MADRAS AGRICULTURAL DEPARTMENT

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MADRAS AGRICULTURAL DEPARTMENT

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ANNATTO EXTRACT FOR COLOURING BUTTER

BY

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The following investigation was carried out at Dr. Norris's suggestion and the quality of the different samples of extracts prepared were tested at the Dairy by Mr. D. Ananda Rao.

The stock of butter colouring in use at the Agricultural College Dairy having run out some time ago (1918) and no fresh extract of the kind being available in the market at the time, attention was directed to the preparation of a suitable butter colouring for use in the Dairy. The choice of a suitable material naturally fell on annatto which, although mostly in disuse as a dye for textiles, has maintained its reputation as a good colouring agent for butter and of which quantities are still available for sale in certain parts of the Presidency.

The first sample of the extract was made by rubbing a small quantity of the seed (obtained from the Assistant Director of Agriculture, Northern Circle) in a mortar with successive quantities of sesame oil. The oil, which readily took up some of the colouring matter into solution and held much more in suspension, was heated on the water bath with enough fresh oil to give a saturated solution. About two pints of extract were obtained from an ounce of the seed. When tried, however, as a colouring for butter, it was found much too weak, sixteen drops of the extract being required to dye one pound of butter as against two of the purchased extract. The butter thus coloured was found to flavour of the oil and spoilt easily.

It seemed therefore necessary to obtain the extract in a more concentrated form. A fresh quantity of the seed having been obtained from the Northern Division, it was decided, for purposes of further experiment, to obtain the colouring matter separate from the seed. Two methods were adopted for extracting the dye :—

(i) The seeds were allowed to soak in water and ferment for several days, after which they were pounded in a mortar. The colouring matter held in suspension in the liquor was washed out of the pounded seed over a coarse sieve and separated from the wash liquor by decantation and final filtering under the pump. The above is essentially the method adopted in preparing the dye for the market. The product thus obtained was found to contain in addition to the colouring matter much mucilaginous matter extracted from the crushed seed. The yield of the dry dye obtained was 10·25 per cent of the seed.

(ii) The seeds were steeped in a 1 per cent solution of sodium carbonate for 24 hours, then rubbed in a mortar and washed with further portions of the alkaline solution until all the colouring matter was dissolved out. The coloured solution was next strained and the colouring matter re-precipitated by the addition of just dilute hydrochloric acid and separated by filtration. The solid dyestuff was then dried in the oven. A little over seven grams of the dried product was obtained from 100 grams of the seed.

An extract in sesame oil was prepared from the dyestuff obtained by method (ii) by digestion on the water bath until the oil took up as much of the dyestuff as it could. The extract thus obtained proved, however, not much stronger than the one first prepared.

An attempt was made to obtain a stronger solution by first extracting the dye with each of the solvents ether, chloroform and alcohol, adding the extracts to the oil and after prolonged agitation driving off the volatile solvent on the water bath. The oil extract was made as strong as possible by adding the ether, chloroform or alcohol solution in excess. It was finally filtered so as to obtain a clear product.

The oil extracts obtained with ether and chloroform were about equal in strength and were both distinctly deeper in colour than those obtained by simple digestion. That prepared from the alcoholic solution was only as strong as the latter.

Similar oil extracts were also obtained by using as solvents :

(i) Ghee,
(ii) Castor oil,
(iii) Groundnut oil,
(iv) Coconut oil,

in place of sesame oil from an ethereal solution of the dye. The extracts showed variations in depth of colour roughly in the order indicated. Ghee and castor oil were strongest in colour, but not stronger than the sesame oil extract, so that there seemed to be no particular reason why a different solvent should be used.

When tested for colouring butter, however, the sesame oil extract was still found to be greatly inferior to the purchased sample. Further, on being kept for some time, it was found to have lost colour owing to some of the dissolved annatto having separated from the solution.

Other vegetable colours, e.g., turmeric, safflower, saffron, etc., are sometimes used in conjunction with annatto in the preparation of butter colourings.* An oil extract, however, prepared on these lines, although possessing greater dyeing power, was found to impart to the butter a disagreeable greenish yellow tinge in place of the rich yellow desired.

The failure to obtain an oil extract of annatto comparable in dyeing power with the purchased sample led to the suspicion that the latter was not annatto. Chemical examination proved it to be a coal-tar product and not annatto.

Attempts were next made to obtain a satisfactory extract of annatto by employing other solvents than oil.

Among those tried were :

(i) Aqueous solution of borax.

(ii) ,, sodium bicarbonate.

(iii) ,, ammonia.

(iv) Glycerine.

Quite strong solutions could be obtained with (i), (ii) and (iii), especially (iii), while glycerine dissolved less, the solution nevertheless possessing a

* Martin's Industrial Chemistry, Org., page 87. Also Scientific American Cyclopædia of Receipts.

stronger colour than the oil extract. When tried for colouring butter in the usual way by adding the colouring to the ripened cream, the difficulty was experienced that the annatto was precipitated more or less completely by the lactic acid present in the ripened cream, with the result that little of the colour was taken up by the butter, the greater portion getting washed out. A way out of the difficulty was sought by adding the extracts to the cream, before ripening, so that the colouring matter may get absorbed by the fat before the acid was developed in the cream. In the case of extracts (i), (ii) and (iv), however, this had no appreciable effect, but much of the colouring matter from the ammoniacal extract appeared to be retained, and four drops sufficed to colour a pound of cream. The marked success of the ammoniacal extract is perhaps due to its superior concentration, ammonia being able to take a much larger quantity of the dyestuff into solution, but possibly ammonia interacts with the dye in a manner different from the other solvents.

The ammoniacal extract which proved to be most satisfactory as a butter colourer is easily made by rubbing the required quantity of annatto (extracted from the seed by means of weak alkali as described above) in a mortar with the minimum quantity of strong ammonia, diluting with enough water to give a clear solution and filtering under the pump. A few drops of chloroform serve to preserve the extract from the attack of moulds. Annatto extract prepared in this manner has been in use at the Dairy for several years now. The best stage at which to add the colouring is perhaps just before pasteurizing the cream.

A few remarks may here be made regarding the relative merits of coal-tar and vegetable dyes as butter colourings. Amongst the former there are many which are known to be harmless, but coal-tar products have from time to time been suggested as butter colourings, which have been found to be distinctly poisonous, while few of the vegetable dyes are really harmful. Apart from the questionable expediency of colouring butter, therefore, safety would appear to demand the use of vegetable in preference to synthetic dyes for heightening the colour of butter.

THE SILVER-SHOOT DISEASE OF PADDY

BY

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The silver-shoot disease of paddy has been this year the cause of much loss to the ryot in South India, for several reports have been received regarding serious outbreaks of that malady on paddy in more than one district. Information as to its occurrence in extraordinary abundance has been obtained in most parts of South Kanara district—especially in Mangalore and Kāsargōd taluks—and in all the northern taluks of Malabar, viz., Chirakkal, Kōttayam and Kurumbranād. News has reached this office as to its presence in abundance this year also in Gōdāvari district. It is probable further reports may be received from other parts of Madras before long.

In view of the fact that the disease in question is a very obscure one and reliable remedial measures cannot be suggested in the present state of our knowledge as regards the factors governing its incidence and development, an attempt is made in this note to present to the public the facts so far ascertained regarding this disease.

Although to a superficial looker-on silver-shoots in paddy do not look as if they were instances of insect attack or, indeed, in their earlier stages, even as cases of a diseased condition of the plant, they are in reality examples of malformation brought about by the activities of the maggot of a gall-fly. The main symptom of the disease is the production of a hollow tube-like outgrowth from the centre of the shoot in lieu of a normal development of internodes and leaves, culminating in the formation of an earhead at the tip. In a case of light attack, in spite of the appearance of the silver-shoot in the main stem, tillers are produced which bear normal earheads, but in instances of serious infestation almost all the side shoots that may be produced by the plant may be successively attacked so that the clump may not produce any earheads, or, if at all, only one or two puny specimens. In really bad years the total damage may amount to 75 per cent or even more.

Previous records and local names.—Numerous reports of the occurrence of this pest are on record in the files from the year 1908. It has been reported from Ganjām, Vizagapatam, Gōdāvari, Kistna, Chingleput, North Arcot, South Arcot, Tanjore, Trichinopoly, Coimbatore, Rāmnād, Tinnevelly, Malabar, and South Kanara, and is probably to be found wherever paddy is cultivated in the Madras Presidency. The disease is known as "Nolla mado" (closed stem) in Ganjām, "Kodu" or "Vulli-kodu" (onion shoot) in the Telugu districts, "Anaikombu" (elephant tusk) or "Thandeethu" (a bearing of stems) or "Thandu-noi" (stem disease) in the Tamil districts, "Vellikkola" (silver ears), "Velli kalan" (silver horn) or "Bengalan" or "Bengalam" (white horn) in Malabar, and "Kané" in South Kanara. The same pest is known from various other rice-growing areas of India and also from Burma, Java, and Indo-China.

The life-history of the pest.—The silver-shoot of paddy is a shoot-gall caused by the maggot of a small gall-fly—*Pachydiplosis oryzae* Woodmason-Fam. Cecidomyiidæ. The adult gall-fly is a small fly of the size of a mosquito. The female has a rather stout abdomen which is generally of a bright red colour, while the male, which is more slender in build, is usually darker coloured. The female fly lays its eggs singly either on the hairs of the ligules of the paddy leaf or on the leaf-sheath either just above or below the position of the ligules. The egg is slender, elongate and cylindrical and is ½ mm. long. The egg hatches into a tiny, pale, almost colourless maggot in three days, which crawls down the shoot and creeps between the leaf-sheaths until it finds its way into the heart of the growing point of the shoot. The growing apex of shoots of graminaceous plants consists mostly of unmodified protoplasmic tissues, the cells of which are in a state of active division, and the tiny maggot ultimately stations itself in the centre of this apex. Partly by actual feeding and partly by irritation it leads to the formation of an oval chamber around itself. The mature maggot is about 3 mm. long and of a pale red colour. It is of the usual build and form of gall-fly maggots, being fairly stout and legless with a pointed anterior end which is devoid of a distinct head and is armed with a breast plate. When full-fed the maggot turns into a pupa inside this chamber. The pupa is of the naked type with the rudiments of all the main organs of the fly visible in relief. The anterior end is armed with two or three pairs of short spines which help it to pierce the walls of the gall, while the segments of the abdomen are possessed dorsally of several rows of closely set, small, sub-equal, backwardly directed spines, and the tip of the abdomen bears two or more stouter ones, all of which enable the pupa to wriggle its way up the tube to the tip of the silver-shoot. The sides of the chamber in which the maggot lies are composed mostly of stem tissues, the cells of which are in a state of active division, and hence, by the time the maggot becomes full-fed and pupates, the sides begin to grow and elongate, so that eventually a long tubular outgrowth—the silver-shoot—is formed, carrying at the tip an undeveloped rudiment of a leaf. By this time the pupa is ready to transform into a fly, and after wriggling its way up the tube pierces its tip and projects half-way out. The skin of the pupa then bursts and the gall-fly crawls out, dries its wings hanging on to the pupal skin and eventually flies away to mate and lay eggs. These gall-flies are very delicate insects which rest during the day and are active only at night. They usually do not live more than three days. They have been noted sucking moisture from tiny water drops on leaves, but do not appear to be able to feed otherwise. The egg-laying powers of the paddy gall-fly have not been worked out, but in certain allied species breeding in grasses at Coimbatore, as many as 350 eggs have been recorded to have been laid by a single female.

The life-cycle of the pest.—The full life-history of the paddy gall-fly has not been worked out, but in an allied gall-fly—*Dyodiplosis fluvialis* Felt.—breeding similarly in a grass—*Panicum fluitans*—where the life-history has been followed, the egg stage occupies three days, while the larva takes four to ten days to pupate. The period of pupation as noted in one case was six days, so that the duration of the period from the laying of eggs by one generation to that of the next would appear to be : egg state three days ; larval, four to ten days ; pupal, six days ; active adult life, one to three days, so that in all, the life-cycle may vary from fourteen to twenty-two days. The larval period, however, may be considerably lengthened under conditions of stress, as when the grasses are unable to make fresh growth owing to drought.

Its rate of multiplication.—From observations made so far, it is believed that the details of life-history of the paddy species will not prove to be different from that of the species reared from *Panicum fluitans.* If this supposition be correct there is a probability of one generation following on the heels of another in the short space of two weeks, but taking into consideration the possibility of adverse conditions occurring, a period of three to four weeks may be taken as an average. The paddy species is almost as big as the Panicum one, and an estimate of 300 eggs may not be considered too high a figure, on the average. Paddy is susceptible to the attacks of this pest during the first three months of its existence, and during this period there may be as many as four generations of the pest following one another in quick succession, and, supposing that there are equal numbers of males and females in each generation, the general rate of multiplication will roughly be about one hundred and fifty fold.

The nature of damage to the crop.—A single maggot—tiny though it be—is capable of transforming an entire shoot into a gall, which therefore spells the utter loss of an entire prospective earhead for the ryot. The plant thereafter makes an effort to make up for this loss by producing fresh tillers. In a bad year these tillers may likewise be affected by the second generation of the fly and similarly develop into silver-shoots. If this process continues there may be an entire loss of the crop. Fortunately, however, parasites usually step in and bring the pest under control, so that at the end the paddy plant is enabled to produce a few puny earheads.

The parasites.—This pest is subject to several parasites which may be broadly classified into two groups : (1) those which oviposit on the larvæ or the pupæ, and (2) those that oviposit in the eggs of the pest. The first group includes three or four different species of the super-family Chalcidoidea. They sting the pupa through the walls of the silver-shoot and lay an egg thereon. The grub that hatches feeds on the host and transforms when full-fed into a naked pupa. The adult parasite that emerges bites a round hole at the tip of the silver-shoot and flies out. This group of parasites increases only after the pest has greatly multiplied and much of the damage has therefore already been caused. The second group is comprised of two species of wasps belonging to the family Proctotrupidæ. Both of them are small, shiny black wasps which actively search for the eggs of gall-flies. When they succeed in finding them they lay an egg in each by puncturing them with their ovipositors. This egg, however, does not develop until the maggot hatching from the egg of the gall-fly has caused the formation of the gall. The larger of the two species kills the maggot when half-grown. Most of the contents of the maggot are eaten up and the remnants of the tissues and the excrement voided by the grub are shoved into a corner of the hollow skin. The parasite grub then prepares a slender cocoon inside the empty skin of the host and pupates. The other parasite—*Platygaster oryzæ*—is remarkable as exhibiting a case of polyembryony, as in the case of *Platygaster vernalis* in America attacking the Hessian Fly of Wheat. The egg divides into numerous embryos ranging from 15 to 25 inside the body of the host. The maggot is attacked when about full-grown. The tissues are completely devoured, so that the host is transformed into a bag of skin inside which the grubs prepare their tiny oval cocoons. This bunch of cocoons is usually found high up in the tube—being carried above as the shoot elongates. The small wasps emerge by biting a round hole at the tip of the hollow gall.

These two parasites—and especially Platygaster—are singularly efficient as checks on the pest, as they make their appearance at the very outset of the attack along with the pest. In fact, in the light of the knowledge at present available, the outbreaks of the pest would appear to occur only when the development of the parasite is retarded by some abnormal external factors.

The host plants.—Although two or three generations of the pest may be passed in paddy when the crop is young, it is unable to breed in the plant when it is older and about to produce ears. In certain areas paddy may be found cultivated during the greater part of the year and the insect may, in such places, have opportunities of breeding throughout the year. However, the pest has been found to appear in young paddy on the advent of the monsoon rains every year even in places where there is but one crop during the year. The adult is known to be but short-lived, while the egg, maggot and pupa can only exist while the host plant is living. Since the paddy plant is always harvested when mature and cannot survive the hot weather, unless it be specially watered and kept alive, it is evident that the pest cannot depend altogether on paddy for surviving the hot weather, but must have some alternate host plant wherein it could tide over the period when paddy is not existent in the field. Hence a search was made in the past among various wild grasses for the wild host-plants of the paddy gall-fly, and as a result thereof nearly 30 grasses showing similar gall formations have been collected. In many cases the flies causing these galls were reared out, and sent for determination to Dr. E. P. Felt of Albany, New York, who has placed the Entomological Section under a debt of gratitude by attending to their identification in the midst of his multifarious work. The paddy gall-fly was, however, found breeding only in three of these grasses, viz., *Panicum stagninum*, *Panicum crus-galli*, and **Ophiurus corymbosus*. Of these grasses, however, silver-shoots were noted in *Pan. stagninum* and *Pan. crus-galli* only in years when the pest was found in extraordinary abundance and not in other years, so that the presence of these galls represents probably more a case of spill-over in times of abundance than of a regular alternate food plant. In *Ophiurus corymbosus*, on the other hand, specimens were bred out while there was no attack on the field, but this grass has so far been noted only once in Kistna district and no generalizations can be made until a detailed examination is made of specimens of galls in this grass collected from other parts of the Presidency.

Certain observations and experiments in connexion with a gall-fly breeding in a common fodder grass, *Pennisetum cenchroides*, made by the writer in 1922 (recorded in a paper entitled "A further contribution to a knowledge of South Indian Grass Gall midges"—Report of the Proceedings of the Fifth Entomological meeting held at Pusa in 1923—pp. 270—274) have conclusively proved that these gall-flies normally pass the dry

* Since sending the above note to the press, certain localities in the Tanjore, Kurnool and Kistna districts, where the grass, *Ophiurus corymbosus*, was known to be present in fair abundance, were examined and gall-flies reared out from all these places. On comparing specimens of these flies as well as of their exuviæ with those of the paddy species, it looked evident that the fly breeding in *Ophiurus corymbosus* was entirely different from the paddy one. Specimens of these are being sent to Dr. Felt for favour of examination. In these circumstances, Ophiurus has to be eliminated as a host plant harbouring the gall-fly during the off season for paddy. Further investigation is therefore necessary for determining where exactly the insect passes the dry season. Perhaps wild paddy may prove to be a likely agent in this respect.

Y. R. RAO

season as tiny larvæ hidden in the dormant buds of perennial grasses. Although during the heat of the dry season all such grasses look quite parched up, yet when the first summer showers are received, they put forth fresh shoots from their stocks and along with these the infested buds containing the maggots also develop, leading to the formation of shoot galls. It is these midges emerging from the wild food plant that would appear to lay eggs on the paddy seedlings in the nurseries and thus start the first generation of the pest. It is interesting to note that a certain percentage of the first silver-shoots bred from the wild grasses also reveal the presence of the cocoon masses of the parasite—Platygaster. This proves that this parasite also passes the dry hot season in the nascent buds of grasses along with the pest and, since it emerges almost at the same time as the parasite and is moreover endowed with great powers of multiplication, it is able to function as a most efficient check on the multiplication of this gall-fly.

General causes of outbreaks.—At Buntwal in South Kanara the ryots were of opinion that the serious development of the pest this year was due to the very early commencement of the monsoon rains (about the close of May 1925) followed by a long break of about a fortnight early in June, whereby there was an enforced delay of about a fortnight in planting. Whereas the early-planted fields were only lightly attacked, those planted after the break suffered very badly from silver-shoots. It was also reported that a similar heavy outbreak occurred about 15 years ago when South Kanara was swept by an early outburst of the monsoon in the form of a cyclone in May. Certain villages in the Chirakkal taluk of North Malabar also reported an experience similar to that of Buntwal this year. An examination of affected plants near Buntwal and Pazhayangadi (North Malabar) revealed the fact that very few of the silver-shoots showed the existence of the parasite—Platygaster—although a fair number of the pupæ showed infestation by a chalcid parasite. It therefore appears to be certain that this year's outbreak is due to the decrease in number of Platygaster owing to some abnormal circumstances and the consequent absence of a check on the multiplication of the pest. The non-development of the parasite is possibly to be attributed to the destruction of the wasp during the early rains or perhaps to the unusual drought that succeeded the early burst of the monsoon. This parasite can oviposit only in the egg stage of the fly and, since the eggs of the latter hatch within three days, they may escape parasitization, if the parasites do not appear within this short period. Since this parasite—Platygaster—breeds not only on the paddy gall-midge, but also on other species of gall-flies, affecting various common grasses, a paucity in its numbers can occur only very rarely.

The following remarks occur in certain reports received at Coimbatore from different places in the Presidency at various times in the past. (1) "Continually cloudy skies and drizzling aggravate the attack" (Pudukkōttai), (2) "Outbreak attributed to very late rains and consequent delay in agricultural operations" (North Arcot district), (3) Due to "late planting and continuous and heavy rains" (Gōdāvari district), (4) "Has appeared in spite of an excellent monsoon, low lands specially affected" (Ganjām—Kallikota), (5) "Continuous wet weather since the break of the monsoon in the first week of June" (Gōdāvari district). All of them point to an occurrence of abnormally wet weather and to a lateness of planting as being favourable factors for bringing about a heavy infestation and are probably to be accounted for by the possible diminution in the numbers of Platygaster brought about by the destructive effect of bad weather and the consequent increase in numbers of the pest as the season advances.

Remedial measures.—As already stated, in the present state of our knowledge of this pest no frontal line of attack would appear to be feasible. By the time the silver shoots are noticed, the fly would usually have already emerged, and a collection and destruction of such shoots would not only be useless but may even be harmful, since thereby the parasites that might be present therein may be destroyed.

The presence of certain grasses exhibiting similar gall formations on the field bunds and surroundings is probably to be welcomed and encouraged, since thereby one can ensure the existence and maintenance of these parasites, in order that the development of the pest may be nipped at the very outset. It is also probable that further investigations may indicate the introduction of these parasites into places where they are not present in sufficient numbers as a possible and perhaps an efficient line of attack.

To a certain extent, manuring with a readily soluble fertilizer may aid the plants to recover from the effects of a severe infestation

Light traps have been found to attract the gravid females in fairly large numbers, but without actual trials it is not possible to say how far this measure would be practicable or useful.

In conclusion, it has to be stated that our knowledge of the life-history and habits of the pest is yet imperfect, and further investigation and research is necessary before any definite recommendations can be made towards the control of this very interesting disease.

VERMICULARIA CURCUMÆ SYD. ON *CURCUMA LONGA*

BY

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This fungus causes a serious disease of turmeric in Gōdāvari, Kistna, Trichinopoly and Coimbatore, where the crop is extensively grown. Many plants in the field are affected and they present a scorched appearance. The disease first attacks the leaves, and later extends to the leaf-sheaths and the scaly leaves of the rhizomes. The quantity of food manufactured decreases, with the result that the formation and proper development of the rhizomes are hindered. A short description of the fungus is given below.

2. Spots epiphyllous, amphigenous (occurring on both sides), mostly elliptical or oblong, 1—3 c.m. long, coalescing, often much enlarged, white, surrounded by a yellowish-brown zone. Pycnidia aggregate in the centre of the spots, superficial, sub-divided, 60—90μ in diameter, dark, setæ erect,

dark-brown, septate, 50—90μ by 6—7μ ; spores sub-fusoid, attenuate at both ends, one-celled, hyaline with minute oil drops 18—29μ by 3—5μ.

3. The fungus grows well in culture media of which oat-juice agar has been found the best. The fungus from culture attacks cabbage, knolkhol, chillies, brinjal and *Withania somnifera* when it is inoculated on to these plants.

4. Rhizomes of turmeric were collected from plots where leaf disease was bad. These showed dark sclerotial masses on the scaly leaves of rhizomes and on the rhizome itself. This indicates the possibility of the fungus being carried over from season to season through the seed rhizomes. This formation of sclerotial masses has been noticed even on oat agar cultures of this fungus. Culture tubes producing profuse spore formation for a time, if kept well sealed, are seen to produce these sclerotia-like bodies within one year. This has been found to be the case in the culture tubes of chillies vermicularia also.

5. Sclerotial bodies from sealed oat agar tube of 18th October 1917, sub-cultivated on 30th September 1920, in turmeric agar tubes produced pycnidia and spores in small quantities. When this culture was sub-cultivated in French bean agar on 16th October 1920, it produced numerous pycnidia and spores. Sclerotial bodies taken from oat agar culture tubes of 4th March 1921, when kept for germination on 19th June 1922, germinated in three days producing hyphal masses. This proves that this fungus can live in cultures for a period of three years in the form of sclerotial bodies.

6. The possibility of treating seed rhizomes with fungicides of different strengths is under investigation.

PRELIMINARY INVESTIGATION ON THE LIMIT OF ECONOMIC PLANTING OF PADDY (KURUVAI CROP) IN THE TANJORE DELTA

BY

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Introduction.—In all crop trials, the final aim of the experimenter is to investigate the different methods by which the yield of the crop can be increased. Some of the fields of investigation are judicious manuring, better cultural methods, and breeding high-yielding strains. Numerous experiments have already been done and several more are still in progress in the fields of manuring and breeding; but investigations on better cultural methods have either not been done intensively or lack definite conclusions. Any result arrived at in this field can be applicable only to the particular locality where the experiment is conducted. It is, therefore, imperative that experiments along this line should be conducted in each well defined tract, and one such problem that requires immediate solution is the economic planting of paddy which is every year getting more and more into general favour with the cultivators.

Scope of the work.—The term "economic planting" as applied to rice is so elastic that no definite idea is conveyed by it. The term can only be explained with reference to a number of factors and conditions obtaining in a particular locality, viz., nature of soil, rainfall, duration of the crop, variety, time of planting, etc. The results of experiments in this line conducted at the Samalkōta Agricultural Station,* the Central Farm, in Madras,†

* Report of the Agricultural Station, Samalkōta, for 1909-10.
† Report of the Central Agricultural Station, Coimbatore, for 1917-18

and at Burdwan, in Bengal,* bear out the truth of the above statement. It will be useful to start intensive and accurate experimental work in as many varied localities as possible to give a correct idea of the economic planting for rice. With a view to find out the limits of economic planting in different varieties and in different cropping seasons of the Tanjore delta, preliminary investigations were started last year at the Paddy Breeding Station, Aduturai, to find out the effect of spacing and the number of plants per hole on the final yield of rice, particularly with the short duration "Kuruvai" variety of the Tanjore delta.

General cultivation.—Kuruvai is the early crop and is of about 100 days in duration. It is sown in the middle of June and harvested by the end of September or the beginning of October. Summer showers are taken advantage of to get the nurseries dry-ploughed as many times as rains are received. As soon as freshes are received in the rivers, beds of convenient size are formed, water is let in and the loose soil at the top worked into a soft puddle and levelled with a shaped bit of the broader end of the coconut frond. Closely following upon the levelling, sprouted seeds are sown in the beds at the rate of about 100 lb. to plant an acre of seed bed. The next irrigation is given on the third day and further irrigations are given at intervals of five or six days in order to keep the soil moist. Enough water is let in to stand in the beds just a day previous to the pulling out of the seedlings. The age of seedlings at the time of transplanting is generally from eighteen to twenty days. The popular belief, so far as this short duration Kuruvai crop is concerned, is, that it must be planted in

* Agricultural Journal of India, Vol. II, pages 344–345.

"bunches" of six to twelve seedlings, at about 6″ to 9″ apart. The experiments described below were designed to find out the truth of this popular belief. Last year, for want of sufficient planting area, the tests of spacing and the number of plants per "bunch" could not be combined, but were laid out separately and the results are therefore given for spacing and bunches independently. Every care has been taken to give uniform treatment to all plots in the matter of the preparation of the nursery, the preparation and manuring of the land and date of planting, the only difference between the plots being in the spacing given in one case and the number of plants per "bunch" in the other.

Spacing.—The different spacings tried were 3″ × 3″, 4″ × 4″, 6″ × 6″, 8″ × 8″, 6″ × 1′, and 1′ × 1′. In every case, the seedlings were planted in strips 40′ × 4′ with an interspace of one foot between strips. Each spacing was repeated six times, but only four repetitions were taken into consideration, as the rest were badly damaged by field rats.

Number of plants per hole or "bunch."—Two, three, four, five, and six seedlings per hole were planted six inches apart each way in strips of 40′ × 4′ with an interspace of one foot between strips. These were also repeated six times.

General observations during vegetative period.—The single plants with greater spacing, and the "bunches" with fewer number of plants, began to tiller more rapidly and had a darker green and healthier look. The strips planted three inches and four inches apart and in "bunches" were conspicuously short and looked yellowish and poor in appearance. The spacing and the number of plants per bunch were also noticed to have some influence on the flowering, in that the strips with a bigger spacing and fewer plants per bunch were found to flower definitely earlier than the strips with closer planting and larger number of plants per bunch. The difference in the time of flowering between three-inch spacing and one-foot spacing can be put down as four to six days.

Except in the cases of 6″ × 1′ and 1′ × 1′ spacings, where the counts were made of the three central rows in five repetitions, the number of tillers per bunch from the central three rows in two repetitions of each treatment was counted and tabulated.

1. EFFECT ON TILLERING.

TABLE I (*a*). TABLE I (*b*).

Number of tillers per hole.	With spacings of						Number o plants per bunch				
	Frequency.										
	3″ × 3″	4″ × 4″	6″ × 6″	8″ × 8″	6″ × 1′	1′ × 1′	2	3	4	5	6
1 …	200	49	3	…	…	…	..	…	…	2	1
2 …	466	205	22	2	8	…	1	3	…	..	3
3 …	230	217	66	14	19	4	12	4	6	3	6
4 …	33	146	111	23	57	3	58	17	30	19	17
5 …	6	10	89	47	91	7	70	41	50	52	59
6 …	2	4	74	57	112	13	214	107	79	77	90
7 …	…	…	54	60	154	14	216	122	102	117	109
8 .		…	26	54	179	26	65	86	90	95	96
9 …	…	…	9	44	147	27	31	62	57	75	56
10 …	…	…	2	26	118	38	8	21	48	28	30
11 …	…	…	2	6	81	46	4	12	16	9	14
12 …	…	…	…	6	39	65	1	2	5	3	5
13 …	…	…	…	4	24	55	…	…	…	3	1
14 …	…	…	…	2	15	66		…	…	3	2
15 …	…	…	…	2	15	61	…	…	…	2	…
16 …	…	…	…	1	3	44	…	…	…		…
17 …	…	…	…	…	2	38	…	…	…	..	…
18 ..	.	..	..	…	2	22		..	…		…
19 …	…	…	…	…	…	14		.	..		…
20 …	…	…	…	…	1	6	…	…	…	…	…
21 …	…	…	…	..		12	…	…	…	..	…
22 …	…	…	…	…	…	6	…	…	…	…	…
23 …	…	…	..	…	…	8		…	…	..	…
Average …	2·1	2·8	5·0	7·0	8·5	12·7	6·5	7·0	7·4	7·2	7·2

In another set of repetitions an equal area of ten feet by four feet was marked out in each treatment and the following results were arrived at :—

EFFECT ON TILLERING.

TABLE II (*a*).

Spacing	Number of bunches	Number of tillers	Average number of tillers per bunch	Relative proportion of tillering
3″ × 3″	697	1,366	1·96	100·0
4″ × 4″	403	955	2·35	120·0
6″ × 6″	189	950	5·03	256·0
8″ × 8″	112	885	7·90	403·0
6″ × 1′	105	730	6·95	354·0

TABLE II (*b*).

Bunching	Number of bunches	Number of plants planted	Total tillers counted	Average tillers per bunch	Average tillers per plant planted
Two ...	189	378	950	5·01	2·50
Three..	189	567	1,050	5·55	1·85
Four...	189	756	1,228	6·50	1 62
Five ..	189	945	1,220	6·45	1·29
Six ...	189	1,134	1,380	7·30	1·21

The correlation between spacing and tillering is more marked than between number of plants per hole and tillering (Figure I). From tables I (*a*) and II (*a*), it is found that the tillering capacity of plants one foot apart is nearly two and a half times that of plants six inches apart, and five times that of plants three inches apart. The range of variation in tillering capacity of the rice plant when planted in "bunches" is very little. Tillering is induced only when planted in singles or doubles.

Fig. I.

AVERAGE TILLERING PER BUNCH

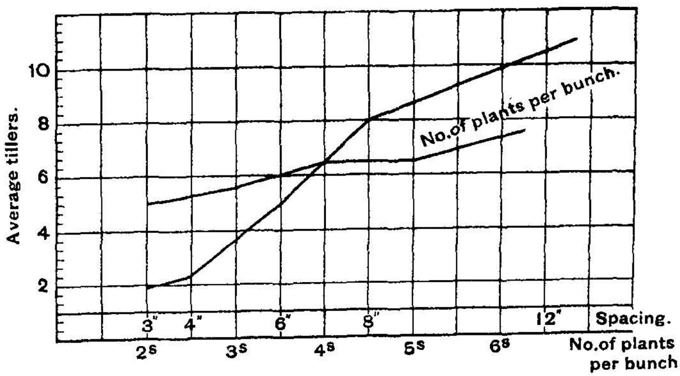

Fig. II.

AVERAGE LENGTH OF PANICLE.

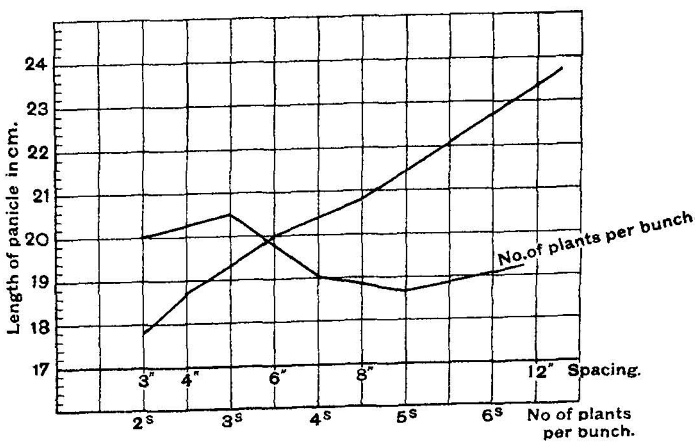

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Fig. III.

AVERAGE WT. PER PANICLE.

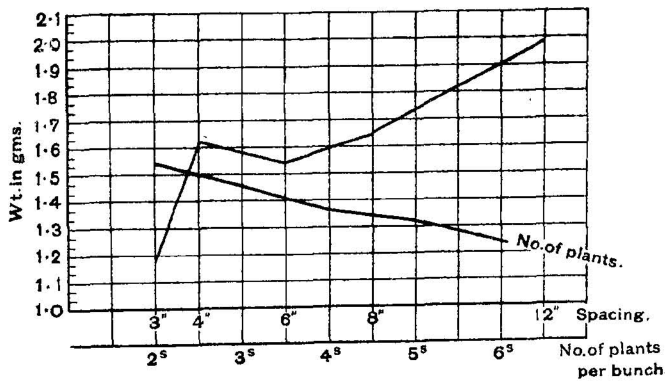
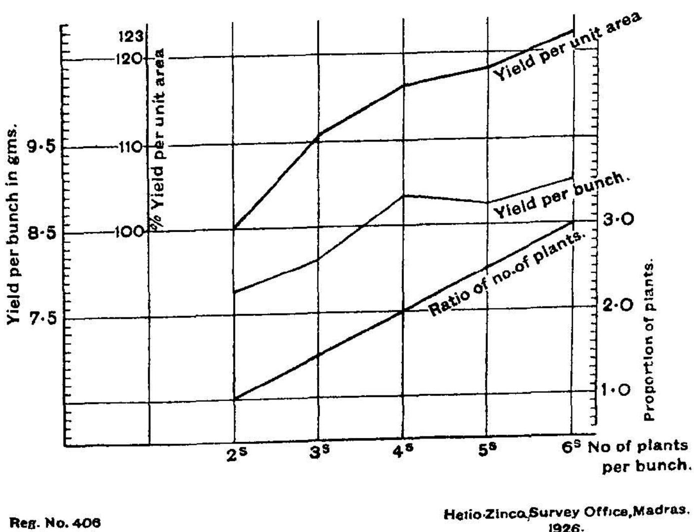


Fig. IV.

AVERAGE YIELD { per unit area. per bunch.



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2. EFFECT ON LENGTH OF PANICLE.

TABLE III (*a*). TABLE III (*b*).

Length of panicle in cm.	Frequency.										
	3″ × 3″	4″ × 4″	6″ × 6″	8″ × 8″	6″ × 1′	1′ × 1′	2	3	4	5	6
8	2	...	..	...	...	...	...	...	..	...	..
9	2	...	...	...	...	...	...	..	..	.	.
10	3	..	...	...		...			...	...	
11	5	3	...	...	...	...	1	...	1		5
12	7	4	2	..	...	...	2	...	2	8	6
13	7	11	4	...	..	...	4	..	6	7	5
14	19	10	8			.	8	1	9	13	7
15	16	12	9	2	3	...	9	9	8	14	15
16	20	17	14	5	7	...	14	14	14	14	15
17	16	22	17	14	9	1	17	10	17	15	15
18	13	15	17	15	18	6	19	13	19	15	16
19	29	13	19	18	22	9	15	26	18	23	16
20	21	19	15	20	14	12	14	24	23	22	12
21	17	26	14	25	26	16	16	21	15	23	12
22	14	24	16	22	23	18	25	20	23	23	34
23	10	16	25	22	18	23	17	17	20	27	23
24	7	8	17	19	22	22	14	16	19	2	12
25	3	3	14	8	19	23	2	15	8	1	2
26	1	1	2	1	18	25	...	6	1	...	1
27	...	..	...	...	4	14	.	1	..	...	...
28	...	...	...	...	..	4	..	...	.	.	...
Average.	17·3	18·7	20·0	20·8	21·6	23·4	20·0	20·5	19 1	18 7	19·1

TABLE IV (*a*). TABLE IV (*b*).

Spacing.	Average length of panicle in cm.	Average weight of grain per head in gms.	Number of plants per hole.	Average length of panicle in cm.	Average weight of grain per panicle in gms.
3″ × 3″	17·8	1·18	2	20·0	1 54
4″ × 4″	18·7	1·62	3	20·5	1·46
6″ × 6″	20·0	1·54	4	19·1	1·36
8″ × 8″	20·8	1·64	5	18·7	1·32
6″ × 1′	21 6	1·78	6	19·1	1·24
1′ × 1′	23·4	1·98	...	..	...

It is obvious from tables III (*a*) and IV (*a*) that spacing is positively correlated with length and weight of head. The more the spacing, the greater the average length and the weight of heads. From tables III (*b*) and IV (*b*) it would seem that the bunch planting has very little influence on the length of panicle and the weight of grain per panicle. The difference in the average length of a panicle in a three-inch and a six-inch plot is 2·7 cm., between six inches and one foot 3·4 cm., and between three inches and one foot 6·1 cm. In the cases of the bunch planting, the differences are within one centimetre, probably within the limits of experimental error.

3. EFFECT ON YIELD.

Table V (*a*).					Table V (*b*).				
Spacing.	Number of plants.	Yield of grain.	Weight per plant.	Ratio.	Number of plants per bunch.	Number of bunches.	Yield of grain.	Weight per bunch.	Ratio.
3″ × 3″	697	1,620	2·32	100	2	189	1,470	777	100
4″ × 4″	407	1,550	3·84	166	3	189	1,540	814	104
6″ × 6″	189	1,470	7·77	335	4	189	1,680	888	114
8″ × 8″	112	1,440	12·86	554	5	189	1,620	857	110
6″ × 1′	105	1,305	12·43	536	6	189	1,710	904	118
1′ × 1′	55	1,140	20·80	900	...	...	.	...	...

The above table brings out clearly the influence of spacing on the yield per plant owing to the greater tillering capacity and the lengthening of the panicle. The increase in yield due to the greater number of plants per bunch is not significant. It is thus seen that spacing has a greater influence on the final yield of the crop than the number of plants per bunch. Taking individual bunches, the spacing and the number of plants per hole influence the tillering, length of the head, and finally the yield, though the effect of spacing is more marked than the number of plants per hole.

The aim of the experimenter is to produce the maximum outturn from a given area. The above-mentioned results do not, perhaps, accord with expectations. The total yield from a greater spaced plot is less than from a very close-planted one. The yield from a closely planted area is greater than in a well spaced lot in spite of its larger number of tillers and longer panicles, because of the greater number of plants in the former. The number of plants in a particular area seems to be the limiting factor in increased production. The following yield-records of the comparative trials are very suggestive.

4. EFFECT OF SPACING ON FINAL YIELD.

Variety—Kuruvai Strain No. 74.

Strip.—40′ × 4′ (Two seedlings per hole). Four repetitions.

TABLE VI.

Spacing.	3″ × 3″	4″ × 4″	6″ × 6″	8″ × 8″	6″ × 1′	1′ × 1′
Total number of plants in each strip.	5,474	3,146	1,458	854	810	410
Relative proportion of number of plants in each strip.	1,326	775	356	208	200	100
Number of plot.	Weight in tens of gms.					
C. 5 (*b*) East I ..	630	586	561	527	527	437
Do. II ..	681	620	557	486	427	415
Do. III ...	684	578	556	523	470	459
Do. IV ...	641	666	560	469	598	426
Total ..	2,636	2,450	2,234	1,995	2,022	1,737
Percentage	152	141	128	114	116	100

5. EFFECT OF BUNCH PLANTING ON FINAL YIELD.

Variety—Kuruvai Strain No. 74.

Strip—40′ × 4′ (bunches 6″ apart each way). Six repetitions.

TABLE VII.

Number of plants per bunch.	2	3	4	5	6
Total number of seedlings planted per strip	1,458	2,187	2,916	3,645	4,374
Number of plots.	Weight in tens of gms.				
C. 5 (*b*) West I	460	571	613	630	636
Do. II	546	542	609	596	682
Do. III	469	435	177	469	489
Do. IV	465	600	541	621	580
Do. V	528	543	555	522	554
Do. VI	442	536	594	604	618
Total ...	2,910	3,227	3,389	3,442	3,559
Percentage ...	100·	110·9	116·4	118·2	122·2

The results recorded above are interesting and encourage further detailed investigations in this line. It is obvious that in field experimental work it is not safe to draw definite conclusions from a year's results. These experiments have to be conducted over a series of years till consistent results are obtained. Yet, from the results worked out above, the following summary of observations is recorded:—

1. Wider spacing and fewer plants per bunch influence early flowering.

2. The average tillering capacity of the rice plant is proportionate to the spacing allowed, the range of variation in the results of spacing experiment being more marked than those with the number of plants per bunch (Fig. 1.).

3. The average length and weight per panicle increase with the spacing and with reduction in the number of plants per bunch (Figs. 2 and 3).

4. Though average weight per bunch increases with greater spacing, yield per area decreases with increased spacing and increases with the number of plants planted in the area.

5. The yield per bunch and per area increases with the number of plants in the bunch (Fig. 4).

6. Wider spacing has a greater influence on the tillering, length and weight of grain per panicle, than the number of plants per bunch (Figs. 1, 2 and 3).

7. Planting a short-duration crop like Kuruvai closely at three to four inches apart, with fewer seedlings per bunch, seems to give the maximum outturn.

A NOTE ON THE LIFE-HISTORY OF *CRYPTORHYNCHUS MANGIFERÆ*, FAB.

BY

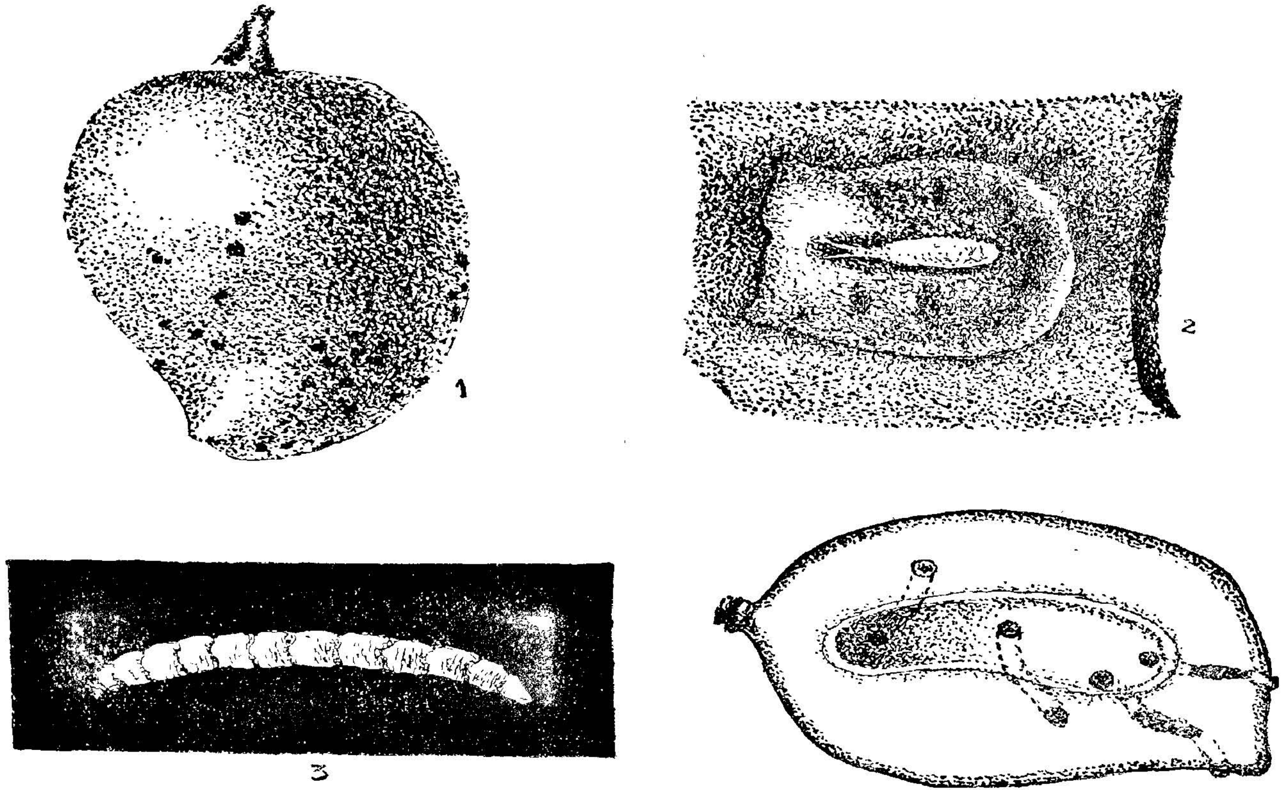
C. K. SUBRAMANYAM.

In the course of an examination of fallen mango fruits in certain mango gardens at Swamichettipalaiyam—a village about ten miles north of Coimbatore—for investigating the causes of abnormal fruit-fall, certain minute, elongate, thread-like grubs were met with in the tender seed-coat of the kernel of some of the fruits. On further examination it became apparent that these represented the first instar stage of the grubs of the

Mango Seed Weevil—*Cryptorhynchus mangiferæ.* The eggs were found deposited on the surface of young or half-grown fruits, and the slender grubs hatching therefrom were found tunnelling the pulp of the young fruit until they reached the seed-coat. After feeding for a short time they assumed the typical short and thick-set form of weevil grubs. The grubs first feed on the seed-coat and then tunnel into the cotyledons and ultimately pupate among the tunnels. The life-history was followed as far as possible and the following are notes recording observations made.

The weevil.—The weevils are familiar objects to lovers of the mango who may find them burrowing out of the stones and soiling the pulp of the last fruits of the season. They are rather small weevils about $\frac{1}{4}$ inch in length with a somewhat stout, thick-set body. Their general colouration is a dark brown marbled with lighter, so as to match the colour of the bark of the stem in which they generally hide themselves. They are rather shy creatures which drop to the ground on being disturbed, and sham death, lying motionless on the ground with their legs and antennæ closely folded over their body. They have been found feeding on the leaves of tender mango shoots in March-April.

Egg and egg-laying.—(Figs. 1 and 2.) The eggs are laid on the epicarp singly and covered with a juice exuded by the mother insect. This liquid is transparent in the beginning and hardens later on, thereby firmly fixing the egg to the rind of the mango. They are about $\frac{1}{2}$ mm. in length and creamy white when freshly laid.



THE MANGO STONE WEEVIL—*Cryptorhynchus mangiferae.*

The mother weevil surveys the fruit, feeling all over with its snout and antennæ, and when a suitable spot is secured she gnaws out a boat-shaped hollow on the surface so gently that no juice escapes from the fruit. Then turning round she extends her ovipositor and feels with it the scooped out surface. Passing the ovipositor backwards and forwards for a while, she places an egg with a small quantity of the transparent liquid referred to, in the hollow. She then turns round once more and scrapes the surface of the rind around the egg and, as in this case she cuts the epicarp rather deep, the juice rushes out of the rind and covers the egg, and later on dries up into a resin-like substance. The weevil now moves away and sets about laying further eggs in the very same manner. It took a weevil 45 minutes to lay 3 eggs, so that on an average 15 minutes may be allowed for each egg.

Eggs begin to be laid on tender fruits from the time they are of the size of an arecanut. Egg laying ceases when the fruits are half-grown, which coincides with the time when the seed-coat becomes fibrous. As many as 12 to 36 eggs have been noticed on a single fruit. Egg laying may be spread over 1 to 3 weeks as may be seen from the tables given. It takes 7 days for the egg to hatch and the grub to tunnel through the pulp or mesocarp and reach the seed-coat. The processes of egg laying and pairing alternate with each other.

Records of egg-laying by five pairs are given below :—

Pair A.	*Collected 27th March* 1924.
23-4-24 ...	24 eggs. In cop.
24-4-24 ...	17 " "
25-4-24 ...	7 " "
26-4-24 ..	4 " "
27 to 28-4-24.	5 " "
29-4-24 ...	No eggs. In cop. In healthy condition with many attempts at laying eggs.
30-4-24 ...	3 eggs.
1-5-24 ...	1 egg. Weevil missing.
Total ...	60 eggs.

Pair B.	*Collected 20th April* 1924.
23-4-24 ...	10 eggs.
24-4-24 ...	11 "
25-4-24 ...	3 eggs. In cop.
26-4-24 ...	4 " "
27 to 28-4-24.	9 " "
29-4-24 ...	No eggs. In cop.
30-4-24 to 2-5-24.	"
7-5-24 ...	1 egg. Weevil dead.
Total ...	38 eggs.

Pair C.	*Collected 20th April* 1924.
23-4-24 ...	3 eggs.
24-4-24 ...	4 "
25-4-24 ...	No eggs. In cop.
26-4-24 ...	"
27 and 28-4-24.	2 eggs.
29-4-24 ...	1 egg. Weevil dead.
Total ...	9 eggs.

Pair D.	*Collected 20th April* 1924.
23-4-24 ...	13 eggs.
24-4-24 ...	8 "
25-4-24 ...	7 "
26-4-24 ...	6 "
27 and 28-5-24.	2 "
29-4-24 ...	2 eggs. In cop.
30-4-24 ...	1 egg.
1-5-24 ...	1 "
2-5-24 ...	1 "
7-5-24 ...	Both alive.
16-5-24 ...	In cop.
27-5-24 ...	1 egg. Weevil dead.
Total ...	41 eggs.

Pair E.	*Collected 20th April* 1924.
23-4-24 ...	4 eggs.
24-4-24 ...	12 eggs. In cop.
25-4-24 ..	No eggs. "
26-4-24 ...	" "
27 and 28-4-24.	7 eggs. In cop.
29-4-24 ...	No eggs. In cop.
30-4-24 ...	1 egg.
1-5-24 ...	1 egg. Weevil dead.
Total ...	24 eggs.

N.B.—These pairs might have already laid eggs in the field before they were captured, and hence these do not represent the maximum number of eggs they may be capable of laying. Egg laying stopped with 29th of April.

Some of the eggs laid above were teased out and examined. In most cases they had not tunnelled into the pulp even though they had hatched. This was because the slices of the mango fruits cut out with the eggs for observation had become dried up. The dead larvæ were found lying doubled up inside the white egg-case. Circular holes were present at both ends of the egg shell, showing the attempts made by the grub to escape. In the case of successfully hatched eggs, the entrance to the pulp was plainly marked by a circular black dot.

The larva.—On hatching, the grub burrows into the mesocarp in search of the seed, tunnels in a zig-zag manner through the pulp, endocarp and seed coat until it reaches the cotyledons. Traces of such modes of entry were first made out in fallen fruits. The zig-zag track of the grub can be easily recognized since it is conspicuously translucent in the whitish pulp of the immature fruit. (Fig. 4 will clearly show the tracks.) At the time of hatching, the grub (Fig. 3) is only 1 mm. long and 1/10 mm. in width, extremely slender, elongate and distinctly segmented. It is dull white in colour with its head an orange yellow. As many as 5 to 6 larvæ may be met with on the membranous covering of the seed. When it begins to bore into the cotyledons it changes the elongated form suited for tunnelling (in which stage it looks quite unlike a weevil grub) into the typical fleshy curculionid larva. From this time onwards it confines its attentions to the cotyledons, till it attains its maximum size, when it measures 15 mm. × 3 mm. and is dull white with the head black. The exact larval period has not yet been ascertained.

The pupa is 10 mm. × 4 mm. The pupating larva constructs among the excreta an oval chamber, mostly along the concave side of the cotyledons, and occasionally in between them. The legs and mouth parts are drawn together and folded on the ventral side, the wing rudiments occupy a small portion of the dorsal surface and extend laterally between the meso and meta thoracic legs, and cover the latter pair. The pupal period lasts 7 days.

The exact total period of life cycle has not been worked out, but from observations made so far in the field it may be stated to occupy about 50 days from egg laying to emergence of adults as indicated below:—

Date of first noting early-stage larvæ in the field	24 III 24
Date of first noting pupa in the field	28 IV 24
Date of first noting adult in the field.	7 V 24

Allowing 7 days for hatching and boring into seed, the total period approximately works up to 50 days.

Brood.—There appears to be only one brood.

Varieties attacked.—Graft varieties such as Malgoba, Bangalora, Naduchalai or Khadir and Omlette and the country varieties of "Ko-mangai" (of the West Coast) and "Kilimukku" (lit. Parrot-bill) and other local varieties are subject to attack by this weevil: 72 to 85 per cent of fallen "Omlette" and 56 per cent of green mangoes ("Khadir") on the trees showed the infestation. The graft varieties showed a greater percentage of infestation than the country varieties—Kilimukku excepted. Fallen fruits with signs of weevil damage invariably showed dead tissues immediately above the place where the vascular bundle came in contact with the mesocarp.

Nature of injury and population of stones.—The principal damage is only to the seed. All traces of tunnelling of the early-stage grub disappear with the growth of the mango. As to the population of stones, 5 to 6 early-stage larvæ, 5 larvæ, 3 pupæ, 3 adults, an adult and a half-grown larva, and an adult and a pupating larva, have been severally found inside single stones. In proportion to the number of eggs laid on a fruit, the population of stones appears rather low. Of course it is quite evident that the stone cannot support all the larvæ that might hatch.

Emergence of weevils.—The adults emerge from the stones by a clean-cut hole on the concave edge of the stone where the fibres are attached. This is the weakest region in the endocarp. In a few cases where the weevils had an opportunity to pupate before the husk had not ripened, such holes may be found right in the middle of the stone. Weevils continue to emerge over a long period. The following table shows the several dates on which the adults emerged from stones of bird-pecked fruits collected from the field :—

A		B		C		D		E	
10-5-24.		17-5-24.		21-5-24		21-5-24.		23-5-24.	
14-5-24.	1	16- 6-24.	1	5-6-24.	2	26-5-24	1	6-6-24.	2
26-5-24.	3	20- 6-24.	1	15-6-24.	4	31 5-24.	1	9-6-24.	2
5-6-24.	2	26- 6-24.	2	20-6-24.	4	5-6-24.	4	15-6-24.	2
9-6-24	4	4- 7-24.	1	29-6-24.	1	7-6-24.	1	20-6 24.	5
20-6-24.	2	16-12-24.	1	1-7-24.	1	9-6-24.	1	26-6-24.	2
26-6-24.	2	Alive.		4-7-24.	4	15-6-24	10		
23-8-24.	1					20-6-24.	4		
						29-6-24.	1		
						4-7-24.	1		
						23-8-24	5		

The weevils that emerged were found living without food up to the end of September, and after this date they were given tender shoots of mango for food in the cages. They fed on them but died after a few days. Perhaps they might have lived longer if they had not been supplied with leaves.

EXPLANATION OF ILLUSTRATION IN BLACK AND WHITE.

Cryptorhynchus mangiferæ: The Mango Weevil.

Fig. 1. An immature mango fruit with eggs laid on the skin.
,, 2. An egg enclosed in the solidified resinous juice: magnified.
,, 3. First stage grub—thin and elongate: magnified.
,, 4. Longitudinal section of fruits showing tracks left by the young grubs in their passage through the pulp.

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*SOME OBSERVATIONS ON THE FLOWERING PHASE OF TWO WILD SPECIES OF ORYZA (*O. longistaminata* AND *O. latifolia*)

BY

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The seeds of these two forms were first obtained from Ceylon and Burma through the kind courtesy of Mr. Stockdale, then Secretary, Ceylon Agricultural Society, and the Chief Conservator of Forests, Burma, respectively. They have been grown in the Paddy Breeding Station, Coimbatore, for the last three or four seasons. Both of them being perennial, they were first raised from seed

* Paper read at the Indian Science Congress, Benares, 1925

the succeeding crops being obtained every year from the stubbles left in the ground, which remain in the soil alive in the off-season—February to June—and shoot up again when the plot is irrigated. Several attempts were made to effect an artificial cross between these and the cultivated varieties with no success. A detailed study of the flowering phase of the above two was started this season to find out the possible causes of the failures, and the facts recorded in this paper are the observations made in the course of this study.

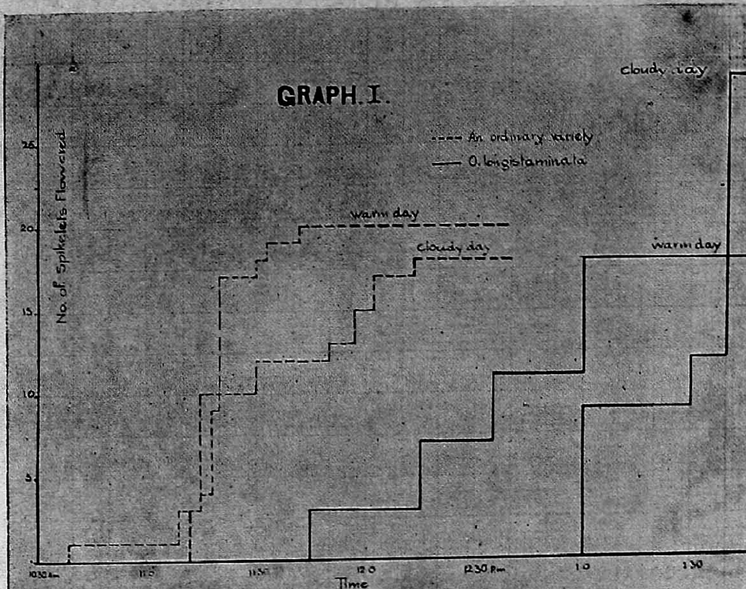
2. *Oryza longistaminata, E.B. 182.*—This species, known also as Senegal paddy, from the place in which it was originally found, was first discovered by Paul Amman and is fully described in French in the journal " L'Agriculture Practique Des Pays Chauds," 1911. It is peculiar in its habit as it spreads rapidly by rhizomes. A detailed description of the anatomy of the rhizomes is dealt with in the same journal. The flowering is particularly interesting. The inflorescence, as in all paddies, is a panicle, with the spikes arranged in a racemose fashion, but there are few or no sub-spikes. Whereas in other varieties of rice the opening of the spikelets starts when the panicle is emerging from the leaf-sheath, in *O. longistaminata* the opening commences only after the panicle has fully emerged from the sheath with the bottom-most spike 7 to 9 inches above the base of the leafblade (see photograph I).

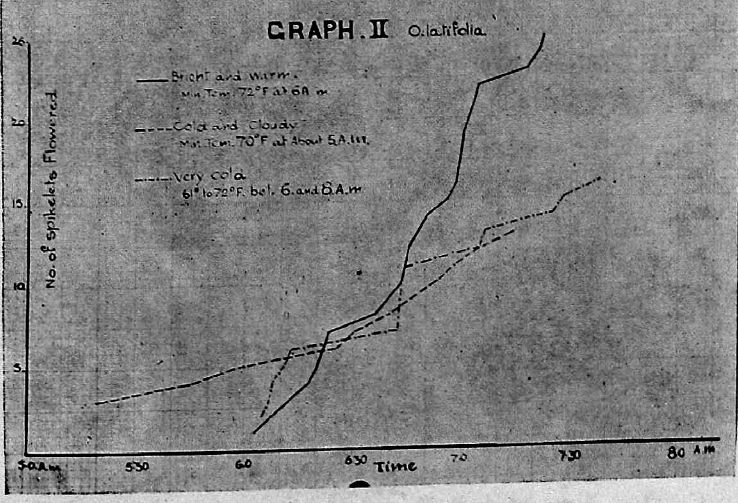
As the name of the species implies, the stamens are especially long, occupying the full length of the cavity, the growth of the filaments taking place after the opening of the glumes (see photograph IV). The anthers are each 6 mm. long, whereas in T. 24, which is typical of the cultivated varieties, they are each 2·5 mm. on the average.

This species differs from most of the cultivated forms in the time at which the flowers begin to open. In Coimbatore during the months of October–November when most of the varieties are in flower, opening ranges between 9–30 to 11 a.m. when the atmospheric temperature is about 78° F. In *longistaminata* the starting time ranges between 11–30 a.m. to 12–30 p.m. when the temperature is definitely higher by about 4 to 5 degrees. Any atmospheric change, as cloudy weather, affects both in the same way. On cloudy days when the ordinary varieties open at 11–30 a.m., *O. longistaminata* opens at 1 p.m. This is an indication that this wild species requires a definitely higher atmospheric temperature.

There is another distinctive feature which has not been noted in most of the varieties so far observed in the manner of flowering. In the cultivated varieties the rate at which the flowers open is very slow in the beginning, i.e., very few flowers open at a time, and after a definite period, a number of flowers open in a short interval and the rate falls again after the distinctive flush. But in this species there are two or more flushes (not more than four) with no flowers opening in the intervals of such flushes (vide graph I).

In common with most of the varieties observed, the glumes open gradually but the time taken to attain the full open condition is comparatively short in *longistaminata*, occupying 2·5 minutes on the average, whereas it is about 5 minutes in all other varieties. Again, the time taken from the opening to the closing of the glumes is definitely


GRAPH. I.
---- An ordinary variety
— O. longistaminata
warm day
cloudy day
warm day
cloudy day
No. of Spikelets Flowered
5.
10.
15.
20.
25.
10.30 A.m
11.0
11.30
12.0
12.30 P.m
1.0
1.30
Time


GRAPH. II O. latifolia
Bright and warm.
Min. Tem. 72°F at 6 A.m
Cold and Cloudy
Min. Tem. 70°F at About 5 A.M.
Very cold
61° to 72°F. bet. 6. and 8. A.m
No. of Spikelets Flowered
5.
10.
15.
20.
25.
5.0 A.m
5.30
6.0
6.30
7.0
7.30
8.0 A.M
Time

much longer than in all other varieties, being nearly $1\frac{1}{2}$ hours, whereas it is only 30 to 40 minutes in the latter.

The length of the filament after it has fully elongated is only three-fourths the length of the anther, i.e., 4·5 mm. in *longistaminata.* In T. 24, typical of the cultivated forms, and also in *latifolia*, the filament is nearly three times the length of the anther, i.e., the average length of the filament is 8 mm., the average length of the anther being 2·5 mm. to 3 mm.

Another marked feature of this species is the peculiar arrangement and position of the various essential parts of the flower at the time of the opening, which precludes all possibility of the flower being self-fertilized. Photograph II gives the various stages of the opening of the glumes. In (1) the glumes start opening In (2) the filaments have started growing and the anthers fall out when they may begin to gently shed their pollen. The anthers dehisce in this species apically by two lateral pores at the tip of the lobes. On account of this the stigmas have no chance of receiving the pollen from the dehiscing anthers of the same flower. When once the pores open, the pollen is actually poured down as it were from a long bag with the slightest disturbance. In stage (3) the filaments have grown to their full length, the anthers waving about pouring down the pollen. The stigmas bend downwards, and even then the tips of the anthers are further below, showing the impossibility of the stigmas receiving the pollen of the same flowers. Stage (4) shows the dehisced anthers and the position of the stigmas. Stage (5) shows the complete closure of the glumes with the stigmas caught between, and their freshness even after a day. If the stigmas are examined under the lens after the dehiscence of the anthers, hardly any pollen is found to adhere to their feathers. This probably accounts for almost all the flowers remaining unset, giving no grain at all. These empty spikelets begin to fall off very soon and after a few days we hardly find anything in the panicle.

The pollen of this variety is different from the pollen of the cultivated forms so far observed, in that it is slightly bigger in size and a little elliptic in shape.

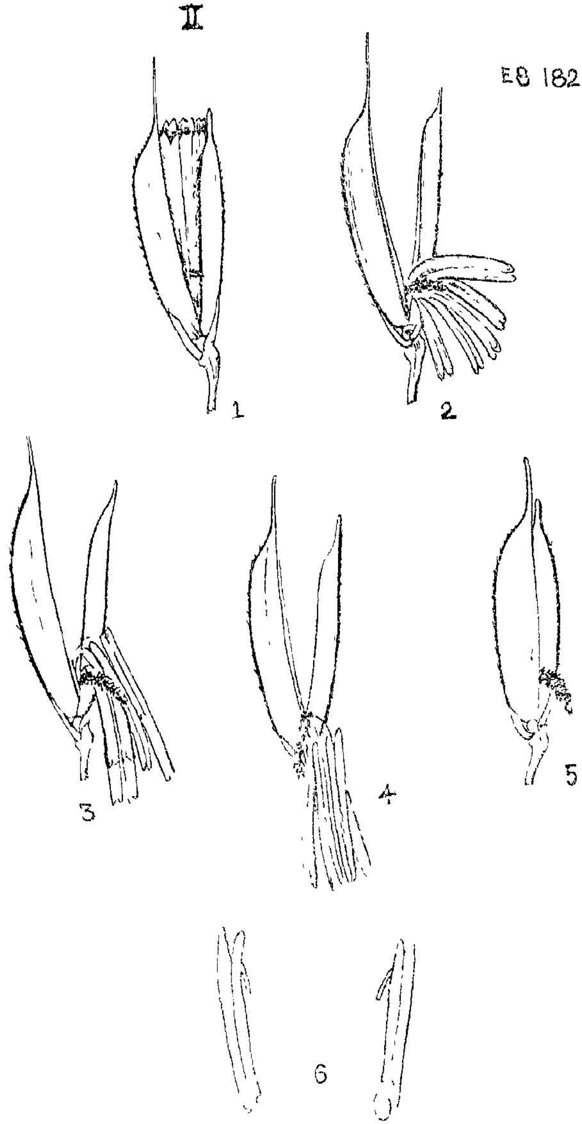
3. *Oryza latifolia, E.B. 40.*—This form is known in Burma as "Wild spirit rice." The arrangement of the spikes and sub-spikes in the panicle is the same as in the cultivated forms, except that the branches of the panicle are situated far apart from each other, making it a very open one. Unlike all other forms there is a thick, fleshy pulvinus-like structure at the base of each spike in the panicle of this species, which probably helps the spikes to stand almost at right angles to the axis of the panicle. Just as in all the cultivated forms, and unlike the *longistaminata*, the commencement of the flower opening takes place even before the panicle has completely emerged out of its leaf-sheath. The most important special feature of this species is the time at which the flower opening starts in the day. This happens between 5 and 6 a.m. The opening of the glumes, the dehiscence of the anthers, and the glumes closing again, all finish off long before any of the cultivated forms commence flowering.

This opening is greatly influenced by the atmospheric conditions of temperature and humidity. The combined effect can be seen from the graph II. On a bright sunny morning the graph rises up steeply, whereas on a cold cloudy morning the graph shows a slow and gradual rise. In the month of September the morning is clear and warm and the minimum temperature for the day of about 72° F. is recorded at about 6 a.m. The flowering commences just then and finishes off rapidly, but if the morning is a bit cloudy and cool and the minimum temperature for the day—about 69° F.—is recorded much earlier than 6 a.m. with no subsequent rapid rise in the atmospheric temperature, flowering also commences earlier than 6 a.m. and drags on for a comparatively longer time. In a colder month like November when the temperature in the morning at 5 a.m. is as low as 63 F. and does not rise much before 7 or 8 a.m. the flowering commences before 6 a.m. and goes on till about 7-30 a.m. It can be definitely stated, so far as this variety is concerned, that its flowers may begin to open with a temperature as low as 63° F. and the blooming continues slowly if the low temperature is maintained for a fairly long period but finishes off rapidly if there is a rapid rise in temperature later on.

The time taken for the flowers to attain the full open condition is much longer than in all the cultivated forms, being nearly 10 minutes. On very cold mornings the time is still further extended to about 15 minutes. The time taken for the glumes to close again is about an hour and fifteen minutes, a much longer period than in the cultivated forms, but at the same time not so long as in its wild fellow—*longistaminata*. This is again influenced by the prevailing weather conditions—being longer on cold and cloudy days and shorter on warm and sunny days. So far as the size of the filaments and the anthers are concerned, very nearly the same figures are obtained as in the cultivated forms (vide photographs III and IV). Unlike all other wild and cultivated forms the anthers are pigmented in this, resembling some of the common grasses. The dehiscence of the anthers and the pollination are the same as in the cultivated varieties. The dehiscing is almost simultaneous with the opening of the glumes, giving thereby ample facilities for self-pollination (vide photographs III). It is believed that the common honey bee (*Aphis florea*) which visits the flowers at the time of the opening so early in the morning also helps in the self-pollination as no other variety flowers at this time. Cross-pollination among the flowers of the same panicle seems to be possible by a large number of the flowers opening in pairs. When the stigmas are examined after the dehiscence of the anthers we find quite a mass of pollen sticking to them. The setting is normal but most of the spikelets do not attain the full ripening stage, but remain half-filled.

4. Experiments are in progress to make the *longistaminata* flower earlier in the day and the *latifolia* later in the day artificially. Detailed studies have also been started on the germination of the pollen of these two species.

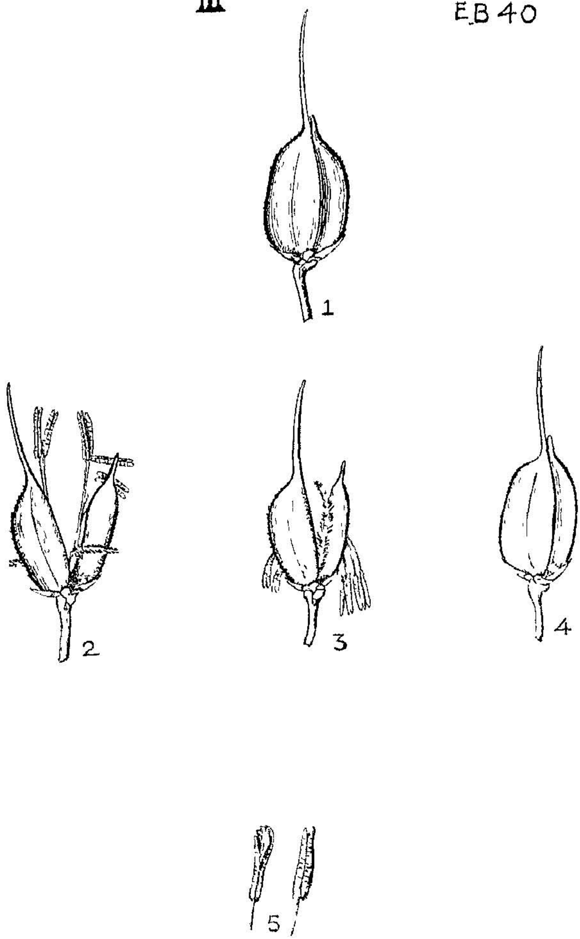

I
EB 40
T24
EB182



Oryza longistaminata

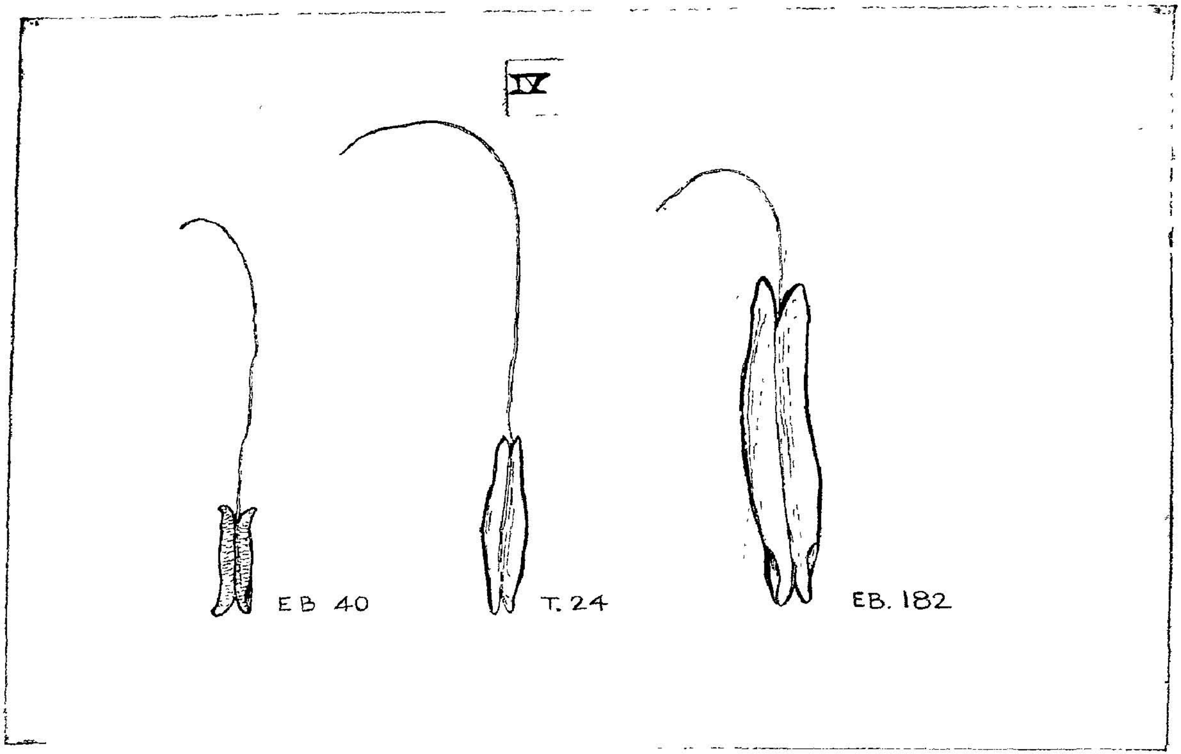
III

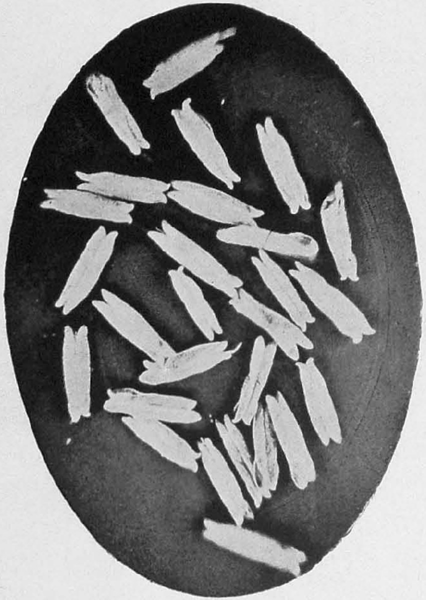
E.B 40



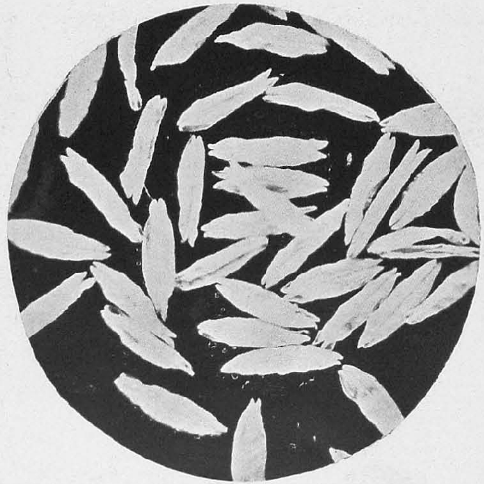
Oryza latifolia

IV





E.B. 40.



T. 24.

F. B. 182

V

POLLINATION IN COCONUT

BY

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Deputy Director of Agriculture

AND

E. K. NAMBIYAR,
Farm Manager.

The importance of seed selection is a well-recognized fact in the case of any crop and it is especially so in the case of a valuable perennial crop like coconut. It would seem that Nature has fitted it mostly for cross-fertilization. Naturally therefore one is ignorant of the characters of the father and also as to whether the particular mother tree has got the recessive or the dominant character herself. An ordinary ryot selects the seeds from the best trees as they appear in the fields and as a result, when his trees grow up, he notices all sorts of variations. To his utter dismay he finds some trees very weak and others poor yielders. Even in the Government Coconut Stations at Nileshwar and Pilicode of South Kanara, though the seeds were collected from some of the best trees available on the West Coast, yet variations are observed in the young trees.

It is a matter of common observation that in spite of similar conditions of light, spacing, cultivation, and manuring, remarkable differences may often be seen between individual trees of any coconut garden, not only in the yielding capacity, but also in the colour, size, and shape of nut, the length of the flower stalk, the formation of the crown and the like. Trees bearing 100 to 150 nuts a year are often found side by side with others producing less than 50 nuts.

With the object of controlling the natural pollination a study of the inflorescence was made and self-pollination begun at Kasaragod Farm. Some of the actual observations recently made on this subject are given below:—

For the purpose two types of coconut trees, viz., (1) regular yielders, i.e., trees which put forth a spathe in the axil of every leaf and contain a fairly equal number of nuts, and (2) irregular yielders which do not put forth spathes in all the axils except in some favourable seasons, were taken up. Some trees of the former type were selected and watched and notes taken as to the regularity with which the spathes appeared and split, male flowers opened and shed, and the female flowers became receptive. Daily records were made after careful observation as to the (1) date of appearance of the spathe deep in the axil, (2) the date of splitting of the spathe, (3) the distances along each spike the male flowers opened, or opened and shed, (4) the time taken for all the male flowers to open, (5) the date when the stigmas come out of their perianth, (6) when they commence secreting honey, (7) when they open and become receptive, and (8) when the stigmas turn brown in colour.

From the observations so far made it has been found that there are variations, not only between one tree and another, but also in the same tree in the durations between the appearance of successive spathes, the rate of splitting, etc., according to the difference in seasons.

The following conclusions drawn so far are restricted to the observations made on six particular trees and we do not claim that they necessarily apply to all trees in general:—(1) The minimum period between the appearance of two successive spathes appears to be about 18 days. (2) After the appearance of the spathe deep in the axil, the maximum time taken for bursting is 138 days and the minimum 104 days. There is no specific time for the bursting of the spathe since it occurs at any part of the day. (3) It takes 16 to 23 days for all the male flowers in an inflorescence to open after the bursting of the spathe. The opening of the male flowers occurs mostly in the morning, but it continues throughout the whole day and may happen even during the night. The males situated at the apex of the central spikes, and those at the sides of the female flowers generally open first, though sometimes those at the middle of the spikes also are found opening. Though the male flowers at the apex of the spike commence opening, all in that spike do not open at one stretch. They open progressively up to about half or two-thirds way down the spike and remain sticking on, sometimes till almost all the spikes up to the lowermost one have their males similarly opened. Subsequently the male flowers in the base of the first spike open, followed by the rest in general progression. It must, however, be pointed out that there is not much regularity in the opening of the male flowers. Those that are under the cover of the spathe, and thus not fully exposed to the sun, take a longer time to open and it appears likely, though it has not yet been tried, that the opening of the flowers may be delayed to a certain extent if necessary by keeping them covered. The number of the male flowers in an inflorescence varies a good deal, as would be evident from the observations recorded, viz., in the case of two inflorescences where the male flowers were collected as they shed, and counted, it was 4,374 and 6,943, respectively.

The receptive stage of all the female flowers will have passed by the time the next spathe opens, but in some cases the latter may open earlier and the female flowers in one and the male flowers in the next may open simultaneously and afford facility for self-fertilization. In any individual spathe the female flowers as a general rule become receptive only two or more days after all the males have finished opening, but exceptions to this rule are found especially during the monsoon. Instances were noticed where the female flowers opened on the very day when the last set of male flowers opened and sometimes even two days earlier. The opening of the female flower happens usually in the morning, but just as in the case of the male flower, it is not restricted to any particular part of the day. Generally the female flowers situated at the apex open first, but as in the male flowers their regularity in opening is variable.

From the above observations it is clear that there is provision both for self, and cross-fertilization. For cross-fertilization the agents are chiefly the bees. Different kinds of ants are found which very probably help to transfer pollen from one spadix to another on the same tree, if not from other trees, as also different kinds of insects which are found visiting both male and female flowers. In some cases a small bird has been noted to help the function. It is quite probable that wind plays an important part in cross-pollination. The large amount of pollen grains in each spadix, their minute size, and their capacity of being viable for six to ten days would appear to be adaptations for wind pollination. But it is not yet known how far it helps in transferring the pollen grains.

After having recorded these preliminary observations, an attempt was made at artificial pollination. The first difficulty was to find a suitable method of controlling natural pollination. Bagging individual female flowers was found difficult and laborious, especially when there were more than one female flower in each spike. The best way therefore appeared to be the bagging of the whole spathe with double bags of fine muslin and this method was finally adopted. Male flowers were collected five or six days before the probable date of the opening of the female flowers and after removing all the male flowers still left on the spike and after thoroughly cleaning the inflorescence, the whole spathe was very carefully bagged.

The next problem was to find out how best to preserve the pollen grains thus collected. Various methods were tried and it was found that wrapping them up in tissue paper was the best. By so doing we found the pollen grains would retain their vitality for six to ten days. The test of viability was their power to germinate and develop pollen tubes in a 7 per cent solution of gelatine with sugar added in the ratio of 2 : 5. Up to a period of six days pollen was found to germinate in this solution, but after that time it rapidly lost this power. Hence endeavours were made to secure the pollen not sooner than five or six days in advance of the probable date of the opening of the female flowers. In some instances it happened that the next spathe emerged by that time so that it became possible to use fresh pollen grains from this. Whenever possible such pollen grains were preferred. Pollen taken from unopened spathes was also tried and in some cases it was possible to get fairly ripe grains, which germinated very well indeed, and fertilization was successful with such pollen.

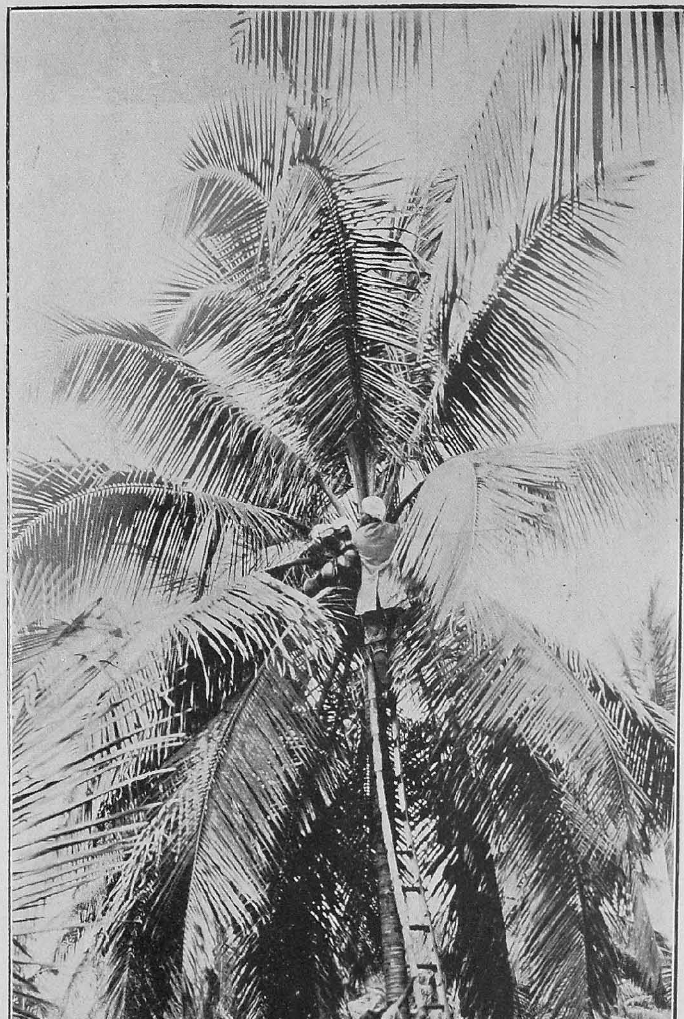
In almost all cases it was found possible to forecast the probable time of opening of the female flowers correctly so that there was no necessity to open the bags to find out whether the receptive stage had been reached until the actual day of artificial pollination. In the majority of cases all the female flowers opened in the course of two days and if one or two female flowers still remained unopened they were not made use of. The bags were invariably removed 10 days after pollination had been effected.

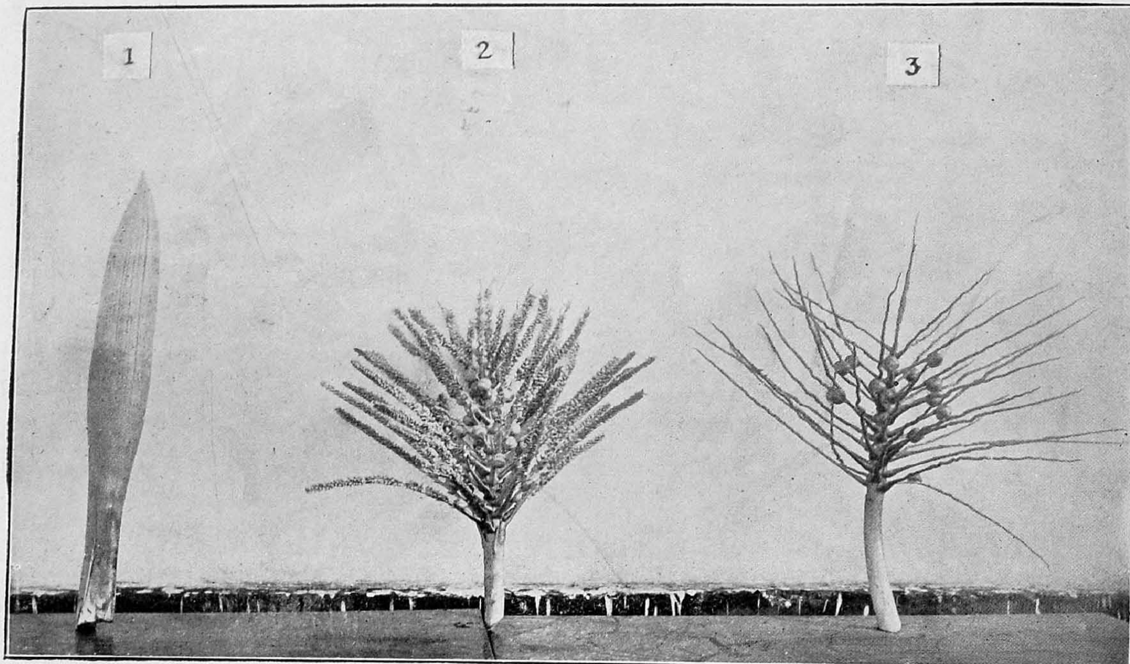
The pollination was on the whole very successful and, with one solitary exception, all the spathes thus pollinated have developed fruits. Out of 198 nuts thus obtained and sown in the nursery, 178 nuts germinated.

To ensure that the pollen grains used were all viable a sample was subjected to a germination test. In a few cases even though the grains failed to germinate the flowers were found developing into fruits. It was first doubted whether the bags used had been effective in controlling the entrance of foreign pollen and therefore to test the efficiency of these bags some spathes were covered with similar bags after removing all the male flowers. In all such cases, fertilization failed to take place. Hence it is evident that the bags were quite safe

APPENDIX A.

Fig 1.—A part of the flowering branch
" 2.—Female flower bud just opening
" 3.—Male flower opening
" 4.—Branchlet after all the males opened and shed and when the female flowers open




1
2
3

and the probability therefore is that the grains which had failed to germinate in the culture germinated and developed in the medium of the stigmatic fluid of the female flower.

SUMMARY.

(*a*) The seedlings raised out of nuts from any selected tree do not all show the characters of the mother tree, in spite of similar conditions of treatment.

(*b*) There are variations not only between one tree and another, but also in the same tree in the durations between the appearance of successive spathes, the time taken for splitting, etc., according to the seasons.

(*c*) In the same spathe, generally all the male flowers open and shed their pollen grains before the female flowers become receptive; but cases have been noticed in which the female flowers of one are in the receptive stage, when the male flowers of the next spathe are shedding pollen. Thus opportunities for cross-fertilization are afforded.

(*d*) The pollen grains preserve their viability for 6 to 10 days.

(*e*) Insects and small birds were observed helping pollination. It is probable that the wind plays an important part as the size of the pollen grains is very minute and the number innumerable.

(*f*) Cross-fertilization can be prevented by bagging with muslin double bags.

(*g*) By artificial pollination of 32 spathes of 11 trees, with pollen from the respective trees, 198 nuts were obtained. 178 nuts out of these germinated.

REPORT ON THE ANIMAL NUTRITION EXPERIMENT CONDUCTED AT THE AGRICULTURAL COLLEGE, COIMBATORE, IN 1924-25

BY

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Assistant Lecturing Chemist.

In April 1924, the Physiological Chemist at Bangalore suggested to the Deputy Director of Live Stock, Coimbatore, a scheme of experiments to be conducted at Coimbatore on the "Production value of feeds." The Government Lecturing Chemist was asked to co-operate so far as analytical work was concerned. Later, however, the head-quarters of the Deputy Director of Live Stock were transferred to Hosūr, and the Government Lecturing Chemist was practically in full charge of the experiment.

A few alterations having been made to the stalls, the experiment was started in September 1924 under the immediate supervision of the Assistant Lecturing Chemist who attended to the sampling, feeding and weighing out of food-stuffs and fodders, to the periodical weighing of animals and to the analysing of samples and tabulating of results. The experiment was kept on for four months, from September to December 1924, at the end of which period five heifers were pregnant and it was considered expedient to conclude the experiment. The experiment was in the nature of a tentative one, nothing of this sort ever having been undertaken at Coimbatore. Great accuracy is not claimed for the results obtained, but it has been decided to publish this account of the work to indicate that a beginning has been made with this kind of work. Experience has been gained which may be useful to others. It is to be remarked, however, that the rations employed are abnormal.

2. *Animals.*—The Deputy Director of Live Stock had already selected for the experiment six heifers of the cross-bred Bangalore herd, nearly alike in physical condition and ranging in age from 21 to 23 months. Particulars of the animals are shown in Table I.

TABLE I.

Animal No.	Age on 1st Sep. 1924. Y.	M	D.	Breed.	Date of service.
81	1	11	6	Ayrshire-Montgomery-Nellore ...	..
82	1	10	14	Ayrshire-Sanival (2nd generation).	16th Sep. 1924
83	1	10	11	Ayrshire-Jersey . .	17th Sep. 1924
85	1	9	28	Nellore-Kangayam Kerry-Aden.	11th July 1924
86	1	9	28	Ayrshire Sindhi (2nd generation).	26th Sep. 1924
87	1	9	27	Ayrshire-Sindhi (2nd generation).	7th Dec. 1924

3. *Ration.*—The animals started with a ration of 6 lb. of concentrate and 40 lb. of green fodder, as shown in Table II, this being the ration adopted at the time by the Deputy Director of Live Stock for the above animals.

TABLE II.

	Weight fed (lb.).	Containing					
		Water	Protein	Fat.	Fibre.	Carbohydrate.	Ash.
Groundnut cake	2	0·181	0·832	0·241	0·132	0·504	0·110
Cotton seed	1	0·075	0·134	0·086	0·258	0·410	0·037
Dhall husk	1	0·117	0·455	0·006	0·438	0·389	0·041
Rice bran	2	0·128	0·091	0·088	0·662	0·599	0·433
Total concentrate ...	6	0·501	1·512	0·421	1·494	1·903	0·621
Guinea grass	40	32·000	0·700	0·312	1·992	3·792	1·204
Total for ration ..	46	32·501	2·212	0·733	3·486	5·695	1·825

At the end of six weeks, the concentrate was increased by half a pound of groundnut cake, at the suggestion of the Deputy Director of Live Stock. While the animals left a residue of fodder daily, the concentrate was always entirely consumed.

4. *Object of the experiment.*—The object of the experiment was to determine the production value of a feed. By the term "Production value of a feed" is meant the gain in weight made by animals with a given ration during a specified time. To determine this, the daily rations were weighed out accurately and, after being fed to the animals, any residues left over were also weighed. The moisture contents of the foods and residues being determined, the difference in the two dry weights gives the actual quantity of dry matter eaten during the period of experiment. This is shown in Table III.

TABLE III.

Animal No.	Food.	Dry matter eaten.				Total dry matter consumed in 122 days.	Average dry matter consumed per day.
		September.	October.	November.	December.		
		LB.	LB.	LB.	LB.	LB.	LB.
81	Fodder	249·24	275·34	212·59	245·53	1,679 83	13·77
	Concentrate ...	164·48	175·85	178·40	178·40		
82	Fodder ...	239 51	254·68	229·76	265 10	1,686·18	13·82
	Concentrate ...	164·48	175·85	178·40	178·40		
83	Fodder ...	243 65	268·54	210·95	256·30	1,677·03	13 74
	Concentrate ...	164 94	175·85	178·40	178·40		
85	Fodder ...	247·90	299 76	232·24	258 48	1,735·97	14·23
	Concentrate ..	164·94	175·85	178·40	178·40		
86	Fodder ...	265·74	269 09	229·01	240·94	1,702·37	13·95
	Concentrate ...	164·94	175·85	178·40	178·40		
87	Fodder ...	190 83	182·03	180·18	181·97	1,425·11	11·68
	Concentrate ...	157 45	175·85	178·40	178·80		
	Average ...	...	...	...	...	1,651·08	13·55

5. *Live Weights of Animals.*—Simultaneously the animals were weighed every fortnight on three consecutive days, the average of the three days' weights being taken as the mean weight of that period. The difference between the initial and final weights gives the increase in live weight for each animal for the period of experiment. The increase in live weight and the quantity of food eaten being known, "Production Value" of the feed, is expressed by stating that so many pounds of dry matter of food will produce one pound increase in live weight.

The weighing of animals was done on the Farm weigh-bridge which was found to be defective at the outset A calibration curve was plotted and weights as recorded in the balance were corrected according to the curve. After a month, this method was abandoned in favour of the method of taring which gave satisfactory results. The live weights of the animals are shown in Table IV.

TABLE IV.—Showing average fortnightly live weights of animals in pounds from 1st September to 31st December 1924 (122 days).

Animal No.	Average weights (in lb.) fortnightly.										Gain in weight for 122 days.	Gain in weight for 1 day.
	I	II	III	IV	V	VI	VII	VIII	IX	X	LB.	LB.
81	512	520	555	566	580	608	631	667	649	676	154	1·344
82	482	497	505	517	518	552	568	598	594	613	131	1·074
83	459	464	483	497	512	522	534	583	570	589	130	1·065
85	503	521	529	540	564	599	637	675	677	695	192	1·574
86	475	483	497	490	512	536	559	592	589	602	127	1·041
87	447	451	461	470	492	484	503	538	515	554	107	0·877

6. *General Routine.*—The stalls for housing the animals were not specially constructed for carrying on experiments on animal nutrition, but those which were made available were temporarily altered to serve the purpose, e.g., by providing partitions between the mangers and the stalls, by rounding the bottoms of mangers with cement plaster, etc.

The usual routine followed was the feeding of the concentrate at 7 a.m., followed by exercise in a bare paddock for an hour, during which period the freshly cut Guinea grass was weighed and put up in separate bags and the residues of previous day's fodder were collected and weighed. The morning's grass ration was put into the manger and the animals returned to the stalls. On weighing days, the animals were first weighed and then fed with the concentrate. Water was provided for drinking. In the afternoon, feeding with concentrate was done at 4 o'clock, after which the evening's grass ration was put into the manger and the animals were left for the night.

7. *Analysis.*—A sample of about 2 lb. of daily ration of Guinea grass was taken in a mosquito net bag to the Laboratory, weighed accurately and hung up to dry; the air-dried fodder was weighed again an aliquot of which was dried in the oven at 100°C after being finely chopped up, whereby the actual dry matter of the daily ration of green fodder was determined. It is admitted that the accuracy of this method of sampling leaves much to be desired and in future work it will be improved upon.

Aliquots of dried daily samples of Guinea grass were stored in a bottle and the composite sample was analysed for the nutrients once a month.

Similarly the foodstuffs forming the concentrate were each sampled and analysed for nutrients, whenever there was a fresh supply, which was usually once a month.

8. *Digestive Coefficients.*—Along with the determination of Production Value, the Digestive Coefficients of the ration were determined in the usual manner, the experiment lasting for 11 days, from 19th to 29th November. During this period, feeding was done as before, but the animals were not taken out. Two men were posted day and night to collect the dung, in tared kerosene tins, as it dropped from each animal. The dung excreted during the previous 24 hours was weighed every morning and aliquots were sampled into stoppered bottles and the composite samples were preserved by the addition of a little carbolic acid, in the absence of provision for cold storage, and then analysed for nutrients in the usual way.

Table V shows the digestive coefficients of the nutrients in the ration fed, the figures for each animal being given in the Appendix.

TABLE V.

Animal number.	Digestive Coefficients.					
	Dry matter.	Protein	Fat.	Fibre.	Carbo-hydrate.	Fibre + Carbo-hydrate.
81	53·47	84·93	69·24	43·50	43·57	43·54
82	44·79	79·80	62·07	22·02	58·46	40·24
83	48·75	81·37	65·16	27·16	66·48	46·82
85	46·67	78·24	58·65	23·91	64·27	44·09
86	47·97	73·91	69·61	27·89	65·45	46·67
87	49·39	79·86	63·69	28·32	65·47	46·90
Average.	48·50	79·68	64·72	28·80	60·61	44·71

DISCUSSION OF RESULTS.

9. *Production Values.*—The animals kept in good condition throughout the experiment, with the exception of No. 87 which suffered for a while from the after-effects of a severe attack of Foot and Mouth disease. Animal No. 85 was pregnant at the beginning, while four other animals were served during the course of the experiment. While discussing the results of the experiment, it is necessary, therefore, to bear in mind that the effect of the ration was not only to produce growth in the animal, but that a portion of it was used in nourishing a fœtus at the same time.

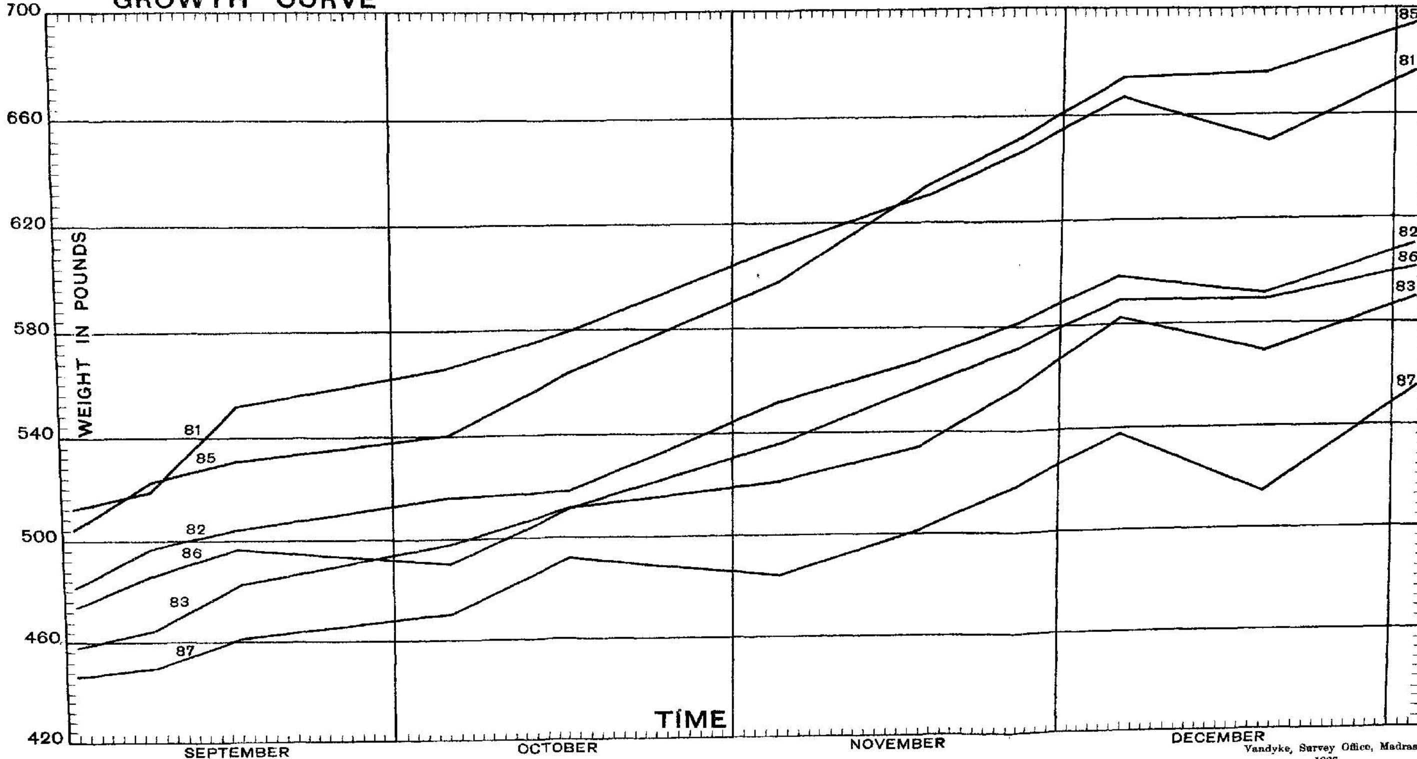
The Production Value of a given ration may be gauged, in the case of each animal, either (*a*) by the amount of average daily gain in live weight or (*b*) by the amount of dry matter consumed to produce the increase of one pound in live weight.

(*a*) Judged by the former standard, the average daily increase in live weight works out to 1·162 lb., the extremes being No. 85 which put on 1·574 lb. daily and No. 87 which gained only 0·877 lb.

It is worthy of note that animals which were largest in size put on the greatest amount of weight, for instance Nos. 81 and 85; and these happened to have some Nellore blood in them. The smaller sized animals put on less weight and two of them, Nos. 86 and 87 are cross-bred Sindhi heifers.

The Growth Curve plotted in the Chart showing fortnightly weighments (see next page) seems to be of a normal character, except in the beginning of December, when all the animals fell off in weight, due apparently to the after-effects of confinement during the previous fortnight when the digestion experiments were in progress.

GROWTH CURVE



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(*b*) While the daily gain in weight of an animal is useful in showing the probable total gain in a given period, the amount of dry matter consumed to make this gain is of equal importance in the economics of cattle raising, since the thrifty nature, or otherwise, of the animal is indicated thereby. Table VI sets out the total dry matter and the digestible portion thereof, consumed to produce an increase of one pound in the live weight of each animal :—

TABLE VI.

Animal No.	Dry matter of food eaten.	Gain in live weight of animal.	Total dry matter of food to produce one lb increase in live weight	Digestible dry matter of food to produce one lb. increase in live weight.
	LB.	LB.	LB.	LB.
81	1,680	164	10·24	5·47
82	1,686	131	12·87	5·76
83 ...	1,677	130	12·90	6·21
85	1,736	192	9·04	4·22
86 ..	1,702	127	13·40	6·90
87 ...	1,425	107	13·31	6·58
Average	1,651	142	11·72	5·86

Here again it will be noted that No. 85 is the most thrifty animal eating only 9·04 lb., No. 81 coming next with a food requirement of 10·24 lb., while Nos. 86 and 87 required no less than 13·30 lb., to produce an increase of one pound in live weight. The average quantity of total dry food consumed was 11·72 lb. per pound increase in live weight. A reference to the last column will show that the same order prevails with reference to the digestible dry matter eaten by the animals. Here again, the effect of the breed may be noted, in that the Nellore crosses were associated with low food requirements, while the Sindhi ones ate much larger quantities, to produce an increase of one pound in live weight.

It is interesting to note that Lawes and Gilbert at Rothamsted* found that, to fatten a steer, 11·09 lb. of dry matter of a mixed ration were required to produce one pound increase in live weight.

10. *The Concentrate-Roughage Ratio and Daily gain.*—Table VII gives the quantities of roughage and concentrate eaten and the ratio of concentrate to fodder calculated on a dry basis. The digestibility of the ration and the average daily gain are also shown :—

TABLE VII.

Animal No.	Total ration eaten.		Total dry matter.	Concentrate / Roughage ratio.	Digestibility of ration	Average daily gain.
	Roughage.	Concentrate.				
	LB.	LB.	LB.		PER CENT.	LB.
81 ..	982·70	697 13	1,679 83	1 : 1·40	53 47	1·344
82 .	989·05	697 13	1,686·18	1 : 1·41	44 79	1·074
83 .	979·44	696 59	1,677·03	1 : 1·41	48·75	1·065
85 ..	1,038·38	697 59	1,735·97	1. 1·49	46 67	1·574
86 ..	1,004 78	697 59	1,702·37	1. 1·44	47 97	1·041
87	735·01	690·10	1,425·11	1 · 1 06	49·39	0·877

The ratio was practically the same, varying from 1 : 1·40 to 1·49 in the case of all animals, except No. 87 which had a ratio of 1 : 1·06. This animal was, from the beginning of the experiment, a poor roughage eater, having consumed only 735 lb. of dry matter as roughage, as against the other animals which consumed about 1,000 lb. each, although she ate as much concentrate as the others.

The relation between the ratio $\frac{\text{concentrate}}{\text{roughage}}$ and the daily gain in weight is also interesting. The

* Henry and Morrison, Feeds and Feeding, 17th Edition, 1919, page 90.

animals eating a large quantity of fodder and with a ratio of 1: 1·4 made a good gain in daily weight, while No. 87, with a ratio of 1: 1·06, made comparatively poor increase. The digestibility of the ration has also not been depressed to any appreciable extent, by the quantities of roughage eaten.

It may be stated that the above inferences are almost similar to what have been deduced recently by Mr. Warth at Bangalore (vide Pusa Scientific Reports, 1924–25).

Mr. Warth's $\frac{\text{concentrate}}{\text{roughage}}$ ratio varies, however, from 1: 1·84 to 1: 2·84 being wider than the figures obtained at Coimbatore, showing that the ration in the latter case was much richer.

NUTRITIVE RATIOS.

11. That the ration adopted at Coimbatore was very rich indeed is shown by the nutritive ratios of foods eaten by each animal, shown in Table VIII.

TABLE VIII.

Animal No.	Nutritive Ratio.
81	1 : 1·62
82	1 : 2·11
83	1 : 2·30
85	1 : 2·37
86	1 : 2·62
87	1 : 2 29
Average	1 : 2·22

The nutritive ratios are remarkably narrow. The animals could probably have done quite as well on a wider ration, *i.e.*, one containing much less concentrate. The narrow ratios may also be due to the abundance of rich green fodder supplied.

SUMMARY.

12. The present experiment must be considered first, as having afforded experience in the technique of carrying on experiments under conditions prevailing at Coimbatore. These conditions were not ideal as stated above. The results obtained must, therefore, be considered encouraging as far as they go. They may be summarized as follows :—

(i) In determining the production value of a mixed ration, the amount of dry matter eaten by a heifer of about 2 years of age, to produce an increase of one pound in her live weight is 11·72 lb.

(ii) Heifers with Nellore blood in them seem to put on weight faster than those of Sindhi cross.

(iii) Larger sized animals also seem to put on weight better than smaller ones.

(iv) Judged by the $\frac{\text{concentrate}}{\text{roughage}}$ ratio, the greater the capacity of the animal to consume roughage, the greater is the weight put on.

(v) The digestibility of the ration does not seem affected by the different proportions of roughage eaten by the animals.

(vi) Judged by nutritive ratios, the rations adopted at Coimbatore are narrow.

Conclusion.—The Assistant Lecturing Chemist wishes to express his grateful thanks to Mr. F. J. Warth, Physiological Chemist, for valuable suggestions given ungrudgingly from time to time, both by correspondence and personal inspection, to Mr. R. W. Littlewood, Deputy Director of Live Stock, for lending stalls, animals, food and labour, and to the Government Lecturing Chemist for helpful guidance throughout.

APPENDIX.

No. 81.—Digestive Coefficients.

Daily average.	Dry matter.	Protein.	Fat.	Fibre.	Carbo-hydrate.
	GMS.	GMS.	GMS.	GMS.	GMS.
In food eaten—					
Fodder	2,890·0	266·0	108·3	590·6	1,464·0
Concentrate ...	2,616·4	790·5	203·5	831·8	832·0
Total eaten ...	5,506·4	1,056·5	311·8	1,422·4	2,296·0
Voided in foeces ..	2,661·0	137·2	95·93	801·9	1,297·0
Digested	2,845 0	919·6	215·97	620·5	999·0
Digestive Coefficients.	53·47%	84·93%	69·24%	43·50%	43 57%

No. 82.—Digestive Coefficients.

Daily average.	Dry matter.	Protein.	Fat.	Fibre.	Carbo-hydrate.
	GMS.	GMS.	GMS.	GMS.	GMS.
In food eaten—					
Fodder	2,900·0	267 3	108·7	592·7	1,467·0
Concentrate	2,616·4	790·5	203·5	831·8	832·0
Total eaten ...	5,516·4	1,057 8	312 2	1,424·5	2,299·0
Voided in foeces ...	3,044 0	214·2	118·4	1,099 0	954·5
Digested	2,472·4	843 6	193 8	323·5	1,344·5
Digestive Coefficients.	44·79%	79·8%	62·07%	22·02%	58·46%

No. 83.—Digestive Coefficients.

Daily average.	Dry matter.	Protein.	Fat	Fibre.	Carbo-hydrate.
	GMS.	GMS	GMS	GMS.	GMS.
In food eaten—					
Fodder	2,850·0	262·6	106·9	582·4	1,444·0
Concentrate ...	2,616·4	790 5	203·5	831·8	832·0
Total eaten ...	5,466 4	1,053·1	310 9	1,414·2	2,276 0
Voided in foeces ..	2,862·0	196·3	110 2	1,030·0	756 0
Digested .. .	2,604·4	856·8	200·2	384·2	1,519·3
Digestive Coefficients.	48·75%	81·37%	65·16%	27·16%	66·48%

No. 85.—Digestive Coefficients.

Daily average.	Dry matter.	Protein.	Fat.	Fibre.	Carbo-hydrate.
	GMS.	GMS.	GMS.	GMS.	GMS.
In food eaten—					
Fodder	3,030 0	279·2	113·6	619·1	1,532·0
Concentrate	2,616·4	790 5	203·5	831·8	832·0
Total eaten .	5,646·4	1,069·7	317·1	1,450 9	2,364·0
Voided in foeces ..	3,011·0	246·8	131 2	1,104·0	835 2
Digested	2,635·4	822·9	185·9	346·9	1,528·8
Digestive Coefficients.	46·67%	78·24%	58·65%	23·91%	64·27%

No. 86.—Digestive Coefficients.

Daily average	Dry matter.	Protein.	Fat.	Fibre.	Carbo-hydrate
	GMS.	GMS.	GMS.	GMS.	GMS.
In food eaten—					
Fodder	3,000 0	276·4	112 5	613 2	1,519·8
Concentrate ...	2,616 4	790 5	203·5	831·8	832·0
Total eaten ...	5,616·4	1,066·9	316·0	1,445·0	2,351·8
Voided in foeces	2,922·0	288·4	95·12	1,042·0	812·3
Digested . ..	2,694·0	778·5	220·88	403·0	1,539·5
Digestive Coefficients.	47·97%	73 91%	69·61%	27 89%	65·45%

No. 87.—Digestive Coefficients.

Daily average.	Dry matter	Protein.	Fat.	Fibre.	Carbo-hydrate.
	GMS.	GMS.	GMS.	GMS.	GMS.
In food eaten--					
Fodder	2,720 0	250·7	102·0	555·9	1.410·0
Concentrate ..	2,616 4	790·5	203·5	831 8	832·0
Total eaten ...	5,336·4	1,041·2	305·5	1,387 7	224·20
Voided in foeces..	2,701·0	208·0	110 9	993·8	774·3
Digested	2,635·4	833·2	194 6	393·9	1,467·7
Digestive Coefficients.	49·39%	79·86%	63·69%	28 32%	65·47%