest of cucurbits.

(6) Fruit diseases. The spraying of peach orchards on the Government farm at Taru, North-West Frontier Province, against peach leaf curl was continued during the year under review. The difference between the sprayed orchards and unsprayed orchards became very marked as the season advanced and proved conclusively the advantage of spraying against this disease.

Specimens of crown gall on quince and pomegranate were collected in Peshawar orchards, this being the first time this destructive disease has been recognized in India.

A number of enquiries from apple orchards in Kumaun resulted in the following diseases of apple being identified :—

Root rot of apple due to the attack of Rosellinia. This fungus is well known as the cause of extensive damage in orchards in Europe and elsewhere. It appears to be most severe in strongly acid soils and an analysis of the soil from the orchard in question showed a marked deficiency of lime.

Apple cracking and branch blister. The cracking of apple fruits, which is common in these orchards, is due to the fungus *Coniothecium chomatosporium* Corda. This fungus has recently been the subject of investigation in South Africa and Europe—the parasite has been obtained in culture and will be kept under observation. A system of

spraying against this disease is being tested during the current season.

Fire blight. This destructive bacterial disease seems to be present in Kumaun orchards and will be kept under observation.

During the year under review the " foot rot " disease of papaya in Pusa was again investigated and found to be due to a species of *Pythium*. Infections with pure cultures of *Pythium* were successful in producing the disease and moreover the species of *Pythium* concerned appears to be identical with that which causes " damping off " of tobacco seedlings and soft rot of ginger. Excision of the diseased tissue and treatment of the wound with a wash of 50 per cent. carbolic acid in water appears to be effective remedy.

A ripe rot of peaches caused by a species of *Aspergillus* was for the first time found in Pusa during the past season. The same species has been known to attack mangoes as well.

(7) " Tikka " disease of groundnut. The groundnut crop is attacked by two distinct fungi, one the cause of true *tikka*, *Cercospora personata* (B. and C.) Ellis; the other, an undescribed species of *Cercospora*, which occurs commonly in the crop in various parts of India. The disease due to the unnamed *Cercospora* is apparently only known in India and, in the last ten years, has been collected in various parts of this country. The outbreak at Ranchi in the past year was the first case in which it was observed as a serious disease. In the Ranchi plots the distribution was quite erratic and did not seem to bear any relation to either the variety grown or the manurial treatment. It was exceedingly difficult, without microscopic examination, to distinguish the two attacks : the symptoms were similar, and the damage much about the same in both cases. It appeared to be a matter of chance which fungus was most prevalent in any particular plot. It is probable that the increased amount of this disease in the groundnut crop at Ranchi is due either to some deterioration in the plant or some unsuitability in the locality. It would possibly be worth

while testing the first of these possibilities by growing newly-imported varieties received direct from abroad or from some other part of India. It was found in Bombay that directly imported Madras seed did nearly as well as the foreign importations, but it was not known how long the Madras varieties had been in the country. The view that the disease in the crop is due to phosphatic depletion, suggested tentatively last year, must be abandoned.

(8) **Other diseases.** A damping off of tobacco seedlings due to *Pythium gracile* came under observation and control measures were tested. The treatment of seed beds with copper sulphate and sulphuric acid in varying proportions did not check the disease.

An outbreak of a fungal disease upon the Rangoon bean (*Phaseolus lunatus*) in Burma was attributed to the fungus *Phytophthora* in articles in the public press. Investigation of specimens showed that this diagnosis was quite erroneous and that the preliminary alarmist reports were without adequate foundation. This fungus is a sclerotial fungus and is under observation in culture at Pusa.

A serious outbreak of disease on opium poppy was reported by the Agricultural Adviser, Central India States, and proved to be due to *Erysiphe Polygoni*, a mildew not previously known as a parasite of poppy. The disease will be kept under observation during the coming season.

Work on sclerotial diseases of sugarcane and paddy was continued and the results are being prepared for publication. It has been established by inoculation that the sclerotial fungus which produces the disease known as " Djamoer Oepas " on sugarcane will infect upon paddy.

Some observations were made correlating the incidence of wilt disease in *rahar* (*Cajanus indicus*) with the composition of the soil. The results were obtained from the permanent manurial plots on the Pusa farm and the work will be continued every year. Field work on *tokra* of tobacco was continued and the results confirmed the conclusions published in the last annual report; the investiga-

tion will be carried on during the coming season with different varieties of tobacco seed obtained from other parts of India.

IV. Miscellaneous.

The year under review was marked by the passing of an order, under the Destructive Insects and Pests Act, regulating and restricting the importation of plants and seeds into British India. By the provisions of this order no plant may be imported into British India through the letter or sample post, and the importation of plants other than fruit and vegetables intended for consumption, potatoes and sugarcane is restricted to certain prescribed ports, where fumigation with hydrocyanic gas can be carried out. Since fumigation, although satisfactory in the case of insect pests, is not an efficient method of killing fungal parasites in seed and plants, the importation of fungal disease is provided against by a series of clauses regulating the introduction of potatoes, sugarcane, rubber plants, coffee plants, coffee, flax, berseem and cotton seeds. This list includes the plants and seeds on which the introduction of dangerous fungal diseases into India is most probable, and the provisions of the notification ensure that these plants shall only be introduced if accompanied by a certificate from a competent authority in the country of export stating that they are free from certain fungal parasites. In the case of coffee plants and seeds importation may only be done by the Madras Department of Agriculture.

Dr. Butler's book entitled *Fungi and Disease in Plants* was published during the year under review and supplies a long felt want in the literature of scientific agriculture in India.

Additions to the herbarium numbered 122 foreign specimens and 97 specimens collected in India.

V. Programme of work for 1918-19.

(1) *Research work.* New diseases of Indian crops that come to the notice of the Section will be investigated as

opportunity permits, but the following diseases will receive special attention and will constitute main lines of investigation :—

(*a*) Ufra of paddy.
(*b*) *Orobanche* of tobacco and mustard.
(*c*) Die-back and anthracnose of chilli.
(*d*) Sclerotial disease of sugarcane and paddy.
(*e*) Root rot of sál tree.
(*f*) Wilt disease of cotton, sesamum and pigeon-pea.
(*g*) Black ring disease of jute.
(*h*) Black thread disease of rubber.

Minor investigations will include the study of some fruit anthracnoses, soft rot of ginger, root rot of cotton and bud rot of areca palms.

It is hoped to publish a handbook of diseases of crops.

(2) *Systematic work.* This will be in abeyance for the present owing to difficulties in obtaining assistance from abroad on account of the war.

(3) *Training.* This will be continued on the lines indicated in the prospectus. Short courses may also be given as necessary.

(4) *Routine work.* Advice and assistance will be given as usual to Provincial Departments of Agriculture, the Forest Department, Planters' Associations and the general public.

VI. Publications.

(1) Butler, E. J. . Report on Mycology, 1916-17, for the Board of Scientific Advice.

(2) Butler, E. J. . Immunity and Disease in Plants. *Agri. Jour. of India*, Special Indian Science Congress Number, 1918.

(3) Butler, E. J. . Fungi and Disease in Plants, June, 1918.

REPORT OF THE IMPERIAL ENTOMOLOGIST.

(T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S.)

I. Administration.

The Imperial Entomologist held charge of the Section throughout the year ended 30th June, 1918. The post of Supernumerary Entomologist remained vacant throughout the year owing to the difficulty of obtaining any suitable candidate under present conditions. Mr. Y. Ramachandra Rao, M.A., Entomological Assistant in Madras, was on deputation throughout the year to work under the Imperial Entomologist on an investigation of the insects which occur on *Lantana* in India and Burma.

II. Training.

One student, V. G. Deshpande, B. Ag., deputed by the Bombay Department of Agriculture, was received on 1st June for a special short course in Entomology.

III. Insect Pests.

The numerous observations made on Insect Pests during the year under review cannot be given in detail here, and a Report of this nature is necessarily restricted to inclusion of the more important or interesting facts elicited anent the more important pests dealt with during the year. A summary of our knowledge of Indian Crop-pests up to practically the end of the preceding year has been published in the "Report of the Proceedings of the Second Entomological Meeting," to which the following observations may be regarded as supplementary.

Cotton. Work on Cotton Bollworms was continued throughout the year. From the data available it is found that at Pusa, at the beginning of the cotton season, especially from July to the middle of October, *Earias fabia* and *E. insulana* are the bollworms mostly present, but later on, from the middle of October to the end of January, the Pink Bollworm, *Platyedra* (*Gelechia*) *gossypiella*, is mostly

present and damages the crop considerably. This latter period covers the cotton-picking season and it is then that *P. gossypiella* is at its worst. The bollworm parasite, *Microbracon*—probably more than one species are concerned—which normally parasitizes *Earias*, is also able to parasitize the larvæ of *P. gossypiella* whilst these are in the shoots and pods of the plant; but it seems to be unable to attack the larvæ once these have got into the cotton-seeds. Large numbers of the larvæ in cotton-seeds were collected and bred out in the quest for parasites but not a single parasite was reared from these. It is undoubtedly owing to the absence of control by natural parasites that *P. gossypiella* is so destructive in some parts of India, notably the United Provinces, and it seems likely that its control will be best effected by the discovery and introduction of an efficient natural parasite. This is not a problem which affects India only, the control of this pest being equally important to Egypt, the United States and practically all the cotton-growing districts throughout the World: but *P. gossypiella* is apparently endemic in India and it therefore seems possible that the required parasite, if such exists, is most likely to be found in India.

As in previous years, the best trap-crop for bollworm larvæ was *Hibiscus abelmoschus*. At the beginning of the cotton season, when *Earias* were increasing, the pods and shoots of *H. abelmoschus* were found to contain a relatively larger number of parasitized bollworms than did either cotton or any other trap-crop. The advantage, so far as incidence of insect pests is concerned, of sowing cotton intermixed with another crop was apparent as in the previous year, but *Cajanus indicus* (*tur*, *arhar*) is not a good crop to be inter-sown with cotton.

Pempheres affinis was very bad this year in the cotton plots and many varieties suffered so badly that they had to be removed. On some varieties *Pseudococcus* sp. was very destructive, and others were attacked by *Machærota planitiæ* so badly that the infested plants had to be removed. A mite, *Eriophyes* sp., was also bad on a few varieties.

Rice. Stem-borers in rice were under observation throughout the year as far as it was possible with the staff available. The insects concerned were (1) *Schœnobius bipunctifer*, (2) *Chilo simplex*, (3) a second species of *Chilo*, as yet unidentified and apparently undescribed, hitherto confused with *C. simplex*; this is for the present called Rice Chilo, (4) *Sesamia inferens*.

Whilst rice was growing it was observed that the prevalence of these borers varied from field to field and also to some extent according to the age of the plants. Considerable further observation is required in order to arrive at definite facts and conclusions regarding their relative prevalence.

Sesamia inferens remained active throughout the year, whilst the other three species mentioned above hibernated in the stubble. In order to observe the hibernating habits of these insects four large rice fields outside the Pusa Estate, amounting in the aggregate to about 180 acres, were kept under observation throughout the cold weather from December to March, samples of stubble being collected at intervals from all over these fields and examined. As a result of the examination of 18,514 stubble-stems it was found that:—

(1) Reckoning as affected only those stems which showed distinct signs of borer attack, the percentage of damage varied from 14 to 55 in the various countings and on the average was about 29. As attack by a borer causes the entire ear to fail to develop, this percentage may be taken as representing the proportion of chaff in the harvested grain.

(2) At the lowest computation there were about 30,000 larvæ hibernating in each acre of the rice fields in December. This number fell to about 15,000 per acre towards the end of March. This reduction was apparently due to the fact that, as the temperature rose at the end of the cold weather, these hibernating larvæ became active and left the stubble, and either fell victims to natural enemies or took shelter in cracks in the soil. In the samples of stubble, however, there was no sign of the presence of any enemy worthy of

the name, so that the larvæ seem fairly safe from such whilst they remain in the stubble. Towards the end of the season many *Schœnobius* larvæ were found dead and dry inside the stubble, but dead larvæ of the two species of *Chilo* were rarely met with. This fact is in accordance with the habits of the larvæ, those of *Schœnobius* being extremely sluggish and too slow to move to safer quarters when climatic conditions in the stubble become unfavourable. The following table shows in detail the main facts about these hibernating larvæ :—

Dates between which stubble was collected and examined.	No. of stems examined	No of stems which had been damaged by borers	Total number of larvæ actually found	Percentage of larvæ in column 4				Percentage of dead *Schœnobius* larvæ in total number shown in previous column
				Sesamia inferens	*Chilo simplex*	Rice Chilo	*Schœnobius bipunctifer*	
5th-20th December, 1917 .	7,255	2,109	363	0·8	12·7	63·6	22·9	9·6
25th January-28th February, 1918.	6,484	2,001	284	..	4·9	14·8	80·3	21·0
18th-21st March, 1918 .	4,775	1,260	110	..	14·6	31·8	53·6	40·7
TOTAL . .	18,514	5,370	757	..	..	..	..	..

During this last examination, in the third week of March, it was found that the percentage of dead in the total number of *Schœnobius* larvæ found was about 66 in the case of stubble which had been ploughed some time previously and allowed to lie exposed to the sun, whilst it was only 28 in the case of larvæ found in the unploughed stubble. The simple process of ploughing the stubble at this time of year had therefore brought about the death of a very large percentage of *Schœnobius* larvæ. Before advocating this as a routine practice, however, further observations are desirable. Further work on these rice-borers was discontinued at the end of March when the adults began to emerge in the Insectary from the larvæ collected from the stubble.

In recent years crabs have come into prominence as pests of rice-plants in the Indian Empire, and, although not strictly subjects for entomological investigation, some work has been done on them in their capacity as crop-pests,

because it appears to be nobody else's business to do anything in this line. They cut the rice-plants, especially the young plants, and are reported to damage rice in this way in Burma, Madras, some parts of the Bombay Presidency and also in some parts of Bihar. They are known to occur in rice fields in Western Bengal but not as doing any damage there. About six miles from Pusa there is a large rice-growing tract known as Barail where crabs were reported to be doing great damage, and this locality was visited in October, at the end of the Rains, and again in April, in the dry weather. The crabs collected from the rice-fields here were identified by Mr. S. W. Kemp, as belonging to three distinct species, *viz.*, (1) *Paratelphusa* (*P.*) *spinigera*, Wood-Mason, (2) *Potamon* (*Acanthopotamon*) *martensi*, Wood-Mason, (3) *Potamon* (*A*) sp. nov. allied to *wood-masoni*, Alcock. Apparently all these three species are not concerned in the damage to rice, but it requires further observations to determine which species are incriminated. From observations made hitherto it appears that these crabs take three or four years to become fullgrown and capable of reproduction. In the hot weather they go deep down into the soil, coming out and resuming activity in the Rains. From a dry field at Munni, in the Muzaffarpur District, in April five crabs, young as well as adults, were collected at a depth of between 11 and 13 feet below the ground; of these five, three were *P. spinigera* and two were *P. martensi*.

Sugarcane. Considerable attention has again been paid during the year to the important subject of cane-borers and to the question of alternative wild foodplants of these. In the past, several different species of borers, all superficially much alike, were mixed up together under the name of Moth Borer (*Chilo simplex*), which was supposed to attack sugarcane, *juar* (*A. Sorghum*), maize and rice. In last year's Report it was mentioned that this "Moth Borer" had been differentiated into four distinct species. Further research during the year has extended this number until we can now discriminate no less than ten forms distinguishable from one another by morphological differences in their

larval and pupal stages, these differences being most easily appreciable in the pupæ as a rule. As regards the adults, except in a few cases, the types of coloration and pattern of markings are very uniform in all the species, and it is extremely difficult to distinguish these or to make the minute distinctions between them easily apparent by description or figures; study of the male genitalia has, however, indicated that the differences found in the immature stages correspond with differences in these structures, and further study of more ample material will doubtless enable us to differentiate between the adults, a thing which we are unable to do at present with any real satisfaction.

The nomenclature of these various forms is at present in such a state of confusion that it seems inadvisable to apply any names at all pending a thorough systematic revision of the whole of this group. Many of the species now discriminated are probably undescribed, and the application of the names in the cases of those species of which descriptions have been published is extremely doubtful in most cases. In last year's Report, for example, I referred to a species under the name of *Diatræa suppressalis* (*auricilia*), quoting *auricilia*, Ddgn., as synonymous with *suppressalis*, Wlk., on the authority of Sir George Hampson (*Bombay N. H. S. Journal*, XXI, 1250); further examination, however, shows that our cane-borer, which is apparently identical with *auricilia* (specimens of which, named by Dudgeon himself, are in the Pusa and Indian Museum collections), is quite distinct from examples agreeing exactly with the "Fauna" description of *suppressalis*, which latter species we have not bred as yet either from cane or any allied plant and whose early stages are as yet unknown to us although it is sufficiently common at Pusa. It may also be queried whether *Diatræa striatalis*, described by Snellen from Java, is truly synonymous with *venosata*, Wlk., from Sarawak. It seems better, therefore, to refer to these different species at present simply under the numbers of the Cage-slips under which they have been reared at Pusa, leaving to the future the allocation of exact specific names.

The names used here for these borers (*Chilo* and *Diatræa* spp.) in Gramineous plants must be regarded for the present only as those under which we have known these species hitherto, without any guarantee of accuracy of application, and they are only given here to allow of comparison between the current Report and that for last year.

Bearing the above remarks in mind, we may now turn to the species distinguished up to date. Those included in last year's Report were :—

(1) *Chilo simplex* (C. S. 1561 and 1580). (Plate III.)
(2) *Diatræa auricilia* (C. S. 1560 and 1574). (Plate IV.)
(3) *Diatræa venosata* (C. S. 1607 and 1635). (Plate V.)
(4) *Diatræa* sp. (C. S. 1610). (Plate VI.)

In addition to these we have now discriminated :—

(5) ? *Diatræa* sp. in sugarcane at Dacca (C. S. 1674). (Plate VII.)
(6) Rice Chilo in rice at Pusa (C. S. 1677). (Plate VIII.)
(7) ? *Chilo* sp. in rice (C. S. 1768).
(8) ? *Chilo* sp. in *Saccharum arundinaceum* (C. S. 1769).
(9) ? *Chilo* sp. in *Saccharum fuscum* (C. S. 1795).
(10) ? *Anerastia ablutella* in sugarcane (C. S. 1801). (Plate IX.)

Of these, the first six occur in large numbers, whilst the last four have only been found in very small numbers. Of these ten, three (C. S. 1768, 1769 and 1795) have as yet been insufficiently studied, but the other seven species may be separated in their larval and pupal stages by means of the following dichotomic keys, and figures are added to enable the distinctions to be grasped more readily.

Key to larval forms of Borers.

1. Spiracles round . . . . . (C. S. 1801)
   Spiracles oval 2
2. With mid-dorsal stripe; spiracles open 3

EXPLANATION OF PLATE III.

Fig. 1. *Chilo simplex* (C. S. 1580).

a, lateral, and, *b*, dorsal view of larva, × 5.
c, details of spiracle on fifth segment, more highly magnified.
d, details of first proleg, seen from below, more highly magnified.
(*Note*.—Anterior hair on right side of anal plate was absent in this specimen.)

Fig. 2. *Chilo simplex* (C. S. 1561).

a, Pupa, × 5.
b, Posterior segments of pupa, lateral view, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

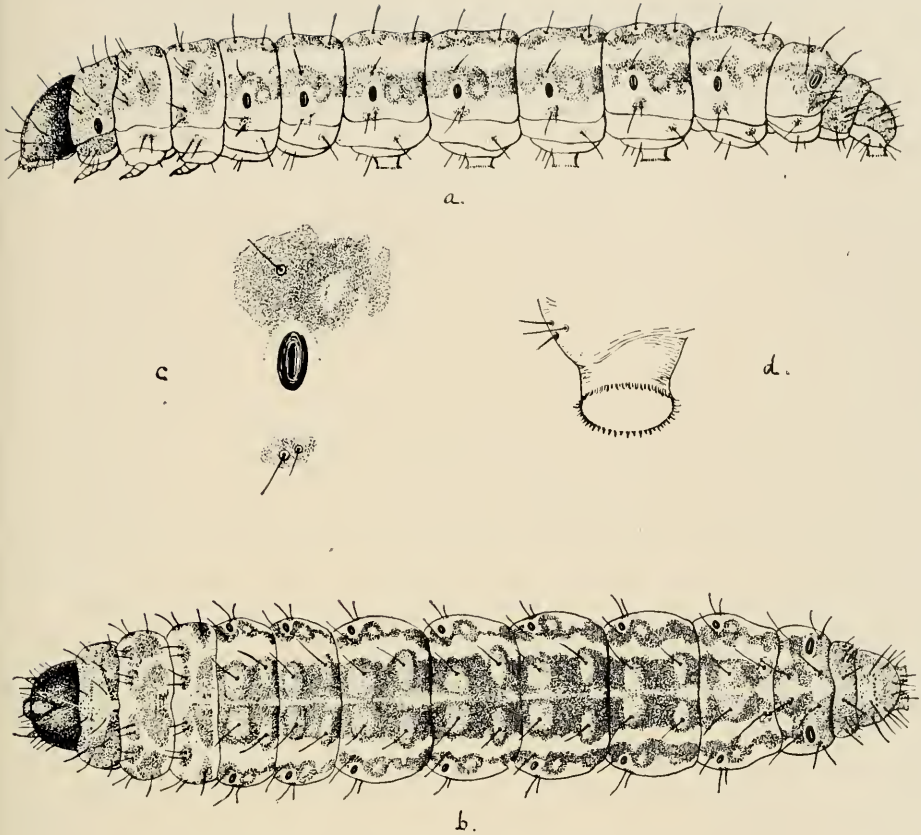


Fig. 1. *Chilo simplex* (C. S. 1580).

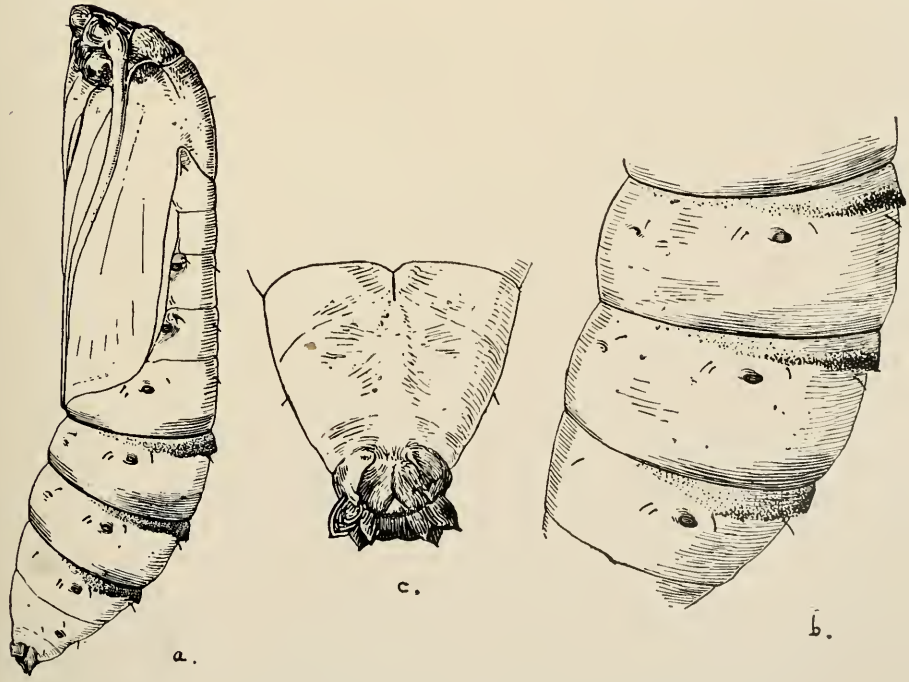


Fig. 2. *Chilo simplex* (C. S. 1561).

EXPLANATION OF PLATE IV.

Fig. 1. *Diatræa auricilia* (C. S. 1574).

a, lateral, and, *b*, dorsal view of larva, × 5.
c, details of spiracle on fifth segment, more highly magnified.
d, details of proleg, seen from below, more highly magnified.

Fig. 2. *Diatræa auricilia* (C. S. 1560).

a, Pupa, × 5.
b, Posterior segments of pupa, seen laterally, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

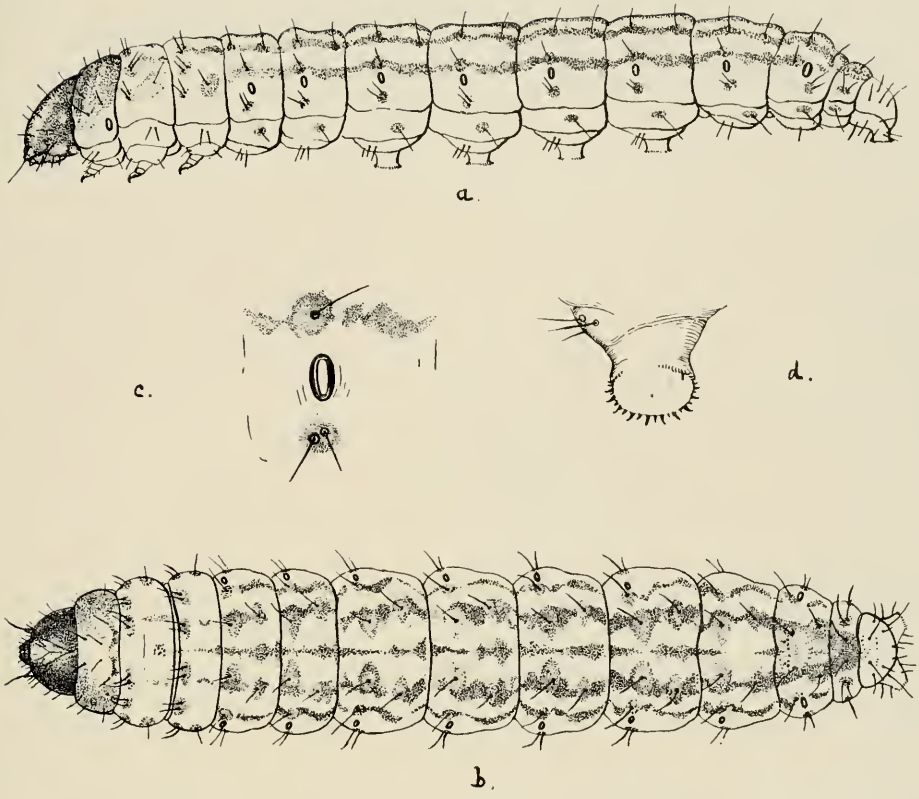


Fig. 1. *Diatræa auricilia* (C. S. 1574).

Fig. 2. *Diatræa auricilia* (C. S. 1560).

EXPLANATION OF PLATE V.

Fig. 1. *Diatræa venosata* (C. S. 1635).

a, lateral, and, *b*, dorsal view of larva, ×4.
c, details of spiracle of fifth segment, more highly magnified.
d, details of first proleg, seen from below, more highly magnified.

Fig. 2. *Diatræa venosata* (C. S. 1607).

a, Pupa, ×5.
b, Posterior segments of pupa, lateral view, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

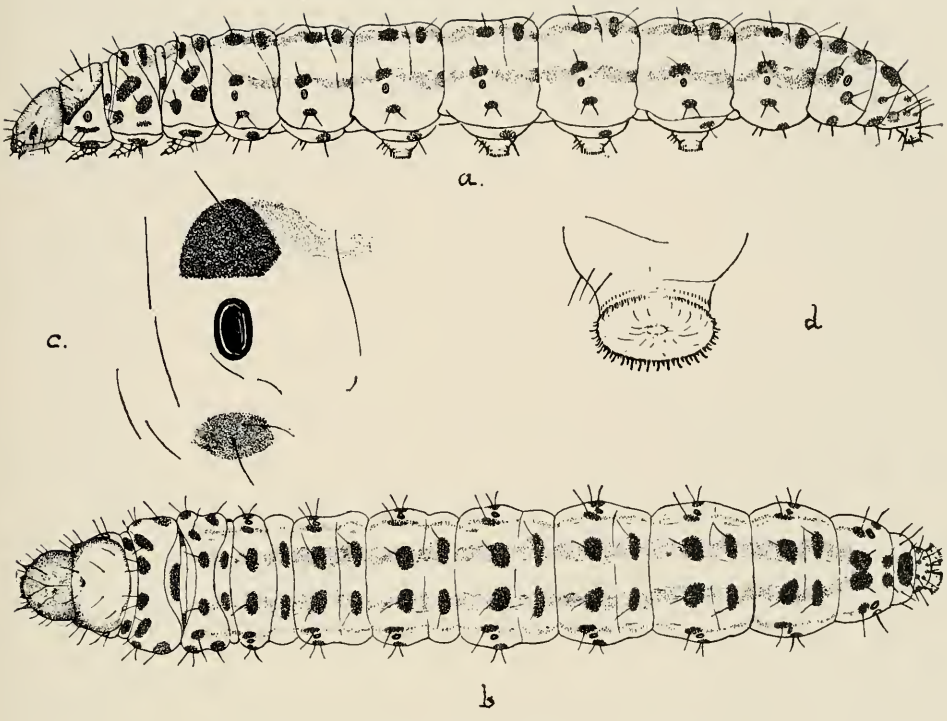


Fig. 1. *Diatræa venosata* (C. S. 1635).

Fig. 2. *Diatræa venosata* (C. S. 1607).

EXPLANATION OF PLATE VI.

Fig. 1. *Diatræa* sp. (C. S. 1610).

a, lateral, *b*, dorsal, and, *c*, ventral view of larva, ×4.
d, details of spiracle on fifth segment, more highly magnified.
e, details of proleg, seen from below, more highly magnified.

Fig. 2. *Diatræa* sp. (C. S. 1610).

a, Pupa, ×4.
b, Posterior segments of pupa, seen laterally, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

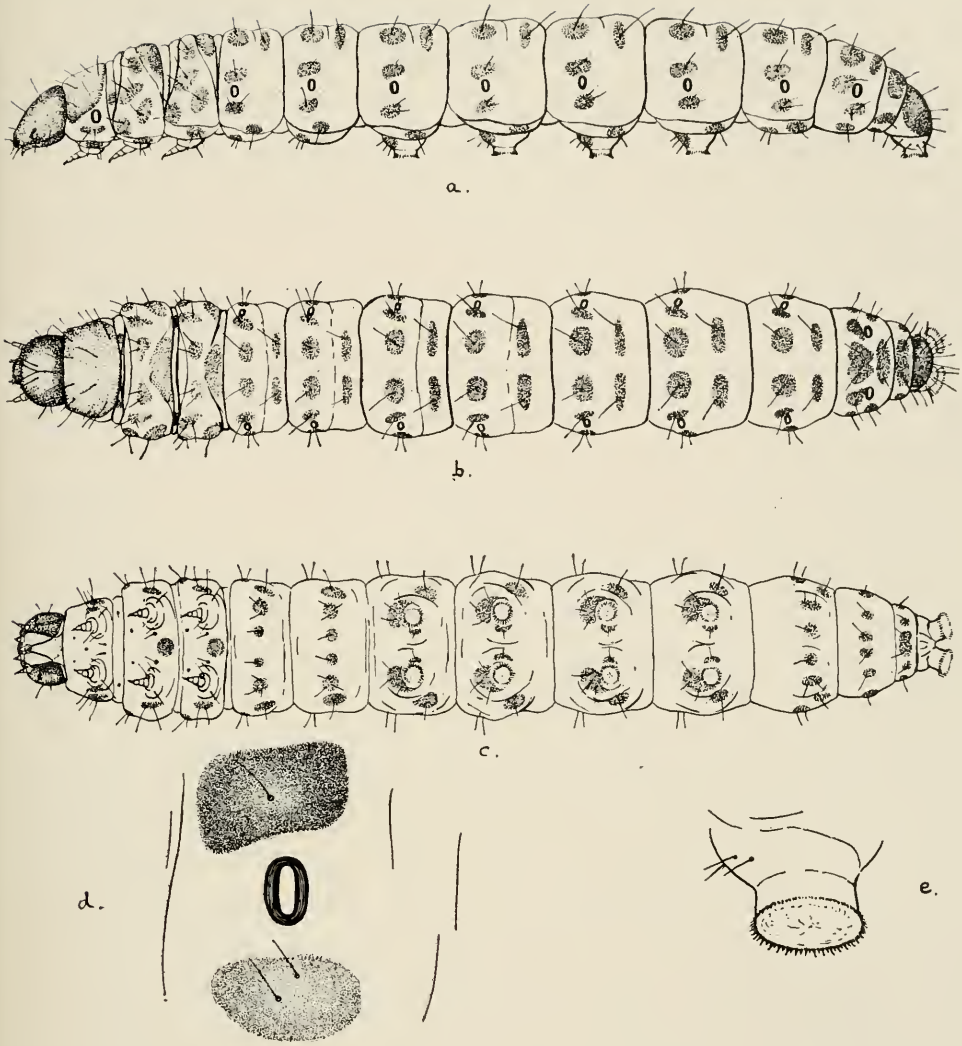


Fig. 1. *Diatræa* sp. (C. S. 1610).

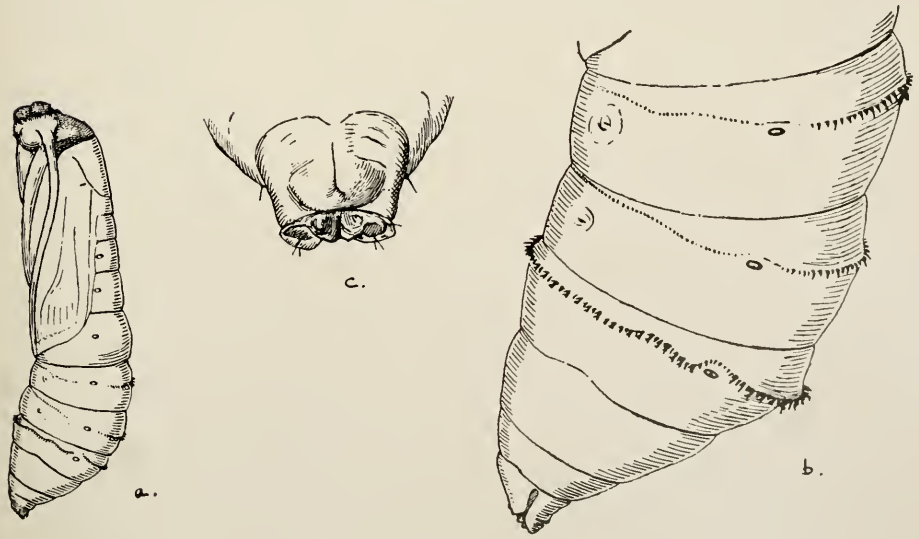


Fig. 2. *Diatræa* sp. (C. S. 1610).

EXPLANATION OF PLATE VII.

Fig. 1. ? *Diatræa* sp. in sugarcane at Dacca (C. S. 1674).

a, lateral, and, *b*, dorsal view of larva, × 4.
c, details of spiracle on fifth segment, more highly magnified.
d, details of first proleg, seen from below, more highly magnified.

Fig. 2. ? *Diatræa* sp. in sugarcane at Dacca (C. S. 1674).

a, Pupa, × 5.
b, Posterior segments of pupa, seen laterally, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

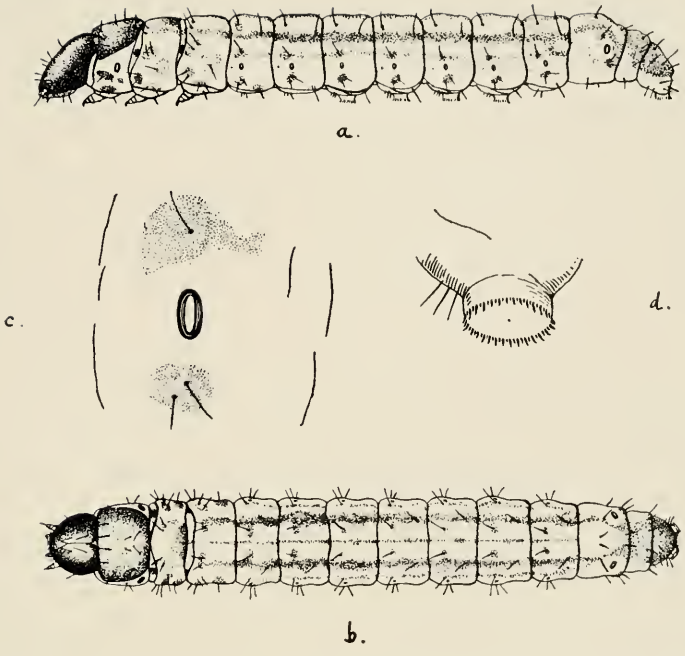


Fig. 1. ? *Diatræa* sp. in sugarcane at Dacca (C. S. 1674).

Fig. 2. ? *Diatræa* sp. in sugarcane at Dacca (C. S. 1674).

EXPLANATION OF PLATE VIII.

Fig. 1. Rice Chilo in rice at Pusa (C. S. 1677).

a, lateral, and, *b*, dorsal view of larva, × 5.
c, details of spiracle on fifth segment, more highly magnified.
d, details of first proleg, seen from below, more highly magnified.

Fig. 2. Rice Chilo in rice at Pusa (C. S. 1677).

a, Pupa, × 5.
b, Posterior segments of pupa, seen laterally, more highly magnified.
c, Anal segment of pupa, ventral surface, more highly magnified.

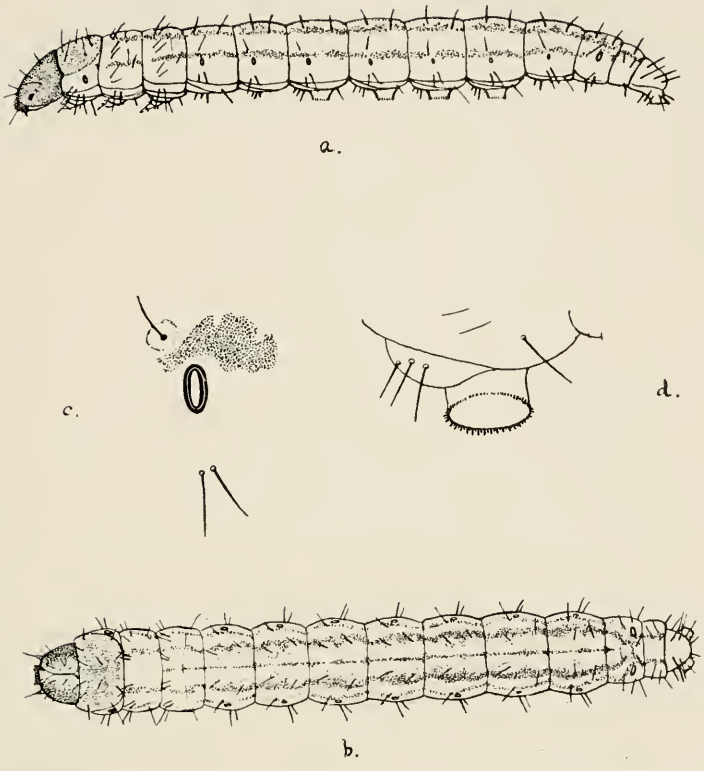


Fig. 1. Rice Chilo in rice at Pusa (C. S. 1677).

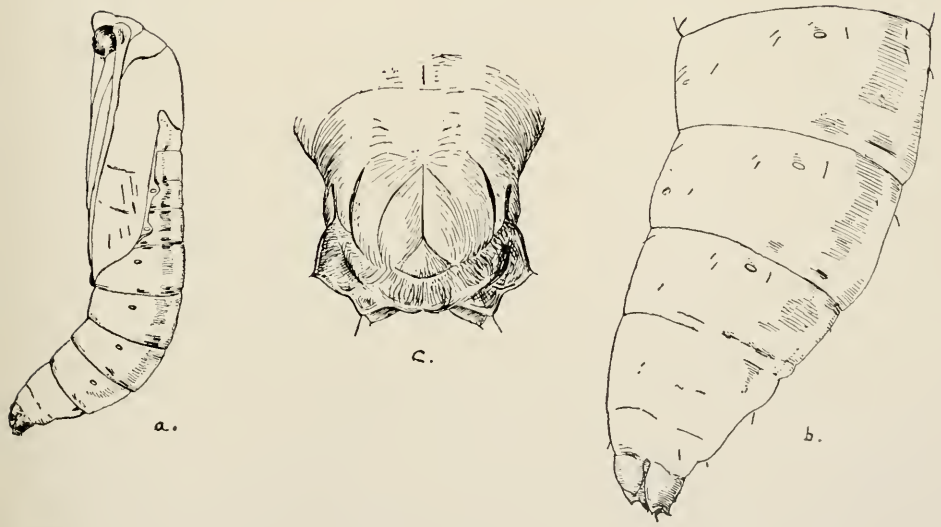
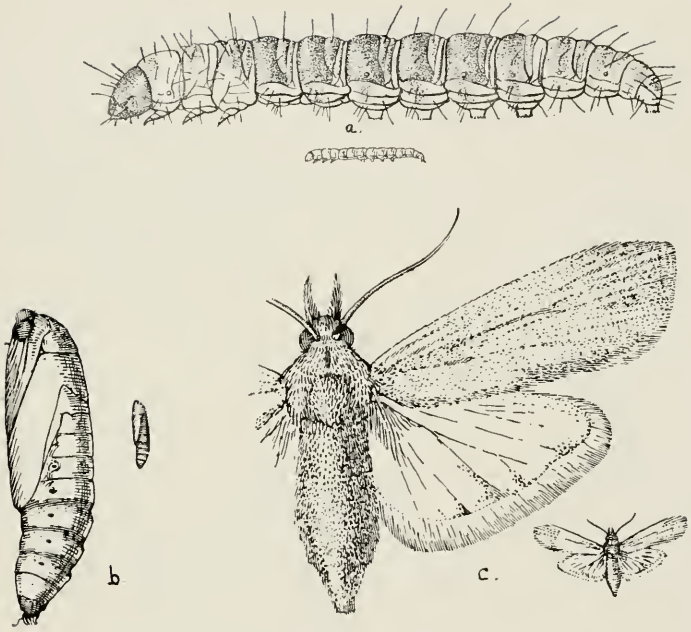


Fig. 2. Rice Chilo in rice at Pusa (C. S. 1677).



? *Anerastia ablutella* in sugarcane (C. S. 1801).

a, Larva, × 5.
b, Pupa, × 5.
c, Imago, × 5.
The smaller figures show the natural sizes.

	Without mid-dorsal stripe; spiracles open or closed.	5
3.	Hooklets on prolegs forming a complete circle.	4
	Hooklets on prolegs forming a half-circle only.	(C. S. 1560, 1574)
4.	Hooklets practically equal in size .	(C. S. 1674)
	Hooklets on internal edge of sole largest and gradually diminishing in size externally.	(C. S. 1677)
5.	Spiracles open (*i.e.*, with a clear space inside).	(C. S. 1610)
	Spiracles closed (*i.e.*, without a clear space inside).	6
6.	Spiracles with a slit along their major axis. Hooklets on prolegs forming a complete circle and all of equal size.	(C. S. 1561, 1580)
	Spiracles with an oval-shaped concavity whose major axis coincides with that of spiracle. Hooklets on prolegs in a more or less complete circle but becoming shorter externally. A spot in middle of sole of prolegs usually present. Usually with shiny large dark-brown warts (absent in hibernating larvæ).	(C. S. 1607, 1635)

Key to pupal forms of Borers.

1.	Pupa without any chitinous protuberances on anal segment.	(C. S. 1801)
	Pupa with chitinous protuberances on anal segment.	2
2.	Pupa without ridges or hooks on 7th abdominal segment.	(C. S. 1677)
	Pupa with such	3
3.	With complete circle of ridges, hooks, or roughness on 7th abdominal segment.	4
	With incomplete circle as above .	5
4.	Circle composed of distinct and separate spinous hooks.	(C. S. 1610)

Circle composed of joined ridges . .	(C. S. 1560, 1574)
5. Incomplete circle of distinct hooks .	(C. S. 1674)
Incomplete circle of roughness without hooks.	6
6. Tenth abdominal (anal) segment with stout spines on ventral surface in addition to two pairs of spines on dorsal surface.	(C. S. 1561, 1580)
Tenth abdominal (anal) segment without spines on ventral surface.	(C. S. 1607, 1635)

Chilo simplex (C. S. 1561, 1580), *Diatræa auricilia* (C. S. 1560, 1574), *D. venosata* (C. S. 1607, 1635) and the Rice Chilo (C. S. 1677) have been observed to hibernate in the larval stage.

Not much is known about C. S. 1610 and C. S. 1674, two species found in cane at Dacca; of the former a single specimen was also reared from a rice stem sent from the Karimganj Subdivision in Sylhet, and a single example of the latter has recently been found in rice at Pusa. Both these species were found to be injuriously prevalent in sugarcane at Dacca in July 1917, whilst the ordinary cane-borers found in other parts of India were not found at Dacca. Sugarcane in Sylhet seems to be remarkably free from borers, and the Entomological Assistant in Assam reports that borers give little trouble in cane in that Province. It is therefore the more curious that C. S. 1610, which is present in Sylhet and injurious to cane at Dacca, does not damage cane in Sylhet; and similarly that C. S. 1674, which was also injurious to cane at Dacca, has not yet been found at all in cane at Pusa, although it occurs in rice in this district. Extensive fieldwork, combined with a thorough study of the different species of borers, will doubtless throw more light on these and similar problems. Meanwhile it may be suggested that the damage done to cane or any other similar crop by any particular borer may be connected with the presence or absence in the district of particular alternative foodplants which are preferred.

A good deal of work has been done during the year on borers and other insects occurring in the several species of

wild *Saccharum* and other grasses occurring in the neighbourhood of Pusa. Besides *Diatræa venosata*, *D. auricilia*, *Sesamia inferens* and *S. uniformis*, which are also found in sugarcane, nine other borers not yet known to occur in cane have been found in these wild grasses. Of these one is a Curculionid grub, another a Lamiad grub, and the remainder are lepidopterous larvæ, these including *Scirpophaga* sp., and *Papua* sp., a Zeuzerid and a Noctuid. This last has since been found to occur in sugarcane at Munni, Muzaffarpur District, and all of these insects may be looked on as potential pests of cane. Almost all of the root-feeders mentioned under cane have also been found to occur amongst the roots of these wild grasses.

Besides borers, the insects, mostly coleopterous larvæ, found underground amongst the roots of sugarcane, were under observation during the year, the following being noticed :—

(1) *Anomala bengalensis.*
(2) *Anomala biharensis* (Plate X).
(3) *Adoretus caliginosus* (Plate XI).
(4) *Autoserica* sp. (Plate XII, fig. 1).
(5) *Myllocerus discolor.*
(6) *Myllocerus blandus.*
(7) *Monolepta signata* (Plate XII, fig. 2).
(8) *Formicomus* sp.
(9) *Pachnephorus* sp.
(10) *Alissonotum piceum.*
(11) *Alissonotum simile.*
(12) *Apogonia* sp.
(13) An unidentified Chrysomelid.

Besides the above, one Chrysomelid grub and two kinds of weevil grubs were found but could not be reared out.

Of these insects, the grubs of *Anomala bengalensis* were observed both at Pusa and Dacca to gnaw into the basal parts of new shoots from the side, thus causing a "dead-heart;" in this way they were causing a small amount of damage. In the case of the other insects, no appreciable

idea could be formed of the part they were playing, but they appear to be of very minor importance as pests.

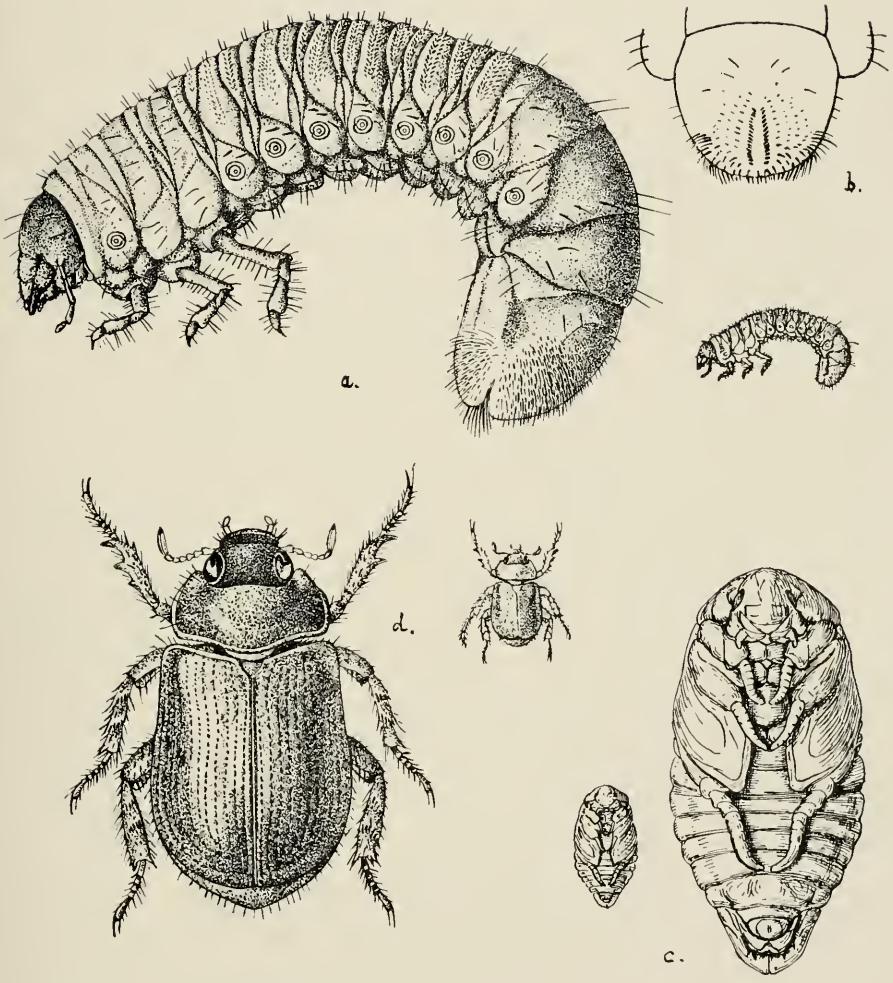
Records of observations on the pests of sugarcane at Pusa were given in last year's Report. These observations were continued during this year although it has not been possible to keep such close observation on the different varieties of cane as was done last year. The period of injurious activity of the borers in cane extended from March to August, when the total damage due to insects and fungi amounted to about 35·5 per cent., due to the following causes :—

Fungal diseases	21·8 per cent.
Papua depressella	8·3 ,,
Diatræa auricilia with a few *D. venosata* .	2·7 ,,
Scirpophaga xanthogastrella . . .	1·9 ,,
Termites	0·8 ,,

At this time there was a distinct difference between the canes which would go to make up the harvest and those which were retarded in growth by pests and diseases. The monsoon rains had stimulated the growth of the former and they were growing vigorously, while the latter remained stunted and ultimately died, and, although new shoots and lateral branches were appearing, these would not add materially to the harvested result. The activity of the borers after August was mostly confined to these stunted canes and new shoots.

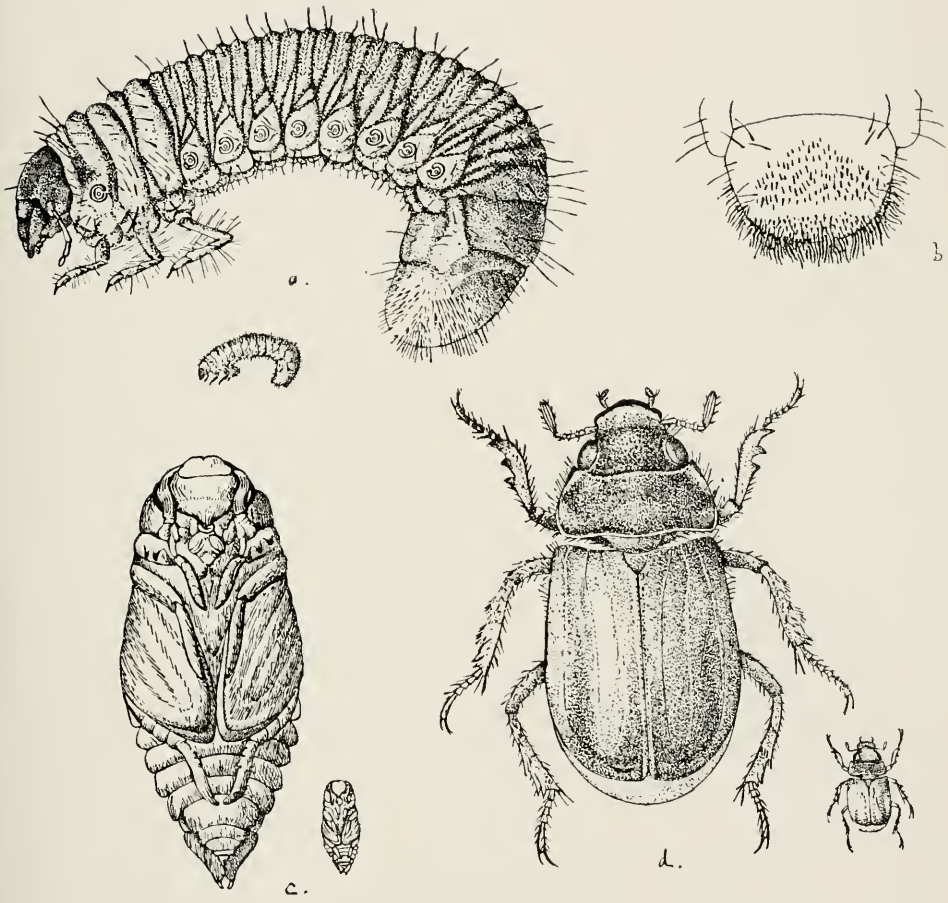
As mentioned in last year's Report, the plot of Purple Mauritius sugarcane had all " dead-hearts " and dry plants systematically removed together with the insects found in them. As this is the treatment usually recommended against borers in cane, the results obtained in this plot and in the other plots of thick canes which were left untreated and undisturbed seem interesting and appear to show the uselessness of the cutting-out treatment. The percentage of non-stunted, harvestable canes actually harvested to the number of setts planted may be taken as a standard of comparison,* as this shows the number of canes which survived

* The actual outturn of sugar would be the most satisfactory comparison between the various plots, but this cannot be adopted at Pusa because sugar is not made here.



Anomala biharensis (C. S. 1744).

a, Larva, natural size and magnified × 4.
b, details of posterior extremity of larva.
c, Pupa, natural size and enlarged.
d, Imago, „ „ „ „



Adoretus cealiginosus (C. S. 1793).

a, Larva, natural size and magnified × 5.
b, details of posterior portion of larva, magnified.
c, Pupa, natural size and magnified.
d, Imago.

EXPLANATION OF PLATE XII.

Fig. 1. *Autoserica* sp. (C. S. 1654).

a, Larva, natural size and magnified (×8).
b, details of posterior portion of larva, magnified.
c, Pupa, natural size and magnified (×8).
d, Imago, ,, ,, ,, ,, ,,

Fig. 2. *Monolepta signata* (C. S. 1632).

a, Larva, natural size and magnified (×8).
b, Pupa, ,, ,, ,, ,, ,,
c, Imago, ,, ,, ,, ,, ,,

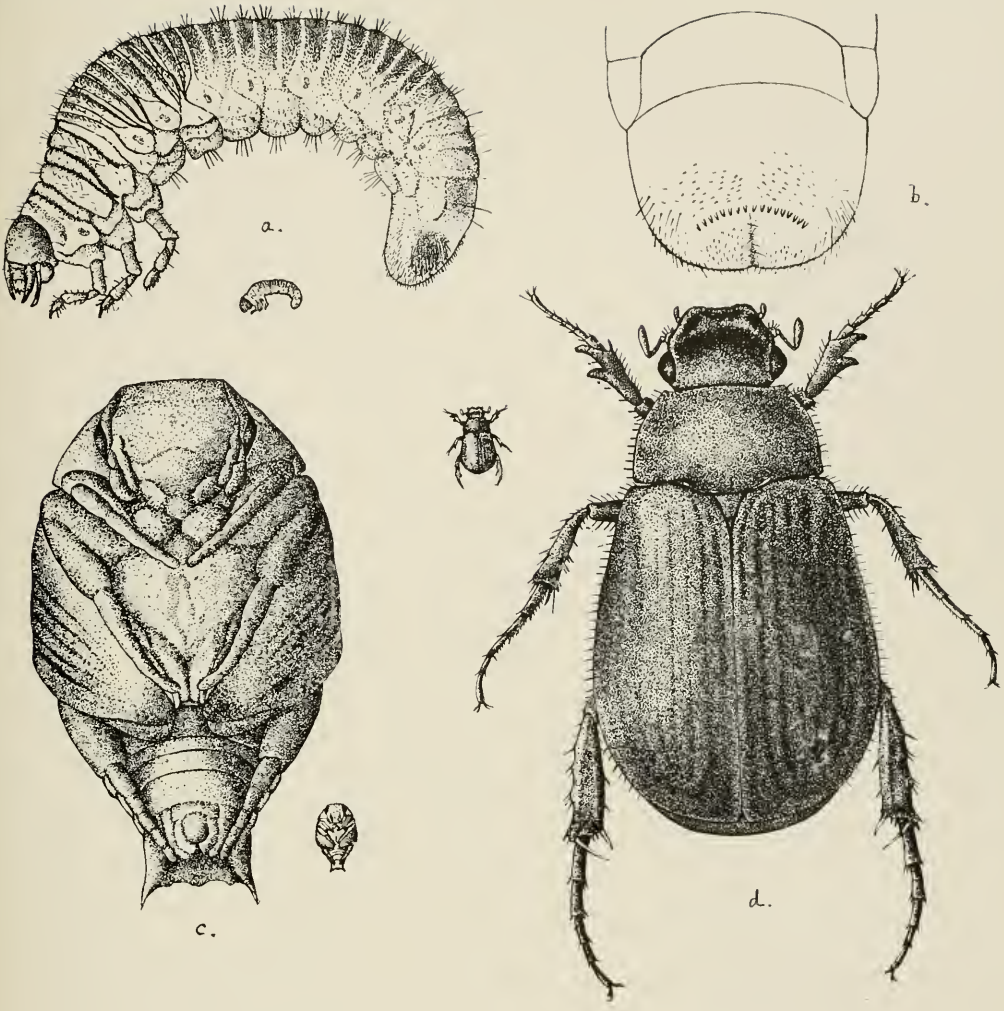


Fig. 1. *Autoserica* sp. (C. S. 1654).

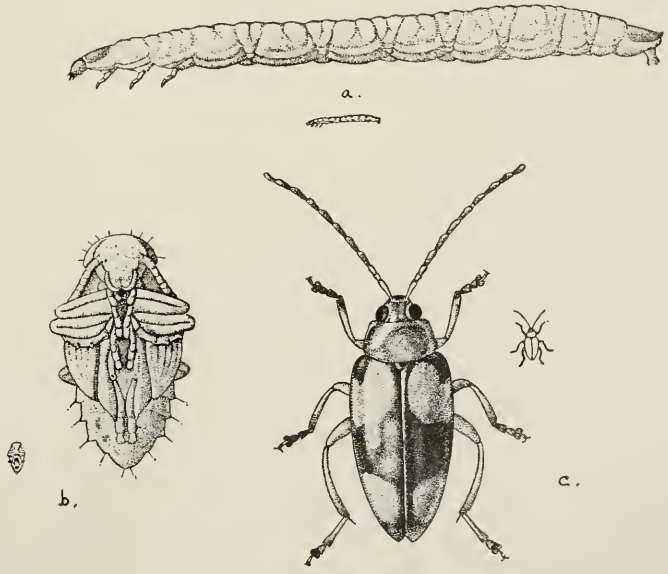


Fig. 2. *Monolepta signata* (C. S. 1632).

and outgrew the attack of pests and diseases. This percentage in the case of the different thick varieties enumerated in last year's Report was :—

Purple Mauritius (treated)	82 per cent.
Sathi No. 131 (untreated)	167 ,,
Sathi No. 15 (untreated)	161 ,,
Kaludai Budhan (untreated) . . .	101 ,,
D. 99 American (untreated) . . .	129 ,,

From the half-acre under Purple Mauritius, 14,277 affected shoots had been cut out, whilst the other plots were left undisturbed. The harvested canes in the case of these other plots therefore contained an unknown quantity of canes which, though classed as non-stunted and harvestable, had been presumably bored more or less, and the outturn of sugar from such bored canes would be poorer in quality and quantity than from unbored canes. The above percentages therefore fail to give an exact estimation of borer damage. It was unfortunate that no check plot of Purple Mauritius was available last year for observation and comparison of results, but in February, 1918, two half-acre plots of Sathi No. 131 were planted, one for treatment by cutting out and removing plants and shoots which were dry or showed "dead-heart" together with the insects found in them, and the other to be left untreated as a check. These two plots are practically similar as regards soil, are not contiguous (having a crop of indigo separating them), and are situated at a considerable distance from the main sugarcane crop of the Farm. The results so far obtained (up to July, 1918) go far to corroborate those obtained in the Purple Mauritius plot and to show that the cutting-out treatment retards the proper growth of the canes to a great extent.

The foregoing trials have been made with thick canes because these are more liable to borer attack, the thin varieties being damaged to a much smaller extent. With one exception the yield of canes in the seventeen thin varieties ranged from 122 to 746 per cent. of setts planted.

The two experimental plots of Sathi No. 131 referred to above are situated in a piece of land which was brought

under cultivation five or six years ago. It was previously a piece of waste land overgrown with *Saccharum spontaneum* and *Imperata arundinacea*, and it is even now bordered by similar waste lands. Sugarcane grown on this land has brought *Gryllotalpa africana* prominently into notice as a pest of young cane. This insect was the first to attack the young crop and in April and May in the treated plot as many as 15 per cent. of the plants were damaged by it.

In last year's Report mention was made of the suitability of Lead Arsenate solution as a dip for the protection of cane setts against termites. This year it was tried in the half-acre treated plot of Sathi No. 131, a strength of 1 lb. of Lead Arsenate in two gallons of cold water being used. The planting was done in the third week of February, and germination was good in both the treated and untreated plots. In April and May new shoots as well as the setts themselves were damaged by termites in both the plots, and those dipped in the Lead Arsenate solution had no advantage over those left untreated. The liability of cane to damage by termites seems to depend largely on the nature of the soil in which it is grown. Generally speaking, the crop suffers much less when grown in clayey soils than in sandy soils. In soils which are liable to be infested by termites, no single treatment of the setts can render them permanently immune from attack nor can it save the shoots; whilst in other soils little or no damage is done by termites even when no treatment is adopted, and the amount of damage done does not always seem dependent merely on the presence of the insect concerned.

Indigo. In April, 1918, an investigation was commenced of the parasitization of the Indigo Psylla (*Arytaina isitis*). This study is only in its initial stages and only four months' figures are available, but three species of Chalcididæ have been obtained and of these one species is very common. The amount of parasitization was small at the beginning of April, but began to increase in the beginning of May and reached its highest (about 30 per cent.) at

Shoot of mulberry affected with "Tukra."

the end of that month, began to decline again in the third week of June and reached its lowest at the end of July.

Mulberry. The "Tukra" disease of mulberry, resulting in curling and malformation of the shoots and new leaves, has been known for a long time in Bengal, where it is sometimes bad, and a few affected plants have lately been found at Pusa also. An investigation of the cause of this disease was carried out during the year, and it was found by experiment that the curling and subsequent malformation of the shoots was due to the presence of a mealy-bug (*Pseudococcus*), and that, although two species of *Pseudococcus* are to be met with on mulberry, it is only one of these (as yet unidentified) which causes *tukra*. This mealy-bug becomes active at Pusa at the beginning of March and passes through a complete life-cycle in 24 days. The generations, however, overlap one another, and it is not infrequent to find nymphs, gravid females and pupæ or adult males on one and the same plant. The mature nymphs as well as the females are parasitized by three species of Chalcididæ, one of which keeps down the number of nymphs and females to a large extent. A Cecidomyiad fly (? *Coccodiplosis* sp.) larva has been found to attack the eggs, the fly maggots being found chiefly in the ovisacs of the mealy-bug and having been observed to suck the eggs dry. The larvæ of a Coccinellid beetle also attack the nymphs and females of this *Pseudococcus*.

As regards treatment of *tukra*, it was found that the practice of removing the affected shoots and burying or burning them was not effective by itself, as the nymphs hide themselves in the crevices of the unexpanded leaf-buds on the plants, and, as soon as these leaves expand, they in their turn become affected and the disease is continued. Removal of the affected shoots followed by thorough spraying with Fishoil-resin soap will probably prove more effective.

Fruit Flies. Over five thousand pupæ of the Peach Fruitfly were collected at Pusa in May, 1918, and kept under observation to see whether any would lie over until the

following year and to rear out any parasites. No pupa lay over and no parasites were reared.

Fruit Pests. Special attention was paid during the year to the pests of *Citrus* spp., jak (*Artocarpus integrifolia*), apple, pear, peach, nectarine, grape, guava, custard-apple and plantain. A large amount of information on Indian Fruit-pests has now been accumulated, and it is hoped to write this up when opportunity admits. The Gracilariad found on apple in North-West India and Assam has been identified as *Gracillaria zachrysa*, Meyr.

Life-histories of Insects. In the Insectary, besides the rearing of the various borers and rootfeeders of cane and rice already mentioned and which constituted about 100 lots, some 200 other lots of insects were reared and observations made on their life-histories and habits. Amongst these at least five new pests have come to light, *viz.*:—

(1) An unidentified Longicorn borer, C. S. 1645 (*?Nupserha* sp.) (Plate XIV, fig. 1), found in stems of *Vigna catjang* in August. It bores in the main stem and may attack the young plants. The bored stem swells to some extent, and, although in the majority of cases the plants are not killed, they are stunted and bear no fruit.

(2) A caterpillar found boring into young coconut fruits in the bunch on the tree and causing the young fruits to drop off. An accumulation of frass webbed up with silk indicates the presence of the borer. This insect is apparently an undescribed species of *Tirathaba* (Pyralidæ) (Plate XIV, fig. 2). It is interesting to note that *Tirathaba trichogramma*, Meyr., is also known to attack young coconut fruits in Fiji,[1] but this type of damage has never been noticed before in India so far as we are aware.

(3) *Calandra stigmaticollis* (Plate XV, fig. 1) is reported to kill large coconut trees in Ratnagiri by boring into the stem in which it breeds in large numbers. This is an interesting confirmation of a former record of this weevil attacking coconut in Malabar. In confinement it has been

[1] *Novitates Zoologicæ*, XXIV, 32.

EXPLANATION OF PLATE XIV.

Fig. 1. Longicorn boring *Vigna catjang* stem (C. S. 1645).

a, Stem of *Vigna catjang* attacked by larva.
b, Larva, natural size and magnified (×4).
c, Pupa, ,, ,, ,, ,, ,,
d, Imago, ,, ,, ,, ,, ,,

Fig. 2. *Tirathaba* n. sp.

a, Young coconut fruit attacked by larva, showing frass ejected.
b, Larva, natural size and magnified (×3).
c, Pupa, ,, ,, ,, ,, ,,
d, Imago, ,, ,, ,, ,, ,,

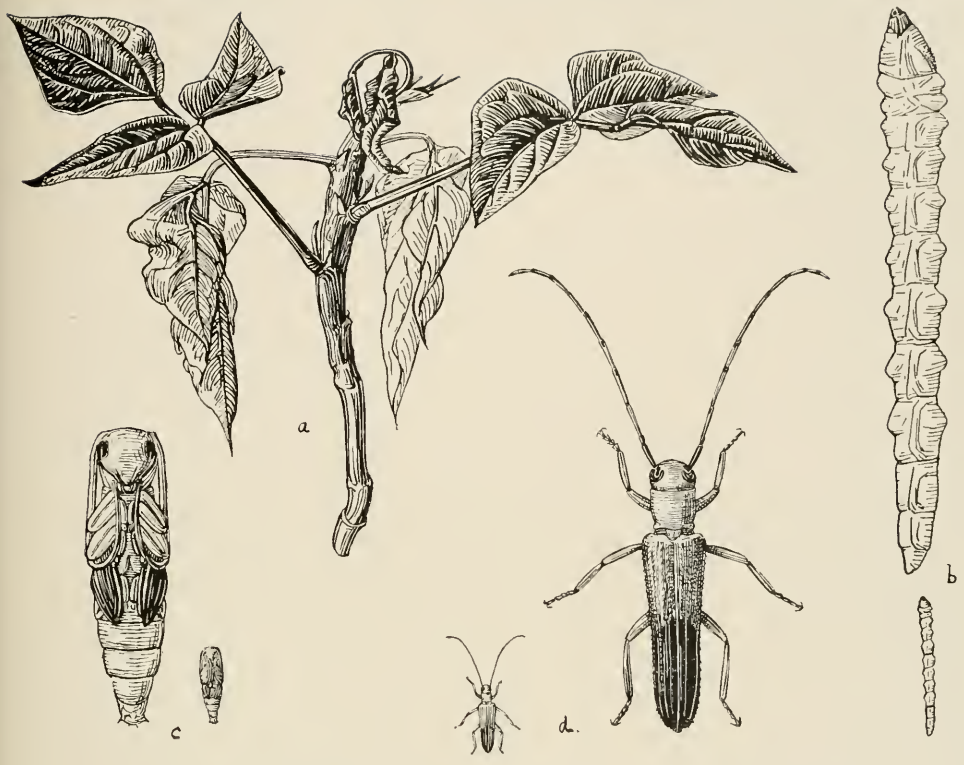


Fig. 1. Longicorn boring *Vigna catjang* stem (C. S. 1645).

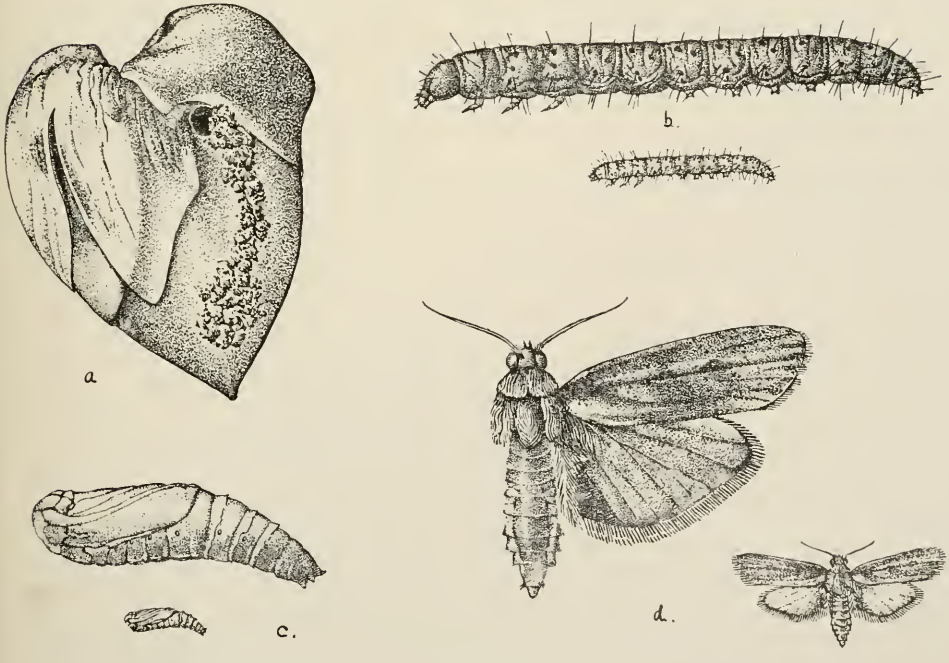


Fig. 2. *Tirathaba* n. sp.

EXPLANATION OF PLATE XV.

Fig. 1. *Calandra stigmaticollis* (C. S. 1752).

a, Portion of attacked coconut stem, showing larval galleries and larvæ *in situ*.
b, Larva, natural size and magnified (×11).
c, Pupa, ,, ,, ,, ,, ,,
d, Imago, ,, ,, ,, ,, ,,

Fig. 2. Longicorn beetle boring orange shoots (C. S. 1766).

a, Larva, natural size and enlarged (×5).
b, Pupa, ,, ,, ,, ,, ,,
c, Imago, ,, ,, ,, ,, ,,

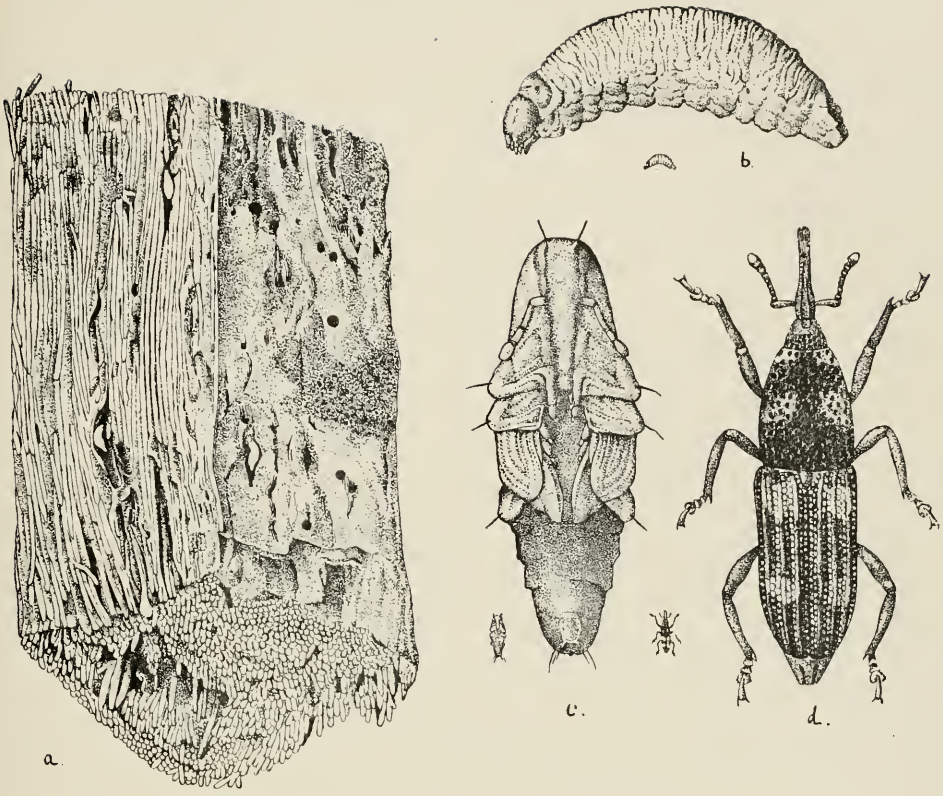


Fig. 1. *Calandra stigmaticollis* (C. S. 1752).

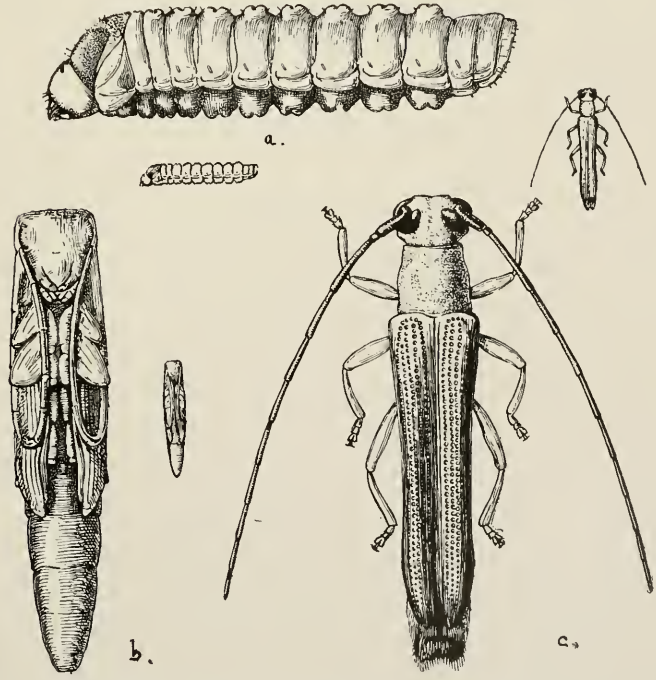


Fig. 2. Longicorn beetle boring orange shoots (C. S. 1766).

found that it is possible to rear this insect on sugarcane stems also.

(4) An unidentified Longicorn (Plate XV, fig. 2) was found boring and killing orange shoots in Sylhet. The grubs bore into the new shoots which appear in spring and cause them to wither.

(5) Eurytomine wasp in *Sesbania* pods. A small Eurytomine Chalcidid was observed to infest *Sesbania* pods at Pusa in September, 1917, and was kept under observation throughout the year. The eggs are laid in the green pods, the larvæ feeding on the seeds, almost all of which are destroyed. Pods infected when young do not develop any seed but shrivel up; in older pods the seeds are rendered useless, their contents being consumed. At the end of the season the damage in a small experimental plot amounted to about 90 per cent. Various remedial measures, such as deterrent spraying, were tried, but picking off the dry pods at frequent intervals gave the best results.

Investigations into the life-histories and habits of pests and other insects were continued. Brief accounts of the observations on the pests of sugarcane, rice and other main crops are given above under those crops. The more important points noted with regard to some of the other insects under rearing during the year are noted below :—

(6) *Amsacta moorei sara.* Hibernating pupæ were received from Dohad in May, 1917. In the Insectary at Pusa moths emerged from these up to 24th June, 1917. Eggs were obtained and a cycle observed; this took a full year, the pupal period extending from July, 1917, to June, 1918. This Gujarat form seems to be biologically distinct from the typical South Indian form *moorei*, but I have been unable to detect any morphological differences.

(7) *Eugnamptus marginatus* (Plate XVI, fig. 1). The salient points in the life-history were given in last year's Report. A point determined by subsequent observation is that the grubs sometimes remain underground in a resting condition for more than a year.

(8) *Agrotis ypsilon.* In a previous Report an account was given of the rearing of this insect under artificial conditions throughout the hot weather; successive broods were then obtained up to August, when the eggs failed to hatch. During the current year full-grown caterpillars were observed on 3rd September, 1917, feeding in an experimental plot of tobacco on the Farm. Eggs must have been laid in this tobacco plot during the first half of August. This insect is therefore capable of breeding in the Plains during the Rains, though whether the parents of these larvæ had bred in the Plains or were early migrants from the Hills remains uncertain.

(9) *Azygophleps scalaris* (Plate XVI, fig. 2). This year caterpillars were found here for the first time boring *Sesbania* stems. The moths appear in May, there being only one generation in the year, aestivation and hibernation taking place in the larval state.

(10) *Agromyza* sp. About fifteen acres of pea (*Pisum arvense*) grown alone and about seventeen acres grown intermixed with other crops were under observation during the Pea Stem-fly season. In both the plots about 0·4 to 0·5 per cent. of the pea plants were found drying up with external symptoms of Stem-fly attack, but closer examination showed that only about 8 per cent. of the drying plants were affected with the fly and that the loss of the remainder was not due to insect attack.

(11) *Ancylolomia chrysographella.* From further observations it seems evident that this is not usually a pest of rice around Pusa. A search over large areas revealed only a single larva in a dry seed-bed.

(12) *Cryptorrhynchus gravis.* This weevil causes serious damage to mango fruits in Eastern Bengal and Assam, the fruits being bored by the grub and rendered valueless. The damage done is very great, so much so that it is often difficult to find fruits which are unattacked. This pest was investigated at Dacca at the end of July, 1917, when more than three dozen adult weevils were found on a single mango tree, hiding amongst the roots of an epiphyte.

EXPLANATION OF PLATE XVI.

Fig. 1. *Eugnamptus marginatus* (C. S. 1457).

a, Mango shoot; an adult weevil (natural size) is seen cutting off a leaf for the purpose of ovipositing in the detached portion.

b, Larva, natural size and magnified (×8).

c, Pupa, ,, ,, ,, ,, ,,

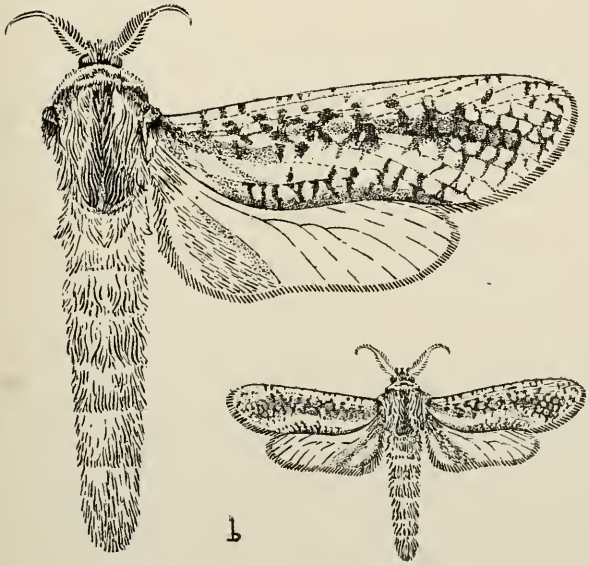
d, Imago, ,, ,, ,, ,, ,,

Fig. 2. *Azygophleps scalaris* boring *dhaincha* stem (C. S. 1807).

a, Larva, natural size and magnified (×3).

b, Moth, ,, ,, ,, ,, ,,

Fig. 1. *Eugnamptus marginatus* (C. S. 1457).



Further observations were made in June, 1918, in Sylhet, where isolated mango trees growing wild in the jungle as well as those cultivated in rather isolated portions and having hardly any epiphytes growing on them were found to be equally infected. In confinement at Pusa the adult weevils did not live beyond September, but it seems likely that in Bengal and Assam it may pass the winter as an adult. This pest requires close observation for a full year under field conditions to enable remedial measures to be suggested.

(13) The Longicorn borer (? *Oberea* sp.) in stems of *Phaseolus aconitifolius*, mentioned in last year's Report, has been observed to rest for two years in the larval state.

(14) *Odontotermes assmuthi.* Colonies were again established in tile nests from eggs laid by winged imagines, but we have been unable to carry them on beyond October, by which time the first-hatched eggs have become adult soldiers and workers.

(15) *Microtermes obesi.* After several failures in former years, colonies have this year been established in artificial nests. Eggs have been obtained from winged imagines and are hatching out at the time of writing this Report.

(16) The following insects have been observed to have only one generation in the year, *viz.*, *Anomala bengalensis*, *A. biharensis*, *Adoretus caliginosus*, *Cryptocephalus sexsignatus*, an unidentified Lamiad borer in *Saccharum* sp., and three unidentified lepidopterous borers in *Saccharum* spp.

(17) *Cosmopteryx phœogastra.* This was referred to in last year's Report under the name *C. manipularis*, but has since been differentiated and described by Mr. Meyrick in the *Entomologists' Monthly Magazine.* Larvæ mining bean leaves were collected in November, 1916, and were apparently resting at that time; they continued to rest and emerged in July, 1917.

(18) *Stictaspis ceratitina.* The maggots of this Fruit-fly were found in large numbers in July and August in new

bamboo shoots which were dying. Experiments undertaken to ascertain whether this fly was the direct cause of the death of the shoots were inconclusive.

(19) *Argyroploce paragramma* (Plate XVII, fig. 1). The larvæ of this Eucosmid moth were found to be very common at Pusa in July, boring into new bamboo shoots. Generally a great many caterpillars were found in the same shoot boring the stem, completely hidden under the protection of the leaf-sheaths. They seemed to be responsible for the death of a fair percentage of new shoots.

(20) *Nodostoma subcostatum* (Plate XVII, fig. 2). This Chrysomelid beetle had been known hitherto as a pest of plantain, nibbling the leaves and fruits. In October, 1917, it was observed to nibble the surfaces of young grape-vine leaves to such an extent as to kill the young leaves. The larvæ were found underground amongst grass-roots in July.

(21) *Balaninus c-album* (Plate XVIII, fig. 1). This weevil had been reared before from seeds of *Eugenia jambolana*, but little was known about it. This year observations were made to determine its real connection with the fruits. It has only one generation in the year. The adult weevils emerge in May and June, and feed on young green fruits by puncturing them with their snouts. The punctured fruits grow and ripen but the punctured spots on them do not grow and appear later on as so many pits in the ripe fruits; this is why the majority of ripe fruits are deformed in shape. The eggs are deposited in the fruits whilst the latter are still on the tree. The weevils appear in enormous numbers and by the time the fruits are ripe practically every seed harbours a grub. Later on, the grubs, when full-grown, leave the seeds and go into the ground and rest there until the next season. The obvious remedy is thorough destruction of the seeds.

(22) A white Mite occurred on the tender leaves of jute in the experimental plots of the Imperial Mycologist. The mites fed on the under-surfaces of the leaves which had a lacerated brownish appearance and were somewhat

EXPLANATION OF PLATE XVII.

Fig. 1. *Argyroploce paragramma* (C. S. 1631).

a, Bamboo shoot with outer sheathing leaves removed, showing bore-hole of larva.

b, Larva, natural size and magnified (×5).

c, Pupa, „ „ „ „ „

d, Imago, „ „ „ „ „

Fig. 2. *Nodostoma subcostatum* (C. S. 1719).

a, Grape-vine leaf eaten by beetles.

b, Beetle, natural size and magnified.

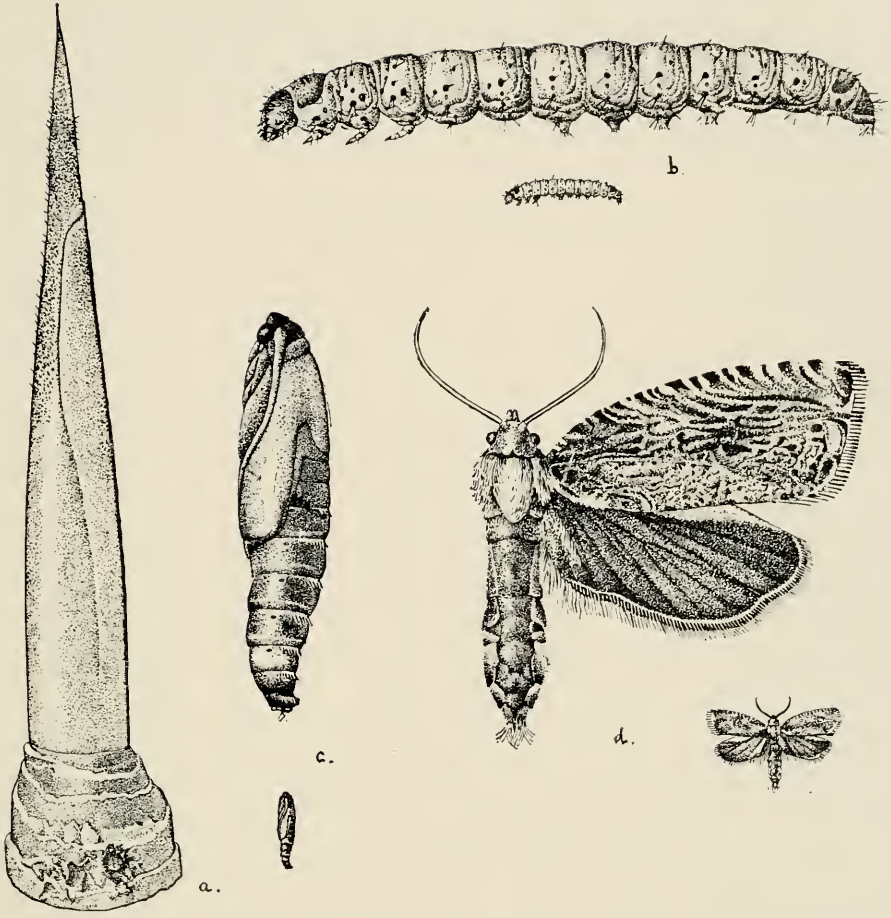


Fig. 1. *Argyroploce paragramma* (C. S. 1631).

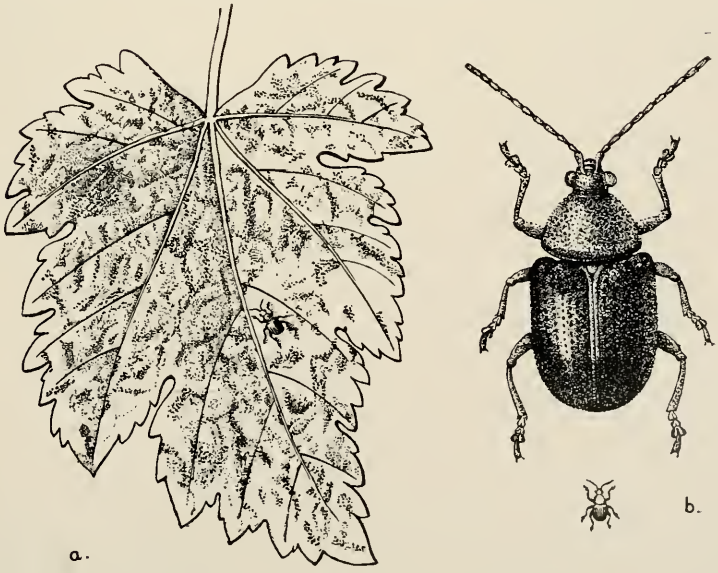


Fig. 2. *Nodostoma subcostatum* (C. S. 1719).

EXPLANATION OF PLATE XVIII.

Fig. 1. *Balaninus c-album.*

a, Immature fruits of *Eugenia jambolana* with adult beetles puncturing them (natural size).
b, Mature fruit of *Eugenia jambolana*, showing distortion and pits caused by punctures of *B. c-album* (natural size).
c, *Eugenia jambolana* fruit cut open, showing larva of *B. c-album* feeding inside the seed (natural size).
d, Larva, natural size and magnified (×7).
e, Imago, magnified. (The natural size is shown in *a*.)

Fig. 2. *Belionota prasina* (C. S. 1720).

a, Larva, natural size and magnified (×2⅓).
b, Pupa, ventral view, natural size and magnified (×2⅓).
c, Pupa, dorsal view, magnified (×2⅓).
d, Imago, natural size and magnified (×2⅓).

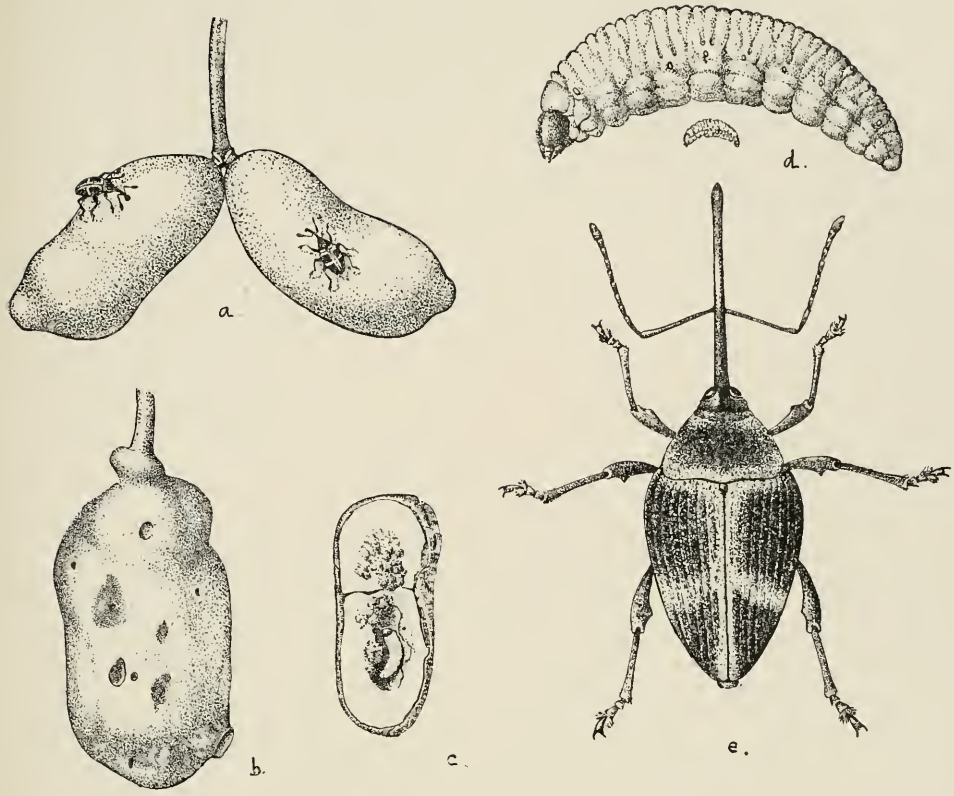


Fig. 1. *Balaninus c-album.*

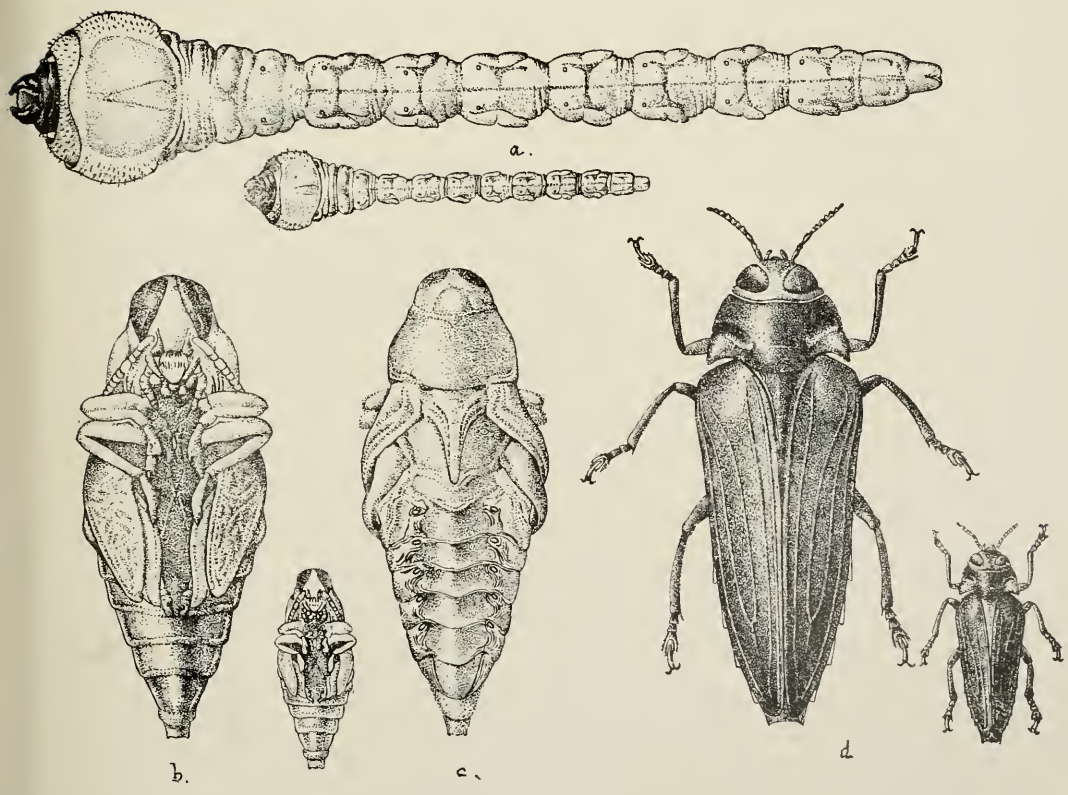


Fig. 2. *Belionota prasina* (C. S. 1720).

EXPLANATION OF PLATE XIX.

Fig. 1. *Alcides frenatus* (C. S. 1672).

a, Larva; natural size and magnified (× 5).
b, Pupa, ,, ,, ,, ,, ,,
c, Imago, magnified (× 5).
d, Mango shoot bored by larva, natural size.
e, Imago puncturing mango shoot, natural size.
f, Punctures made by adult weevil for feeding and egg-laying.
g, Hole of exit of adult weevil from mango shoot.

Fig. 2. *Giaura sceptica* (C S. 1659).

a, Larva, natural size and magnified (× 5).
b, Cocoon, ,, ,, ,, ,, ,,
c, Pupa, ,, ,, ,, ,, ,,
d, Imago, ,, ,, ,, ,, ,,

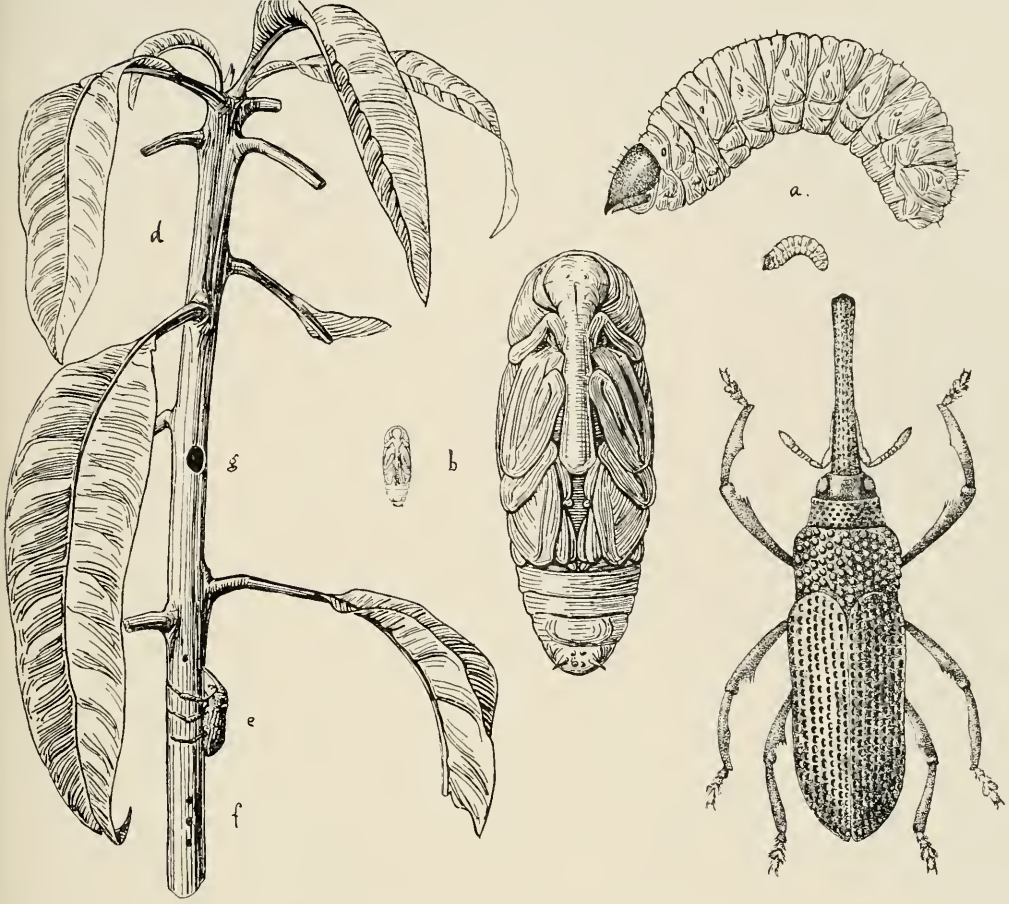
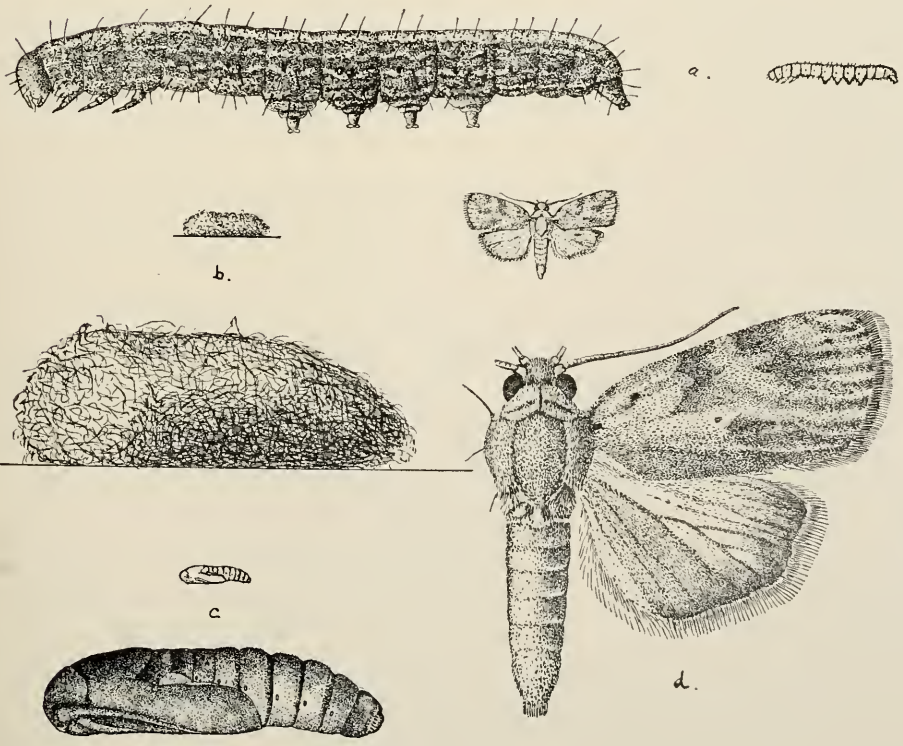


Fig. 1. *Alcides frenatus* (C. S. 1672).



crumpled longitudinally. Unlike Red Spider, there was no webbing. A single spraying with a spray composed of 1 lb. olene soap and six ounces of flowers of sulphur in 12 gallons of water proved effective.

(23) A species of Tingidid bug was noted to cause severe damage to *Bela* (*Jasminum sambac*) leaves at Bankura. Spraying with simple soap solution was effective.

(24) *Glyphodes caesalis* was observed to attack practically every fruit of jak throughout Sylhet, even large fruits not being immune. This insect is known as a jak-pest in Southern India, but has not been noted before as a pest north of the Madras Presidency.

(25) *Belionota prasina* (Plate XVIII, fig. 2). At Surat a dead mango tree was found to be full of the larvæ of this Buprestid beetle, and the death of the tree had apparently been caused by them. The larvæ were in various stages of growth and apparently represented more than one brood. The adult beetles began to emerge at Pusa in October, 1917, and continued to do so until April, 1918.

(26) *Alcides frenatus* (Plate XIX, fig. 1). This weevil was observed at Dacca in July as a pest of mango. Eggs are deposited in the shoots which are tunnelled by the grub, whose pellets of excrement are thrown out through small holes gnawed in the sides of the tunnel. Pupation takes place inside the burrow, the adult weevil gnawing its way out through a large hole of exit. The adult weevils are found pairing and ovipositing freely on the shoots.

(27) *Chlumetia transversa*. The larvæ have been found at Pusa tunnelling fresh mango shoots in a way very similar to that of *Alcides frenatus*, the frass being ejected exactly in the same manner.

(28) *Giaura sceptica* (Plate XIX, fig. 2). The larvæ of this moth were found in large numbers at Pusa in August rolling the tender leaves of velvet bean.

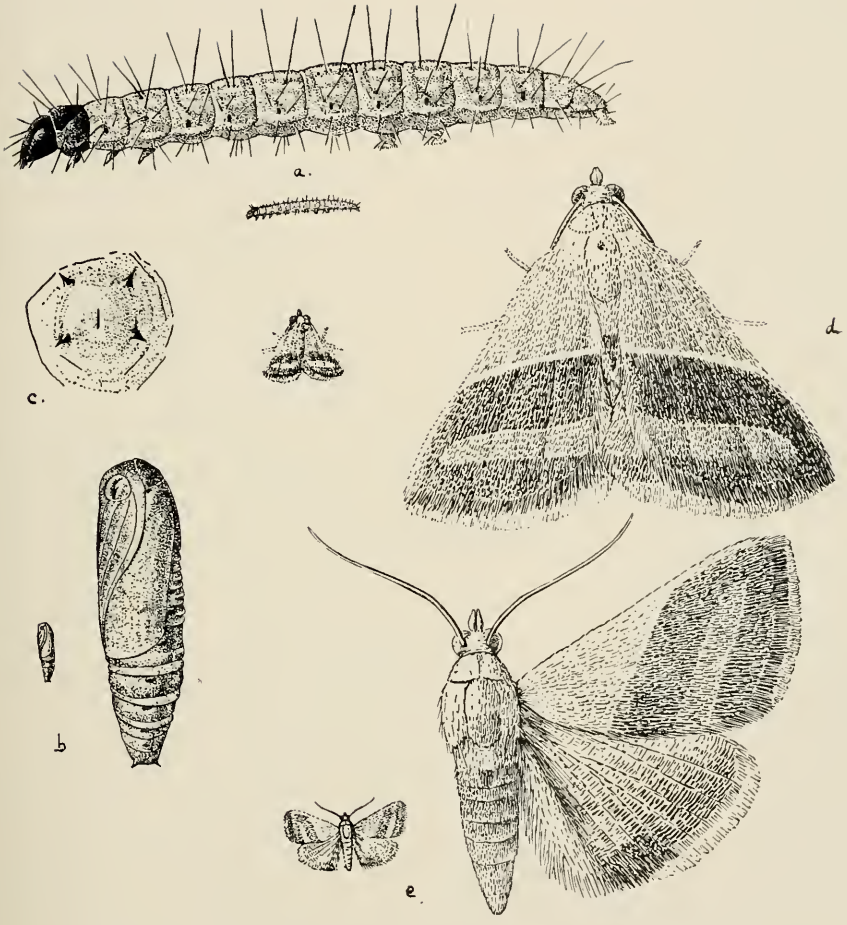
(29) Severe damage was observed to be caused to a crop of Mung (*Phaseolus mungo*) at Pusa in August by the

following, *viz.*, *Catochrysops cnejus*, *Anarsia ephippias*, *Eucosma melanaula* and *Eublemma hemirhoda* (Plate XX). *A. ephippias* and *E. melanaula* commenced the attack by rolling and damaging the tender top-leaves, and, when the crop began to flower, all four appeared and damaged the flowers. They continued their injurious activities when the pods formed, all the four boring into the pods and eating the seeds. *Eucosma melanaula* was also observed to cause similar damage to the flowers and pods of *Phaseolus aconitifolius* and also to damage the tender top-leaves of an experimental crop of Florida Beggar Weed.

(30) Quite appreciable damage was done in August to the new tender leaves of litchi by *Acrocercops hierocosma*, whose larvæ mined them, and by *Argyroploce leucaspis*, whose caterpillars rolled and nibbled them. The latter especially was very common.

Grain Storage Experiments. The storage experiments undertaken three years ago were concluded and an account of them will be written up. The method of storage under a layer of sand gave the best results, the grains and pulses remaining perfectly safe and in good condition. The straw granaries mentioned in last year's Report did not give as good results as had been expected.

The status of *Tribolium castaneum* was definitely determined during the year. It is essentially a pest of ground wheat (flour, *atta* and *suji*) and does great damage to these products, especially during the Rains, by imparting to them a characteristic nauseous smell and taste, which lowers their value as food and consequently also the price of infected material; in cases of bad infection, indeed, the flour may be quite uneatable. In order to determine its capacity for injury to sound wheat, *i.e.*, whole grains unaffected by *Calandra oryzæ* or *Rhizopertha dominica*, several thousand adults of *Tribolium castaneum* were confined in an earthen vessel with a quantity of wheat which, at the end of a year, was found to have been hardly damaged, although breeding on a small scale had taken place, as was evident from a few cast larval skins. This



Eublemma hemirhoda (C. S. 1649).

a, Larva, natural size and magnified (× 5).
b, Pupa, ,, ,, ,, ,, ,,
c, details of anal extremity of pupa, posterior view.
d, Imago, resting position, natural size and magnified (× 5).
e, Imago, natural size and magnified (× 5).

observation was also corroborated by the fact that the wheat obtained last year for storage experiments contained *Tribolium* when stored; but, in the samples which were unaffected by *Calandra* and *Rhizopertha*, no damage was done by *Tribolium*, whereas, in samples which were affected by *Calandra* and *Rhizopertha*, these two pests first produced wheat dust in which *Tribolium* could breed and it was only in these samples that *Tribolium* bred profusely.

For the first time, at least in the Pusa area, *Bruchus chinensis* and another unidentified[1] species of *Bruchus* were observed to breed in the fields in pods of cowpea (*Vigna catjang*), but only a few could be found after a good deal of search. Whilst *Bruchus chinensis* is thus shown to be capable of breeding in the field, it is essentially a pest of stored pulse, to which it causes serious damage.

Another unidentified[1] species of *Bruchus* was observed breeding in *Sesbania* pods in the field, and was kept under observation both in the Insectary and in the field. The beetles did not breed in the stored seeds and the emergence of the adults extended over a long period from February to June.

In last year's Report mention was made of an experiment to find out the effect of sunning pea (*Pisum arvense*) seeds affected by *Bruchus affinis*. Twenty-six pounds of pea seeds were taken from a crop harvested from a field known to be affected. Half of these were dried in the sun for seven days, when their weight was reduced to 12 lb. 9½ oz.; the other half was kept as a check. After a period of a year, in the sunned sample the damage was one-third of that in the untreated sample. Thus, although damage was not entirely prevented, it was checked to a very large extent.

Insecticides. Incosopol, a contact insecticide manufactured by the Indian Cotton Seed Oil Company, Navsari, was tested on Aphids, Scale-insects and Mealy-bugs, and

[1] A collection of the various Bruchid beetles reared from pulses was sent out during the year for identification but the names had not been received at the time of writing this Report.

in every case gave satisfactory results. Two grades were tested, of which that known as No. 2 gave much better results than did No. 1. Resin Compound, Fishoil-Resin Soap, and Incosopol No. 2 seem all about equally effective insecticides against Aphids, Aleyrodids, Scale-insects and Mealy-bugs, which are common garden pests; Fishoil-Resin Soap and Incosopol No. 2 can be safely recommended as they cause no injury even to tender foliage.

Against the common house Cockroach (*Periplaneta americana*) infesting a godown trials were made of a mixture of Boracic Acid in honey. In an experiment in the Insectary adults as well as nymphs fed greedily on this mixture; after the second day they began to pass liquid excreta and the nymphs died off in the course of five days; the adults, however, resisted longer, not dying even on the eighth day, but by that time they were certainly very sick, unable to walk and lying on their backs. Boracic Acid, though effective, is therefore a very slow poison to these insects. In a house they may be trapped in numbers in an open-mouthed kerosine tin in which is placed a quantity of weak solution of *gur* (molasses) in water; the adults are attracted and drop into the *gur* solution and appear unable to escape.

Protection of wood against Termites. Simple experiments in the protection of wood against Termites (so-called "White Ants") have been in progress since 1910, the termite utilized being *Microtermes obesi.* The name of the species concerned is given here because different species of termites have different habits and tastes, facts which are usually overlooked in carrying out similar experiments. Some kinds of timber may be more or less immune to attack by the local termites in one district, yet the same kinds of timber may be greedily attacked by other species of termites in another district. Our experiments have shown also that any particular method of treatment does not produce the same deterrent effect in all varieties of wood. The deterrent effect depends on (1) the treatment employed, (2) the variety of wood treated, and (3) the kind

of termite against which protection is sought. Under conditions *at Pusa* we have found that teak, sissoo (the red heart-wood), and jarrah naturally resist termite (*M. obesi*) attack without any treatment, and that, in the case of other woods subject to attack, treatment, whatever be the reagent used, in every case gives better results than no treatment. Wood can be rendered immune by impregnating it with (1) arsenicals or (2) creosote or wood-tar or some similar liquid, and the wood will remain immune as long as the arsenic is not dissolved out or as long as the smell of creosote, etc., is present. In actual practice treatment of wood with arsenicals is not easy without employment of a pressure apparatus, as it is difficult to get sufficient arsenic into the wood to preserve it for any length of time. Treatment with creosote, etc., however, is quite simple, as the desired results can be obtained by repeated paintings or by dipping in the preservative those parts of the timber which are to remain exposed to attack; although even in these cases, the use of a pressure apparatus to increase the amount of preservative taken up by the wood will considerably prolong the period of protection. For the ordinary person, however, who can only paint or dip woodwork likely to be attacked by termites, the use of creosote will usually give the best results, especially for underground woodwork.

Lantana Work. This work was taken up in November, 1916, on instructions from Government and has for its object the collection of information regarding the occurrence within the Indian Empire of any insects which may be utilized as efficient checks on the growth of *Lantana*. With this object Mr. Y. Ramachandra Rao, M.A., Entomological Assistant in Madras, has been placed on special deputation under the Imperial Entomologist, and during the year under Report worked in Southern India, Burma and Assam. A very large number of insects has been found to occur on *Lantana* but most of these appear to be merely casuals, not confined to *Lantana* but very polyphagous in their habits, or of no importance as checks on *Lantana*. This investigation is still in progress.

IV. Bees, Lac and Silk.

Bees. The experiments with the Indian Bee (*Apis indica*) were continued. There is, however, nothing of special interest to record.

Advice and help was given during the year to various bee-keepers in India.

A note was written and submitted to Government on the adulteration of beeswax in India.

Lac. Emergence of lac larvæ took place at Pusa on 12th October, 1917, for the winter brood, and on 20th June, 1918, for the summer one. Forty trees were inoculated in October-November and sixty trees in June. Brood-lac was supplied to various inquirers, and numerous inquiries regarding lac were dealt with during the year. No students attended the lac courses during the year. An article on the present position of the Lac Industry in India was written for the *Agricultural Journal of India*. This year it was found that, besides the species of *Eublemma* and of Chalcididæ which normally damage lac whilst on the trees, considerable damage was done to Ber (*Zizyphus jujuba* brood-lac by *Holcocera* (*Hypatima*) *pulverea* (Blastobasidæ). The larvæ of this moth usually damage scraped and unwashed stick-lac in store, but do not damage the growing lac as a rule.

Silk. The establishment of the silk-house, which is on a temporary footing, has been extended up to 31st March, 1919. Large numbers of broods of both mulberry and eri worms have been under rearing during the year, and the work of crossing the races of the mulberry worm has been continued with the object of producing a superior fibre. The multivoltine mongrel races, which we have already succeeded in establishing, continue to yield more and better silk than the indigenous multivoltine races. Eggs of some of these races have been distributed on a small scale to practically all silk centres throughout India, for trial under local conditions there, and the reports received, with the exception of that from the Superintendent of Sericulture, Berhampore, show that satisfactory results have been

obtained from these rearings. It is not yet, however, considered advisable to distribute the eggs of these races on a large scale until we are quite certain that they will not degenerate later on. At present we have twenty different mongrel races under rearing and are carefully recording the results in each case.

Numerous inquiries concerning rearing, reeling, dyeing, bleaching and spinning were dealt with during the year. Silk samples and bulletins on silkworm rearing were distributed to many applicants. Silk exhibits were sent during the year to the following:—(1) Madras Exhibition of Indian Arts and Industries (Diploma of Merit awarded), (2) Exhibition of Foods and Household Requisites, Bombay (Certificate of Merit), (3) Banjetia, Bengal, (4) Gwalior (Gold Medal), (5) Gujranwala (Gold Medal), and (6) Gorakhpur (Certificate of Merit). All the operations in sericulture from the egg to the finished product were exhibited in Madras and Gwalior, and these were much appreciated by the visitors to these Exhibitions. Eri, muga, tasar and mulberry silkworm show-cases were supplied to the Superintendent of Sericulture, Berhampore, Bengal.

Silk pieces and castor seed to the value of Rs. 884-0-5 were sold during the year and the sale proceeds credited to Government.

The Pusa silk-twisting machine, on which about one pound of mulberry, muga or tasar thread can be twisted by one boy or woman in one day of eight hours, was sent to Berhampore (Bengal) for exhibition purposes. This is believed to be an improvement on former local methods of silk-twisting. A silk merchant at Berhampore, who is supplying silk to the Home Industry Association of Calcutta, is twisting cotton and matka (handspun waste mulberry silk) on it, and is satisfied with the working of the machine; with this coarser thread one seer (two pounds) can be twisted in an eight-hour day.

Large quantities of mulberry seeds and mulberry silkworm eggs were supplied to the Agricultural Department

in Mesopotamia. Eri seed cocoons were sent to the Entomological Department, Egypt, where the worms are being reared successfully, to the Department of Agriculture in Mauritius, and to the Salvation Army for sending to East Africa. Eri and mulberry silkworm eggs were supplied to 84 and 85 applicants respectively, and mulberry seeds and cuttings and castor seeds were supplied to 14 applicants. Univoltine eggs of French and Japanese races, and Japanese bivoltine eggs, were sent to Guindy, Shillong and Muktesar for cold storage, and were successfully reared at Pusa in October, 1917, and March, 1918. Eggs of two Chinese univoltine races were received from the Salvation Army, Simla, and were successfully reared.

Seven students completed short courses in sericulture during the year and three students remained under training at the close of the year. Of the seven who completed their courses one came from Travancore, one from the Salvation Army Silk School at Bangalore, one from Bengal, and two each from Bihar and Indore.

A Second Report on the Experiments carried out at Pusa to improve the Silk Industry in India and a pamphlet on the anatomy of the silkworm and moth were published during the year; a Bengali translation of the former is in the press and one of the latter was published in the *Krishi Sampada* of Dacca.

V. Illustrations.

Coloured plates illustrating the life-histories of the following insects were prepared during the year, *viz.*, *Pseudococcus* sp. causing *tukra* disease of mulberry, *Ophideres materna*, *Cryptorrhynchus gravis*, *Platyptilia pusillidactyla* and *Eretmocera impactella*. Drawings in black-and-white, showing life-histories in more or less detail, were prepared of about seventy of the insects reared in the Insectary, and about the same number of other drawings of insects were also done.

Thirty-four new coloured plates of pests were issued in the *Report of the Proceedings of the Second Entomological*

Meeting, published during the year. No new coloured plates were printed during the year, but there is an ever-increasing demand for the plates already available.

The issue of coloured lantern-slides of insect pests has been continued as far as possible but only under considerable difficulties regarding the preparation of these slides. As there is a considerable demand for these slides on the part of the Provincial Agricultural Departments, every endeavour will be made to arrange for their preparation and supply.

VI. Miscellaneous.

Correspondence. A total of 114 parcels of specimens, mostly of crop-pests, was received during the year for identification and advice, whilst 911 letters were received and 1,221 issued, but all these numbers are exclusive of a large amount of routine correspondence, which every year becomes more and more onerous and takes up time which should be devoted to more scientific work.

VII. Insect Survey.

Steady progress has been made in additions to, and arrangement and identification of, the collection which continues to grow so that the question of space will become pressing in the near future. Temporary ease has been obtained by the removal of the Lepidoptera to a new room, 30×30 feet, but there is no further room for expansion in the present building. Keeping the collection in boxes in open racks, as has been done hitherto, has the serious disadvantages of exposing the specimens to risk of damage owing to the climate at Pusa and also of occupying an unnecessary amount of space; storage in cabinets or in double-sized store-boxes kept in closed almirahs would considerably improve the conditions of preservation of the specimens and also economize space. In this connection it may be of interest to compare the growth of the collections during the last ten years. It is not practicable to

take a census of the total number of specimens, which would run into hundreds of thousands, or to consider the unnamed and unsorted material, but, taking the definitely named species, we obtain the following figures:—

Order	1908	1910	1918
Hymenoptera	400	419	758
Diptera (excluding disease-carriers) .	...	...	168
Lepidoptera	600	1,235	2,540
Coleoptera	650	1,236	1,939
Rhynchota	500	606	743
Neuroptera (*Sensu antiquo*) . .	1	60	180
Orthoptera (*Sensu antiquo*) . . .	70	91	143
Totals . .	2,221	3,647	6,471

The staff required for the upkeep (which includes the sorting and identification, as well as the mere preservation, of the many thousands of specimens received every year) has not been increased during this time, although it will be seen that the work is constantly expanding and has already become very heavy, although this is only one branch of the activities of the Entomological Section. The War has interfered considerably with the transmission of specimens for identification, but the following collections have been sent out to specialists in the groups named and our thanks are due to them for the ready help afforded:—

(*i*) Microlepidoptera to Mr. E. Meyrick, F.R.S. Named and returned. The descriptions of numerous novelties have been published in *Exotic Microlepidoptera.*

(*ii*) Diptera to Mr. E. Brunetti. Mostly named and returned.

(*iii*) Rhynchota to Mr. W. L. Distant. Numerous novelties have been described in his recently issued seventh volume in the *Fauna* series, but the specimens have not been returned as yet.

(*iv*) Cicindelidæ to Mr. S. W. Kemp. Not yet returned.

(*v*) Aquatic Rhynchota to Mr. C. A. Paiva. Not yet returned.

(*vi*) Aculeate Hymenoptera to Mr. R. E. Turner. Returned named, and descriptions of novelties published in an Entomological Memoir and in the *Annals and Magazine of Natural History.*

(*vii*) Dryinidæ to Mr. J. C. Crawford, Washington.

(*viii*) Psyllidæ to Mr. D. L. Crawford, California.

(*ix*) An Aphid forming galls on *Rhus semialata* to Mr. A. C. Baker, Washington.

(*x*) Muscid flies affected with *Empusa muscae* to Mr. H. T. Gussow, Ottawa.

(*xi*) *Paruscanoidea* sp. (Chalcididæ), parasitic on eggs of *Hilda bengalensis*, to Dr. L. O. Howard, Washington.

(*xii*) A large consignment of *Microbracon* spp., parasitic on Cotton Bollworms, sent to Professor C. T. Brues, was unfortunately lost owing to enemy action. This loss was particularly unfortunate as this sending contained some very valuable material which it will take a long time and much work to replace.

(*xiii*) Ichneumonid parasitic on *Pseudagenia blanda* to Mr. C. Morley. Named as *Gotra longicornis* and returned.

(*xiv*) Carabidæ to Mr. H. L. Andrewes. Not yet returned.

(*xv*) Bruchidæ to Dr. G. A. K. Marshall. Not yet returned.

(*xvi*) Hispinæ and Cassidinæ to Mr. S. Maulik. Not yet returned.

(*xvii*) Odonata (part) to Major F. C. Fraser. Not yet returned.

The following collections sent out in previous years have not yet been returned :—

(*xviii*) Histeridæ to Mr. G. Lewis.
(*xix*) Longicorn beetles to Dr. Gahan.
(*xx*) Anthribidæ to Dr. K. Jordan.
(*xxi*) Rhynchota to Mr. W. L. Distant.
(*xxii*) Tettigidæ to Dr. J. L. Hancock.

Various collections of Indian insects have been received and named and returned as far as possible. These included collections sent by the Provincial Agricultural Departments and by numerous correspondents.

VIII. Programme of Work for 1918-19.

Major.

This will follow generally on the lines of work of the current year and will include general investigations of crop-pests and especially of the pests of sugarcane, rice and cotton, of fruit-trees, of stored grain, and of insects affecting *Lantana*.

Minor.

Results in various lines of work require to be written up and published as far as possible. Work and experiments in silk, lac and bee-keeping will be continued, and new insecticides and insecticidal methods tested as occasion arises. Systematic work on Indian insects will be carried out with our own resources and the help of specialist correspondents. Advice and assistance will be given as far as possible to Provincial Departments and to all inquirers on entomological subjects.

IX. Publications.

The following publications, either written by the Pusa staff or based on material sent from Pusa, have been actually issued during the year :—

Bagnall, R. S. . . Brief Descriptions of new Thysanoptera. IX. (*Ann. Mag. Nat. Hist.* (9), I, 201-221.)

Bagnall, R. S. . . On two species of *Physothrips* (Thysanoptera) injurious to tea in India. (*Bull. Ent. Res.*, IX, 61-64, 2 figs.)

Crawford, D. L. . Philippine and Asiatic Psyllidæ. (*Phil. Journ. Science*, vol. XII, sect. D, 163-174, 1 tab.)

De, M. N. . . Anatomy of Silkworm and Moth. (Grihastha Publishing House, Calcutta.)

De, M. N. . . Second Report on the Experiments carried out at Pusa to improve the Mulbery Silk Industry, compiled under the direction of the Imperial Entomologist. (*Agricl. Res. Inst., Pusa, Bull.* no. 74, pp. 28.)

Distant, W. L. . Rhynchota, Vol. VII. Homoptera; Appendix. Heteroptera; Addenda. (*Fauna of India Series*, pp. 210, 90 figs.)

Fletcher, T. Bainbrigge. *Icerya purchasi* in Ceylon: A warning to India. (*Agricl. Journ., India*, XII, 525-531, tab.)

Fletcher, T. Bainbrigge. Report of the Proceedings of the Second Entomological Meeting held at Pusa on the 5th to 12th February, 1917. Pp. xii+340, 34 col. tabs.; Government of India Press.

Fletcher, T. Bainbrigge. Agricultural Entomology. (*Annual Report, Board Sci. Advice for India*, 1916-17, pp. 78-95, 149-158.)

Marshall, G. A. K. . *Platymycterus*, a new genus of Asiatic Curculionidæ. (*Ann. Mag. Nat. Hist.* (9), I, 245-252.)

Meyrick, E. . . Exotic Microlepidoptera, vol. II, parts 2-5, pp. 33-160.

Meyrick, E. . . Two new Indian species of *Cosmopteryx*. (*Ent. Mo. Mag.*, LIII, 257-258.)

Misra, C. S. . . The present condition of Lac Cultivation in the Plains of India. (*Agricl. Journ., India*, XIII, 405-415, tab. 23, 1 map.)

Ramachandra Rao, Y. Notes on some South Indian Cecidomyiids causing galls in grasses. (*Journ. Asiat. Soc., Bengal*, n. s., XIII, 299-306, tab.)

Turner, R. E. . . Notes on Fossorial Hymenoptera, XXXV. On new Sphecoidea in the British Museum. (*Ann. Mag. Nat. Hist.* (9), I, 356-364, fig.)

REPORT OF THE IMPERIAL PATHOLOGICAL ENTOMOLOGIST.

(F. M. Howlett.)

I. Introduction.

I was in charge of the Section for 10 months of the year, from August 28, 1917, when I returned from military duty in England. From 1st July to 27th August, 1917, Mr. T. Bainbrigge Fletcher, Imperial Entomologist, was in charge of this Section in addition to his own duties.

The greater part of the work of the Section during this period may be put under four main heads, work under each head being done chiefly by the officers named against each :—

(1) Mr. P. G. Patel. Observations on the life-histories and habits of blood-sucking and saprozoic insects.

(2) Mr. H. N. Sharma and the Imperial Pathological Entomologist, with M. Shaffi and M. Karim. Experimental and practical work on mosquitos.

(3) Mr. S. K. Sen and the Imperial Pathological Entomologist. Experimental work on insect psychology in relation to feeding and oviposition.

(4) The Imperial Pathological Entomologist. Experimental and practical work on insect-repellants and insecticides.

II. Blood-sucking and Saprozoic Insects.

Attention was chiefly directed to the comparative study of the habits of the larvæ of Tabanidæ, which show marked and interesting differences in the various species, and to working out the life-histories of the Pusa midges (genera *Culicoides* and *Ceratopogon*), a group of minute blood-sucking insects of which very little is known. The main features of several of these life-histories have been ascertained and illustrative coloured plates prepared, the

eggs and aquatic or semi-aquatic larvæ showing somewhat unusual characteristics. In view of the possibility that these flies may convey disease, observations on this curious and little-known group will be continued.

III. Experimental and Practical Work on Mosquitos.

Practical anti-mosquito work has consisted in the continuance of the mosquito campaign in Pusa. So far, with the aid of a very limited temporary staff, this work has, I think, sufficiently justified itself to warrant an extension on the "trap-breeding" lines first advocated by me in connection with the *Stegomyia* investigation of a few years ago. The main idea of trap-breeding is to supplement the ordinary (and almost inevitably incomplete) destruction of natural breeding-places by supplying a large number of alternative breeding-places of a suitable type which will absorb the local egg-supply, but which are in one way or another kept under control so that none of the eggs laid in them shall reach maturity.

The method has now been tried in various parts of the world and seems to have proved uniformly successful. It enables one materially to economize energy in reducing the mosquito population, and minimizes the difficulties associated with imperfect inspection and the discovery by the mosquitos of unnoticed or inaccessible breeding-places, this latter being the main and frequently unavoidable difficulty of the purely destructive methods generally advocated.

Proposals are being submitted for the construction of a number of permanent breeding-places in order to extend the work on the above lines, most of the breeding-places would take the form of small ornamental fishponds inspected and stocked with suitable local fish by the campaign staff.

A certain number of organic compounds have been tested as larvicides, but no results of any practical interest have been obtained except in the case of the Xanthates, which have a very high toxicity for mosquito larvæ.

A long series of experiments has been carried out with the object of ascertaining the factors which influence mos-

quitos (especially *Stegomyia scutellaris*) in their choice of breeding-places, and the deterrent or attractive effect of dilute solutions of a number of chemical substances as compared with pure water.

The results at present obtained indicate that—

(1) Temperature has a definite influence, eggs being laid more freely in warm water.

(2) Various chemical compounds have a deterrent effect when dissolved in small quantities ($\frac{1}{2}$-1 per cent.) in the water.

(3) A few chemical substances (especially sodium citrate and tartrate) have an attractive effect, a far larger number of eggs being laid in dilute solutions of these substances than in pure water.

This work is being continued, in conjunction with experiments on the effect of dilute solutions of chemical compounds on the development of mosquito larvæ.

IV. Insect Psychology in relation to Feeding and Oviposition.

A good deal of work has been done in this direction, but the results are not of a kind to be profitably discussed in a report of this nature.

One immediate outcome of them was the series of experiments on the egg-laying of mosquitos mentioned in the preceding section, and they have had a direct bearing on the work in connection with repellants.

V. Insect Repellants and Insecticides.

The subject of repellants and insecticides is one to which I have given much personal attention in the course of the last four years, and since my return from England I have continued experiments on repellants, and have attempted to devise standard methods for testing repellants and insecticides which will give a reliable index of their actual practical value.

Practical work in this connection, in collaboration with Captain Pool, A.V.C., was undertaken at the instance of

the Surra Committee meeting at Simla in May. This work has for its object the discovery of a repellant, limited as regards cost, which shall effectively prevent Tabanidæ from attacking camels, and so help to check the spread of surra among transport and other animals.

Through the kindness of the Inspector-General of Forests and the officers of the Forest Department at Dehra Dun, arrangements have been made to carry on the work in the laboratories of the Forest Research Institute, and it is still in progress.

VI. Programme of Work for 1918-19.

The most probable *main lines of work* are—

(1) General methods of insect-control.

(*a*) Attempts to ascertain the nature of the reactions which determine the processes of feeding, pairing, and egg-laying in insects.

(*b*) The direct effect of certain physical and chemical conditions or agents on the above reactions, more particularly with reference to disease-carrying insects.

(*c*) The physiological action of insecticidal and deterrent substances.

(2) General bionomics of insects and Arachnids which suck blood or otherwise cause disease in man or animals.

(3) Special work on surra-prevention, undertaken at the instance of the Surra Committee, in collaboration with officers of the A.V.C.

(4) Investigation of methods for combatting mange in transport camels, in collaboration with the military authorities.

VII. List of Publications.

Sen, S. K. . . . Beginnings in Insect Physiology and their Economic Significance. (*Agric. Journ. of India*, vol. XIII, pt. IV.)

REPORT OF THE IMPERIAL AGRICULTURAL BACTERIOLOGIST.

(C. M. Hutchinson, B.A.)

I. Administration.

I held charge of the Section throughout the year.

Mr. J. H. Walton, Supernumerary Agricultural Bacteriologist, continued to be on military duty throughout the year.

II. Training.

Mr. S. N. Bose, Bacteriological Assistant to the Agricultural Chemist to the Government of Bengal, was under training in this Section from 3rd January, 1916. He finished his course and was relieved from this Section on the 6th January, 1918.

Mr. Kripa Ram, a student from Punjab, was under training, specially in media preparation, in this Section for a short period from 25th September to 18th October, 1917.

Mr. P. C. Chaudhury, Superintendent of Sericulture, Bengal, was under training in bacteriological technique in connection with the silkworm disease, from 6th to 17th December, 1917, and 6th to 19th February, 1918.

Mr. K. L. Mahta, a student from Kashmir State, was under training in the microscopic technique in connection with the silkworm disease, from 15th March to 30th June, 1918.

Work was done on the following subjects:—

III. Soil Biology.

Nitrification. Further observations were made as to the conditions determining maximum nitrification in various types of Indian soils. Field observations of the seasonal variation and the effect of cropping and of fallow were continued. It was found that the presence of a crop,

whilst diminishing the apparent amount of nitrification as measured by the nitrate found in the soil, actually increased the amount if it is assumed that the crop takes its nitrogen entirely as nitrate.

In connection with nitrification studies, further observations were made as to the formation of bacterio-toxins in soils, and a paper on this subject was read at the fifth session of the Indian Science Congress at Lahore.

Nitrogen fixation. The First Assistant continued his experiments upon the specific nature of various strains of *B. radicicola* and upon apparent symbiotic fixation of nitrogen without nodule formation in the case of inoculation with foreign strains. Clear evidence of activation of growth by non-symbiotic nitrogen fixation both by azotobacter and nodule organisms was obtained. These observations will form the subject of a paper now in course of preparation.

Green-manuring. The field trials arranged in collaboration with the Imperial Agriculturist were continued on the experimental area of the farm; they are designed to test the field value of the modified method of green-manuring described in *Bulletin 63, Agric. Res. Inst., Pusa;* the increased returns obtained on the *rabi* (winter) crop, although considerable, are not a measure of the practical value of this method which depends largely upon its sustained and residual effect. This has been well illustrated in the various crops on the experimental area of this Section, which have given consistent increases of some 30—60 per cent. not only over the unmanured but over plots receiving adequate applications of such manures as nitrate of soda and oilcake, over a period of three seasons including the year of application. The effect on Java indigo in the third year is especially marked.

Phosphate requirements of soil bacteria. Further work on this subject led to the following general conclusions :—

(1) Increase in available P_2O_5 greatly increases the general bacterial activity of a soil, and there-

with the formation of CO_2; there is a positive relation between the amounts of CO_2 thus formed and the solubilization of phosphate in the soil, but this varies with the character of the latter.

(2) Addition of soluble phosphate increased the ammonification rate in all the soils examined.

(3) Addition of phosphate in many cases diminished the nitrification rate, apparently owing to the disproportionate increase in non-nitrifying organisms. The final result over long periods of time in most cases showed no increase in the total nitrate formed.

IV. Indigo.

The experimental factory referred to in the previous annual report came into use at the beginning of the current year (July 1917), and although its working was seriously handicapped by the over-maturity of the plant, many valuable and interesting observations were made during the short manufacturing season remaining. It is impossible here to give any detailed account of the results obtained which will form the subject of a full report shortly to be issued as a memoir of the Department; the following general summary will give some idea of the conclusions arrived at and of the lines of further work made necessary by the character of the results obtained.

Inoculation with specific bacterial cultures. In the previous year's report of this Section it was shown that good reasons existed for believing that yield of indigo in the process of manufacture depended in the first place upon the completeness of bacterial hydrolysis of the indican content of the leaf; that this was determined by the presence or absence of sufficient numbers of specific bacteria, and that variations in yield between individual factories probably depended mainly upon the character of the bacterial flora of the steeping vat, this being again determined by that of the water supply. This contention was fully sup-

ported and the whole theory confirmed by the experiments carried out in the Pusa factory in 1917.

The main line of experiment lay in the comparison of results obtained in artificially inoculated steeping vats and in uninoculated control vats, making use of pure cultures of various hydrolyzing bacteria isolated from the *khazana*, or *seet* water, or from the walls or timbers of the steeping vats of various indigo factories. Isolation of such bacteria was effected by the use of indican agar, on which those bacterial species capable of splitting off indoxyl from indican formed indigo blue colonies, and examination of a large number of samples from various factories has led to the general conclusion that the known yield of a factory is closely and almost directly proportional to the content of such hydrolyzing bacteria in its water supply.

The first problem to attack was the method of inoculating the water used for steeping in such a way as to ensure the presence of sufficient numbers of the specific bacteria. It may be said at once that this problem rapidly revealed itself as the basic one of the enquiry as a whole, and its solution is still under investigation. Nevertheless the results of the comparatively limited number of experiments made in the Pusa factory conclusively established the main principle that yield of indigo depended upon bacterial action, and consequently upon the presence of adequate numbers of bacteria of the proper kind. The very first experiment in which a comparison was made between the yields of two vats, one inoculated with a pure culture of a bacterium (laboratory mark In_{10}) and the other untreated, gave an increase of 15 per cent. in the inoculated vat, notwithstanding the unsuitability of the over-mature plant available which should have been cut for manufacture at least a month earlier. Subsequent experiments were not invariably conclusive so far as yield of indigo was concerned, but owing to the careful analytical watch, both chemical and bacteriological, kept over every stage of the process, it was not only possible to account for discrepancies but to come to definite conclusions as to the underlying

causes of negative results and the feasibility or otherwise of removing them. The general procedure adopted in carrying out each experiment involved chemical examination of the plant before and after steeping, of the liquor at various stages of fermentation and also after blowing and settling, and of the indigo precipitate or *mal* and lastly of the waste or *seet* water. Thus a close watch was kept upon the fate of the original indican content of the leaf, and the effect of any method of treatment upon the percentages of this constituent which appeared at various stages either in its original form or as indoxyl or indigotin, was accurately ascertained. This naturally involved a very large number of analyses and as the quantitative estimation of indican, indoxyl, or indigotin is a tedious process and as each analysis was made, during the later period, both by the persulphate and isatin methods, it will be realized that the number of experiments was limited by the possible pace of output of the analytical data.

In the same way bacteriological analysis of the fermentation process was carried out for each stage of manufacture, but this analysis necessarily began with measurements of the rate of bacterial growth (by plating) in the mass cultures used for inoculation some hours before manufacture commenced, in order to discover the best conditions for securing successful inoculation. Plates were made from the mass culture after various periods of time from the original inoculation, from the *khazana* (reservoir) before and after the introduction into it of the mass culture, and at intervals up to the time of "watering" the vats, *i.e.*, running the water from the *khazana* into the steeping vats containing the cut plant. Fermentation continues after watering for varying periods of time up to some 12—15 hours, and plates were made at intervals to determine the rate of multiplication or otherwise of the specific bacteria artificially introduced with the water. The water used at Pusa was drawn directly from the river, and a large number of plates was made to ascertain the bacterial content of this water and the proportion of active hydrolyzers.

This series of plates showed the very great variation in this respect which occurs in river water from day to day according to the incidence of the rainfall; immediately after rain large numbers of bacteria, derived no doubt from surface wash, appear in the river water; after 24 hours or less this extra supply may have completely disappeared but in the meantime the character of the fermentation may be entirely changed owing to the presence of a relatively enormous number of bacteria in the steeping vat. It is a serious defect in the design of the Pusa factory that no provision exists for settling or filtration of the water, so that in a larger number of cases the extreme dirtiness of the water used introduced excessive numbers of bacteria of all sorts, the activities of which so far complicated the results as to make the latter of little more than negative value. Thus it will easily be realized that when endeavouring to compare an artificially inoculated vat with an uninoculated control, the existence in the water of both of a natural bacterial population already up to the limit of its capacity would inevitably reduce the artificially induced difference in bacterial content to a negligible quantity. A natural criticism immediately suggests itself; would it be practicable on a factory scale to remove any such excess of bacteria in order to make room for artificially introduced species? It may be said at once that the importance of this point was realized very early in the course of the experiments, and our aim has been to find some practicable means of overcoming the difficulty.

In order to understand fully the points involved it must be realized that so far as indigo manufacture is concerned we may divide bacteria into three classes:—

(1) active hydrolyzers,
(2) inert so far as indican is concerned, and
(3) active destroyers either of indican or indoxyl or both.

The artificial cultures isolated at Pusa have been selected for their positive and negative virtues, *i.e.*, they are active

indoxyl producers and do not destroy any large quantity of indican without hydrolyzing it to indoxyl. On the other hand a large number of the bacteria found in the dirty river water are active indican consumers and may, even in twelve hours, destroy some 30—40 per cent. of the indican present, thus reducing the yield of indigo to that extent. In addition to this positive action the competition which goes on between bacteria in any culture medium whether natural or artificial, will seriously reduce the hydrolytic action of the beneficial bacteria if the activities of the latter are curtailed by the presence of superior numbers of the inimical species or even of otherwise inert kinds. It was found in 1917 that interference with bacterial control of the fermentation was due sometimes to excessive numbers of destructive bacteria and not infrequently to the presence in the untreated river water of a sufficiently large number of hydrolyzers to reduce the difference between the artificially produced water content of these desirable organisms and the natural one, and with it the yield of indigo, to insignificance. The frequent, but not constant, occurrence of this phenomenon provided an addition to the evidence upon which the theory underlying this work is based, namely, that the notable differences observed between the yields of individual factories can be correlated with the differences in the bacterial content of their water supply.

Thus in the case of low yields we are confronted at the outset with a condition and not a theory, the presence of destructive, and the absence of constructive bacteria, and the alteration of this condition is the object of our present research.

Two methods of attacking this problem appear to present themselves; the first and most obvious being the removal of all deleterious bacteria from the water supply and the second, the use of artificial cultures of such quantity and vigour as to overwhelm the original population of undesirable bacteria.

It is a well-known fact that bacterial numbers in water can be greatly reduced by settling and still more so by pre-

cipitation; mere storage in reservoirs also reduces them in quantity. Most factories use their *khazanas* or reservoirs as settling tanks, drawing off the water from the top by surface drainers; this is intended to remove suspended mud which would contaminate the indigo, but an extension of the method would undoubtedly serve to reduce the bacterial numbers, and in cases where bad fermentation sometimes followed by bad settling in the beating vat is a common experience of the factory, the use of *khazanas* of greater capacity and designed to effect more complete settling of the suspended matter in the water, would almost certainly lead to improved manufacture. Larger reservoirs would also reduce the proportion of water directly pumped without settling from the river or lake, which in many cases appears to be responsible for bad fermentation. It is a frequently observed fact that certain vats habitually give better fermentation than others in the same factory; various explanations have been given of this difference but the following one which does not seem to have been suggested appears to fit in with the conditions in many cases. In many factories the *khazana* is not large enough to supply water to all the vats in use at one time, so that a certain number of the latter are filled with water which has stood for several hours in the *khazana*, the remainder being watered by practically direct pumping from the outside source, whether river, lake, or tank. This would at once tend to create differences in the bacterial content of the steeping vats, which might very well be of a sufficiently high order to produce variations in the fermentation going on in the latter. Such variations would be reduced together with the number of bacteria by the use of *khazanas* of adequate capacity, allowing of settling the whole amount of water used each day. It is suggested that the not infrequent superiority of the yield of small factories and small vats may be traced to the very generally adequate size of their *khazanas*.

Apart from the bacteria present in the water it is to be remembered that the plant itself introduces an enormous

number into the steeping vat. In the 1917 experiments it was frequently found that whereas the uninoculated *khazana* water might contain very few hydrolyzers yet the corresponding fermented liquor contained an abundance of these bacteria; this implied the introduction of the latter by the plant, and it may be asked how manufacture could be benefited by purification of the *khazana* water, if the plant itself brings in so large a number of bacteria. There is reason to think, however, that this difficulty is not so serious a one as at first sight may appear, first because the bacteria generally associated with the plant do not seem to include as a rule any large number of deleterious organisms, and secondly because these bacteria, if they find the water already in possession of others, as would be the case with successfully inoculated *khazana* water, do not have time to exercise much influence upon the character of the fermentation. For this same reason beneficial plant bacteria must frequently be prevented from carrying out normal hydrolysis by the presence of unduly large numbers of detrimental organisms in the *khazana* water. The problem therefore is how far is it practicable to provide fairly clean water for steeping, and how to produce a satisfactory artificial inoculation sufficiently vigorous to overcome the destructive action of detrimental bacteria already present.

A great deal of experimental work was done to determine the best way of making a " mass " culture, *i.e.*, a pure culture of the specific bacterium sufficient in quantity to stand distribution through the 6,000 to 10,000 gallons of water in the steeping vat without undergoing too high dilution. It was found possible to make a simple culture medium of ammonium sulphate, superphosphate, wood ash and sugar, and to activate fermentation by the use of about one gallon of this culture, after 6 hours' incubation, in each 1,000 gallons in the steeping vat. In many cases, however, growth of the artificial inoculum appeared to be interfered with, probably owing to excessive competition with other bacteria and in some instances to failure to make the proper adjustments between the temperature of the mass

culture and that of the steeping water, or even to the presence of unfavourable chemical conditions in the latter, and further work must be done to find out how to secure the most favourable conditions for the multiplication and activity of the artificially introduced bacteria. In other industries depending upon controlled bacterial fermentation the use of sterilized raw material is generally adopted; this would seem to imply that the absence of other bacteria is a condition of success for the employment of pure cultures, but it does not necessarily follow in the case of indigo. Here we have in the ordinary factory working frequent cases of losses of the order of 30—40 per cent. due largely to imperfect hydrolysis, partly as a consequence of the absence of the proper bacteria and partly to the presence of abnormal numbers of destructive species. It appears probable from the past season's experience that by sedimentation and the introduction of sufficient amounts of vigorous cultures of the proper species it should be possible to alter the character of the fermentation in the steeping vat so as to secure more complete hydrolysis, but a considerable amount of work must be done before it is possible to elaborate a routine method suitable for use in a factory without immediate scientific control.

Hot water extraction. In the report for the previous year (1916-17) reference was made to the use of hot water extraction as a means of eliminating undesirable bacteria; a further advantage of such a method would be to secure a higher percentage of extraction of the indican in the plant; the Indigo Research Chemist has shown that imperfect extraction in many cases leads to a loss of 30—40 per cent. in ordinary factory working, and if hot water extraction could be successfully adapted to factory conditions, it should be possible to obtain a liquor not only comparatively free from bacteria (although of course not absolutely sterile) but containing a much higher percentage of the indican present in the plant from which it was derived.

With a view to obtaining information as to the possibilities of this method a hot water extraction vat was added

to the factory equipment at the beginning of the current year; this consisted of a masonry vat sunk in the ground and having sloping ends and a draining platform. The water in the vat is heated with steam and the hot extract can be pumped to the steeping vats for cooling and inoculation. Plant is carried into and out of the vat by a length of large mesh wire fencing net, thus obviating the trouble in handling hot material.

The experiments made with this method do not come within the scope of this year's report, but it may be said here that there appears good reason to suppose from results already obtained, that the method will allow not only of a high percentage of extraction, but of complete bacterial hydrolysis and the production of good quality indigo. It is, of course, quite possible that its use on a factory scale may prove uneconomical in view of the fuel consumption involved, but engineers whose opinion has been taken do not consider that this is likely to be the case.

V. Pebrine.

Further work was done upon this subject with special reference to the mechanism of infection, a paper on which is now in hand. Microtome preparations and dissection gave clear evidence of the rapid rate of development and spread of the parasite in the tissues of the host in this country as compared with that described by Pasteur; thus artificial infection of a larva, by feeding only once with pebrine-infected food just before spinning, resulted in a heavily pebrinized moth, and in earlier stage larvæ similar treatment resulted in the presence of numerous actively dividing forms of the parasite in the epithelial cells of the gut of the host only three days after infection, as compared with a necessary interval of ten or fourteen days in France. Similarly in hereditary infection through the egg the epithelial cells of the gut of the embryo were found to be infected several days before oviposition. It is therefore clear that *Nosema bombycis* in India has attained parasitic

activity of a high order which is liable to make the spread of the disease even more rapid than was the case in Europe in the middle of last century, when the silk industry was very nearly destroyed, and it is all the more necessary to adopt the strictest measures to prevent such an occurrence in this country. It seems probable that the climatic conditions which enhance the activity of the parasite have a compensating action in reducing the length of time during which the spores retain their infective power, and it may be that this factor has been the only one which has so far prevented the disease from wiping out the Indian silk industry altogether. It should be remembered, however, that this factor only affects the spread of the disease by contaminative infection, and does not at all reduce the hereditary transmission, which is certainly of equal importance.

The viability of pebrine spores was further tested and the results of the experiments showed clearly that under moist conditions such spores rapidly lose vitality, whereas in dry air, even at high temperatures, their viability is retained for considerable periods of time.

The reliance which has been placed upon copper sulphate as an antiseptic for rearing houses was shown to be based on theory rather than observation, as 75 per cent. infection was obtained with pebrine spores treated with 1 per cent. copper sulphate solution, whereas 1 per cent. formalin secured complete immunity under similar conditions.

At the request of the Government of Mysore I visited the State in January and inspected typical rearing establishments, both Government and private. Demonstrations were given of the revised method of examination of moths, and a report was subsequently written embodying a series of suggestions as to the best method of securing adequate and reliable supplies of disease-free seed, and of diminishing the amount of contaminative infection during rearing. These suggestions have been adopted by the Sericultural Department of the State.

Amongst other recommendations the following were emphasized:—

Provision of disease-free seed. Revision of technique of microscopic examination of moths. Proper trained supervision of this examination. Adequate provision of nurseries for production and distribution of disease-free seed. Rejuvenation of stock by hill rearing.

Improvements in rearing. Demonstration rearing houses where improved methods can be shown to local rearers.

Such improved methods to include:—

(1) Sanitary measures to avoid spread of infection such as disinfection with formaldehyde and dust prevention by false ceilings and moist floors.

(2) Proper dieting and spacing, and provision of ventilation especially by openings in roofs of rearing houses.

VI. Programme of work for 1918-19.

Major subjects.

1. The decomposition of organic matter in the soil by bacterial action.

2. The reciprocal relationship between bacterial activity in soil and the mineral constituents of the latter with special reference to phosphates, and an enquiry into the possibility of producing soluble or available phosphates in India without the use of sulphuric acid.

Special enquiries.

3. Indigo.
4. Pebrine.
5. The sterilization of water for troops in the field.

Minor subjects.

6. Biological analysis of soils.
7. Bacterial diseases of plants.

VIII. List of Publications.

Hutchinson, C. M. . Report on Agricultural Bacteriology, 1916-17, for the Board of Scientific Advice in India.

REPORT OF THE IMPERIAL COTTON SPECIALIST.

(G. A. Gammie, F.L.S.)

I. Charge.

I held charge of the post throughout the year.

II. Cottons in the Provinces.

Bombay Presidency.

Khandesh. The whole energies of the local Department have been devoted to the growth and distribution of the **N. R. cotton** (Khandesh *neglectum roseum*, almost identical with the *roseum* of the Central Provinces). There is a large seed farm at Jalgaon, and it is supplemented by areas under registered seed-growers. During these last two years, however, it has been found that *roseum* suffers more from untimely late rains than the ordinary Khandesh mixture, and many cultivators are voluntarily reverting to the former practice of growing the old mixture. In cotton, as in other crops, there are sound reasons underlying the cultivator's method of mixed cropping. While much progress has been made in the distribution of purified N. R. cotton, which is the most profitable type of cotton to the cultivator in the Khandesh mixture, it was felt that some account should be taken of its comparative failure in the last two abnormal seasons and more attention should be paid to the production of a yellow-flowered variety which could take its place, an alternative to be preferred to that of the cultivators returning to their old mixture derived from fresh and uncertain sources. To this end we have introduced, for experimental purposes, the **Sindewahi Cross** from the Central Provinces and **K.22** cotton produced by Mr. Leake at Cawnpore.

The comparative values of the varieties now under experiment can best be calculated from the following statement, based on figures obtained at the Jalgaon farm :—

Variety	Yield per acre	Ginning percentage	Value per acre
	lb.		Rs. A. P.
N. R.	108·30	38·475	28 9 0
N. R. C.	83·80	41·875	23 12 0
Sindewahi Cross	55·23	35·600	15 11 0
K. 22	41·80	36·000	11 1 0

On account of the partial failure of the cotton crop throughout Khandesh, there is a shortage of good seed for sowing purposes, and it is understood that large quantities of seed have been brought from Jamner, a place bordering on the Nizam's Dominions, which grows the ordinary *jari* mixture giving a ginning percentage of 34 to 36 and fetching a slightly higher price than the ordinary Khandesh cotton. Efforts should be made to prevent such inferior types from establishing themselves in tracts which can carry better varieties.

There is a village, called Saising, in the Bhusaval Taluka, which grows a cotton exactly like N. R. excepting that the cotton is not released when the boll opens, even when unpicked for some time. This variety is worth further enquiry on the part of the Department.

Gujarat. In the Dhollera tract Mr. Mankad investigated the extent and limits of the white-flowered form of *mathio* which resembles N. R. in its high ginning percentage. In some villages in the Dhandhuka Taluka of the Ahmedabad District the percentage of white-flowered plants was found larger (varying from 40 to 65 per cent.) than in the tracts of Kathiawar growing *mathio*, where the percentage of white-flowered plants rarely exceeds 25 per cent. The larger percentage of white-flowered plants

in this tract appears to be due to two causes:—(1) N. R. and N. R. C. types ripen a little earlier than the other types of the *mathio* mixture, the fully ripe bolls also appear more fluffy and larger in size. It is therefore probable that the first opened bolls may have been selected by the cultivators for their future seed requirements. (2) Middlemen, who actually sell the *kapas* after testing the out-turn of lint, may have sorted coarse cotton (N. R. and N R. C. having a high ginning out-turn) from the general heaps in the ginneries. As in other parts, *e.g.*, Kathiawar, there is a general complaint that *mathio* exhausts the soil and the succeeding crop of *jowar* (*A. Sorghum*) or *bajri* (*Pennisetum typhoideum*) with which cotton is rotated, has considerably fallen off in out-turn. Cultivators of late have gradually taken to the growing of *wagad*, but it will be difficult to oust *mathio* altogether.

In the Dhollera tract, *rozi* is being rapidly replaced by *ghogari*.

In the Ahmedabad District, *wagad* is restricted to *besur* and black soils, while *lalio* is reserved for *goradu* or the lighter class of soils; on these, when irrigated, its out-turn is sometimes almost doubled. In *wagad* it is better to select round rather than pointed bolls for quality and out-turn.

In the Panch Mahals the prevailing type was *kanvi*, but this has been replaced by *ghogari* on account of its high ginning percentage. At Dohad farm a number of varieties have been tried, amongst them Cambodia and *bhuri*. These have been rejected and tests are being continued with N. R. strains, Sindewahi Cross, and K.22. Owing to the retentive nature of the soil and the chance of frost which occurs at intervals of years these are not altogether satisfactory. Cotton as a crop is not extending on this area as the people get a good return from the double-cropping of maize and *san* (*Crotalaria juncea*).

It would be well if the Department refrained from further experiments towards the introduction of N. R.

which will only accentuate the difficulties regarding mixture in Gujarat, and watched the results with *ghogari* and *kanvi* conducted in the Broach District.

Judged by the valuations, the cottons tried at Dohad stand as follows :—

(1) N. R. ordinary. Rs. 710 per *candy* (784 lb.), spinning 8's; the same day's value of *bengals*, Rs. 730.

(2) N. R. black-seeded. The same as No. 1.

(3) K.22 from Cawnpore. Rs. 800 per *candy*, spinning 14's.

(4) Sindewahi Cross. Rs. 825, spinning 16's; the same day's value of *khandesh* and *akola* being Rs. 760 and Rs. 800.

Comparative tests have been carried out between **Broach Deshi** and *ghogari* at the Broach Experiment Station. Much work remains to be done on the former to bring it even on a par with *ghogari*. The following statement demonstrates conclusively the formidable competition between *broach* and *ghogari* and the Department will have to strain every nerve to prevent the latter from ousting *broach* altogether.

Statement of the results of alternate trials of Ghogari types versus *Broach Deshi.*

Variety o cotton	Yield of seed cotton per acre	Ginning percentage	No. of seeds per tola	Yield of lint per acre	Yield of seed per acre	Gross money value per acre		Total gross income per acre.
						Lint according to valuation	Seed	
	lb. oz.			lb. oz.	lb.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Broach Deshi .	175 14	32·3	231	56 5	119·37	68 7 4	5 3 6	73 10 10
Ghogari A type .	167 7	43·1	235	72 2	95·23	75 15 7	4 2 10	80 2 5
Ghogari B'3 type .	156 10	43·8	241	70 5	83·12	75 1 4	3 12 3	78 13 7
Ghogari E 15 type.	164 7	45·8	238	77 0	87·43	81 0 5	3 13 4	84 13 9

In the Dhollera tract samples of the principal types were taken from general crops and valued in order to

adjudge their respective merits. With *dhollera* of the day standing at Rs. 900, cotton from irrigated *lalio* was valued at Rs. 815, spinning 14's to 16's; that from purified *lalio* at Rs. 880, spinning 20's; and from pure *wagad* Rs. 850, spinning 16's.

In the Junagadh State, two years ago, selections were made in *mathio*. These were put out last year, but owing to the unfavourable character of the season it is premature to say anything on the relative merits of the different types. The Sindewahi Cross is also being tested there.

At Ajupura, in the Thasra Taluka of the Kaira District, where cotton is being grown on newly broken up grass lands, experiments were made with four different sorts of cotton to test the most suitable type for this part which is a new extension of the tract.

The prospects of the successful introduction of a high class selection of **Surat cotton** into this part are very favourable, but the data are not yet sufficient to indicate the most suitable.

At Surat, while the ordinary local cotton gave a profit of Rs. 167 per acre, Selection II gave Rs. 214, Selection I-A, Rs. 200, and Selection 1027 A. L. F., Rs. 184. The last named was considered in the Bombay market to be superior even to *navsari* and was valued at a premium of Rs. 35 per *candy*. There is no doubt that these strains are all superior to the local product and when the difficulties incidental to the distribution of seed of improved cottons on a large scale are overcome the Surat-Broach tract bids fair to supply a very high class cotton.

Southern Mahratta Country. Sholapur and the northern part of the Bijapur District, by growing *neglectums*, have become merged into the Khandesh tract for commercial purposes, and the testing of **Kumpta-Dharwar** varieties is confined to Satara, Belgaum and Dharwar districts and the lower part of Bijapur.

The experiments with *kumpta*, which are confined to the Dharwar farm, gave the following results:—With

kumpta ordinary crop, taken for comparison, and yielding a profit of Rs. 106 per acre, *kumpta* selected for tall compact growth gave Rs. 149, *kumpta* bushy type, Rs. 134, and two *kumpta* crosses, Rs. 149 and Rs. 141 respectively. A *kumpta* crossed with *broach* type gave Rs. 161, and a selection of *broach* gave Rs. 121. The *kumpta* selected is being grown on a field scale for distribution to the cultivators amongst whom it is becoming increasingly popular.

At the Gadag farm, which is the centre for trials with the American types, all evidence points to the superiority of the **Upland** over the **New Orleans** variety, the selection of the former giving a profit of Rs. 218 per acre and of the latter Rs. 149 against Rs. 164 for ordinary **Dharwar-American** per acre. As the value of the Upland type becomes more clearly realized it is expected that the mixture of New Orleans will gradually disappear from cultivation. The **Cambodia** selection was valued on a par with ordinary Dharwar-American giving a profit per acre of Rs. 160. It is difficult to maintain Cambodia in a pure state as it cannot be readily distinguished from Upland Dharwar-American.

In the auction sales, which were conducted by the Co-operative Sale Societies, assisted by the local members of the Bombay Agricultural Department, the crops of Dharwar-Broach and Cambodia were disposed of. Each was arranged in grades based on the ginning percentage, and from the remarks of Messrs. Tata & Sons it was found that this arrangement was also accompanied by definite grades of quality.

The Central Provinces and Berar.

At the Akola farm, the last two seasons have been unfavourable for the cotton crop and under these conditions *buri* has yielded a good profit, Rs. 118 per acre, Berar *jari*, Rs. 71, and *roseum*, Rs. 67-12. The first was originally introduced from Chota Nagpur where the rainfall is copious, the second enjoyed the advantage of being a mixed

crop of which some of the members withstand a wet season, and the third is doubtfully resistant to adverse conditions.

Burma.

The varieties of cotton grown in Burma are the following :—

(1) Wagale (*Gossypium neglectum* v. *Burmanicum*) with yellow flowers.

(2) Wapyu (*Gossypium neglectum* v. *avense*) with white flowers, said to produce a longer boll and whiter lint.

(3) Wani (*Gossypium neglectum* v. *kokatia*), yellow-flowered, but the cotton is khaki which is chiefly used in the making of jackets.

Scattered plants of this type may be found in the local early cotton crop and the pickings contain a slight admixture of this drab cotton, which is usually partially sorted out before the stuff is ginned.

The naked eye is unable to detect any difference in the shape and size of the plant of these three forms until the (2) and (3) come to flower and to pickings.

(4) Wagyi (*G. obtusifolium* v. *Nanking*). This is grown in Prome and Thayetmyo districts and occupies the ground for full nine months. The quality of cotton is superior to the local early type *wagale*.

(5) Pasi cotton (local Kachin name) (*Gossypium neglectum* v. *cernuum*), yellow-flowered. This is similar to the small bolled form found in Khasi and Jaintia hills of Assam, and as it is grown in the same way, in all probability the seed must have been brought from these hills. This is sparingly grown by the Kachins in hills of the Namyin Valley of the Myitkyina District. A thin jungle is cleared and seeds broadcasted along with paddy and vegetable seeds. All these crops come to maturity in succession, cotton being last so that the pickings are not interfered with. The land is abandoned after taking the first year's produce.

(6) Shan State cotton. The plants are reported to be identical with those of the local cotton *wagale*, but the quality of cotton is far superior to any of the races found in Burma. The quality of cotton is almost on a par with *fine surat* and can spin up to 30's. The ginning percentage, however, is said to be only 28 which is far too low to attract attention, but the percentage of cotton to seed of a sample brought from Aungban (Southern Shan State) and tested in the office laboratory was found to be 33·5.

(7) Pernambuco cotton (*G. brasiliense*), kidney or chain seeded. This is not found on a field scale anywhere except that it exists as an ornamental plant in gardens here and there. It is said that a few years ago trials were made with this variety near Moulmein but the cultivation had to be abandoned on account of its failure on a field scale.

Of these varieties the first, *wagale*, is the most important, forming the bulk of Burmese cotton. The quality of cotton as determined by Messrs. Tata & Sons is midway between *bengal* and *khandesh*.

Wagyi is no doubt superior in point of quality, but the longer period required by it will not suit a Burmese cultivator whose land must be got ready in the hot weather.

Experiments with Egyptian and Upland Georgian were conducted for two or three seasons on the Mandalay and Bugi Stations, but though the germination was good the crop was a failure and the trials had to be abandoned.

Some authorities maintain that the Burma cotton crop contains a proportion of fairly long-stapled cotton which if carefully picked and grown separately would be as valuable as the best Indian cottons and command an equally good price.

With this end in view the study of cotton has been taken up seriously by the Department. The Tatkon farm in the Yamethin District and Padu in Saigaing District are both devoting attention to this crop.

Of the type *wagale* a large number of single plant selections were made and isolated in 1914 and their ginning

percentage determined; variation was observed and the best were kept and grown in 1915 and since then the pure strains are grown.

Wagale on the Tatkon farm now gives a ginning percentage of 36 and *avense* up to 42.

In the case of *wagyi*, from a single plant selection a strain has been isolated which gives 45 or about 6 per cent. higher ginning percentage than the unselected crop. Mr. McKerrel thinks that these cultures will maintain their superiority and thus seed will be available for distribution purposes in the near future.

Cambodia on the Tatkon farm and Utopia (New Orleans type) on the Padu farm did not show promise. The former is considerably subject to insect pests and red leaf blight and the latter appeared to be a very poor yielder, bolls do not open properly and it is particularly attacked by insects.

Some crosses with *wagyi* and *broach* have been made to replace *wagyi* which ripens late, but it is doubtful whether these crosses will remain fertile.

On the Tatkon farm, a very promising cross between Shan State cotton and *wagale*, var. *avense*, is made; this strain has a ginning out-turn of 40 per cent. as compared with 33 in ordinary *wagale*. The testing of this strain on a field scale will in a short time throw sufficient light on the cotton question in Burma.

It is certain that a great advance can be effected by selection of the local types alone.

In order to increase the area under cotton it is essential that the grower be given a reasonable price for the produce, ginneries be opened in suitable tracts to induce keen competition among buyers. and that the cultivator should use the drill in sowing, thus saving a lot of seed and rendering after cultivation easier whereby the crop will grow even and should give a better out-turn.

Acknowledgments. Thanks are due to Messrs. Tata & Sons for their generous help in passing judgment on all the samples submitted to them.

III. Programme of work for the year 1918-19.

Major.

(1) To visit and advise on points regarding cotton and its cultivation whenever required to do so by the Provincial Departments of Agriculture.

Minor.

(2) The study of the behaviour of *bhuri*, Cambodia and other such cottons in non-cotton-producing tracts, as detailed in the last year's programme, will be continued.

(3) An enquiry into the manurial requirements of cotton will be made.

(4) Researches on the botany of cotton will be continued.

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