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MADRAS AGRICULTURAL DEPARTMENT

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AN INQUIRY INTO THE CAUSE OF BUD AND BOLL SHEDDING IN COTTON

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INTRODUCTION.

The premature shedding of the bud and boll in cotton has for several years been an outstanding problem in all cotton-growing countries. According to Cook (1913) a kind of competition exists between the flowering and the vegetative branches, an excessive development of the latter resulting in the blasting of the bud or boll. Balls (1912, 1915) considers that the shedding of the young fruits which he would term " bolls by courtesy " is due to a shortage of water either for the whole plant or for the particular fruit concerned and that the shedding of the open flowers which is stated to be a general phenomenon in Egypt is possibly connected with the chemical side of pollination or with the greater transpiration of water from the open flower. He further observes that shedding may be provoked by non-pollination but he does not consider this to be common under ordinary conditions. A deficient root-absorption is in his opinion the primary cause of shedding in Egypt. Harland (1917) quotes Nowell and agrees with him that bud-shedding is caused by any factor that brings about a deficiency of water to the bud though in another place he states with regard to the West Indian native cotton that the shedding is not influenced greatly by root conditions or rainfall since plants subjected to control of water supply showed the habit all the same. Meade (1918) thought that inadequate pollination is a possible cause of shedding and he made the interesting suggestion that bee-keeping may improve the crop. He did not account for bud-shedding. The most recent work on the subject is that of Lloyd (1920) who has made a study of the effect of environmental changes on boll shedding. It is to be regretted that in most of the above works stress has been laid on the doubtful presence of a factor for causing abscission rather than on the absence of a factor or factors for the expansion of the bud or boll.

The views of the present writer do not run counter to those advanced by the above distinguished authors but they are presented here with the hope that they will open a new line of investigation wherein may lie the solution not only of this problem but of others connected with the improvement of crops in general. None could excel Balls in the remarkably valuable results obtained for cotton but as Balls (1917) himself says " We do not know enough about cotton. The real scientific exploitation of the cotton plant has not yet begun, because exploitation cannot begin without exact knowledge of the plant exploited."

The work outlined in this paper was confined to *Gossypium herbaceum* (Uppam cotton) which was growing in the black cotton field close to the laboratory but the fact of the occurrence of shedding in the other species of cotton both in India and in other countries was not lost sight of. As a result of close study and observation both in the field and in the laboratory the writer has come to the conclusion that, in so far as the phenomenon is physiological, the natural shedding, whether of the bud or boll or flower, occurs in the most critical stages of the flower when it is reduced to an osmotic inefficiency consequent on the changes involved in the development of the flower from its bud stage up to the final boll formation such inefficiency being indicative of a general deterioration which is due to long cultivation and self-pollination.

FLORAL BIOLOGY.

The opening of the flower commences after 8 a.m. and is complete by 10 a.m. It is a commonly observed fact that, as is usual in other plants, the flowers of cotton do not open simultaneously but do so one after the other with certain interval of time. This opening generally proceeds from the base of the plant to its apex but it at the same time appears to depend on the nutritive condition of the particular branch at whose end the flower arises. A representation showing the order of opening of the flowers on the scaffolding of the branches has been presented by Balls (1915) which vividly explains this view.

To a question put by himself as to what internal changes produce a transition from vegetative growth to sexual reproduction Klebs (1910) makes the forcible suggestion that " quantitative internal changes in the cells, and with them disturbances in the degree of concentration, are induced through which the chemical reactions are led in the direction of sexual reproduction. An increase in the production of organic substances in the presence of light, chiefly of the carbohydrates, with a simultaneous decrease in the amount of inorganic salts and water, are the cause of the disturbance and at the same time of the alteration in the direction of development." That such internal changes vary in the plant and produce a corresponding gradient in the osmotic concentration of the cell-sap has been shown by Harris and Lawrence (1917) who have given the osmotic pressures in atmospheres for leaves of trees at different heights. A similar state of circumstances must undoubtedly exist in the case of flowers also for which reason they open at intervals being in different courses of development. As Klebs points out the difficulties in the way of exact researches being carried out on this subject are very great and a method as attempted below for the study of pollen will, it is believed, materially aid the furtherance of our knowledge regarding the organs that are most concerned in reproduction.

The prevalence of cross-pollination in cotton by means of insects may be taken as definitely settled. The flower is as good an instance as any other of adaptation for insect visits owing to the display of colour and the presence of nectar and pollen which provide enough attraction for the insects. Among those that are constant visitors the writer noticed between 9 and 10 a.m. the bees *Anthophora cingulata* and two species of *Halictus* that are guided into the flowers by a certain amount of opening of the corolla. Leake (1912), however, was of opinion "that the flower exhibits none of those adaptations which would indicate that it is normally either cross or self fertilized," and he further thought that as the stigma becomes receptive soon after the expansion of the petals and the pollen also gets dry very soon the flower undoubtedly becomes self-fertilized (self-pollinated ?) within a very short time after opening leaving no chance for cross-pollination to take place. It is difficult to say whether in spite of the facilities for self-pollination pollen of another individual of the same variety will not assert itself over the plant's own pollen. For, instances are known where as Goebel (1910) points out "in self-fertile plants the flowers of which have not been deprived of the male organs, pollen brought to the stigma by the wind or by insects from another plant effects fertilization even if the plant's own pollen has reached the stigma somewhat earlier." That self-pollination is now the rule in cotton is not denied but there appear to be enough reasons for considering the flower as an efficient mechanism for cross-pollination to be carried on by insects the dearth or paucity of which alone is responsible for the present absence of cross-pollination. Any constitutional unfitness for effecting cross-pollination is, the writer thinks, due to continuous self-fertilization for several generations.

POLLEN STUDY.

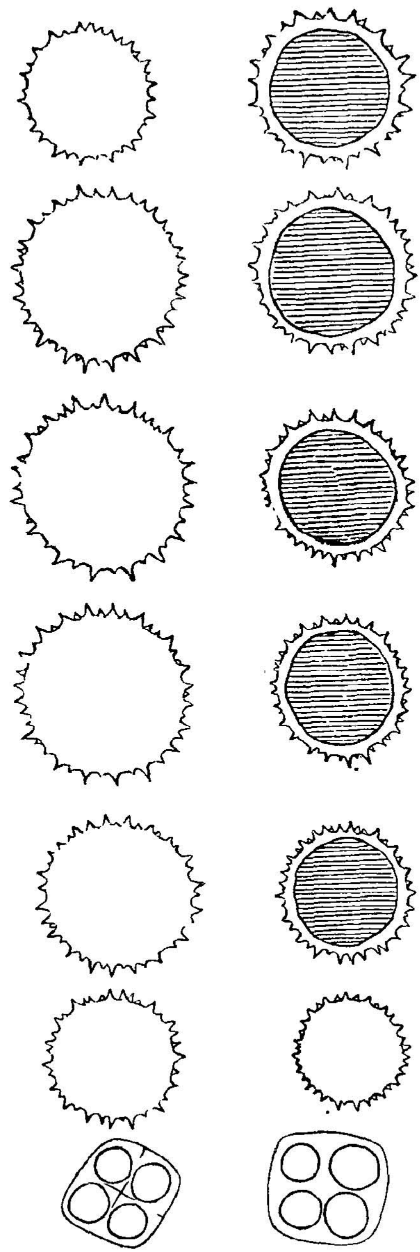
At the outset of the investigation it was felt that the cause of shedding of the bud and boll probably lay in a sterility of the pollen or ovule. Such sterility is observed more readily in the pollen than in the ovule and its occurrence has been studied for a long time and more recently by Hoar (1916), Forsaith (1916), Cole (1917) and others for certain genera of plants. An examination of the flowers of cotton showed that whereas in very many cases the pollen was not definitely sterile, in quite a large number of plants partial and complete contabescence of the stamens was noticed to such a marked degree that flowers with perfectly sound pollen were a rare feature. As mere morphological perfection of the pollen grains, wherever it was found, could not be taken as a sure criterion of their ability to function a study of the physiological development of the pollen suggested itself as such a study will be of value for interpreting the facts regarding self-sterility or fertility of the individuals among the same or different varieties and species.

(1) *Method of investigation.*

Having regard to the opening time of the flowers the examination of fresh material was, as a rule, made in the mornings between 8 and 11 a.m. and the rest of the material was from spirit specimens collected by the writer himself at the hours noted. The most indispensable tools were the camera lucida and the eyepiece micrometer with 100 divisions for the millimeter. The reagent employed was chloralhydrate iodine which has the special advantage of bringing into prominence within a short time the starch content which is a special feature not only of the pollen grains but of the other floral parts as well.

(2) *Results.*

The growth of the pollen grains from the beginning to their final stages reveals interesting peculiarities. The number of days required by the youngest bud to develop into the open flower was not ascertained as it must vary according to environmental conditions, but a few distinct stages could be recognized in the transformation. Six such buds were chosen and the grains of a single anther were mounted directly in chloralhydrate iodine. The accompanying figures bring



FIGS. 1 and 2 —Pollen grains in successive stages examined in distilled water and chloralhydrate iodine respectively out the increase in the size of the grains from the tetrad condition to the fully matured stage over the seven stages and also show the presence of starch in them. The size of the grain is by no means constant for the single anther and much less for the whole flower but it is intended to show those that are of frequent occurrence. An idea of the variation in size can be had from a reference to the following table which also contains the combined results of further studies :—

TABLE I.

The figures denote the number of divisions of the micrometer.

Each division = 1·55 u.

No.	Sizes of bud.												(7) Open flower.	
	(1) 5 × 3½ mm		(2) 7 × 4½ mm.		(3) 9 × 5 mm		(4) 11 × 6½ mm		(5) 13 × 7½ mm.		(6) 18 × 8½ mm			
	DW.	CI	DW.	CI.	DW.	CI.	DW.	CI	DW	CI	DW.	CI.	DW.	CI.
1	23	23	57	48	70	54	70	60	70	65	78	70	55	70
2	19	20	58	47	70	56	75	60	70	62	75	66	56	65
3	20	20	57	55	70	55	70	60	75	62	75	63	58	66
4	19	25	55	50	68	53	70	60	70	62	80	70	55	67
5	19	23	55	47	66	52	70	60	70	63	75	69	55	70
6			60	46	65	55	70	60	73	62	78	65	64	70
7	..		60	48	70	56	70	60	75	60	80	70	62	68
8	...		55	48	69	55	70	60	70	64	70	70	55	70
9	.		58	48	64	55	69	58	80	64	75	66	59	79
10	..		60	49	71	55	70	60	73	60	75	71	55	73

DW = Distilled water. C.I. = Chloralhydrate iodine.

The increase in size to some extent suggests an increase in the osmotic pressure of the grains in the growing buds but this will be more evident when the grains are viewed in a drop of distilled water. For this purpose single anthers from each bud were cut into two by means of the razor and they were mounted separately but simultaneously in chloral iodine and in distilled water after carefully releasing the grains by means of the needle. Measurements were taken by means of the micrometer of ten grains in each half of the anther so as to get an idea of the variation in size among them. By this method a rough indication of the increase in osmotic pressure is made evident owing to the swelling of the grains in distilled water due evidently to the absorption of water by the sugar present in them. The osmotic pressure is carried to its maximum in the final opening stage of the flower when the grains placed in distilled water shoot out within a few seconds ejecting their contents when a marked contraction ensues. Figures 1 and 2 show the contrast in the size of the grains between those placed in distilled water and those mounted in chloral iodine especially the contraction of the grains placed in distilled water in the case of the open flower.

It is of some interest to note that the shooting of the grains in this manner is not brought about simultaneously in all the grains but occurs one after the other adding force to the suggestion of a differential osmotic pressure prevailing among the grains. Exact studies on this matter, viz., the determination of the pressures of the grains were not possible owing to the difficulty of the methods involved even the less favoured plasmolytic method being of no use as the grains do not show any visible plasmolysis but only a general contraction which is complicated by the circumstance that the mature grains burst in the manner referred to.

A study was, however, made to notice the behaviour of the pollen in solutions of varying concentration of potassium nitrate and the results are embodied in the following table. Three stages of bud formation and a flower which had just opened were examined and the sizes of the former are given at the top column.

TABLE II.

Statement showing the size of the pollen grains in different percentage solutions of potassium nitrate.

Each division = 1·55 u.

No.	Sizes of bud.								Open flower.						
	6 × 4½ mm.		11 × 7 mm.		18 × 7½ mm.										
	1%	3%	1%	3%	1%	3%	4%	5%	1%	2%	3%	4%	5%	8%	10%
1	56	45	70	60	70	66	67	68	Bursting after one minute	Bursting slower	77	73	70	67	68
2	55	45	70	60	68	69	72	68			72	74	75	65	70
3	53	45	68	65	73	70	70	65			77	77	74	70	65
4	50	45	70	63	72	75	68	67			78	75	73	70	65
5	55	46	70	65	73	71	72	70			75	75	76	70	65
6	57	50	70	66	72	76	68	70			75	74	73	70	66
7	54	47	66	60	72	73	70	67			74	70	70	70	68
8	55	47	60	63	70	73	70	65			78	72	72	70	70
9	60	47	69	63	68	73	70	70			74	74	73	70	70
10	57	48	70	62	72	72	69	70			77	70	76	69	65

A separate examination of pollen from an open flower on another day gave the following results :—(1) Bursting of the grains and discharge of contents after one minute and within two minutes in 1 and 2 per cent solution of KNO_3. (2) In a 3 per cent solution a few grains alone shot but not the rest. The latter burst on the addition of distilled water. (3) None of the grains burst in a 4 per cent solution even for five minutes. But irrigation with distilled water induced slight bursting and slow discharge of contents.*

* Lloyd (1915) noticed bursting in 0·45/N. KNO_3 (=4·54 %) but the exact species investigated is not known.

Similar explosion of pollen in water was observed by Lidforss (1896) in many plants. The irritability in such cases is due to intense osmotic pressure prevailing in the vacuoles owing to the presence of osmotically active substances in them, e.g., sugar (cf. Livingston, 1903).* The resistance of the grains is therefore hampered under conditions of precipitation in the atmosphere especially where there is no device to protect the inner organs of the flower. It is thus a matter for serious consideration as to how far the extensive shedding of the young bolls immediately after rains and also the general unsuitability of cotton for rainy districts may be ascribed to this peculiar weakness of pollen.

The foregoing account of pollen in cotton has enabled the writer to interpret the open flower as representing biologically a condition where the microspores reach their greatest osmotic pressure, each grain containing within it the potentiality to germinate in a manner consistent with its individual osmotic capacity. The variations in the size of the grains are thus seen to be advantageous in meeting the needs of the ovules which are differently situated and for germination on stigmas of different receptive capacities.

STIGMA.

The stigma of the flower represents in its detailed structure an efficient medium for the germination of the pollen grains. It protrudes beyond the level of the staminal column even in the earlier stages of floral development except in a

* Lloyd's (1915) view that the bursting depends on the hydration capacity of emulsion colloids and not upon the presence of solutions of high concentrations does not affect the arguments of this paper.

small number of flowers (from 5 to 10 per cent) where it is partially covered up by the anthers. The three rows of hairs at the three corners extend for some distance on the style and their exact condition at different times during the day determines the success or failure of the germination of pollen grains coming in contact with them.

As the germination of pollen on the stigma is caused by the sugar solution secreted by the stigmatic hairs it follows that the most favourable condition is that when the hairs are in a state of turgor due to absorption of water from the underlying tissues ; in other words, a high degree of turgidity must prevail in the ovary (and in ovules) of which the stigmatic hairs may be taken as the index. To clear up this point as far as anatomical details will permit, flowers were collected on the same day at intervals of two hours from 8 a.m. to 6 p.m. and sections of stigmas were examined in chloral iodine.

Figure 3 shows the cross sections of stigmas of two flowers collected at 8 a.m. and 2 p.m. The hairs are at first turgid without any contents in the

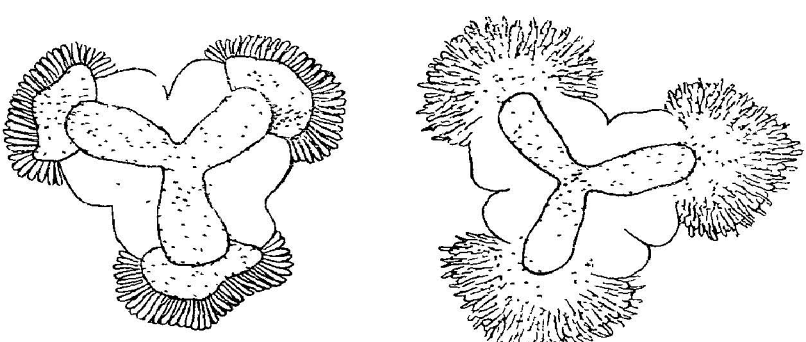


FIG 3 — Transverse sections of stigmas from open flowers collected at 8 a m and 2 p.m.

earlier stage but at 2 p.m. and after they show partial collapse by which time several pollen tubes have already penetrated. The special feature of the stigma is the copious amount of starch present in the central three-rayed core which is brought into close contact with the hairs by means of further starch accumulation in the "cortex." After midday starch makes its appearance in the stigmatic hairs, but it gradually disappears in the cortical bands beneath the hairs. It may be inferred from the structural differences that (1) the stigma is receptive immediately after the opening of the corolla, probably even before the pollen is shed, (2) that it becomes unfit for receiving pollen between 12 and 2 in the noon and (3) that there are variations in the receptive nature of the stigmas which facilitate to varying extent the germination of the pollen from the same or another flower.

OVULE.

The ovules are quite healthy in the flowering stage and do not show any sign of sterility. Though the reserve material in the mature seed is in the form of oil the ovules of younger bolls are characterized by abundance of starch whose function apparently is to feed the growing embryo. Bolls under observation for 1 to 7, 14 and 21 days showed the presence of starch whereas it had disappeared in those that were collected after 30 days. On the analogy of the pollen grains it is to be thought that ovules also contain saps of different concentrations, but the method of study adopted in that case could not be followed here owing to the difficulty experienced in dealing with a large number of entire ovules under the microscope and the tardiness with which they will respond to changes in the surrounding medium. The only way of ascertaining this was by means of the relative abundance of starch as it may be presumed that variations in the quantity of this substance will mean greater or less quantity of the material which will be converted into sugar for the utilization of the embryo. The following method was adopted :—

On steeping in chloralhydrate iodine the ovules of fresh flowers show an uniformly intense black colouration and so, flowers collected at the opening time were left exposed in the laboratory and spirited after 30 and 48 hours and the ovules then examined. Prominent differences are then noticed among the sets of ovules owing to the partial disappearance of starch by respiration or translocation and this serves as a clear indication of the original difference existing among them with regard to the starch-sugar proportion.

BUD SHEDDING.

Material for examination was gathered by shaking the plants when those that have a disposition to shed fall off easily. The size of the buds thus shed varied from 5 × 4 mm. to 10½ × 6 mm. which roughly include the first four stages of bud formation given in Table I. The pollen from the younger stages of these showed a reddish brown colour with chloral iodine whereas those from the rest showed plenty of starch.

The shedding of buds is thus seen to occur only in the earlier stages of floral development when the growing parts are in a low state of osmotic activity. A reference to the tables and figures in connexion with the study of pollen will show that this is the case and the existence of a competition between the flower buds and vegetative shoots as suggested by Cook becomes intelligible on this basis. This view is also further supported by the important work of Chandler (1914) who has shown in certain special cases he studied regarding the osmotic relationship of flowers and fruits that the molecular concentration of the leaves of fruit trees is generally greater than that of the fruit and where such a difference prevails the leaves are able to remove water from the fruit.

BOLL SHEDDING.

The fruit contains within it the germ of the future plant and its fall must naturally be due to those factors that arrest the development of the ovules. An attack into the young boll by insect larvae, for instance, soon results in the fall of the boll. To provoke this end pistils with the surrounding corollas were removed from 20 flowers that had just opened. Out of these two fell on the next day and all the rest on the succeeding day.* (*Experiment I* below). The removal of the bracts also hastens such a fall by lessening nutrition (*Experiments II and III*). The same effect is produced by the prevention of pollination which was made out in the following way :—10 flowers were labelled and their stigmas were brushed with iodine glycerine at 10 a.m. These began to drop after three days (*Experiment IV*). Further study was directed to ascertain to what extent the shedding of the boll is due to ineffective fertilization.

* As the bud or boll carries with it the persistent bracteoles and the pedicel in the act of falling the entire part that is shed is taken as the unit.

Flowers were ticketted on the day of opening and a record was made of the young fruits that fell during the course of development. It was found as a rule that shedding rarely commenced before the fourth day of opening (*Experiments V and VI*). The ovules of shed bolls were steeped in chloral iodine and they were found to be utterly free from starch and they showed very little signs of enlargement.

Six experiments.

Days after opening.	I	II and III		IV	V and VI	
	20	20	20	10	20	50
1	18	20	20	10	20	50
2	0	19	20	10	20	50
3	..	14	19	9	20	47
4	...	13	16	6	19	44
5	..	12	11	4	18	40
6	...	10	11	2	17	37
7	..	9	9	2	17	34
8	...	...	...	0	17	16

In his paper detailing the sexuality of cotton, Balls (1905) has given precise information on the time relationship of pollination and fertilization and the development period of the embryo in the case of *Gossypium barbadense*. It is a remarkable feature of the boll shedding that with regard to *G. herbaceum* the shedding commences on the fourth day of opening, i.e., after the period taken by the resting fertilized embryo to commence its division which according to Balls is 3½ days for the Egyptian cotton.

The exact chemical changes that take place inside the bolls previous to shedding cannot be known but with regard to starch content there is a gradual reduction in those flowers that are not fertilized. This fact is easily demonstrated. A number of open flowers were iodined in their stigmas at the time of opening and these were collected on the four succeeding days and their ovules examined for starch. The result of the observation showed the disappearance of starch on the fourth day of opening in flowers so treated.

To gain further knowledge on this subject it was thought necessary to deal with large numbers as there is nothing in the external appearance of the flower or young fruit to indicate that it will be blasted in its development except the somewhat general symbol shown by the persistence of the dried up corolla at the summit of the fruit beyond two or three days. With this object about 60 flowers were labelled in the field and these were collected on the evening of the fourth day when three flowers alone had dropped. The ovules of the rest were treated with chloral iodine after mounting them on glass plates and it was found that 32 out of these had lost starch and the rest were filled with it. Similarly 35 flowers labelled on another day and collected on the morning of the fourth day showed 7 non-starchy ovules and the remaining with starch. Ninety flowers collected on the evening of the third day showed starchy ovules in 87 and non-starchy in the rest. In all these cases the disappearance of starch in the ovules before the bolls are actually shed is a sure indication that their development had ceased and the only reason for this must be that either fertilization does not take place or it is not effective.

Our present knowledge regarding the physiology of fertilization is still defective and so far as the writer is aware the activation of the fertilized egg has not been thoroughly explained by any current theories. In the absence of precise knowledge on this matter it is not to be expected that methods exist for distinguishing the fertilized from the non-fertilized egg. As regards the present problem, however, it may be stated that there was no evidence to show that pollination (either self or cross) does not take place in cotton because sections of styles from shed flowers showed the penetration of pollen tubes in all cases that were examined.

CONCLUSIONS.

The idea presented in the above pages is to the effect that the shedding whether of the bud or flower or boll is brought about in a critical condition of the flower when it is unable to absorb enough water owing to the low osmotic strength of the sap in the growing portions. Such a conception does not militate against the views put forward by others regarding the cause of the phenomenon in so far as it is physiological. It is significant that the later stages of bud and boll are not subject to such shedding which must be accounted for by the superior osmotic pressure they possess for obtaining the sap.

Boll shedding arises as a consequence of in-effective fertilization or its failure. The problem is bound up with the question how far the plant pays the penalty for self-pollination. The present view is not to suspect anything "abhorent" in self-pollination but rather to dwell on the virtues of cross-pollination. So far as the cotton plant is concerned there seems to be enough evidence based on the work of Leake (1912) and others that repeated self-pollination brings about a condition of sterility in the plant.

East and Park (1917) went into the general question of sterility at considerable length and came to the conclusion that the "immediate difference between a fertile and a sterile combination is in the rate of pollen tube growth." Such difference was by Jost (1907) supposed to be due to differences in "Individual stoffe." The views of these authors and of Correns, Morgan, Stout, Compton and others have been ably summarised by F. R. Lille (1919) who leaves the problem with the conviction that genetical studies cannot solve the problem in a physiological sense but a physiological solution will be of value in interpreting the genetical results.

To the present writer the problem of incompatibility appears to meet with solution by means of a osmotic hypothesis which is briefly this : the pollen grains grow by absorbing the fluid of the stigma by means of their osmotic pressure (or hydration capacity according to Lloyd, 1915) which varies within wide limits. A certain resemblance in pressure will be necessary as a higher osmotic pressure of the stigma will retard germination whereas a very low pressure will result in a turgidity all too sudden or an explosion of the grains as in cotton. The general prepotency of foreign over the individual pollen is probably due to the fact that a larger number of fully matured grains will be shed at one time and carried by wind or insects whereas the stigma that is self-pollinated may receive only a mixture of strong and weak pollen from the anther or anthers close by and even this at an improper time, or the prepotency may arise by reason of the pollen going to an younger flower whose stigma is more receptive on account of a different osmotic pressure.

This conception is also in accord with what Balls (1915) considered to exist in the case of cotton, viz., a " pseudo-parasitic nature of the pollen tube which attacks some styles more easily than others." The presence in the pistil of diffusible substances which stimulate or retard pollen tube growth after cross or self-pollination respectively was suggested by Compton (1913) to whom the growth of pollen tubes in the style and the growth of fungus hyphæ in a host appealed as analogous. The writer is in full agreement with this view and ventures to suggest as Compton has done though in a different manner that a osmotic hypothesis will further clarify our ideas regarding the factors that govern the immunity or susceptibility in animals or plants.

Much light has been thrown on the physiology of fertilization in plants by the recent discoveries made by zoologists on animals. Among these the observations of Gray and R. S. Lille are of special significance in support of the hypothesis suggested in this paper. Lille, for instance, has shown that in the case of arbacia the eggs take up water by osmosis several times more rapidly after fertilization than before. A method will be evolved to test this point in cotton and in the meanwhile the subject is suggested as a general problem for those that are more fortunately situated.

Since completing this paper the writer found that extensive shedding of fruits takes place in the vegetatively propagated plants of Thespesia populnea. As the occurrence of the phenomenon in a genus so closely allied to Gossypium is of great significance a note on bud and fruit shedding in that plant is appended.

My grateful thanks are due to M.R.Ry. Rai Bahadur K. Ranga Achariyar Avargal, for giving me the benefit of his advice and criticism on various points referred to in this paper. I have also to thank M.R.Ry. D. Ananda Rao Garu, the then Superintendent of the Farm, for affording facilities for examining the plants in the fields.

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A NOTE ON POLLEN STERILITY AND THE SHEDDING OF BUD AND FRUIT IN THESPESIA POPULNEA

BY P. S. JIVANNA RAO, M.A.,
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Stumps of *Thespesia populnea* were planted three years ago for a short avenue behind the College and most of them are now in flower and show excellent vegetative growth. Shedding of fruits on a large scale was noticed in these trees and observation extended to the other oldest trees in the neighbourhood revealed the same phenomenon coupled sometimes with dropping of young buds also. There are, however, a few small trees not more than ten or twelve years old planted in the college arboretum and one in the Botanical Garden which bear mature fruits heavily. The writer is assured by the persons in charge of the planting at that time that these plants were raised from seedlings. Whether this is true or not, the existence of two such types of plants, one bearing fruits and the other sterile, has given rise to the popular conception of a "flower Portia" and a "fruit Portia" being found in the same species. It is to be noted that the plant has so far not been observed in a wild state in South India and the ease with which it can be propagated vegetatively by means of stumps makes it one of the most successful of avenue trees.

There are a few special interesting features which characterise the two kinds of plants. In the aborting type the leaves are large and distant and the flowers are also larger and borne on long, thin peduncles whereas in the fertile plants the leaves are small and crowded and the flowers are distinctly smaller and placed on short and stout peduncles. A difference in habit is also apparent as, in the case of the latter type, the branching commences from the base and the plant has a somewhat pyramidal shape. At the time of observation it was also noticed that, in the case of the fertile plants the flowering had almost come to an end whereas the sterile plants were still putting forth a large number of flowers.

The abscission of the organ that is shed is at the extreme base of the peduncle in the axil of the leaf and the size of the pistil at the time of shedding varies from 10 mm. in the younger stump planted trees to as much as 21 mm. (owing to parthenocarpy) in the older ones, this being about the size of the mature fruits that set seeds. It may be stated at this stage that the abortion of fruits is not absolute for any plant, for fruits may sometimes be found which contain one or two developing ovules out of the fifteen or twenty which will normally be found inside fully matured fruits.

The pistil has four or five loculi with four ovules in each locule. The ovules at the time of flowering appear to be morphologically perfect.

They do not show any sign of defective nutrition but contain enough reserve material in the form of starch as treatment with iodine will easily show.

The case is, however, different with regard to pollen. In fertile flowers the anthers are large and densely arranged on the staminal column and at the opening time which is between 8 and 9 a.m. are fully loaded with masses of pollen grains 100 to 110 u. in diameter and containing plenty of starch in them. Mounted in distilled water the grains having a higher osmotic pressure begin to shoot out their contents after one or two minutes and contract to a marked degree. The flowers which abort on the other hand, contain a very large number of sterile grains varying from 74 to 95 u. in diameter which are smaller in size with no starchy content in them and are useless for bringing about fertilization. The perfect grains among these are from 95 to 110 u. diameter when viewed in chloralhydrate iodine and resemble those in the fertile flowers. The percentage of such healthy grains is extremely small and only the best among them explode in distilled water.

It was found by scraping the stigmas of both kinds of flowers 24 hours after opening that pollen grains adhere to the stigmas in sufficiently large numbers but in the case of the barren flowers the grains, as stated above, are mostly sterile.

Stout (1916) distinguishes three kinds of sterility, viz., (1) sterility from impotence of pollen, (2) sterility from incompatibility and (3) sterility from abortion of embryo.

Sterility of the second type has been reported by Jost (1907) in Secale, by East and Park (1917) in Nicotiana and by Stout (1916) in Cichorium.

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Dorsey (1919) has presented an exhaustive account of sterility in the plum which he attributes to incompatibility and embryo abortion.

Shedding of fruits in cotton is very well known and the phenomenon has been attributed by the writer* to sterility from incompatibility due to self-pollination.

The present instance is a case of sterility from impotence of pollen brought about by vegetative propagation. The following interpretation is offered : The number of fully matured pollen grains being extremely small the chances of a larger number of potent grains reaching the stigma preferably from another flower are very much reduced. In the plenitude of vegetative growth a corresponding increase in growth takes place of the style and stigma much to the disadvantage of the pollen grains very few of which are at their highest osmotic activity. There is so to speak an osmotic dilution of the pollen grains on the one hand and of the pistil on the other which prevents effective fertilization. It also accounts for the dropping of buds under circumstances similar to those explained for cotton.

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* Vide previous article.

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NOTES ON INSECTS.

ENTOMOLOGICAL SECTION, AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE.

The following are a few notes collected from cage slips. They record the observations of various members of the staff, and appear to be of sufficient interest to be published. In every case the notes have been paraphrased from the original and condensed when necessary. The authorship of the observations is acknowledged by the initials.

The initials stand for the writer; First Assistant Entomologist, T. V. Ramakrishna Ayyar; Second Assistant Entomologist, Rao Sahib Y. Ramachandra Rao; T. V. Subrahmanyam and P. Susainathan.

Aphis gossypii.

A few fragmentary notes were made on *Aphis gossypii* early in 1914.

I. In one case a very young aphis (? some 6 hours old) was put on a cotton leaf in a cage on 14th April 1914. Later on, on the 22nd April 1914 another was put on the leaf. On 2nd May, three young aphids were seen, on 3rd two large and two small. One of these larger ones had vanished three days later. Several large ones were seen on

10th May 1914 and there was some suspicion that aphids were getting on to the plant from neighbouring plants in the cage.

By 3rd June 1914, 45 aphids were counted. By 25th June 1914 the plants were covered with mealy bugs and observations were given up.

E.B. & Y.R. 1914.

II. 1st April 1914, one winged and one wingless aphid put on a cotton plant.

2nd April 1914, winged female died.

3rd April 1914, three aphids were seen one large, two small.

7th April 1914, 10 aphids in various stages.

8th April 1914, 11 aphids in various stages.

9th April 1914, 13 aphids in various stages.

10th April 1914, 13. One was crushed. The original large female could not be found.

15th April 1914, about 50.

29th April 1914, about 150.

2nd May 1914, about 220. Descendants of one wingless female.

E.B. & Y.R. 1914.

Clavigralla sp.? horrens.

A species of Clavigralla was reared from eggs laid on red gram (Cajanus indicus) pods. Eggs were found, 4th June 1914., Hatched, 8th June 1914. The first hatched nymphs instead of wandering away remained around the empty egg shells.

By 22nd June 1914, one nymph had become adult and the last became adult during the night 23rd–24th June 1914.

T.V.R. 1914.

Megacoelum esmedorae Ballard (M.S.).

3rd April 1915. Adults found hiding in cracks of nîm tree bark during the day. Confined in tubes, eggs were laid in nîm twigs. Eggs were pale blue and provided with a single tag, and were laid under the bark or in the tissue when it was soft enough. As embryo develops egg turns red.

Eggs, laid 3rd–4th April 1915, hatched 10th-11th April 1915.

Eggs laid 5th April 1915, hatched 11th–12th April 1915.

Just emerged nymphs have very long legs and antennae and are coloured brown.

Y.R. 1915.

Helopeltis antonii.

A female put in tube with twig of nîm laid about 32 eggs between 6th–7th April 1915 and 10th–11th April 1915.

Egg of *Helopeltis antonii* is provided with two tags or filaments. The incubation period is six days. Eggs are pushed right into the twig wherever it is soft enough, otherwise eggs are laid under the bark.

Y.R. 1915.

Brachyplatys vahlii, Fabr.

In June 1917, these bugs were found swarming on young Agathi plants in the Insectary garden. One or two found in copulation were taken for obtaining egg-laying records.

Eggs were laid in two rows on the lid of the box in which the bugs were confined. The eggs are white, flattened laterally and provided with a lid which is pushed up when the young nymph emerges. After hatching nymphs still remain clustered round the empty eggs. Incubation period is three days.

Eggs laid on 20th June 1917, hatched on 23rd June 1917.

Others found on 21st June 1917, hatched on 25th June 1917.

Others laid on 25th August 1917, hatched on 31st August 1917.

Nymphs: eyes red and prominent; thorax black with whitish lateral fringe. Abdomen yellow, dark middle patch with white patches on each side. Just hatched nymphs are recorded as being orange coloured. Adults were not obtained from any of these batches of eggs.

T.V.R. & T.V.S. 1917.

Dysdercus cingulatus.

In the course of a series of notes on the life history of this red cotton stainer from *Hibiscus esculentus* is the remark that two nymphs were found dead and one of them being sucked by a nymph of the same brood. I do not remember to have seen this habit recorded before. Out of 72 eggs laid by one female only two nymphs, both males, were raised to maturity. Perhaps cannibalism had decided the fate of the others.

P.S. 1914.

A nest of *Eumenes esuriens* was found on a coconut leaf stalk and on being opened revealed the presence of geometrid caterpillars and also the larvæ of Earias either *E. fabia* or *E. insulana.* The interest of this lies in the fact that there were no malvaceous plants in the vicinity and the nearest cotton was half a mile away. The wasp therefore must have flown that distance at least in order to secure her prey.

P.S. 1914.

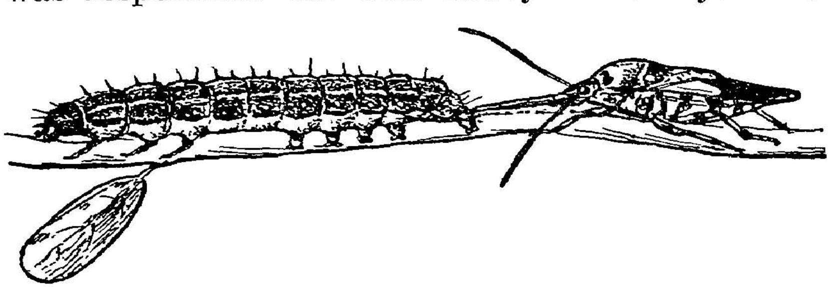
E. BALLARD,
Government Entomologist.

AN ENEMY OF PRODENIA LITURA, Fb

By E. BALLARD, *Government Entomologist.*

Prodenia litura is an insect of such wide distribution and destructive habits, feeding as it does on so great a variety of crops, that any form of natural control for it is of interest.

On the Government Farm at Anakapalle in August this year (1921) there was a very severe outbreak of *Prodenia.* Larvæ swarmed everywhere on Turmeric, Sann hemp, Daincha. Castor, Tapioca, etc., and on weeds. Assistant in Entomology, S. Ramachandran, who visited the farm to deal with the outbreak reported that many dead caterpillars were found hanging from leaves on which they had been feeding. Investigation into the cause of this phenomenon lead to the discovery that the Pentatomid, *Canthecona furcellata* (Wolff), was responsible for this heavy mortality. The



Canthecona furcellata attacking caterpillar of *Prodenia litura.*

method of attack was to approach the *Prodenia* larva from behind and from a short distance the proboscis was thrust into the posterior part of the larva. He observed several cases of *Prodenia* larvæ being attacked in this way. In "Some South Indian Insects" *C. furcellata* is noted as being an enemy of *Athalia proxima* (Klug), but to the best of the writer's knowledge it has not before been reported as being predaceous on *Prodenia litura*.

NOTE ON HOSPET SUGARCANE CULTIVATION IN BELLARY DISTRICT

BY S. SITARAMA PATRUDU, *Farm Manager*.

PART I.

INTRODUCTION.

Hospet taluk is the north-westernmost of the nine taluks comprising the Bellary district and is bounded on the north and north-western side by the perennial river Tungabhadra which separates the Madras Presidency from the Nizam's Dominions lying north of the river. This taluk is historically important. Hampi the famous ruins of Vijayanagar is only 7 miles from Hospet, the headquarters town of the taluk. Bellary district can be roughly divided into two main sections. The one comprising the western taluks where red soils predominate and the other eastern taluks with extensive black cotton soils. Less land is under irrigation in Bellary than in any district in the Presidency except Nilgiris, Malabar and South Kanara. The percentage of protected area is 2·2 per cent but Hospet taluk contributes 14·2 per cent much above the per cent of miserable area for the district and practically more than 75 per cent of the area under sugarcane is contributed by this taluk.

GENERAL.

2. Across the perennial river Tungabhadra exist several anicuts built centuries back, from which water is led off through channels to irrigate lands on either side of the river.

The wet lands in this taluk are commanded by channels leading off from anicuts at—

(1) Vallabhapuram.
(2) Hosakota.
(3) Thurtha.
(4) Hosur.
(5) Ramasagaram.
(6) Kampli.

The channels from the respective anicuts, in the order mentioned above are—

(1) Basavanna channel.
(2) Roya Channel.
(3) Bella Channel.
(4) Thurtha channel.
(5) Ramasagaram channel.
(6) Kampli channel.

The statement below gives the details of the length and the total commandable ayacut under each channel. The total area shown against each channel includes not only the permanent *registered* wet but also other dry lands commanded by the channel and cultivated as wet, after getting the necessary permission every year from Public

Works Department. These latter are called temporary wet. Permission is always granted except in abnormal years of exceptionally low rain fall.

Name of the canal.	Length in miles.	Registered wet area.	Temporary wet.	Total commandable area.
		ACS.	ACS.	ACS.
Basavanna	15	392	109	1,101
Roya	20	3,457	963	4,420
Bella	3	1,323	153	1,476
Thurtha	12	2,132	21	2,153
Ramasagaram	10	2,490	400	1,800
Kampli	12	830	520	1,350
	...	.	.	12,300

Besides the above channels there are two more by name Kalaghatta and Belagoduhal, the former is fed by the surplus and drainage from Roya and Bella channels with an ayacut of 515 acres, and latter by Kampli channel with equally good area (513) under it. Again at the tail end of the Roya channel lies Kamalapuram tank receiving its supply mainly from Roya channel and supplemented by the rainfall in its own free basin. This has got 679 acres under it.

Thus the total commandable area under the Tungabhadra channels in Hospet taluk is 14,007 acres of which 11,749 acres is registered wet under all the channels and the whole area lies in three firkas (Revenue divisions in a taluk), namely (1) Narayana Devara Keri, (2) Hospet and (3) Kampli.

Firkas	Registered wet.	Temporary wet.
	ACS.	ACS
Narayana Devara Keri ..	928	48
Hospet	7,487	1,273
Kampli	3,334	937
	11,749	2,258

AGE OF SUGARCANE.

3. Sugarcane plant is known to Hindus from prehistoric days and the earliest mention of it is made in Atharva Veda, one of the oldest and sacred books (vide Bloomfield's Translation, XLII, 100, 277). Sarkara (cane sugar) is very often mentioned in ancient medical books. Several instances can be quoted about the mention of sugarcane in Sanskrit. But the cane cultivation at Hospet can be traced as far back as the days of Ramayana. It is asserted by many and generally acknowledged by learned men that Kishkindha was very near to Hampi, the famous ruins of Vijayanagar. Krishna Devaraya, the most powerful of the Telugu kings, made mention of cane and manufacture of jaggery in his *Amuktamalyada*. This area is identical with the Thungabhadra tract now under report. Lastly, from the available revenue statistics it would appear that for several decades it is said for over four centuries, sugarcane is being grown in this tract.

AREA UNDER SUGARCANE.

4. The area under cane in this tract, that is, under the Tungabhadra channels in Hospet taluk was never less than 5,800 acres ; it went up to 7,200 acres in certain years. The area under sugarcane in each of the above mentioned divisions is as follows :—

	Villages.	Acres.
Narayana Devara Keri firka ...	6	550
Hospet firka...	20	3,400
Kampli	9	2,450

The following table L gives details that are obtained from reliable revenue records. The table shows the area under sugarcane and paddy during previous 28 faslis up to 1329 (i.e.) for 28 years prior to 1919–20 including 1919–20. For the earlier 20 faslis, i.e., from 1302 to 1321 averages for every five faslis are given for the villages for which such information is available. Side by side with the cane area in each year is shown the paddy area also which shows the general trend of the rotation of crops.

For four of the villages, figures for faslis 1302 to 1322 were not available. Still it can be seen that the area under sugarcane should have been the greatest in fasli 1322 (i.e.) in 1912–13 and should have been over 3,173 acres which is the figure for fasli 1325, i.e., 1915–16. The area under cane was steadily on the increase from fasli 1302 to fasli 1322 (i.e.) from 1892–93 to 1912–13, and then again declined to 2,542 acres in 1914–15, the year when the Great War was declared in August, four months after the planting of cane. Shortage of supply of sugar from Germany coupled with very high prices of jaggery, made the people to rush in for larger areas under cane. The sudden jump from 2,542 to 3,173 acres is clear enough to substantiate the above statement. From the table it will be seen that the area under cane has been again on the decline, though it is well over the minimum area. The causes that contribute towards the fluctuation of cane area are as follows:—

First, the first is the supply of water in the river after the north-east monsoon. For silt clearance canals are closed and opened at intervals of a fortnight and they are finally opened on 15th March when the planting of cane is commenced. If the supply of water falls short of the demand the reduction in area is inevitable and vice versa when the supply is sufficient. But till now total failure is unknown and the area never went down below 5,200 acres in the whole taluk and 2,500 acres in the immediate neighbourhood of Hospet within a radius of three miles.

Second, there is an all round cry for food crops all over the world and Hospet taluk is no exception. The scarcity of food grains being keenly felt during these years, there was general propaganda started by the Government and others to increase the area under food crops in preference to industrial crops. Again with the abnormal high prices for paddy, the agriculturist saw that a fairly good income could be obtained (though less than in case of cane) by growing paddy which requires much less trouble and much less capital towards cultivation expenses than cane.

Third, the price of jaggery during the planting season has a very important influence on the area planted.

Fourth, insufficient labour due to the ravages of plague, cholera, malaria and influenza.

Fifth, the comparatively easy way of cultivating paddy and the present ease-loving tendency of the ryots are some of causes responsible for the decline.

NATURE OF SOIL AND ROTATION OF CROPS.

The soil consists mostly of a mixture of red loam and gravel with a slight admixture of black cotton soil. Large quantities of bulky organic matter in the shape of green manure, green-leaf manure and cattle manure is worked into the soil and this process is continued year after year with the result that top layer of the soil presents a sort of blackish appearance. The soil is highly porous and very fertile.

The highly fertile nature of the soil, combined with the poracity, makes it possible to cultivate sugarcane year after year a thing unknown in other parts of the country. When the land is rich and when the ryots are in a position to manure well, sugarcane succeeds sugarcane for two, three, four or even five years. There are instances of cane being grown consecutively for twelve years. But the general rotation is one year paddy and two years cane. This is very common. It is only in the case of very poor fields owned by very poor ryots, unable to spend money on manures such as oil-cakes and fish-guano, etc., that paddy and cane are grown in alternate years.

WATER-SUPPLY.

All the channels follow the general contours of the ground and hence they are curves and bends. All these anicuts were constructed and canals formed by the kings of Vijayanagar. Competent authorities say that the positions for anicuts were chosen with great judgment and canals formed with consummate skill. The fall of the bed of the channels ranges from 1 to 4 feet per mile but that across the country, i.e., the fall from the channel to the river is as much as 20 to 25 feet per mile.

The duty of water for cane is very low which works out at 25 to 30 acres per cusec, while that for paddy is much less, i.e., 10 to 12 acres. The misuse of water by ryots, the highly porous nature of the soil, the high fall across the country (20 to 25 feet per mile) are the main causes for the low duty. It compares very miserably with other deltaic tracts and the experience of ryots is, the more irrigations they give the better will be the condition of the crops.

These channels are silted to a certain extent and the Public Works Department attends to it. The whole country in this tract is almost rocky and very often the bed is not cut to a proper depth as it was perhaps found very expensive. This tends to retard the velocity of water resulting in the deposition of silt. Proper cutting of these rocks in the opinion of some engineers will do much towards reduction of expenses under silt clearance. For the purpose of these repairs, canals are closed every year for three fortnights—

(1) 1st to 15th January.
(2) 26th January to 9th February.
(3) 26th February to 11th March.

Water is let in during the intervals to irrigate the standing sugarcane crop and "stand-overs" left in the field for seed purposes. Irrigations at this time are most important and unless canes are irrigated just before harvesting, good jaggery cannot be obtained. Even at these short intervals when canals are closed much inconvenience is felt by the ryots. The third period of closure would be unnecessary, if repairs are attended to with care and proper organization. Some say that money invested in cutting rock beds will pay itself in savings towards silt clearance. Strict supervision with the co-operation of the people will do a good deal in putting a stop to the damages generally caused to the sluices in attempts to steal water. A movable dredger on rails along the channel may make it possible to remove the silt without closing the canals at all. Some money and thought in clearing the silt without closing the canals will be a great move towards assuring the area under cane. As matters stand at present the work of silt clearance is not what it ought to be. For a week after "closure of canal beds will be slushy" and the remaining week is too short a period for any useful work.

RAINFALL AND TEMPERATURE.

Rainfall.

The average rainfall of the Bellary district is 21 inches which is less than that received in any other district of the Presidency. The average rainfall in Hospet is slightly in excess of the above figure, being 26·56 inches.

Years.	Average rainfall	Maximum rainfall	Minimum rainfall.
	INCHES.	INCHES.	INCHES.
1870 to 1879	26 56	47·90	10 32
1880 to 1889	26·16	33 47	16·29
1890 to 1899	27 51	44 11	12·43
1900 to 1909	24 65	32 96	16 70
1909 to 1919	27 98	45·77	16·65
Average for 50 years.			
1870 to 1919	26 56	47 90	10·32

The maximum rainfall of 47·90 inches was in 1874, and the minimum 10·32 was in 1876.

Out of the 50 years preceding 1919, there was rainfall—

Over 40 inches	... ... in	5 years.
Between 35 and 40 inches	... in	1 year.
„ 30 and 35 „	... in	11 years.
„ 25 and 30 „	... in	13 „
„ 20 and 25 „	... in	7 „
„ 15 and 20 „	... in	10 „
„ 10 and 15 „	... in	3 „
		50 „

The rainfall in 1920 was 18·46 inches, and is received in a series of light showers. The average rainfall is distributed thus :

The figures are averages for 50 years.

	INCHES.	
January	0·03	0·21
February	0·06	
March	0·12	
April	0·73	3·06
May	2·33	
June	3·16	17·16 S.W. Monsoon.
July	3·19	
August	4·45	
September	6·36	
October	4·10	6·13 N.E. Monsoon.
November	1·66	
December	0·37	
		26·56

It will be seen from the above that the cane crop has to depend entirely on the water from the Tungabhadra from January to the end of April.

Temperature.

The average temperatures of the locality are given below in degrees Fahrenheit :—

—	Average maximum	Average minimum.	Mean.
January	87·6	60·5	74·0
February	94·2	65·4	79·8
March	100 3	72·1.	86·2
April	103 4	77·1	90·2
May	102·4	77·5	89·9
June	94·5	75·7	85·1
July	90·9	74·6	82·7
August	90·8	73·6	82·2
September	90·6	72·7	81·6
October	89·7	71·1	80·4
November	86 7	65·6	76·1
December	85·6	60·9	73·2
Average for year	93·1	70·6	81·8

In point of humidity of its atmosphere, Bellary is the driest of the districts in the Presidency. The driest week is 1st to 5th March and the dampest that from 21st to 28th September.

METHODS OF CULTIVATION.

The country plough is the common implement and the preliminary cultivation consists in digging drainage channels, ploughing, clod crushing, laying the plot in ridges and furrows and finally planting.

(a) *Preparation of land.*

Generally paddy is harvested in December and cane between 15th December and 15th March. All fields preceded by paddy and cane fields harvested within the 15th of February are cropped with sugarcane. First operation is to dig deep trenches, 1 foot wide and 1 to 1½ feet deep, they are dug across the field as necessity arises, and the number of trenches depends generally on the slope of the land. It is left in that condition for about a month and when the fields are completely dry, water is let in to flood the fields. Country plough is the common implement that is used when the field is sufficiently dry. As many as four to six ploughings are given and generally 30 to 40 cart-loads of cattle manure are applied and another two or three ploughings are given to cover the manure. Clods if any are crushed by wooden malets and occasionally pedda guntaka is passed. Finally the field is laid into ridges and furrows at 2 to 2 feet 3 inches apart from top to top.

(b) *Planting.*

Setts are generally prepared from "stand-overs" left in the field after crushing. There is always a difference of about a month or two between the reaping and planting seasons in this tract. Portions of fields are left over as "stand-overs" till water is allowed into the channels for planting purposes. Whole canes are used, though the cultivator admits the top halves are always very good for germination. Setts are about a foot long with three buds. It is considered very good to plant canes just after they are cut. Seed rate is never more than 10,500 setts per acre and there are instances here the rate is reduced to 8,000 setts. This seed rate is still more reduced to 4,000 when canes are planted in very low lying lands where hand watering is resorted to during early stages after planting. When questioned as to the number of setts planted the ryots say they use only four savurus (four thousand) but the actual number is $2,250 \times 4 = 9,000$ setts. The art of cutting setts is common everywhere, i.e., they are cut quite clean and as close to the joints as possible with very little pith at the ends. If the cut be jagged and more pith is left the sett ferments and loses its vitality. Setts thus cut, are all arranged on the top of the ridges leaving a space of nearly nine inches from end to end. Water is allowed into the furrows and a man gets into the trench, removes the sett from the top of the ridge, puts into the furrow and lightly presses it with his foot and proceeds in this way till the field is finished. It is needless to say that tops are planted with ends a little above ground.

Varieties.

There are three varieties of sugarcane by name (1) Hotta Khabbu or Bela Khabbu or Thella Cheruku,

(2) Mara Khabbu or Javari Khabbu and (3)Hullu Khabbu. Of the three, the first is most popular and from the records it is understood that this was introduced by one Mr. Blane, Sub-Collector of Hospet, in the year 1840 (vide pages 258 and 259 in Volume II, Bulletin No. 46). Some are of opinion that this cane is something like that of Pundia cane of Bombay Presidency. Some corrobarate the statement mentioned above that this cane was introduced by the Board of Revenue in early forties, but no authenticated information is available and hence it is treated as a local cane. The variety satisfies the ryot in all its qualities, except that it is low in its sucrose content when compared with other equally good exotic varieties. This variety has entirely superceded other varieties. The cane that is soft, thick and juicy with good outturn, high sucrose content is all that is needed for the locality. Five varieties (1) Fiji B, (2) Coimbatore No. 1, (3) D 74, (4) B 3412, (5) Javahebbal, have just been introduced and the first of these should have some future before it.

(*c*) *Manures and manuring.*

Green manure and green leaf manure are in vogue, the former is represented by Sunnhemp (crotalaria juncea) and the latter by Kanuga (Pungamia glabra). These are considered direct manures for paddy but their residual effect on sugarcane is really very great. It is a practice in these parts to grow "pungamia glabra" all round the fields with a view to get enough leaf for manuring paddy fields. The quantity when insufficient is generally supplemented by other leaf from forests near at hand.

It is already stated that ryots apply cattle manure at rates varying from 26 to 75 cart-loads and sometimes fields where cane is successively grown, get 100 to 150 cart-loads. Sheep-penning is given generally from 2,000 to 4,000 head per acre. Generally when cane succeeds paddy, the cost of manure is less, but when cane succeeds cane, heavy doses are applied. Castor cake, fish guano are also applied to a greater or less extent, the rate ranging between 4 to 8 bags per acre (1 bag = 120 lb.).

(*d*) *After-cultivation.*

Weeding is resorted to as often as is found necessary ; i.e., about 3 to 4 times. In the third month or after a thorough soaking rain in June, every ridge is split by working a plough first and another behind to widen and deepen the trench. Any earth falling in the furrows is removed with mamoties. It is at this time that concentrated manures are applied. This is the final operation and nothing more but irrigations at intervals of 8 to 10 days are necessary till the crop is harvested. Propping and wrapping are unknown in this locality.

(*e*) *Harvesting.*

This begins generally during the middle of December and continues till the 15th of March. The best time for cutting canes in this locality is February when very good yields are obtained. But the natural law of demand and supply in the early part of the season induces the ryot to cut his canes, prepare jaggery, and dispose of it with the least possible delay. He is quite conscious that the percentage of jaggery is low but the high price he gets when there is good demand, compensates the loss. The Hospet ryot is one of the best cane cultivators in the Presidency, and he knows precisely the right time at which he should cut his canes. When the canes are ripe, they cease to grow and the top leaves get conjested and show themselves erect. The pale yellow colour, the metallic sound of the rind when struck by a finger nail, the congestion of the leaves, the sweetness, and above all the time limit of 9 to 10 months are some of the signs taken into consideration when canes are cut.

A sickle is always used for cutting canes and these are always crushed with the least possible delay as the ryots are fully aware of their deterioration when left without crushing for more than 12 hours.

Statement showing area under sugarcane in each fasli in each of the villages.

Revenue number.	95		94		93		92		91		90		89		88		85		84		83		
Village.	Hospet.		Amaravati.		Chittuvadigi.		Hosur		Kalliram-puram		Narasa-puram		Belagodu		Mudlu-puram.		Nagena-halli.		Gudiobala-puram		Kala-ghatta		—
Fasli	Cane.	Paddy	Cane	Paddy	Cane	Paddy	Cane	Paddy.	Cane.	Paddy.	Cane.	Paddy	Cane	Paddy	Cane	Paddy	Cane	Paddy.	Cane	Paddy	Cane	Paddy	
	ACS	ACS	ACS	ACS	ACS	ACS	ACS	ACS.	ACS	ACS	ACS	ACS	ACS	ACS.	ACS	ACS	ACS	ACS.	ACS.	ACS	ACS.	ACS.	
Average of																							
1302—1306	9	15	140	140	.	.	815	931	...		.	.	94	157	..		68	116	58	150	170	260	...
1307—1311	5	13	163	128	..	..	921	934	..		.	.	102	135	...	...	76	156	80	162	200	261	...
1312—1316	6	10	175	117	...		915	773	..	..	..	..	98	130	..	..	87	105	93	110	189	252	...
1317—1321	5	11	173	99		...	1,012	835	..	..	..	...	138	116	..	..	105	88	99	117	213	180	...
1322	1	9	198	114	...	.	1,315	528	..	..		..	188	67	...	..	122	84	129	117	262	195	...
1323	8	12	172	124		.	950	850	...		.	..	115	93		.	108	95	90	132	176	259	...
1324	34	9	173	128	294	190	941	927	101	120	186	250	135	134	363	227	83	119	69	168	203	235	2,542
1325	6	6	231	88	347	130	1,129	617	138	106	237	209	175	91	424	121	163	43	118	124	205	244	3,173
1326	27	10	182	152	333	148	1,127	632	146	70	191	118	150	100	398	148	95	113	91	146	205	239	2,945
1327		13	191	121	333	148	1,031	660	123	105	231	189	135	110	380	142	140	65	118	124	211	212	2,893
1328	3	11	207	213	296	173	980	696	115	109	191	112	151	109	380	160	78	121	96	130	163	240	2,660
1329	.	26	225	93	273	222	1,024	691	105	126	143	118	143	118	373	180	125	81	87	132	152	263	2,650
1330	..	..	..	...	..	..	.	..	..	.	...	..	...	...	394	..	.	.	...	...	...	..	...

NOTES ON SOME SOUTH INDIAN RUSTS

By S. SUNDARARAMAN, M.A.,
Government Mycologist.

1. (*a*) *Æcidium bicolor* Sacc. *on Maba buxifolia* Pers. *var. Ebenus* Theo.

The fungus causes the leaves to be small and crowded on the infected branch like a small witches' broom.

Æcidia—hypophyllous.

Peridium—protruding, pale-yellow, edges lacerated, cells verrucose, oblong, 5–6 sided.

Æcidiospores—pale-yellow, oblong, 5–6 sided, punctiform, 20 to 30 × 15 to 18·5 μ.

Pycnidia—epiphyllous (spores not seen).

(*b*) *Æcidium bicolor* Sacc. *on Maba buxifolia* Pers.

Æcidia—maculicole, hypophyllous, numerous arising out of small carbonaceous spots, æcedial cups presenting a large orange-coloured spore mass with a white fringe of peridium.

Peridium—protruding, recurving, lacerated ; cells oblong to angular, punctiform, finely dotted and angular, 19 to 26 × 15 to 18·5 μ.

(*c*) *Æcidium bicolor* Sacc. *on Maba nigrescens.*

Æcidia—hypophyllous, sunk half deep into the leaf, cups broader at base and narrow at top while immature, and as they mature they broaden at top bursting the peridium. 283·20 to 438·96 × 226·56 to 335·65 μ.

Peridium—protruding, cells flat, grey, sometimes overlapping but with short grooves and elevations radially arranged at the margins, with greenish orange-coloured bodies amid their contents, ornamented with fairly fine warts, thick walled, oblong, square, hexagonal, triangular to roughly round. 16·5 to 39·6 × 11·5 to 25·74 μ.

Thickness of walls of peridial cells 2·31 to 4·29 × 5·94 to 7·59 μ.

Æcidiospores—spores in the centre of the mass light orange-coloured while those above and below grey. 18·15 to 36·63 × 14·85 to 21·45 μ. Thickness of walls 0·99 to 2·3 × 3·3 to 7·59 μ.

2. *Æcidium Ipomœa on Ipomœa obscura.*

Æcidiospores, grey, roundish sometimes four to five sided, smooth, thick walled, 16·2 to 20·3 × 14·8 to 17·7 μ.

3. *Æcidium Kaernbachii* P. Henn *on Ipomœa eriocarpa.*

Æcidia—hypophyllous, on more or less round and dark spots with reddish fringe all round, gregarious, pseudoperidium present.

Peridium—cells pale-yellow or grey, oblong or angular, warted all over, 21·0 to 29·0 × 12·2 to 18·2 μ.

Æcidiospores—sub-globose, angular or oblong, pale-yellow, grey, guttulate, smooth. Sub-globose spores 15·0 to 22·7 μ diameter. Oblong spores 16·4 to 23·8 μ. × 11·2 to 15·7 μ.

4. *Æcidium Pavettæ on Pavetta indica.*

Æcidiospores—19·6 to 22·9 × 14·8 to 17·7 μ.

5. *Æcidium Blepharidis* Hart. *et* Pat. *on Blepharis boerhaa viaefolia.*

Æcidia—hypophyllous, not definitely arranged, sometimes in circular patches, cup shaped, margin fimbriate.

Æcidiospores—globose or sub-globose to angular, corners punctate, pale. 14·8 to 22·9 × 12·9 to 18·5 μ.

6. *Æcidium Ocimi* P. Henn *on Ocimum canum.*

Teleuto sori—present in the midst of æcidial sori.

Teleutospores—brown, mostly 2-celled, some of the spores having vertical or slant septum in one of their two cells, mostly constricted at the septum. Epispore—much thicker at the apex than at other parts, smooth. Spores, 31·5 to 47·2 × 19·2 to 27·6 μ.

Æcidium—maculicole, solitary or grêgarious, on the under side and rarely on the upper side, margin of pseudoperidium white and laciniate.

Peridium—cells, hyaline, polygonal, warty. 21·0 to 33·2 × 14·0 to 28·0 μ.

Æcidiospores—globose or elliptical, sometimes angular, punctiform, with yellow oil drops. 16·8 to 21·7 × 14·0 to 18·2 μ.

This is probably a Puccinia.

7. *Uredo socotræ* Syd. *on Cassia sophora.*

Uredo sori—gregarious, on both sides of the leaf, small, yellowish-brown.

Uredospores—greenish-yellow to orange-brown, sub-globose, oval or oblong, finely warted, pedicels hyaline or slightly coloured, 13·5 to 19 8 × 10·8 to 14·1 μ.

8. *Uredo sp. on Orthosiphon tomentosus.*

Uredo sori—on both sides of the leaf, rotund.

Uredospores—yellowish, warty, round to ovoid, 21·4. to 26·6 × 17·0 to 21·8 μ.

9. *Uredo sp. on Leucas helianthemifolia.*

Uredospores—round, oval or elliptic, yellowish-brown, warty. Oval spores 25·5 to 28·7 × 21·9 to 24·5 μ, round spores 24·5 to 26·6 μ diameter.

10. *Uredo sp. on Polygonum alatum.*

Uredo sori—hypophyllous, small, gregarious, round and brown.

Uredospores—light-brown, echinulate, oval to elliptic to nearly round, pedicels hyaline or slightly coloured, no paraphysis. 21·02 to 32·2 × 16·12 to 22·0 μ.

11. *Puccinia polliniæ* Barcl. *on Strobilanthus Cuspidatus.*

Æcidia—hypophyllous, gregarious, forming concentric circles, margin of pseudoperidium lacerated.

Peridia—cells oblong to angular, grey to pale-yellow, warty, 26·2 to 40·2 × 17·5 to 27·3 μ.

Æcidiospores—sub-globose or oblong to angular, grey, punctiform, 22·0 to 30·1 × 17·5 to 24·5 μ.

12. *Puccinia sp. on Senecio candicans.*

Teleuto sori—dark brown, small, gregarious hypophyllous.

Teleutospores—yellowish, two-celled, constricted at the septum, top cell papillate, wall thickened at apex, stalks persistent, 56 to 77 × 5·2 to 8·7 μ. Spores 29·7 to 43·7 × 17·5 to 24·5 μ.

Æcidia—hypophyllous, gregarious

Peridium—protruding, irregularly lacinate.

Æcidio-spores—pale green irregularly round to angular, guttulate, delicately punctiform, 14·7 to 19·2 × 14·0 to 15·7 μ.

NOTE ON THE CAPE GOOSEBERRY

By F. H. BUTCHER,
Curator, Government Botanic Gardens and Parks, Ootacamund.

The Cape Gooseberry or Tipari (*Physalis peruviana* Linn.) sometimes, but erroneously, called the Brazil cherry, belongs to a large family of useful plants known to botanists as *Solanaceæ*. To this natural order belong the potato, tomato, tree tomato, tobacco, belladonna, and various other plants of great economic value. It is a native of South America and has become naturalized in many of the warmer regions of the world. It is found growing wild on the Nilgiris and the fruits are collected and brought to the local markets where they are purchased for making into jam and for tarts. The demand exceeds the supply and the fruits are small, moreover, the cost of collecting is considerable and in consequence they are comparatively expensive. The Curator of the Gardens being of opinion that the fruit could be improved commenced to cultivate the plant as far back as 1897, and by selection gradually increased the weight of its fruit from 85 grains to 289¼ grains in 1909. It must be remembered, however, that the abnormally large fruit mentioned above was by far the largest individual fruit found in a plot containing several hundred plants, and did not represent the average size of the fruits of the whole plot, but in spite of this there is no doubt the size and the quality of the fruits as a whole have been improved by cultivation in the Government Gardens on the Nilgiris, and since last year, when the cultivation of the Cape Gooseberry was taken up in earnest at the recently established Pomological Station at Coonoor, the fine fruits grown there have been in great demand by the general public who have constantly remarked on the superiority of our fruits over the wild variety. But I have not been able to convince the ryots that it is a good business speculation to cultivate the improved variety and there is little or no demand for the seeds which are now available for sale at the Gardens. It is hoped, however, that when the Jam Factory at Coonoor is working the ryots will take up the cultivation of this most useful and appreciated preserve fruit. The cultivation of the Cape Gooseberry is extremely simple. It grows almost anywhere on the Nilgiris and in any good garden soil, but it should be planted in situations sheltered from the South-West Monsoon and frost. It should never be grown in swamps; dry sunny banks suit it best. The potato lands in the Keti valley, at Anakori, Coonoor, and Kotagiri could very well be planted with this fruit once in every two years in order to give the land a rest from potatoes. Seeds should be sown thinly in seed beds in January–February and the seedlings planted out in March–April when large enough to handle. They should be planted in groups of three, each group being about 3′ apart in the rows and the distance between the rows should be 5′ to 6′ to enable the fruit being picked without damaging the plants. Immediately after planting, the seedlings should be shaded with bracken or green wattle branches and watered daily during the late afternoon. When well rooted, the shade should be removed and only sufficient water given to keep the plants from withering. Growth will be slow until the April showers commence, when the plants will grow rapidly. No cultivation is required after planting other than an occasional hoeing to keep down weeds and the soil loosened to conserve moisture. About September the fruits will commence to ripen when they should be gathered in the ordinary way, care being taken not to damage the plants in doing so. The fruits being enclosed in a calyx it is somewhat difficult to tell when they are ripe, but a little experience will show that when the calyx has turned yellow and is commencing to dry the fruit is ripe enough to pick. The ripe fruits are greenish yellow in colour. The calyx should not be removed from the fruit until about to be cooked as the calyx prevents the fruits from being crushed when handled in marketing. The plant is a heavy cropper and about a ton of fruits may be harvested on an acre of land, the yield, however, may be as much as a ton and a half per acre on very rich land. The plant can either be treated as an annual or perennial. If the latter, the plants should be cut down to the ground in February when they will commence to grow again from the roots and produce fruits as before. Plants treated as perennials should not be kept more than two years as after then the soil becomes exhausted and the yield is poor in consequence. They will fruit from 4 to 6 months when the dry weather or frosts stop growth. Prices vary considerably but the usual price in the local markets is annas 4 per lb.

A NOTE ON THE OVIPOSITION OF PODAGRION Sp. ON A MANTIS EGG MASS

By A. G. RAMASWAMAYYA,
Sub-Assistant.

The following observation of the oviposition by a species of *Podagrion* on a mantis egg mass was made by me on the 7th January 1922 in the Botanical garden.

There were six female Chalcid parasites sitting on a mantid egg mass that was firmly fixed to a branch of *Lawsonia alba.* The egg case of the mantid was found to have been composed of a series of ring-like layers arranged one behind the other indicating the manner in which the foamy liquid with the eggs had been laid by the mantid. As noted below it was between such layers that the parasites elected to oviposit. The parasites had no definite idea of the particular spot where the eggs were nearest to the surface of the case as they were found unceasingly roaming over the case for about 3 to 5 minutes feeling all the time with their antennæ for the exact spot for oviposition. The parasites quarrelled among themselves while engaged in the search. When one of them was fortunate enough in finding the correct spot earlier than the others, the remaining unlucky parasites were found struggling to secure the same spot, which their more fortunate sister was able to locate.

In spite of the incessant attack of the other parasites the first one either held on to the spot until she had finished, attaining her object in her life, or if she had not already thrust in her ovipositor yielded to the others and flew away, subsequently re-occupying the same spot.

The parasites presumably had some scent of their own to enable them to return to the very same place they had first selected. The spot chosen lay always in the furrow caused by the union of the two ring-like layers above mentioned.

The successful parasite then began to oviposit by standing erect on her posterior pair of legs. She lifted her abdomen and curved it to such an extent that the ovipositor was inwardly at an angle to the surface of the object. It might be mentioned here that the ovipositor was longer than the length of the parasite's abdomen.

The parasite then gently separated the main egg laying instrument from its two sheath-like coverings and slowly began to pierce the mantis egg case.

The flexible sheaths curved well backwards forming an arch with their tips alone touching the main ovipositing tube one on each side. In the course of this work the sheaths acted as props or supports and prevented the main instrument or tube from bending or breaking. The ovipositor when it was half thrust home was left in that position for 3 to 6 minutes, sometimes longer. Afterwards the whole instrument was drawn out and gently smoothed by the posterior legs and then left in its normal position. A single parasite, oviposited 4 to 5 times. While attached to the case, however much disturbed, the parasites were found to persist in adhering to the egg case. Ten days after oviposition I gently split open the case and found grubs inside.

On 6th February, 1922, i.e., after a period of 29 days, a number of mantis nymphs and parasites emerged for 3 days consecutively. The nymphs were fed on eye-flies and other small flies, but did not survive. After 3 days all had died. The parasites were identified as *Podagrion pachymerum*.

CEREAL—GROUNDNUT—ROTATION EXPERIMENT ON THE PALUR AGRICULTURAL STATION

By M.R.Ry. N. S. KULANDAISWAMI PILLAI,
Assistant Director of Agriculture in Charge of IV Circle

AND

M.R.Ry. K. AVUDAINAYAKAM PILLAI,
Farm Manager.

1. Groundnut is one of the chief industrial crops of the Madras Presidency. Its cultivation is spreading rapidly everywhere. Owing to the suitability of the soil and the nearness to the French market (Pondicherry), South Arcot was one of the districts where groundnut was first introduced. As far back as 1851, the Collector of South Arcot reported that it was a profitable crop in the district, having 3,000 acres under it. How rapidly this crop spread in the district, may be seen from the table given below :—

Year.	Area in acres
1851	3,000
1856	6,000
1870	20,000
1882	48,000
1895–1896	185,000
1899–1900	343,000
1909–1910	375,000
1913–1914	463,000
1919–1920	335,350

2. Like any other introduced crop, it had its own rise and fall. In 1896–97, the area under this crop dropped suddenly to 88,000 acres and in 1897–98 to 52,000 acres. The reason for this is not far to seek. So profitable was its cultivation that the ryots, in their eagerness to get as much money as they could, began to gamble on it. They cultivated the crop on all sorts of soils unmindful of rotation. Adequate supply of manure was not given. The natural consequences were the yield of groundnut and the percentage of oil were very poor. The crop became prone to insect attacks and fungus diseases, and the crop ceased to pay as well as before.

3. With the introduction of new seed from Mauritius, however, in 1897–98 there was a revival of the groundnut cultivation. The effect of the new seed did not last long. The farmers who had for sometime forgotten themselves and their cattle by neglecting to grow grain crops became more wise and began to grow their usual cereals.

4. But at the same time they did not give up groundnut, although their confidence in the crop was shaken. They interdibbled groundnut in the cereals. The rains in South Arcot are so well distributed that this mixed cropping was a success. But the ryots were not decided as to which cereal was best suited as a mixture with groundnut, nor were they quite certain whether rotation or mixed cropping was more profitable.

5. To test these two points, an experiment was started at the Palur Agricultural Station in 1907–08.

6. Before proceeding with the experiments it would not be out of place to give here an idea of

the soil conditions of the tract in general, and of the Palur Farm in particular, and the rainfall of the locality.

7. The Palur Agricultural Station is fairly typical of a strip of alluvial soil which lies between the Pennaiyar and the Gadilam rivers. It is a very fertile tract with a high water level. The dry lands, in consequence, are mainly commanded by wells and very intensive cultivation is practised. Thus, it may be observed that the dry land of the Farm is hardly typical of the ordinary groundnut tract. The tract depends on both the south-west and north-east monsoons for its rainfall, and it seldom happens that both fail. Sowing rains are generally received at the end of June or the beginning of July, and subsequent rainfall gradually increases as the monsoon weakens so that the bulk of the south-west rains usually fall in August-September. The rainfall of the north-east monsoon is cyclonic and is much more uncertain than that of the south-west. Often the Gadilam gets flooded in November, the average rainfall in the month being 14·85, and not infrequently the farm crops are under water for some days. To add to the unfavourable situation of the farm, the growth of korai (*Cyperus rotundus*) on the farm is another source of trouble. This pest grass is so bad in all the fields, including the experimental plots, that the yield and development of groundnut are materially affected. But the effect of this evil being common to all the experimental plots, the results of the experiment may be taken as fairly accurate.

EXPERIMENTS.

8. In 1907-08, a simple trial was started to study the following points :—

(i) The best cereal that could be used as a mixture with groundnut.

(ii) Whether a change of the cereal every year in the mixture would be more profitable.

9. These were compared with a pure groundnut crop raised every year on the same field.

10. The cereals selected were those that were commonly cultivated by the farmers of the tract, viz., cumbu (*Penisetum typhoideum*) and tenai (*Setaria italica*).

11. For this purpose, five half-acre plots were selected, and the experiment was arranged as shown below :—

(i) Plot No. 22. Tenai every year followed by groundnut.

(ii) Plot No. 29. Cumbu every year followed by groundnut.

(iii) Plot No. 34. Groundnut every year without a cereal.

(iv) Plot No. 23. Cumbu and tenai alternating (tenai in odd years) followed by groundnut.

(v) Plot No. 24. Cumbu and tenai alternating (tenai in even years) followed by groundnut.

12. In all these cases, the cereals were sown with the first rains of the south-west monsoon (i.e., in June-July) and groundnut dibbled in a month later.

13. This experiment was carried on till 1910-11 when, in order to test the value of rotation, viz., a cereal followed by groundnut in one year with the same rotation spread over two years, the plots which were half acre in area were divided into

quarter acre plots A and B. In the A series the experiment with groundnut interplanted in a cereal in the same year has been continued, while in the B series groundnut was grown in even years with the cereals in odd years.

14. In 1912–13 another cereal was added to the list, viz., ragi (*Eleusine coracana*). In fairness this should not have been included in the experiment as ragi unlike cumbu or tenai has to be irrigated now and again. It should be noted here that groundnut in plot 34, i.e., in the pure groundnut plot, was being sown with the first showers of the south-west monsoon which means a month earlier than in the other plots. As it was thought that the early or late sowing might affect the experiment, in 1917–18, plot No. 34 was divided into two quarter acre plots—in one of which groundnut was sown just at the time when the cereals were sown and in the other a month or so later, i.e., when groundnut was dibbled in, in the cereal crops.

15. Only figures from 1913 are taken as the experiment took shape from that year.

RESULTS OF THE EXPERIMENT.

16. The following are the inferences that can be drawn from this experiment. All these are borne out by the statements attached :—

(i) Yield of groundnut is greatly reduced by growing it year after year on the same field without any rotation. From statement No. 3 it may be observed that except in a few years when the season was very favourable there is a decline in the yield.

(ii) Mixed cropping groundnut interplanted in a cereal has a great advantage from a monetary point of view over the cereal groundnut rotation (i.e., cereal one year and groundnut another year). In the one case both a grain crop and money crop are raised in one year, while in the other case two years are taken to get these two crops. A glance at the summary given below in statement 2 clearly shows that in all years mixed cropping is more profitable.

(iii) Having come to the conclusion that so far as groundnut is concerned mixed cropping is better than rotation it now remains to decide which is the cereal best suited to be used as a mixture with groundnut. From the statements 1 and 2 it may be observed that the results in plot 30-A, 31-A, 32-A and 33-A where ragi is one of the cereals which is used as a mixture with groundnut the yields and money value are invariably high. But as explained in paragraph 14 ragi being an irrigated crop it would be unfair to compare its yield with the purely rainfed crops of cumbu and tenai. Barring ragi, therefore, it may be observed that cumbu seems to be a better cereal than tenai to use as a mixture with groundnut.

(iv) The same statement shows that a change in the cereal in which groundnut is inter-planted has a better effect on the yields of groundnut and the cereal than the same cereal repeated every year. The results in plots No. 23-A, 24-A, 30-A, 31-A and 32-A where there is a change in the cereal every year are better than in plots 22-A and 29-A where the same cereal was repeated every year.

It is worthy of note that the practice current in the district agrees with the inference of this experiment, viz., mixed cropping of groundnut is better than rotation and cumbu is the best cereal as a mixture.

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation.

Note.—(1) C = Cumbu, T = Tenai, R = Ragi.
(2) Uniform price has been adopted in the calculation both for cereal and groundnut. Cereals are valued at lb. 24 per rupee and groundnut is valued at lb. 20 per rupee

Field number.	Description	Crops.	1913–14		1914–15.		1915–16.		1916–17.	
			Yield in lb	Value.	Yield in lb.	Value.	Yield in lb	Value.	Yield in lb.	Value.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
				RS. A. P.		RS. A. P.		RS. A. P		RS. A. P.
22-A	Tenai intersown with groundnut every year ..	Cereal ...	660	27 8 0	1,040	43 5 4	830	34 9 4	528	22 0 0
		Groundnut ...	532	26 9 7	236	11 12 10	296	14 10 10	572	28 9 7
			...	54 1 7	..	55 2 2	.	49 4 2		50 9 7
22-B	Tenai in rotation with groundnut	Cereal ...	479	19 15 4			1,077	44 14 0	..	
		Groundnut ..		..	858	42 14 5	..		700	35 0 0
			.	19 15 4	-	42 14 5	.	44 14 0		35 0 0
29-A	Cumbu intersown with groundnut every year ...	Cereal ...	608	25 5 4	1,420	59 2 8	711	29 10 0	740	30 13 4
		Groundnut ...	304	15 3 2	188	9 6 5	292	14 9 7	604	30 3 2
				40 8 6	...	68 9 1	..	44 3 7		61 0 6
29-B	Cumbu in rotation with groundnut	Cereal ..	784	32 10 8	.	..	582	24 4 0		..
		Groundnut ..	.		548	27 6 5		..	986	49 4 10
			...	32 10 8	...	27 6 5		24 4 0		49 4 10
23-A	Tenai and cumbu intersown with groundnut ...	Cereal ..	T 600	25 0 0	C 1,262	52 9 4	T 1,176	49 0 0	C 946	39 6 8
		Groundnut ...	536	26 12 10	215	10 12 0	424	21 3 2	628	31 6 5
			.	51 12 10	...	63 5 4	..	70 3 2	...	70 13 1

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation—*cont.*

Field number.	Description.	Crops.	1917-18.		1918-19.		1919-20.		1920-21.	
			Yield in lb (12)	Value (13)	Yield in lb. (14)	Value. (15)	Yield in lb. (16)	Value. (17)	Yield in lb. (18)	Value. (19)
				RS. A. P.		RS A. P		RS. A. P.		RS. A. P.
22-A	Tenai intersown with groundnut every year ...	Cereal .	1,122	46 12 0	634	26 6 8	1,160	48 5 4	Fail.	...
		Groundnut ...	480	24 0 0	172	8 9 7	136	6 12 10	296	14 12 9
				70 12 0		35 0 3	.	55 2 2	..	14 12 9
22-B	Tenai in rotation with groundnut	Cereal .	1,750	72 14 8	.		1,476	61 8 0		...
		Groundnut ...	.		344	17 3 2	..	.	984	49 3 2
			.	72 14 8	.	17 3 2	..	61 8 0	.	49 3 2
29-A	Cumbu intersown with groundnut every year ...	Cereal	942	39 4 0	1,248	57 0 0	1,140	47 8 0	520	21 10 8
		Groundnut .	636	31 12 10	664	33 3 2	484	24 3 2	480	24 0 0
			..	71 0 10	..	90 3 2	...	71 11 2	..	45 10 8
29-B	Cumbu in rotation with groundnut	Cereal ..	1,388	57 13 4		...	1,104	46 0 0	...	
		Groundnut ..	...	.	380	19 0 0	...	.	856	42 12 10
			...	57 13 4	...	19 0 0	..	46 0 0	...	42 12 10
23-A	Tenai and cumbu intersown with groundnut ...	Cereal .	T 1,472	61 5 4	C 946	39 6 8	T 1,180	49 2 8	C 510	21 4 0
		Groundnut ..	736	36 12 10	252	12 9 7	304	15 3 2	540	27 0 0
			...	98 2 2	...	52 0 3	...	64 5 10	...	48 4 0

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation—*cont.*

Field number. (1)	Description. (2)	Crops. (3)	1913-14. Yield in lb. (4)	1913-14. Value. (5)	1914-15. Yield in lb. (6)	1914-15. Value. (7)	1915-16. Yield in lb. (8)	1915-16. Value (9)	1916-17. Yield in lb. (10)	1916-17. Value. (11)
				RS. A. P.		RS. A. P.		RS. A. P.		RS. A. P.
23-B	Tenai in rotation with groundnut	Cereal	1,068	44 8 0	...	...	1,158	48 4 0	...	...
		Groundnut	.		936	46 12 10		...	1,000	50 0 0
			.	44 8 0		46 12 10		48 4 0	..	50 0 0
24-A	Tenai and cumbu intersown with groundnut	Cereal	C 764	31 13 4	T 870	36 4 0	C 867	36 2 0	T 796	33 2 8
		Groundnut	552	27 9 7	298	14 14 5	512	25 9 7	408	20 6 5
			..	59 6 11		51 2 5		61 11 7	...	53 9 1
24-B	Cumbu in rotation with groundnut	Cereal	724	30 2 8		...	952	39 10 8	...	...
		Groundnut	..		960	48 0 0	..	...	914	45 11 2
			.	30 2 8		48 0 0		39 10 8	...	45 11 2
30-A	Cumbu and ragi intersown with groundnut ...	Cereal	R 1,512	63 0 0	C 1,421	59 3 4	R 1,610	67 1 4	C 1,320	55 0 0
		Groundnut	1,040	52 0 0	240	12 0 0	484	24 3 2	692	34 9 7
			..	115 0 0		71 3 4	..	91 4 6	...	89 9 7
30-B	Ragi in rotation with groundnut	Cereal	1,176	49 0 0			1,568	65 5 4	.	..
		Groundnut	.	.	388	19 6 5		.	546	27 4 10
				49 0 0		19 6 5	.	65 5 4	...	27 4 10
31-A	Cumbu and ragi intersown with groundnut	Cereal	C 409	17 0 8	R 946	39 6 8	C 742	30 14 8	R 936	39 0 0
		Groundnut	424	21 3 2	222	11 1 7	132	6 9 7	848	42 6 5
				38 3 10		50 8 3		37 8 3		81 6 5

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation—*cont.*

Field number.	Description.	Crops.	1917-18. Yield in lb. (12)	1917-18. Value. (13)	1918-19. Yield in lb. (14)	1918-19. Value. (15)	1919-20. Yield in lb. (16)	1919-20. Value. (17)	1920-21. Yield in lb. (18)	1920-21. Value. (19)
				RS. A. P.		RS. A. P.		RS. A. P.		RS. A. P.
23-B	Tenai in rotation with groundnut	Cereal .	1,668	69 8 0	...		1,484	61 13 4		...
		Groundnut .	.	.	392	19 9 7	..	.	1,052	52 9 7
			.	69 8 0	..	19 9 7	..	61 13 4	...	52 9 7
24-A	Tenai and cumbu intersown with groundnut ...	Cereal ...	C 1,038	43 4 0	T 734	30 9 4	C 924	38 8 0	T 704	29 5 4
		Groundnut .	648	32 6 5	388	19 6 5	236	11 12 10	216	10 12 10
				75 10 5		49 15 9	...	50 4 10	...	40 2 2
24-B	Cumbu in rotation with groundnut ..	Cereal ...	1,192	49 10 8		..	1,090	45 6 8	.	.
		Groundnut .	...	...	328	16 6 5	.	...	1,310	65 8 0
			..	49 10 8		16 6 5	.	45 6 8	.	65 8 0
30-A	Cumbu and ragi intersown with groundnut	Cereal	R 1,992	83 0 0	C 1,304	54 5 4	R 1,792	74 10 8	C 532	22 2 8
		Groundnut ..	496	24 12 10	656	32 12 10	212	10 9 7	468	23 6 5
			...	107 12 10		87 2 2	..	85 4 3	...	45 9 1
30-B	Ragi in rotation with groundnut	Cereal ...	2,020	84 2 8	..		1,580	65 13 4	...	...
		Groundnut .	.		516	25 12 10	.	...	812	40 9 7
			..	84 2 8	...	25 12 10	...	65 13 4	...	40 9 7
31-A	Cumbu and ragi intersown with groundnut	Cereal ..	C 1,080	45 0 0	R 1,878	78 4 0	C 1,128	47 0 0	R 1,576	65 10 8
		Groundnut .	424	21 3 2	328	16 6 5	432	21 9 7	100	5 0 0
				66 3 2	...	94 10 5		68 9 7	..	70 10 8

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation—*cont.*

Field number. (1)	Description. (2)	Crops. (3)	1913-14. Yield in lb (4)	1913-14. Value. (5) RS. A. P.	1914-15 Yield in lb. (6)	1914-15 Value. (7) RS A. P.	1915-16 Yield in lb. (8)	1915-16 Value. (9) RS. A P.	1916-17. Yield in lb. (10)	1916-17. Value (11) RS. A. P.
31-B	Cumbu in rotation with groundnut.	Cereal ...	712	29 10 8		...	642	26 12 0	...	..
		Groundnut .	...	...	524	26 3 2	...	...	714	35 11 2
			...	29 10 8	...	26 3 2		26 12 0	...	35 11 2
32-A	Ragi and tenai intersown with grundnut.	Cereal ..	R 1,224	51 0 0	T. 960	40 0 0	R. 1,252	52 2 8	T. 856	35 10 8
		Groundnut ..	1,000	50 0 0	152	7 9 7	732	36 9 7	284	14 3 2
				101 0 0	..	47 9 7	.	88 12 3	...	49 13 10
32-B	Ragi in rotation with groundnut.	Cereal ...	1,077	44 14 0	...	...	1,324	55 2 8		..
		Groundnut ...	...		556	27 12 10		.	984	49 3 2
			...	44 14 0	...	27 12 10	...	55 2 8	...	49 3 2
33-A	Ragi and tenai intersown with groundnut.	Cereal .	T 473	19 11 4	R. 924	38 8 0	T. 684	28 8 0	R. 912	38 0 0
		Groundnut ...	288	14 6 5	218	10 14 5	172	8 9 7	824	41 3 2
			...	34 1 9	..	49 6 5	.	37 1 7	...	79 3 2
33-B	Tenai in rotation with groundnut.	Cereal ..	792	33 0 0		...	748	31 2 8		..
		Groundnut ..	..	..	376	18 12 10	.		980	49 0 0
			...	33 0 0	..	18 12 10	..	31 2 8		49 0 0
34-B	Groundnut, pure	Cereal .			...	...	.		..	.
		Groundnut ...	1,100	55 0 0	786	39 4 10	1,380	69 0 0	827	41 5 7
			...	55 0 0	...	39 4 10	...	69 0 0	..	41 5 7

STATEMENT I.—Detailed statement of comparison of money value and yield of produce between cereal groundnut mixture and rotation—*cont.*

Field number.	Description	Crops.	1917-18 Yield in lb. (12)	1917-18 Value (13)	1918-19 Yield in lb (14)	1918-19 Value. (15)	1919-20. Yield in lb. (16)	1919-20. Value. (17)	1920-21. Yield in lb (18)	1920-21. Value (19)
				RS. A. P.		RS. A. P.		RS A. P.		RS. A. P.
31-B	Cumbu in rotation with groundnut.	Cereal ...	1,298	54 1 4		...	896	37 5 4		
		Groundnut ...	.	. .	392	19 9 7	..		808	40 6 5
				54 1 4	.	19 9 7	.	37 5 4	.	40 6 5
32-A	Ragi and tenai intersown with groundnut.	Cereal ...	R. 1,232	51 5 4	T. 728	30 5 4	R. 1,528	63 10 8	T. Fail.	...
		Groundnut ...	412	20 9 7	320	16 0 0	178	8 14 5	296	14 12 10
				71 14 11		46 5 4	. .	72 9 1	...	14 12 10
32-B	Ragi in rotation with groundnut	Cereal ...	1,968	82 0 0		..	1,516	63 2 8		...
		Groundnut		.	356	17 12 10	...		974	48 11 2
				82 0 0		17 12 10	...	63 2 8		48 11 2
33-A	Ragi and tenai intersown with groundnut.	Cereal	T 1,160	48 5 4	R 1,624	67 10 8	T 992	41 5 4	R. 1,736	72 5 4
		Groundnut ...	640	32 0 0	294	14 11 2	116	5 12 10	172	8 9 7
				80 5 4	...	82 5 10	...	47 2 2	...	80 14 11
33-B	Tenai in rotation with groundnut.	Cereal . .	1,650	68 12 0	...	..	1,340	55 13 4		...
		Groundnut .	...	...	340	17 0 0	...		984	49 3 2
				68 12 0		17 0 0	...	55 13 4	...	49 3 2
34-B	Groundnut, pure	Cereal		..	...	..	...	...		...
		Groundnut	1,712	85 9 7	296	14 12 10	696	34 12 10	600	30 0 0
			...	85 9 7	...	14 12 10	..	34 12 10		30 0 0

STATEMENT II.—Statement of comparison of money value of produce between cereal groundnut mixture and rotation.

Field number.	Description.	1913-14 and 1914-15			1915-16 and 1916-17.			1917-18 and 1918-19			1919-20 and 1920-21.			Average		
		RS.	A.	P.	RS.	A.	P.	RS.	A.	P.	RS.	A.	P.	RS	A.	P.
F. 22-A	Tenai every year interplanted with groundnut	109	3	9	99	13	9	105	12	3	69	14	11	96	3	2
F. 22-B	Tenai in rotation with groundnut	62	13	9	79	14	0	90	1	10	110	11	2	85	14	2
F 29-A	Cumbu every year interplanted with groundnut .	109	1	7	105	4	1	161	4	0	117	5	10	123	3	10
F. 29-B	Cumbu in rotation with groundnut	60	1	1	73	8	10	76	13	4	88	12	10	74	13	0
F. 23-A	Cumbu and tenai alternating intersown with groundnut	115	2	2	141	0	3	150	2	5	112	9	10	129	11	8
F 23-B	Tenai in rotation with groundnut	91	4	10	98	4	0	89	1	7	114	6	11	98	4	4
F. 24-A	Cumbu and tenai alternating intersown with groundnut .	110	9	4	115	4	8	125	10	2	90	7	0	110	7	9
F. 24-B	Cumbu in rotation with groundnut.	78	2	8	85	5	10	66	1	1	110	14	8	85	2	1
F 30-A	Cumbu and ragi alternating intersown with groundnut	186	3	4	180	14	1	194	15	0	130	13	4	173	3	5
F. 30-B	Ragi in rotation with groundnut	68	6	5	92	10	2	109	15	6	106	6	11	94	5	9
F 31-A	Cumbu and ragi alternating intersown with groundnut	88	12	1	118	14	8	160	13	7	139	4	3	126	15	2
F 31-B	Cumbu in rotation with groundnut.	55	13	10	62	7	2	73	10	11	77	11	9	67	6	11
F. 32-A	Tenai and ragi alternating intersown with groundnut	148	9	7	138	10	1	118	4	3	87	5	11	123	3	5
F. 32-B	Ragi in rotation with groundnut	72	10	10	104	5	10	99	12	10	111	13	10	97	2	10
F 33-A	Ragi and tenai alternating intersown with groundnut .	83	8	2	116	4	9	162	11	2	128	1	1	122	10	3
F 33-B	Tenai in rotation with groundnut .	51	12	10	80	2	8	85	12	0	105	0	6	80	11	0
F. 34	Groundnut sown pure every year	94	4	10	110	5	7	100	6	5	64	12	10	92	7	5

SUMMARY.

Average money value for two years of cereals intersown with groundnut.				Average money value for two years of cereals and groundnut in rotation.			
Plots.	RS.	A.	P.	Plots.	RS.	A.	P.
22-A.	96	3	2	22-B.	85	14	2
29-A.	123	3	10	29-B.	74	13	0
23-A.	129	11	8	23-B.	98	4	4
24-A.	110	7	9	24-B	85	2	1
30-A.	173	3	5	30-B.	94	5	9
31-A.	126	15	2	31-B.	67	6	11
32-A.	123	3	5	32-B.	97	2	10
33-A.	122	10	3	33-B.	80	11	0

Average money value for 2 years of pure groundnut 92 7 5

STATEMENT III.—Yield in lb. per acre of groundnut in the different experimental plots during the years 1913–14 to 1920–21.

Field number (1)	Description (2)	1913–14. (3)	1914 15. (4)	1915–16 (5)	1916–17. (6)	1917–18. (7)	1918 19. (8)	1919–20. (9)	1920–21. 10)
F. 22-A	Tenai intersown with groundnut	532	236	296	572	480	172	136	296
F. 22-B	Tenai in rotation with groundnut	...	858		700	...	344	...	984
F 29-A	Cumbu intersown with groundnut	304	188	292	604	636	664	484	480
F. 29-B	Cumbu in rotation with groundnut.	...	548	..	986	...	380	...	856
F. 23-A	Tenai and cumbu intersown with groundnut.	536	215	424	628	736	252	304	540
F. 23-B	Tenai in rotation with groundnut	...	936	...	1,000	...	392		1,052
F. 24-A	Tenai and cumbu intersown with groundnut.	552	298	512	408	648	388	236	216
F. 24-B	Cumbu in rotation with groundnut		960	...	914		328		1,310
F. 30-A	Cumbu and ragi intersown with gronndnut	1,040	240	484	692	496	656	212	468
F. 30 B	Ragi in rotation with groundnut.		388	...	546	..	516		812
F. 31-A	Cumbu and ragi intersown with groundnut.	424	222	132	848	424	328	432	100
F 31-B	Cumbu in rotation with groundnut.		524		714	...	392	..	808
F. 32-A	Ragi and tenai intersown with groundnut	1,000	152	732	284	412	320	178	296
F. 32-B	Ragi in rotation with groundnut.	..	556	..	984	...	356	...	974
F 33-A	Ragi and tenai intersown with groundnut	288	218	172	824	640	294	116	172
F. 33-B	Tenai in rotation with groundnut.		376	...	980	...	340	...	984
F. 34-B	Pure groundnut	1,100	786	1,380	827	1,712	296	696	600

NOTE ON THE PERMANENT MANURIAL PLOTS, COIMBATORE

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(with 5 figures).

The permanent manurial plots at the Central Farm, Coimbatore, were laid down in September 1909 and have, therefore, now been under observation for thirteen years. An account of some of the results obtained has already been published by Mr. Wood in the Year Book for 1917. In recent years, however, the differences between the various plots have been strikingly emphasized and various points of interest which escaped notice in the earlier years of the experiment have become obvious. It seems, therefore, desirable to give once more a brief account of the results observed up to date. A more detailed account of these results has been published elsewhere.*

The plots are ten in number and each approximately 4 cents in area. No. 1 plot has received no manure of any kind while the others have received nitrogen, phosphoric acid or potash either alone or in combination. The treatment given to any particular plot has, however, been the same throughout the course of the experiment and is indicated in the table below.

Treatment of plots.

Plot No.	Treatment.	Manure.
1	No manure	...
2	Nitrogen	Ammonium sulphate 1 cwt. per acre

* Norris, Memoir., Dep. of Agric., Chem. Series, 1922, in the press.

Plot No.	Treatment	Manure.
3	Nitrogen .. + Potash	Ammonium sulphate 1 cwt. per acre. + Potassium sulphate 1 cwt. per acre.
4	Nitrogen .. .. + Phosphate	Ammonium sulphate 1 cwt. per acre. + Supherphosphate 3 cwts. ,,
5	Nitrogen ... . + Potash ... + Phosphate	Ammonium sulphate 1 cwt. per acre. Potassium sulphate 1 cwt. ,, Superphosphate 3 cwts. ,,
6	Potash .. + Phosphate	Potassium sulphate 1 cwt. per acre Superphosphate 3 cwts ,,
7	Potash ..	Potassium sulphate 1 cwt. per acre.
8	Phosphate	Superphosphate 3 cwts. per acre.
9	Cattle manure	Cattle manure 5 tons per acre.
10	Cattle manure	Cattle manure Application stopped in 1916 and residual effect observed

The soil of the unmanured plot is typical of many in the Madras Presidency exhibiting a low content of organic matter and a marked deficiency of nitrogen and available phosphoric acid while potash in an available form is present in considerable amount. The figures obtained by an analysis in 1916 are shown below together with those from the plot receiving the complete mineral manure. A striking feature in the latter is the accumulation of available phosphoric acid.

Particulars.	Plot I, No manure.	Plot V, Complete mineral manure.
	Per cent.	Per cent.
Moisture	2·00	2·23
Organic matter (loss on ignition)	2·39	2 13
Lime	0·85	0·75
Magnesia	0·49	0·56
Potash (total) (K_2O)	0·23	0·29
Phosphoric acid (total) (P_2O_5)	0·031	0·059
Nitrogen	0·029	0·030
Available phosphoric acid (P_2O_5)	0·0076	0·043
Available potash (K_2O)	0 017	0·020

By means of intensive cultivation, it has been possible as a general rule to raise three crops a year or thirty-six in all since the experiment started. In this way the differential action of the manures has been emphasized to the greatest possible extent.

The yields obtained with all the crops are shown below in table I, being calculated to lb. per acre.

TABLE

Permanent Manurial

CROP YIELDS

Year.	Crop number.	Nature of crop.	Yield of grain.									
			1	2	3	4	5	6	7	8	9	10
			No manure.	N.	N+K.	N+P.	N+K +P.	K+P.	K.	P.	Cattle manure (*a*)	Cattle manure (*b*)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1909-10	1	Cholam ...	...				...	..	...	..	...	...
	2	Do. ...	...		...	..		...	.	..	..	...
	3	Cumbu ..	..	.		...	...			..	.	...
1910-11	4	Ragi ..	750	1,100	1,025	1,025	1,475	1,550	1,475	900	1,260	1,633
	5	Wheat .	850	1,350	1,250	1,550	1,825	1,350	1,175	1,400	1,300	900
1911-12	6	Cholam ...	1,025	1,850	1,250	1,650	2,125	1,550	1,425	850	1,600	2,017
	7	Gogu ...	..	.	.			.			.	
	8	Paniyaragu.	1,062	1,037	887	1,062	1,112	787	812	787	990	925
1912-13	9	Cholam .	1,400	1,725	1,850	1,875	1,900	1,900	1,375	1,125	1,930	1,850
	10	Ragi	900	1,275	1,150	1,450	1,375	1,375	1,100	1,075	1,600	1,310
	11	Wheat	450	850	800	875	950	750	525	600	400	333
1913-14	12	Cholam ..	1,037	1,250	1,800	1,150	1,637	1,275	1,025	°312	1,410	1,783
	13	Ragi . ..	925	1,225	1,100	1,475	1,325	1,100	1,075	725	1,020	1,117
	14	Panivargu ..	1,112	967	962	1,357	1,350	1,312	925	1,200	1,500	1,517
1914-15	15	Cholam .	725	875	1,000	2,000	1,825	1,700	1,225	1,350	2,500	2,750
	16	Fodder cholam ..	...	..		.		.	..			
	17	Bengal gram.	100	175	250	250	175	125	100	50	175	300
1915-16	18	Cholam ..	400	450	525	1,100	1,050	1,300	800	950	1,240	867
	19	Ragi	875	975	875	1,675	1,725	1,425	757	1,012	1,600	1,500
	20	Wheat ...	312	325	318	594	650	625	356	362	390	546
1916-17	21	Cholam		...	...		..	...	..	...	...	...
	22	Gogu .	...	...	...		...	..	.	...		...
	23	Tobacco ..	..	...	...	.		...	.			.
1917-18	24	Cholam	1,125	950	850	3,075	2,600	2,325	1,000	2,075	2,860	1,900
	25	Cotton ...			.			.				
	26	Panivaragu	1,100	1,750	1,175	2,350	1,500	2,000	1,300	1,850	1,800	1,350
1918-19	27	Cholam ..	300	500	500	600	550	500	500	600	[illegible]	550
	28	Ragi . .	312	487	631	1,857	2,150	1,812	737	1,181	1,665	646
	29	Gogu ...		...	...							
1919-20	30	Cholam .	475	575	500	1,550	1,625	1,500	550	1,375	1,920	1,033
	31	Ragi .. .	187	312	412	1,450	1,500	1,325	537	925	1,560	425
	32	Wheat ...	25	50	225	350	600	450	200	275	720	116
1920-21	33	Cholam .	500	575	550	1,500	1,400	1,425	500	975	1,250	817
	34	Ragi	...	...	.	.	...				...	
1921-22	35	Cholam	920	1,135	1,298	3,000	2,973	2,675	1,545	2,680	3,057	1,762
	36	Ragi	80	189	270	1,371	1,587	776	459	960	1,116	256

N.=1 cwt. ammonium sulphate per acre.

K.=1 cwt. potassium sulphate per acre.

I.

Plots, Coimbatore.

(LB. PER ACRE).

Yield of straw.											
1	2	3	4	5	6	7	8	9	10	Remarks.	Crop number.
No manure.	N	N+K	N+P	N+K +P	K+P.	K.	P	Cattle manure (*a*).	Cattle manure (*b*)		
(14)	(15)	(16)	(17)*	(18)	(19)	(20)	(21)	(22)	(23)	(24)	
...		..	.	...	...	...	.	...		Sorghum vulgare } Yields not recorded.	1
..		..	...	.	...		..	...	.	Yields not recorded.	2
..	...	.	.	...	...	...	...	.	.	Pennisetum typhoideum	3
9,800	11,900	11,600	11,400	12,000	9,800	11,200	8,500	10,000	9,660	Eleusine coracana .	4
1,175	1,500	1,000	1,750	2,325	1,900	1,275	1,575	2,020	1,100	Triticum sativum ..	5
8,600	9,600	9,600	10,000	10,000	8,700	11,200	8,400	12,[illegible]00	16,200	Sorghum vulgare * ...	6
550	675	750	900	800	600	650	900	600	633	Hibiscus canabinus	7
1,325	1,400	1,150	1,250	1,350	950	775	775	1,450	1,800	Panicum mileaceum	8
10,200	13 500	12,200	10,300	12,600	14,500	12,200	9,100	5,350	12,525	Sorghum vulgare	9
6,000	8,300	7,000	8,400	6,700	6,000	6,000	6,000	8,480	7,266	Eleusine coracana	10
1,150	1,800	1,000	2,100	1,875	1,300	1,300	1,100	1,080	1,133	Triticum sativum ...	11
5,400	6,500	5,500	6,600	6,600	5,700	5,500	*3,500	6,480	6,133	* Plot 8 (P) damaged by stray cattle	12
3,300	7,500	3,300	7,000	6,500	9,300	4,400	4,000	5,600	5,133	Eleusine coracana ..	13
1,100	925	877	1,600	1,425	1,237	925	937	1,360	1,316	Panicum mileaceum	14
4,600	5,300	6,900	6,300	7,000	6,300	6,800	4,100	6,500	6,467	Sorghum vulgare ...	15
.	.	...		.	...	.				Crop failed	16
...	.		.							Manures not applied	17
11 200	10,100	16,800	11,800	13,600	13,800	40,000	11,400	12,800	8,400	Sorghum vulgare ..	18
6,37[illegible]	7,175	7,150	13,500	11,625	7,200	5,000	4,650	6,720	6,733	Eleusine coracana ...	19
750	700	700	1,025	1,000	1,075	600	675	760	1,133	Triticum sativum ..	20
9,750	9,650	10,675	17,825	15,975	15,600	11,762	12,875	15,090	16,305	Cut green for fodder	21
21,500	20,000	19,200	22,600	21,300	17,200	19,200	17,500	24,300	21,900	Green stalks { Cattle manure in plot 10, discontinued hereafter	22
.	.			..		.				Crop failed .	23
4,725	5,050	5,125	7,450	7,225	6,275	5,225	5,675	6,018	5,133	Sorghum vulgare .	24
										Crop failed .	25
850	1,175	1,000	2,225	1,900	1,825	1,300	1,800	1,920	1 300	Panicum mileaceum .	26
2,900	4,250	4,700	4,325	4,750	4,025	3,725	3,800	3,900	3,317	Sorghum vulgare ...	27
2,825	4,537	4,812	8,512	11,500	8,962	4,537	5,837	7,740	5,125	Eleusine coracana .	28
.	...	...		.			..		..	Crop failed .	29
2,262	3,410	3,520	4,472	4,180	3,777	3,630	3,777	4,722	3,675	Sorghum vulgare ..	30
600	800	833	3,966	4,466	3,333	1,333	2,800	3,733	1,133	Eleusine coracana	31
300	575	1,375	1,725	2,575	1,925	1,100	1,300	2,600	933	Triticum sativum .	32
2,975	3,750	3,950	6,250	6,275	6,275	4,775	5,450	7,260	4,917	Sorghum vulgare	33
...				..		...	...	.	..	Crop attacked by borer and partially failed	34
5,108	6,270	7,784	11,892	12,10[illegible]	10,811	8,432	10,720	12,686	9,238	Sorghum vulgare ...	35
840	1,705	2,105	6,703	7,459	5,405	2,703	3,600	6,686	2,331	Eleusine coracana .	36

P = 3 cwt. superphosphate per acre

Cattle manure = 5 tons per acre

It is, however, difficult from these figures readily to observe the influence of the various manures. Consequently in tables II to V the yields of all the crops have been averaged and are shown calculated to a common basis, the value of the "no manure" plot being taken as 100. From these figures the percentage improvement brought about by any application of manure can be seen at a glance. The results with cholam and ragi are also shown diagramatically in figures IV and V.

TABLE II.

RELATIVE YIELDS OF CHOLAM.

(See Figure IV.)

No manure = 100.

Plot.	Average of all crops.		Average of crops from 24 onwards.	
	Grain.	Straw.	Grain.	Straw.
No manure	100	100	100	100
N.	124	116	112	126
K.	125	117	123	143
P.	168	121	232	163
N. + P.	182	137	292	191
N. + P. + K.	222	145	275	192
N. + K.	139	131	111	140
K. + P.	203	138	253	167
Cattle manure	235	135	295	192

TABLE III.

RELATIVE YIELDS OF RAGI.

(*See Figure V.*)

No manure = 100.

Plot.	Average of all crops		Average of crops from 19 onwards.	
	Grain.	Straw	Grain.	Straw.
No manure	100	100	100	100
N	138	141	135	133
K.	153	118	173	127
P.	168	119	280	158
N. + P.	261	200	453	307
N. + P. + K	276	226	479	330
N + K.	135	121	150	140
K. + P.	232	174	367	234
Cattle manure	241	164	402	233

TABLE IV

RELATIVE YIELDS OF WHEAT.

No manure = 100

Plot.	Average of all crops	
	Grain	Straw.
No manure .	100	100
N . .	157	135
K.	138	126
P.	161	137
N. + P.	224	195
N + P + K	246	230
N. + K.	158	120
K. + P.	194	183
Cattle manure	171	191

TABLE V

RELATIVE YIELDS OF PANIVARAGU.

No manure = 100.

Plot.	Average of all crops.	
	Grain.	Straw
No manure	100	100
N.	115	103
K.	92	91
P	117	108
N + P.	146	155
N + P + K.	121	142
N + K.	92	92
K + P.	125	122
Cattle manure	131	144

In the case of cholum and ragi which have each been grown a considerable number of times, two sets of figures are shown ; one the average of all the crops grown, the second the average of the later crops only.

It is quite clear from these figures that the controlling factor in the plots is now the supply of phosphoric acid. It was shown by Mr. Wood, vide Year Book, 1917, page 114, that in the beginning, the addition of either nitrogen or phosphoric acid produced much the same increase. After a few years, however, in those plots receiving no phosphate, the supply of phosphate shows evidence of exhaustion and in consequence the addition of nitrogen alone produces less and less effect, phosphate having become a limiting factor. The increasing importance of phosphate is clearly shown in the tables above. Considering the case of cholum it will be seen that, taking the average of all crops, the addition of nitrogen only has increased the yield 24 per cent while phosphate has given an increase of 68 per cent. If, however, the later crops only are considered, for example those from crop 24 onwards, we see evidence of the limiting effect due to the deficiency of phosphate, nitrogen alone now raising the yield only by 12 per cent, while the increase due to phosphate has risen to 132 per cent. The addition of both nitrogen and phosphate naturally produces a larger effect still, both manures then being able to bring about their maximum effect.

Similar results are seen in the case of the other crops grown, though the response to manurial treatment varies, being greatest in the case of ragi and least with panivaragu. In all cases, however, the increase brought about by the addition of phosphate becomes more and more marked each year. This can perhaps be visualized more clearly by a reference to figure I in which are shown graphically the comparative yields from year to year of the "Phosphate" and "No manure" plots, the latter being taken as 100. The increase due to phosphate, at its lowest in crop 13, becomes more and more striking, reaching nearly 500 per cent in crop 31 and 1,200 per cent in crop 36.

The increasing response of the crops to phosphate is also well shown in figures II and III where the average relative yields of all the plots is shown. Figure III, in which are plotted the yields of the later crops only, exhibits a much greater rise due to phosphate than does figure II which includes the earlier crops as well.

The influence of potash is more difficult to follow. From the amount of available potash shown by analysis to be present in the soil, one would have expected but little increase to result from the application of potassic manures. This, however, has by no means always proved to be the case. Alone or with phosphate, potash has generally produced a definite increase of yield. Applied with nitrogen, on the other hand, it has usually given no greater yield than the plot receiving nitrogen only. This effect, however, is doubtless due again, in part at any rate, to the phosphate supply being a limiting factor. Other factors, however, seem also to be involved and further examination of this point is desirable.

So far the question of yield alone has been taken into consideration. It is of interest, however, to examine the variation in the composition of the crops derived from the various plots. Figures illustrating such changes are quoted in table VI below :—

Table VI.

Variation in Nitrogen, Phosphoric Acid and Potash content of Cholum Grain.

Average figures for all the crops grown.

Plot.	Percentage composition of grain.		
	Nitrogen.	Potash. (K_2O)	Phosphoric acid (P_2O_5).
No manure	1·843	0·399	0·549
Nitrogen .	1·821	0·401	0·552
Nitrogen plus potash .. .	1·755	0·349	0·557
Nitrogen plus phosphate ...	1·788	0·439	0·776
Nitrogen plus phosphate plus potash.	1·754	0·456	0·817
Phosphate . .	1·858	0·449	0·794
Phosphate plus potash .	1·788	0·398	0·822
Potash	1·798	0·398	0·618
Cattle manure . ..	1·810	0·433	0·624

Nitrogen	Average nitrogen plots	1·780	Average phosphate plots	1·797
Do.	Average non nitrogen plots.	1·827	Average non-phosphate plots.	1·804

Potash	Average potash plots.	0·433	Average phosphate plots	0 452
Do.	Average non-potash plots.	0 428	Average non-phosphate plots.	0 399
Phosphate ..	Average phosphate plots.	0·801	..	..
Do	Average non-phosphate plots.	0·568	.	..

From an examination of these figures it is clear that so far as nitrogen is concerned there is no significant variation in the composition of the grain between any of the plots. The application of nitrogen has improved the crop yield but not increased the store of nitrogen in the grain, nor has the latter been influenced by the amount of phosphate.

In the case of potash also, the percentage of this substance in the grain has not been increased by adding further potash to the soil, the average result of the potash and non-potash plots being practically identical. If, however, the comparison be made, instead, between those plots receiving phosphate and those without, it will be seen that the addition of phosphate has enabled the grain to take up more potash, there being an average difference of 10 per cent between the potash content in the two series. As pointed out above no such difference due to phosphate is evident in the nitrogen figures.

It is, however, in the phosphate content of the crop that the most striking variation is seen, there being a difference of 41 per cent in the results, comparing the non-phosphate plots against those receiving phosphate. If the later crops only are considered, that is to say those grown after the phosphoric acid deficiency in the non-phosphate plots had become marked the variation is naturally even more noticeable as will be seen from the table below :—

TABLE VII.

PHOSPHORIC ACID CONTENT OF CHOLUM.

(Average of crops from number 24 onwards)

Plot	Percentage of phosphoric acid (P_2O_5).	
	Grain.	Straw.
No manure	0·481	0·082
Nitrogen ...	0·490	0·073
Do. plus potash	0 491	0·071
Potash	0 584	0 094
Average non-phosphate plots	0 511	0·080
Phosphate	0 795	0·159
Do. plus nitrogen	0·810	0 189
Do. do. plus potash	0 808	0·175
Do. plus potash	0 871	0 184
Average phosphate plots	0 821	0·177
Percentage increase over non-phosphate plots	60 0	121 2

The importance therefore of an adequate supply of phosphate is twofold, for not only does any deficiency reduce the yield, but it also seriously diminishes the food value of the crop both in the grain and in the straw. Considering the large areas in the Madras Presidency in which such a deficiency of phosphate actually exists, it is obvious we have here a very serious source of loss and the importance of conserving all possible supplies of phosphatic manures becomes increasingly urgent.

Proportion of grain to straw.

An examination of the yields also shows that the proportion of grain to straw has been influenced by the use of phosphates. The figures for cholum are given below in table VIII :—

Plot.	Ratio of grain and straw. Straw = 100.
	Grain.
No manure	13·7
Nitrogen	14·6
Nitrogen plus potash	13·3
Do. phosphate ...	18·2
Do. potash plus phosphate	20·9
Potash plus phosphate... ...	20·1
Phosphate	19·0
Potash	14·5
Cattle manure	23·7

Averages	Non-phosphate plots	14·27	Increase 37 2 per cent
	Phosphate plots	19·55	
	Cattle manure	23·7	..

Summary.

1. In the early years of the experiment the plots responded to both nitrogen and phosphoric acid.

2. The phosphate has been more rapidly exhausted than the nitrogen and has now become a limiting factor, so that the addition of nitrogen alone produces but a small increase of crop, whereas the effect of phosphate becomes more marked each year.

3. Addition of potash has not had any consistent effect in the case of cholum or wheat but has materially increased the yield of ragi both in grain and straw, though chemical analyses indicated that the soil was already well supplied with available potash.

4. The percentage of nitrogen or potash in the grain has not been increased by the addition of either or both of these substances to the plots.

5. The percentage of phosphate in both grain and straw varies with the amount of phosphate available, the average difference in the case of cholum between phosphate and non-phosphate plots being 60 per cent in the grain and 122 per cent in the straw. The addition of phosphate has also enabled the grain to take up a further supply of potash, though the difference is not in this case anything like so marked.

6. The proportion of grain to straw has been but little influenced by the addition of nitrogen or potash but has been raised by the application of phosphate.

COIMBATORE,
August 1922.

ROLAND V. NORRIS,
Government Agricultural Chemist.

Figure I

PERMANENT MANURIAL PLOTS

PLOT RECEIVING PHOSPHORIC ACID COMPARED WITH "No manure" plot at 100

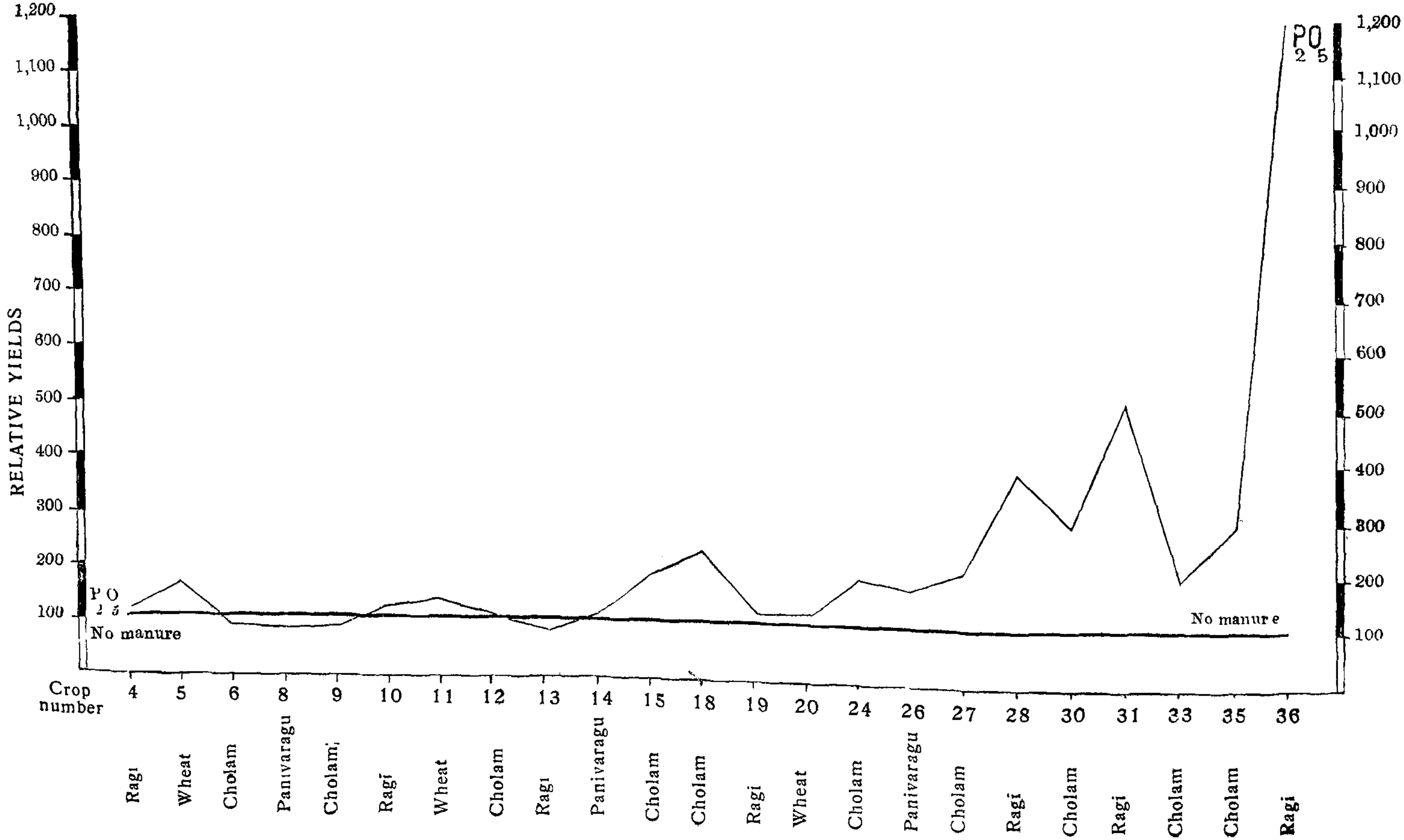

Figure II

RELATIVE YIELDS OF PLOTS

Averages of all crops

"No manure" plot = 100

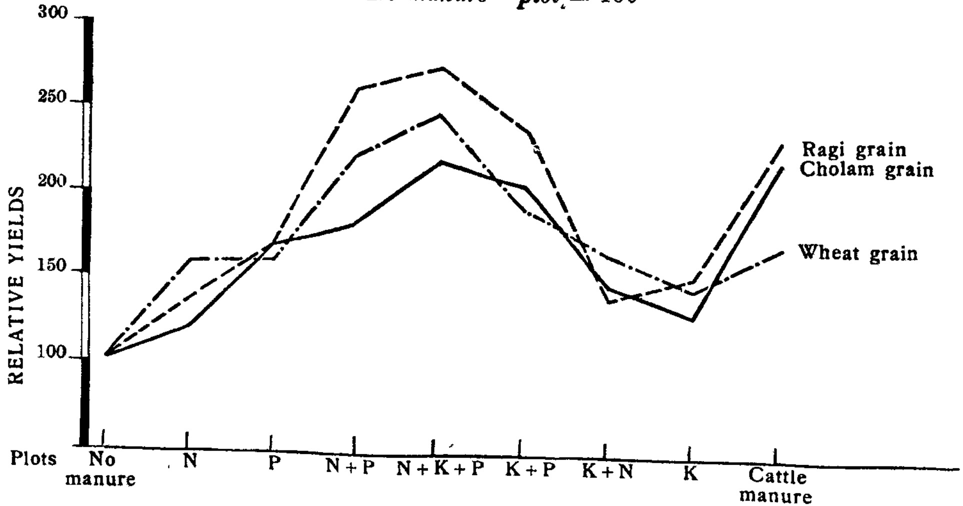

Figure III

RELATIVE YIELDS OF PLOTS

Averages of later crops

"No manure" plot = 100

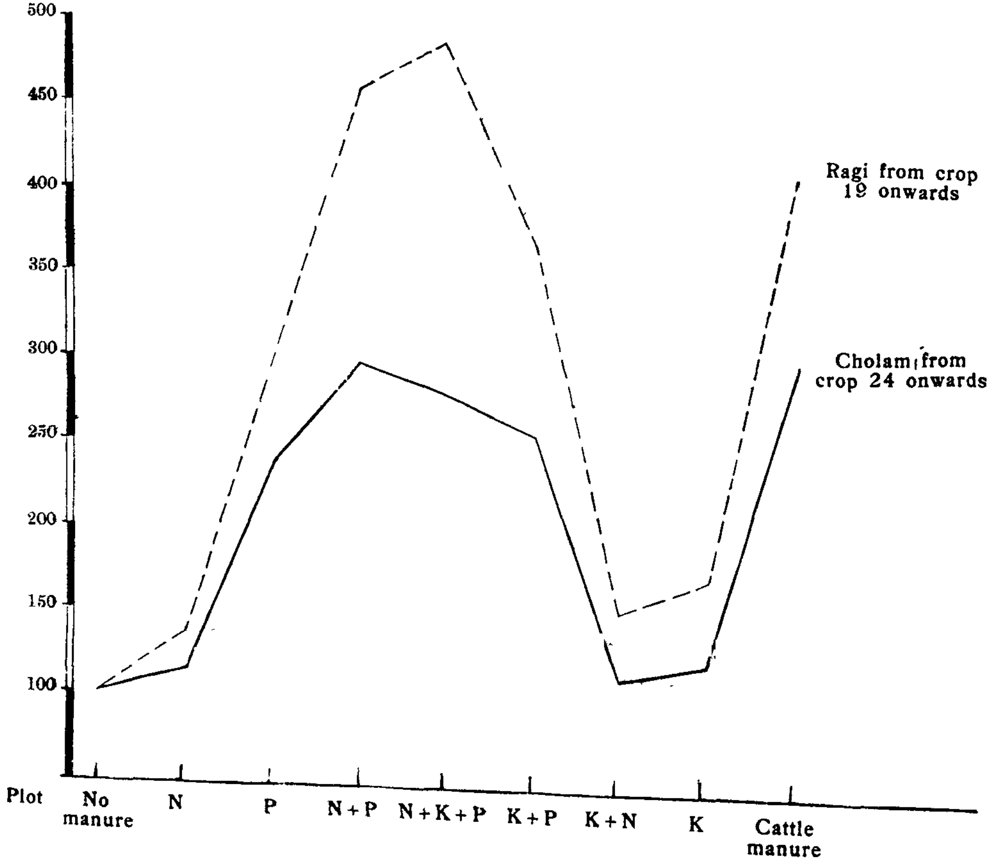

Figure IV

RELATIVE YIELDS OF CHOLAM

No manure plot = 100

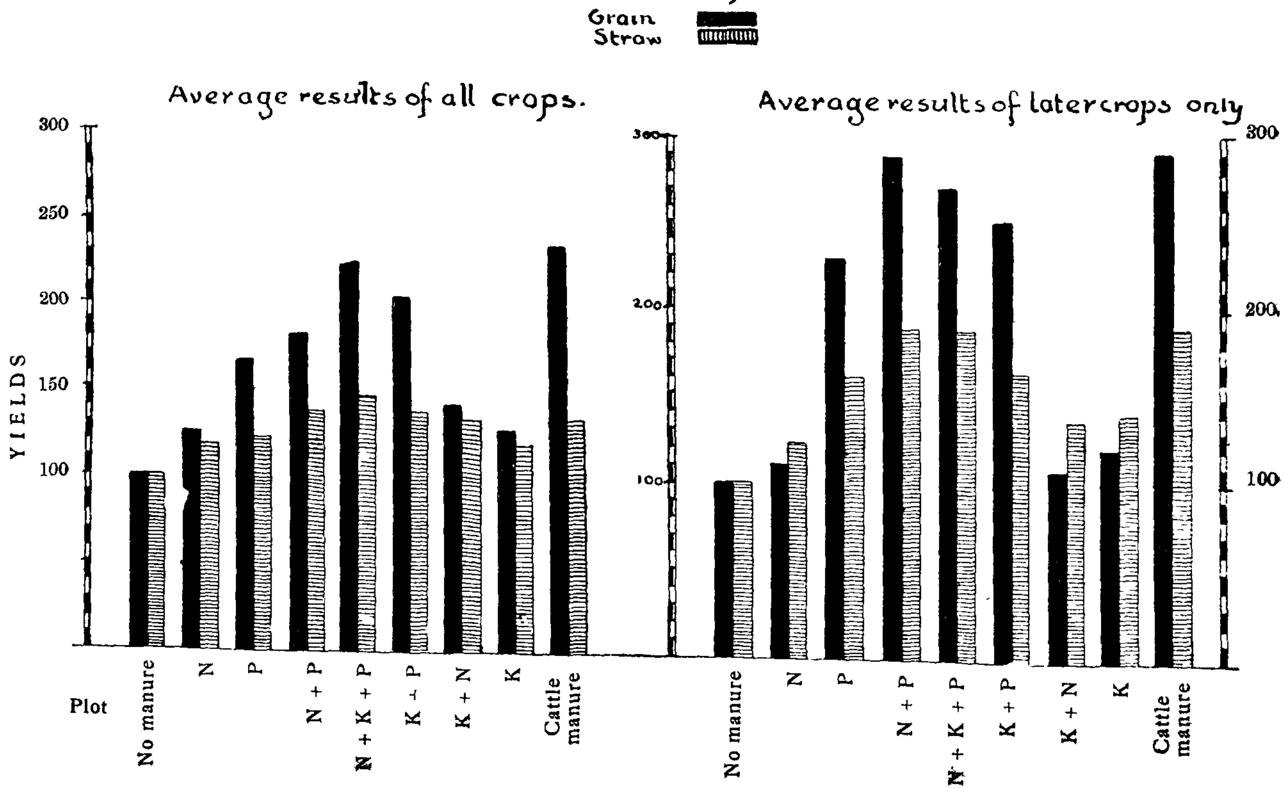

Figure V

RELATIVE YIELDS OF RAGI

No manure plot = 100