DEVELOPMENTAL STUDIES IN RICE—I *

BY K. RAMIAH M. Sc., Dip. Agri. (Cantab)., L. Ag.,
and
M. NARASIMHAM, B. Sc. (Agri).

Introduction:— The aim of the plant breeder is to develop a most promising form with the yield as the ultimate aim. The carrying out of comparative yield trials with different rice varieties or with different strains of a variety of rice is always an important work of the rice breeder. The methods of conducting such trials have received considerable attention and have been brought to a high state of refinement due chiefly to the work of the Statisticians in this branch of agricultural science. Though such trials bring out yield differences between varieties or strains, the causes of such differences are still little understood and have not received adequate attention. Agriculturally, yield may be a single conception as so much of produce per unit area cultivated. Biologically, however, yield is a complex, an end result or integration of the vital activities of the plant which depend on the genetic constitution of the plant and the environment on which it is nurtured. The internal basic physico-chemical characters constituting the vital activities of the plant lead up to the manifestation of external yield characters as growth, tillering, ear size, etc.

The results of the outstanding work regarding the study of the fundamentals underlying yield in cereals by Prof. Engledow of Cambridge and his associates have been published in the several volumes of Journal of Agricultural Science. The aim of this study has been to understand the reasons for the difference in yield of the cereals as expressed in the morphological development of the plant. This knowledge is essential to judge definitely under what conditions a particular form can be grown successfully. The knowledge about the adaptations of varieties to different conditions is mostly traditional based on long experience of practical cultivators. Although one may know that certain forms of rice are more adapted to certain conditions, very little is known about the reactions which the plants exhibit when grown under such conditions. The need for the study of the development of the plant in all its phases and its relation to yield is therefore emphasised. Tillering, both a morphological and a physiological character, common to all cereals is a very important developmental phase of the rice plant, Any favourable treatment to which the plant may be subjected brings about quick response in the increase in the number of culms. Besides soil, some of the agricultural practices that influence tillering are the time of planting, spacing, manuring etc. That tillering apart from its behaviour due to

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environment is a varietal character is well brought out from the study of this character in the large number of varieties—all pure lines—grown at the Paddy Breeding Station, Coimbatore, year after year. Some are inherently poor in the number of tillers they produce while others are more prolific. Since effective tillering i.e., the number of ears per plant is definitely related to yield its study becomes important. Besides tillering, the other factors that contribute to yield in rice are the size of the ear, its density and the size of the individual grain in the ear. The present article treats about the results of studies on the development of tillers, and the size of ear and their relation to final yields in a few pure lines. The effect brought out by factors like changes in the environment, manuring etc, on these developmental phases, and consequently the yield, was investigated with one or two pure lines over two or three seasons and these are dealt with in section II.

Tillering. *Discussion of literature.* Considerable work has been done in cereals in general and on rice in particular on this important attribute of the plant. In a majority of cases the attempt has been to bring out the relationship between tillering and the environmental conditions under which the plant grows. Thompstone (1915) in Burma has found that the high yielding strains have been found among those whose tillering mean is but a little higher than that of the original type while some of the strains with high tillering mean have yielded but comparatively poor outturns of grain. He concludes that long durationed varieties, generally, tiller more than the short durationed ones. Summers (1921) in Ceylon had evidence to show that among the important Ceylon rices short duration paddies possessed a greater tillering capacity in general than those of longer periods of maturation. Ramiah (1927) writing on the growth phases of rice varieties observed that long duration varieties as a rule produced a larger number of tillers than short duration varieties. Saravayya (1932) at Maruteru has found that varieties that finish their tillering in the early stages yield better than those which prolong their tillering phase. Joshi (1923) gathered data regarding the influence of time of planting, age of seedlings, planting of singles or bunches, application of manures, spacing etc, on the tillering and finally concluded that tillering was hereditary in character and that while phosphatic and potassic manures had no influence on tillering, nitrogenous manures did have, and that with the increase in the number of tillers artificially induced, there was a large percentage of loss of late tillers with reduction in the size of the ear. Hector (1921) finds that spacing has a great influence on the number of tillers per plant and the number of grains per tiller but no effect on the weight of the individual grain. Jacobson (1916) differed on this point in his work on the "Correlative characters of the paddy plant", and he was supported by Thompstone. He found that tillering of the individual plant was negatively correlated with the number of grains per panicle and the size of grain. Dionisio Calvo (1927) and Rodrigo (1924) gathered data on the effect of spacing on tillering and yield, and came to the conclusion that the physiological expression of the tillering power of the rice plant was made greater by wider spacing between the hills Inagaki of Japan (1897) as far back as 1897-98 made some experiments on the effect of planting in singles, doubles, trebles, etc., on the total number of shoots per hill, and with the data, developed a mathematical way of estimating the possible number of shoots that would be developed with different number of seedlings per hole, if the shoots in one of them were known. It must be understood however, that in most of the available literature the tillering has been denoted by the number of final ears found at harvest. Engldow's work on cereals has more than emphasised the importance of studying the progress of tillering right from germination up to the time of harvest as it is only then that differences due to variety or environment can be evaluated.

Material and methods. Ten Coimbatore strains varying in duration from 150 to 180 days were all planted side by side with even spacing one foot by six inches under as uniform conditions as possible. Uniform blocks of 300 plants in each variety were chosen and care was taken to avoid plants near the b rders and uneven patches, plants damaged by insects, plants adjoining gaps, etc. The tillering of each of these 300 plants in every block was counted every week. Although for this study 300 plants were actually under observation it was later observed adopting different methods of sampling, that under very uniform conditions obtaining in the plots at the Breeding Station and with crop planted with seedlings of uniform growth, a population of even 50 plants was enough to study tillering. At each weekly count every tiller large enough to be seen i. e., after it has come out of the subtending leaf sheath was counted and no attempt was made to differentiate the size of the individual tillers. As towards the end of the tillering phase death of tillers also commences, count of dead and living tillers at each stage was made note of and to avoid confusion the dead tillers were actually removed from the plants at the time of tiller counts.

General Observations. Unlike in other cereals, irrigated ragi (*Elusine coracana*) being an exception, rice is invariably transplanted i. e., the seed is first sown in the seed-beds, and after the lapse of a period, which would vary according to the life duration of the variety of rice, the seedlings are pulled out and transplanted in open fields puddled and levelled. Though the direct sowing of the seed in the fields is also prevalent in certain tracts such practice is never adopted in tracts where conditions and facilities for transplanting are available. The seedlings after transplantation take some time, 6 to 10 days, to revive as indicated by the casting off of old leaves and production of the new. Although certain conditions like good tilth in the soil, good vigorous seedlings, cloudy weather and light showers at planting, all favour quick establishment of the plants, observations at Coimbatore have shown that the rapidity of establishment is a varietal character. It must also be understood that the roots that remain with the seedlings at the time of transplanting do not function. It is only the fresh roots that start from the nodes after planting that are of help to the plant. In an experiment carried out at the Paddy Breeding Station, Coimbatore, varying degrees of pruning the roots at the time of planting including ones where the roots were all completely removed were put under comparison and it showed, that the pruning had no effect on the subsequent growth and development of the plant.

The production of tillers or side shoots often starts even in the seed-beds particularly on the borders of the beds where the plants have more space and access to light. Ordinarily, side shoots do not arise from the axils of the two scale like structures at the base of the young seedling. By following the course of development of a side tiller, it will be seen that in very early stages the tiller is completely encased by a pinkish while scaly leaf. As the tiller grows, the scaly leaf also grows with it to a fair size. By careful observation, it is possible, even in grown up plants, to differentiate between a primary and secondary tiller, by the position of this scale. Normally a bud is borne in the axil of each leaf and thus a shoot may grow out from each bud. But actually tiller production is restricted to the nodes near the surface of the soil. The tillering zone is restricted to half to one inch in length along the main axis and situated about one to two inches below ground level. The internodes at this zone are all very much suppressed. If planting is done rather deep the bottom most internode elongates up to about one inch below ground level and then the tillering starts. When the crop is planted late, or when it lodges flat during later stages, shoots from the higher nodes may also develop but they are rarely ear bearers. Ratooning is nothing but the development into tillers of dormant buds at nodes below and above ground level of the stubble left over. There are certain types in the Coimbatore varietal collections which have a predisposition to tiller at higher nodes even under normal field conditions. But here the process may probably be rightly called branching rather than tillering and such branches do mature ears. This habit in certain rices has been recorded by Jones (1925)

Formation of tillers. The tillering starts from below and as they are being formed progressively along the main axis, some of the early tillers might start producing secondary tillers in their turn. When there is a large amount of tillering there appears to be a definite relation between these secondary and tertiary tillers (tillers produced by secondary tillers) and the total number as the data in

Table I would indicate. The secondary tillers T_1, T_2, T_3,......do not produce tertiary tillers unless the total number of tillers for the plant exceeds ten or twelve.

Table No. I.

Tiller Distribution. *Variety–GEB. 24.*

Total No. of tillers per plant including the main-shoot.	Number of side tillers produced by											
	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_{1-1}	T_{2-1}	T_{3-1}
3	2	...	...	...	...	...	...	...	...	...	...	...
4	3	...	...	...	...	...	...	...	...	...	...	...
5	4	...	...	...	...	...	...	...	...	...	...	...
6	4	1	...	...	...	...	...	...	...	...	...	...
7	4	1	1	...	...	...	...	...	...	...	...	...
8	4	2	1	...	...	...	...	...	...	...	...	...
9	5	2	1	...	...	...	...	...	...	...	...	...
10	5	2	2	...	...	...	...	...	...	...	...	...
11	5	3	2	...	...	...	...	...	...	...	...	...
12	5	3	2	1	...	...	...	...	...	...	...	...
13	5	4	2	1	...	...	...	...	...	...	...	...
14	5	4	2	1	...	...	...	...	...	...	...	...
15	5	4	3	1	...	...	...	...	...	1	...	...
16	6	4	3	1	...	...	...	...	...	1	...	...
17	6	4	3	1	1	...	...	...	...	1	...	...
18	6	4	3	1	1	...	...	...	...	1	...	...
19	6	4	3	2	1	...	...	...	...	1	1	...
20	6	4	4	2	1	...	...	...	...	1	1	...
25	7	5	4	3	2	...	...	...	...	1	1	...
32	8	5	5	3	3	2	2	...	...	2	1	...

The arrangement of the tillers in every case is alternate. While it may appear difficult to trace the chronological relationship of the several tillers in a plant directly in the field it can be made out by removing the plants and dissecting the parts. The course of tiller formation appears to be identical in all the strains studied (Table II), there being no varietal difference in the mode of tillering or in the distribution of the tillers in the plant. Summers (1921) believes that secondary or tertiary tillers appear in two separate phases. As a matter of fact, after a certain stage, primary, secondary, and even the tertiary tillers begin to produce tillers all at the same time. Under field conditions, however, the tiller distribution is not so absolutely systematical. Some buds fail to develop and others die after some development. During advanced stages of growth, crowding occurs with the result that the process of tillering with respect to one or more side tillers comes to a stand still while others more favourably situated continue to do so.

Tillering commences two weeks after transplanting and goes on rapidly for about four to five weeks thereafter. The active period of tillering is a varietal character mainly dependent on the duration of the variety. This period may be definitely less, 3 to 4 weeks only in a variety of four months and below—Ramiah (1927). Apart from the varietal characteristic, abnormal conditions like too much spacing, late planting, excess of nitrogenous manures in the soil, insect attack like the borer, sometimes cause the normally dormant buds to get active and produce tillers and thus prolong the vegetative phase. Excess of water supply to the fields either artificially or due to excessive precipitation, may accentuate a fresh tillering phase resulting in a few small tillers late in the season. Such prolonged tillering naturally leads to a high percentage of abortive tillers, uneven heading and unsatisfactory harvest. The contribution of such later tillers to harvest is only straw.

Reduction in Tillering. When once the tillering phase has reached the maximum under normal conditions in spite of the ideal conditions for active growth being present, some of the late formed tillers start dying off. Probably the mother tillers cut off all supplies of nutrition to such late tillers and as these late tillers do not develop any root system to lead an independent existence they naturally die. In all probability the primary stem of rice under transplanted conditions acts as a host for the subsidiary daughter tillers for some time only. All the late and undesirable tillers are thus eliminated by the time the plant passes into the reproductive phase. This reduction in tillering is almost the same in all the varieties studied as will be apparent from the data in Table II. The final percentage of ears to the maximum

Table No. II

Tiller Production and Reduction.

(as percentages of the maximum number of tillers produced per plant).

Date of observation (Number of days after planting)	19	26	34	40	47	55	61	68	76	90	98	104	112
Variety						Percentage.							
GEB. 24	...	44	76	98	100	98	87	82	74	73	71	...	...
Co. 2	37	66	93	97	100	92	91	91	73	69	...	68	...
Co. 3	36	70	95	98	100	92	90	87	77	...	68	...	67
Co. 5	44	75	95	98	100	95	90	85	73	...	65	...	64
Co. 6	36	60	95	97	100	95	94	92	83	...	71	68	67
Co. 4	39	61	88	94	100	93	91	85	73	...	59	56	55

tillering produced varies in the different varieties but the percentage of functional tillers to the total in the different tiller classes is practically the same in all the varieties (Table III). The proportion of functional tillers is found to be definitely less in a late variety like Co. 4.

Tiller production and yield. The relationship between yield and tillering is interesting. In wheat the increase in tillering is associated with greater yield and greater tiller production is a sign of greater vigour is evident from the yield per ear gradually increasing as the number of tillers increase in the plants. In rice, in several of the varieties examined, increase in the number of functional tillers is directly proportional to the yield per plant (Table IV).

Table No. III.

Percentage of Functional Tillers in the Different Tiller Classes.

Variety.	Number of tillers per plant.															Co-efficient of correlation (r) of tiller production to ear formation.
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Co. 1	...	84	87	89	87	87	86	85	78	...	...	...	...	...	...	0·81±0·014
Co. 2	...	...	70	66	69	71	65	70	68	67	70	...	...	...	...	0·88±0·008
Co. 3	...	...	...	...	73	69	69	72	66	69	67	69	69	...	...	0·83±0·013
Co. 4	...	...	...	...	...	...	54	62	56	60	59	51	51	52	54	0·71±0·022
Co. 5	...	...	...	...	66	67	67	68	65	61	68	63	66	64	...	0·86±0·012
Co. 6	...	...	76	76	70	67	66	67	63	...	...	...	...	...	...	0·72±0·021
Co. 7	92	88	86	84	82	80	76	82	...	...	...	...	...	...	...	0·72±0·019

Table No. IV.

Yield of grain per plant in grams.

Variety.	No. of ears per plant.											
	3	4	5	6	7	8	9	10	11	12	13	14
GEB. 24	...	...	6·2	9 4	9·9	10·8	13·1	13·3	15·6	15·4	...	...
Co. 1	3·8	5·2	6·9	7·9	9·5	11·0	12·6	15·8	...	...	...	...
Co. 2	...	7·1	8·0	9·5	11·3	11·8	14·0	16·4	...	...	...	...
Co. 3	...	...	9·1	10·5	12·6	14·2	16·7	18·1	20·4	...	...	...
Co. 4	...	8·2	10·2	13·0	13·4	14·6	15·8	17·1	...	...	...	...
Co. 5	...	9·0	12·0	13·7	15·1	17·0	20·8	21·5	23·4	26·4	...	...
Co. 6	6·4	8·1	9·4	11·4	13·2	16·3	16·6	...	...	...	...	...
Co. 7	5·6	7·4	10·3	12·6	14·8	16·6	21 1	...	...	...	...	...

The relationship is more or less linear. In the case of the very late variety like Co. 4, the yield per plant does not increase in the same proportion as the increase in number of tillers. As regards weight of grain and the yield per ear there is not much difference in the plants with different number of ears for several of the varieties studied.

Table No. V. A

Yield of grain per ear in grams.

Variety.	Number of ears per plant.											
	3	4	5	6	7	8	9	10	11	12	13	14
GEB. 24	...	...	1·23	1·57	1·41	1·35	1·46	1·33	1·42	1·28	...	...
Co. 1	1·25	1·31	1·37	1·31	1·35	1·38	1·40	1·58	...	...	...	...
Co. 2	...	1·77	1·60	1·59	1·62	1·48	1·55	1·64	...	...	...	...
Co. 3	...	...	1·81	1·75	1·80	1·77	1·85	1·81	1·85	...	...	...
Co. 4	...	2·04	2·03	2·16	1·92	1·82	1·76	1·71	...	...	...	...
Co. 5	...	2·24	2·39	2·29	2·16	2·12	2·31	2·15	2·13	2·22	...	...
Co. 6	2·12	2·03	1·88	1 90	1·88	2·04	1·84	...	...	...	...	...
Co. 7	1·87	1·86	2·06	2·10	2·12	2·07	2·34	...	...	...	...	...

Table No. V. B

Weight of 100 Grains in Grams.

Variety.	Number of ears per plant.											
	3	4	5	6	7	8	9	10	11	12	13	14
GEB. 24	...	...	1·80	1·82	1·75	1·79	1·75	1·74	1·76	1·72	...	...
Co. 1	2·34	2·29	2·31	2·30	2·26	2·30	2·29	2·25	...	...	...	...
Co. 2	...	1·96	1·02	1·98	1·99	1·95	1·99	1·90	...	...	...	...
Co. 3	...	...	2·13	2·15	2·14	2·16	2·17	2·18	2·12	...	...	...
Co. 4	...	2·45	2·48	2·47	2·49	2·49	2·47	2·48	...	...	...	...
Co. 5	...	2·00	2·02	2·04	2·00	2·02	1·99	2·00	1·95	2·01	...	...
Co. 6	2·07	2·04	2·07	2·01	2·07	2·06	2·03	...	...	...	...	...
Co. 7	2·12	2 08	2·04	2·08	2 03	2·02	1·95	...	...	...	...	...

But in certain varieties like GEB. 24, Co. 1, Co. 7, etc., there is a perceptible, though slight, increase in the yield per ear as the number of ears per plant increases. It is possible that in these varieties increase in the number of ears, apart from its being a normal physiological activity of the plant is an indication of the plant's greater adaptability to respond to environmental changes which affect the production of ears. This is also evident from the fact that the percentage of functional tillers in plants with different number of tillers is almost the same in these particular varieties, whereas there is a slight and gradual drop in the percentage of functional tillers as the total number of tillers increase in the case of other varieties.

Critical period of tillering. The increase in tillering beyond a certain stage does not result in ears. If the ears formed follow the same order as the development of tillers, the plant produces enough tillers to result in ears even two to three weeks before the maximum tillering phase is reached. If we denote the particular stage in tillering where the number of tillers produced is equal to the number of ears formed as the 'critical period' all tillering beyond this period is a waste. As the data given in Table iii would show any increase in the number of tillers per plant leads to a corresponding increase in the number of ears. Since, however, the average yield per ear is almost the same in all the ear classes, an increase in the number of tillers per plant is bound to result in an increased yield per plant. Thus to enhance yield the attempt must be to so adjust the agronomic practices to enhance the rate of initial tiller production as much as possible. It is possible, however, that two varieties or two strains of a variety possessing the same average number of functional tillers per plant might differ in their yields and such a difference has to be accounted for by some yield attribute other than number of tillers. In such a case it is usually the ear size that is responsible for the difference as will be apparent from the below mentioned case. Two strains of *anaikomban*, a Tinnevelly variety have been compared for yield for a number of years and one of them

7567 always recorded a higher yield than the other strain. A comparative study of the developmental phases in the two strains showed that while the average number of ear bearing tillers per plant was not very different in the two, the average length of the ear and hence the number of grains per ear was always more in 7567 than in the other.

Table No. VI

Comparative yield attributes of Anaikomban strains.

	Anaikomban strains.	
	7567.	7566.
Maximum average tiller production per plant.	7·9	7·3
Average number of ears per plant.	4·8	4·4
Percentage of functional tillers.	61	60
Average yield per plant.	9·4 grams.	7·6 grams.
Average yield per ear.	1·96 „	1·73 „
Weight of 100 grain sample.	1·92 „	1·95 „
Average number of grains per ear.	102	89
Average length of panicle.	228·5 mm.	196·2 mm.
Number of grain per unit length 10 cm.	4·5	4·5

Individuality of tiller. To determine the individuality of the tillers and the relationship between the chronology of tillers and their contribution to yield a small subsidiary experiment was conducted. The aim was to find out the effect on yield by planting seedlings with three initial tillers, and also by removing the main, second or both the side tillers to elucidate the function of the respective tillers. Periodical counts of tillers were taken and the final yields were determined. The experiment was conducted with two varieties for two seasons. Though the yield of the plant was the highest where all the tillers were left in tact, the reduction in yield due to the removal of the second or third tiller was not very marked, but when the main tiller was removed the yield went down considerably. As regards the total number of tillers produced per plant it was highest where all the tillers were left in tact closely followed by the one where the third tiller alone was removed. Where the main tiller alone was left the tillering was the same as when the second and third tiller were both left. Where the second or third tiller alone was left to develop, the tillering was very poor and the yield was very much reduced. Incidentally it was also observed that wherever the main tiller by itself or in combination with others was left to develop, the plant flowered definitely a week earlier than plants where the main tiller had been removed. The results of this experiment definitely indicated the advantage of the lead of the main tiller in point of age and development towards the contribution to (a) total tiller production, (b) total yield and (c) earliness in flowering.

Development of the ear. Tillering in rice represents an aspect of vegetative phase while the rapid growth in height in later stages foretells the approach of the reproductive phase. Data gathered during growth studies have yielded some useful information on the subject of ear formation. The factors at work that make a plant to stop vegetative growth and go on to the reproductive phase are not yet sufficiently understood. After a time, all the tillers in the rice plant produce their ear primordia in quick succession. Practically they all appear in the course of a week. Taking a medium duration variety like Co.2 or Co.3, which has an active tillering phase spread over four weeks, T_1, T_2, T_3 appear during the first week while the late ones, T_6, T_7, T_{1-3}, T_{2-2}, T_{3-1} etc. arise during the fourth week. The first batch will therefore have a lead of about 3 weeks to start with, but by the time they come to the primordial ear formation the interval gets reduced by about a week. The dates of ear emergence converge still further and the interval may get reduced to even four days. Thus the rate of development of the later formed tillers is much more rapid than in the earlier formed ones; the later the tiller formed the more rapid is its development.

The frequencies of tillering at each count when plotted give more or less a normal curve. In the later counts a few plants with the modal value for tillering at each count were pulled out and dissected to examine at what stage the ear primordia started forming, and what the connection was between tillering and ear formation. While the figures given in Table II show that the maximum tillering phase is reached almost at the same time for all the varieties under study, i.e., about six weeks after planting, the examination of primordial development showed that ear formation was independent of tillering and was mainly a varietal characteristic. Since no variety of rice under four and a half months in duration had been included in this study the observation was continued on a definitely early variety under four months, in the following season. The approximate time at which the ear primordia was formed was found to depend on the duration of the variety even in this case.

In *kar* Strain Co.10 which is definitely under four months in duration, the formation of the ear commences 15 days before the maximum tillering phase is reached. In varieties—GEB.24 and Co.1 which are 4½ months to 5 months in duration the ear formation begins a few days before the maximum tillering phase, and in varieties Co.2, Co.3 which are about 5½ months in duration the ear formation synchronises with the stage at which the tiller production is at its maximum. In late varieties of over six months' duration, like Co.4 and Co. 8, there is an interval of over three weeks between maximum tillering and the commencement of the ear formation. (Fig. I)

The time at which the ear formation commences has an important significance in yield investigations as the knowledge can be made use of to adjust one of the agronomic practices namely the application of a fertiliser as a top-dressing to the crop, to enhance the yield. The time of application of the fertiliser in its relation to the size of the ear formed is dealt with in section II.

Among the varieties studied primordial ear formation commences 24 to 31 days before the date of emergence of the ear tip from the leaf sheath. The variation in this interval might probably have been wider if varieties earlier to and later than these under study had been included in the experiment. At the first instance the primordium looks like a fleshy globose protuberance measuring about $\frac{1}{8}$ to $\frac{1}{4}$ m.m. By the time it is $\frac{1}{2}$ m.m long, a few hemispherical excrescences are observed at the base, the number of which gradually increase in a short period. These bodies which represent the branches of the panicle, produce afterwards some spherical growths which are the rudiments of spikelets and these are laid down alternately on either side of the basal axis, (Fig. II). When it is 5 m. m. long tiny spikelets get differentiated at the top with stalks at their bases. The rings of hairs that are found along the rachis (in a well developed ear) become apparent even now. The process thereafter is elongation of the different parts of the panicle already formed, and formation of new spikelets at the base. The spikelets taken out of the middle of the ear of a tiller of the modal class for a particular week were measured for length and breadth. From the measurements made it can be stated that the elongation in length of spikelets in the middle and top of the ear is complete by the time the ear completes its elongation i. e., about 15—20 days after the formation of ear primordia. During the week preceeding emergence, the small spikelets at the base develop and assume normal size by the time the ear comes out of the sheath. Though the general trend of spikelet development is from top to bottom it is not quite so regular.

The ear ordinarily takes three days to completely emerge out of the leaf sheath after the appearance of its tip above the last leaf junction. Spikelets commence opening a day or two after they are exposed. Majority of spikelets in a panicle complete opening in six to eight days after they commence to do it, though it may take eight to ten days for all of them to open. The sequence of their opening is not very systematic though the general trend is from tip to base on the sub-spikes.

Rate of shoot-growth. Incidental to the study of tillering, observations on the growth rate were also recorded in the different varieties under study. The height of the rice plant in its earlier stages is mainly contributed by the length of its leaves. There is practically no elongation of the internode. As the tillers throw out new leaves the increase in height is due to the production of longer leaves in succession, with each leaf sheath projecting above the tip of the previous one. It has been recorded previously—Ramiah (1927) that in early varieties growth in height is continuous till they enter the reproductive phase while in

Fig. I.

Tillering and Commencement of Ear Formation

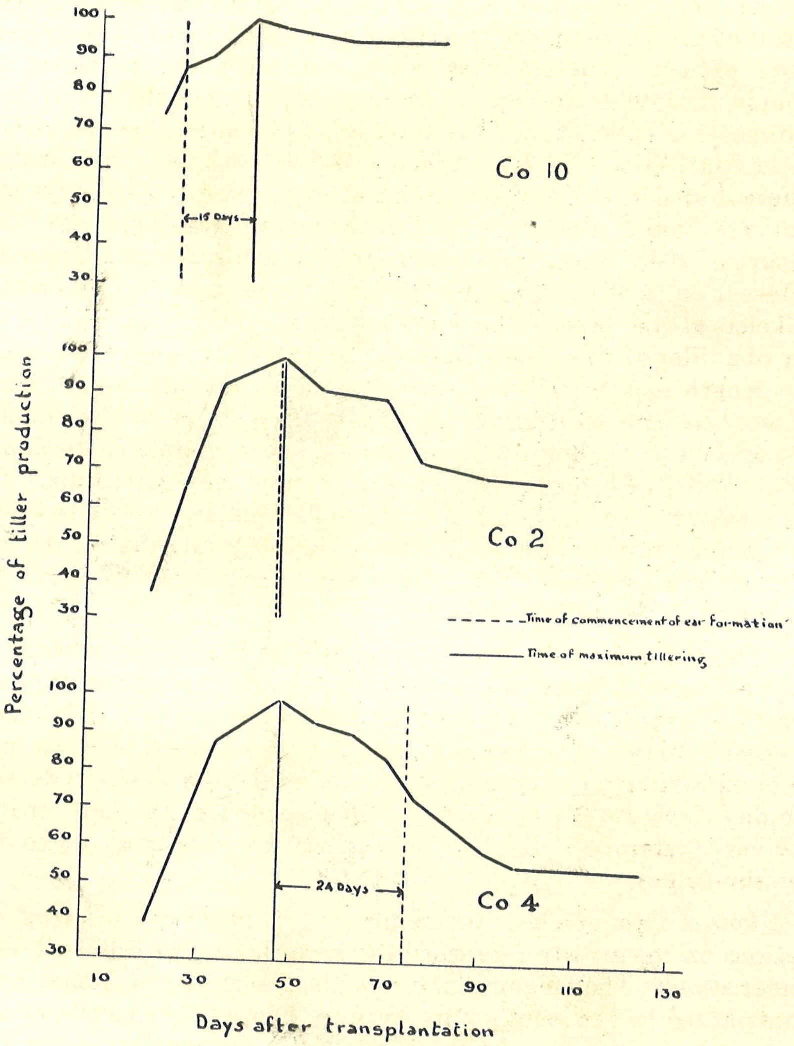
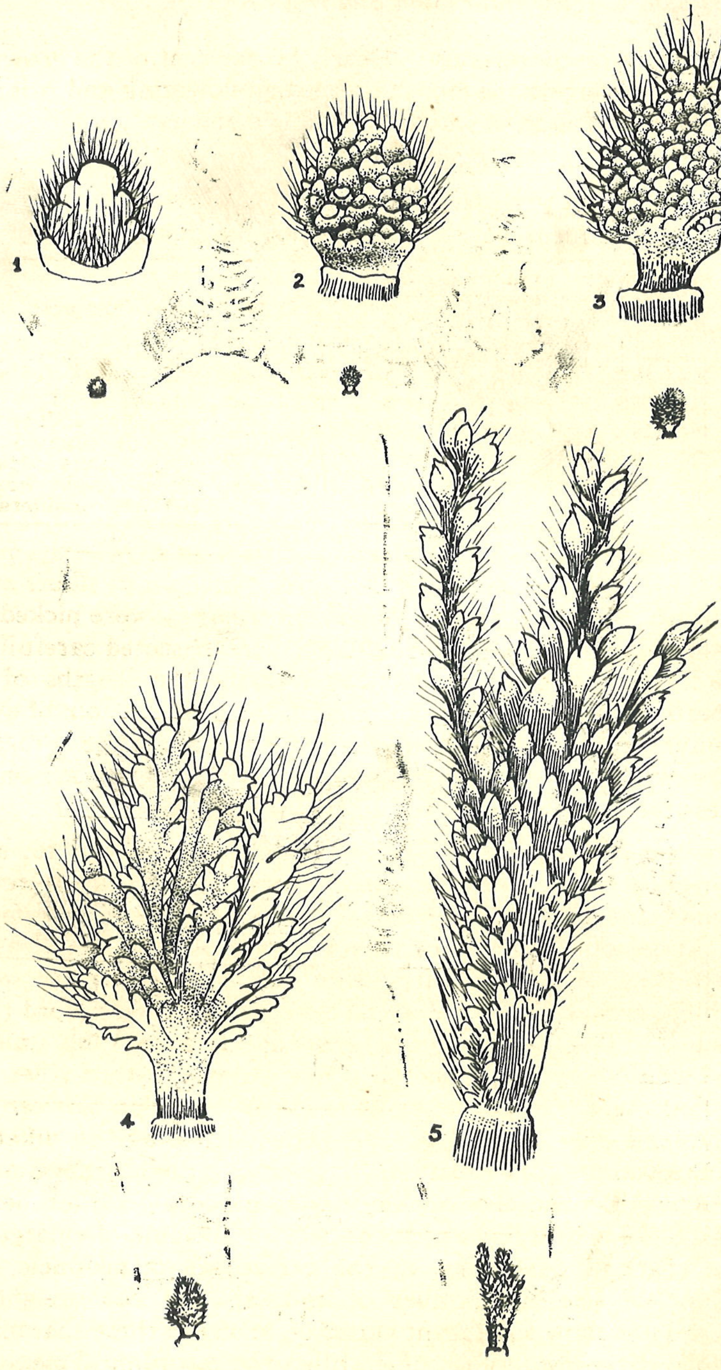


Fig. 2



Development of the Primordium (2 to 7 days.)

late varieties it is discontinuous. Nearly 90 per cent of the growth in height is attained during the month preceeding flowering and is largely contributed by the top-most internode, panicle and ear.

Table No. VII.

Lengths of Different Parts of a Paddy Shoot
(as percentages of the height of the shoot).

Variety.	Internodes (numbered from top down) i	ii	iii	iv	v	Peduncle.	Ear.	Height of shoot.	Remarks.
GEB. 24	21·4	16'2	11·0	3·5	1·2	28·0	18·6	100	Plants with the modal number of tillers were taken at random from an early planted area. Only tillers with the modal height were taken into consideration.
Co. 1	21·6	12·9	7·5	3·6	1·5	32·3	20·4	100	
Co. 2	21'6	15·2	9·5	4·2	2·1	29 2	18·2	100	
Co. 5	22·7	15·7	9·9	4·8	2·9	27 0	17·0	100	
Co. 7	21·2	15·3	9 6	4·7	1·8	29 0	17·9	100	

In six of the varieties, GEB. 24 and Co. 1 representing early, Co. 2, Co. 3, and Co. 7 medium, and Co. 4 late, after the count of tillers every week, six plants with the modal value for tillering were picked out from the adjoining portions in the field and were dissected carefully to denote the chronology of tillering and to measure the lengths of the different parts. By removing leaf after leaf from the bottom of every tiller the internodes between are exposed and finally a stage is reached when there will be seen the rudimentary or developing ear on the shoot, unless the plant is still in the active tillering phase.

The process of dissection and recording of measurements for even six plants every week formed a laborious process. Even in a pure line no two plants are absolutely alike and since growth measurements cannot be carried out on the same plants every week, the only feasible way of recording growth measurements was to select every week, plants with the modal value of tillering for that week and record their measurements. Then there is the question of fixing the unit of observation whether it should be the whole plant or only a tiller. It was found that there was considerable range of variation between the tillers of the same plant or tillers of the same chronology on different plants taken as samples for dissection. Since observations made on number of leaves per tiller, number of elongated internodes per tiller, height of shoot, sequence of tillering and its bearing on the date of emergence of the ear, length of emergence of the ear, length of peduncle and length of flag leaf, size and number of spikelets per ear, weight of grains etc., did not show significant variation in any of these characters with reference to the chronology of the tiller, the recording of measurements at successive intervals was confined to tillers that showed the modal shoot height.

Shoot growth. A rice plant during the process of tillering, and until the formation of the primordial ear does not show any elongated internodes. The only exceptions to this finding are the deep water paddies which throw out elongated internodes even in early stages simultaneously with tillering. Vigorous shoot growth starts only with the commencement of ear formation.

The elongation of the different parts of the shoot follows a regular sequence. If a plant has five internodes, the basal one starts its growth first, quickly followed by the one next above it. The next two commence their growth a week after and almost complete it by the time the top-most one and peduncle begin to grow.

Table No. VIII.

Growth of Shoot.

(N. B.—The numbering of internodes is from top to bottom).

Variety.	Date of observation.	Interval in days.	Growth in length in m. m.								
			Internodes.						Peduncle.	Ear.	Total height of shoot.
			I	II	III	IV	V	VI			
GEB. 24	21/10	...	...	...	23	21	...	...	...	2	46
	28/10	7	...	5	50	26	1	...	...	11	93
	31/10	3	5	50	58	17	1	...	1	94	226
	3/11	3	13	102	61	14	...	...	4	230	424
	7/11	4	14	121	67	31	...	...	5	243	481
	*11/11	4	136	137	66	20	...	...	120	237	715
	14/11	3	246	149	77	22	1	...	361	248	1104
Co. 1	13/11	...	...	1	27	2	...	...	...	4	34
	20/11	7	3	30	32	9	...	...	...	60	134
	*27/11	7	47	66	38	14	2	...	16	232	415
	4/12	7	214	66	36	8	...	...	369	240	933
Co. 7	13/11	...	...	...	2	24	...	...	...	knob	26
	20/11	7	...	1	14	26	3	...	...	2	46
	27/11	7	5	43	45	37	4	...	...	80	214
	4/12	7	51	104	59	29	...	...	15	242	500
	*11/12	7	247	129	42	23	...	...	300	241	982
	8/12	7	273	127	54	29	...	...	344	243	1070
Co. 2	26/10	...	...	...	2	6	1	...	...	knob	9
	2/11	7	...	1	15	32	...	...	...	1	49
	9/11	7	2	12	74	59	7	...	...	27	181
	16/11	7	12	87	97	54	16	...	5	228	409
	*23/11		131	155	95	44	3	...	75	248	751
	30/11	7	275	151	94	48	6	...	344	244	1162
Co. 3	3/11	...	...	2	9	59	36	...	...	1	107
	10/11	7	1	8	64	70	26	2	...	15	186
	17/11	7	8	52	99	69	24	...	1	139	392
	*24/11	7	28	107	102	68	32	...	10	2[illegible]4	601
	1/12	7	244	162	108	70	24	...	313	259	1180
Co. 4	25/11	...	...	1	7	47	44	5	...	0·5	105
	2/12	7	...	...	...	...	...	...	...	1·7	...
	9/12	7	2	22	82	61	21	2	...	26	216
	16/12	7	10	76	151	69	32	3	1	154	496
	*23/12	7	30	131	163	68	45	3	11	223	674
	30/12	7	281	199	142	64	26	...	360	230	1302

* Indicates the date of emergence of the ear.

Table VIII shows the comparative growth of the shoot in the different varieties. From the figures in the table it is clear that the ear completes its growth in length a week to 10 days before the date of emergence of the ear. During this period, the top-most internode and peduncle proceed with their elongation while the internodes below stop almost all growth. The process of elongation of the shoot in general continues four to five days after the emergence of the tip of the ear from the leaf sheath. Late ears take a day less to complete the process.

Incidentally notes were taken regarding the average number of leaves in a tiller, number of elongated internodes per tiller, height of the shoot, sequence of tillering and its bearing on the date of emergence of the ear, length of emergence etc., and they are recorded below:—

Number of leaves per tiller. The number of leaves above the prophyll or tillering zone of the main and side tillers that have formed daughter tillers is a fairly fixed character for a variety under normal conditions. The number is more in the late than in the early varieties. In the varieties studied the range is from five to eight leaves per tiller. (Table IX).

Table No. IX.

Number of leaves per Tiller.

(Above the prophyll or tillering zone).

Variety.	Duration in days.	Average number of leaves per tiller.
GEB. 24	149	5·1
Co. 2	157	5·9
Co 3	161	6·4
Co. 5	164	6·8
Co. 6	176	7·7
Co. 4	192	7·9

The flag leaf and the leaf previous to it commence their development almost along with the ear. Each tiller will have three to six functioning leaves at a time, and the number goes down to three by the time the crop completes the flowering. When it is ready for harvest all except the flag leaf dry away.

Number of elongated internodes in a tiller and height of tiller. As the number of leaves produced in a tiller is a variable character, the number of internodes also has a similar variability. Actually a tiller may have only four to six elongated internodes, the late varieties having a larger number. Early planting and rich soil tend to increase the usual number of elongated internodes and this is generally a predisposing cause for the crop to lodge even before it is quite ripe. The height of a tiller made up by the internodes, peduncle and ear highly reacts to variations in environments. To note the individual variations of the different tillers in a plant with regard to height, ear emergence, length of emergence etc., ten plants with the modal, five with the maximum and five with the minimum class of tillers were marked in the ten varieties under study and the observations recorded.

Poor tillers are invariably short. Plants with the modal and maximum number of tillers do not show much variation in average height. The height of an individual tiller in a plant seems to entirely depend upon its vigour and environment rather than on its chronology. It is not always the primary shoot that is the tallest. Later formed tillers are at times even taller than the first formed ones but those that are formed very late remain short. In spite of initial differences, late formed tillers speed up and attain the same height as the first ones by the time the plant starts flowering. Sometimes in a tiller which has a fewer number of internodes than the normal, the height is made up by the extra elongation of the peduncle. Generally the heights of different tillers on a plant of normal growth are almost the same, the differences being within ten percent of the mean. It has always been a useful criterion in selecting single plants for economic value which have a fair number of ear bearing tillers all of the same height.

Sequence of tillering and ear emergence. Omitting Co. 1 and Co. 7 which had been planted late, the observations recorded below hold good for all the varieties under study. A plant takes five to seven days to complete the emergence of all its ears whether it is a good, average or poor tillerer. If the plant happens to be particularly poor, it may take a slightly longer time. Though very often the first formed tillers throw out their ears first, it is not always the rule. The forwardness at emergence, as in the case of height, seems to depend upon the vigour and environmental conditions of individual tillers. The modal date of emergence of the ear is slightly earlier in a well tillered plant than in one with fewer tillers. Tillers that are formed late in the season are invariably late in earing and they are also definitely shorter in height.

Spikelets – number, setting and size. The length as well as the number of grains per ear, are almost the same in early formed tillers, but the number of spikelets per unit length generally decreases gradually with the lateness in tiller formation though the vigour of the individual tiller might have much to do with it. The percentage of setting in a variety seems to be a fairly definite character. Within the variety, however, the percentage of setting is low in 'late formed' tillers. As regards the weight of grain, those on the early tillers are usually heavier than those in the late tillers. Very late and poor tillers, as in the case of ratoons, definitely have smaller grains.

Summary. Tillering is an important developmental phase in cereals. It is best studied by counting the tillers produced by each plant in a sample of a population. For a transplanted crop with a pure line, and in well uniformly prepared fields, a sample of fifty plants may be found enough to carry on this study. Active tillering phase

commences about two weeks after planting and will be in full swing for three to five weeks depending upon the duration of the variety. When the tillering phase has reached its maximum, reduction in tiller number starts by the death of the late and ill developed tillers. The 'critical period' of tillering i. e., the stage at which enough tillers are formed to result in ears, is reached two to three weeks before the maximum tillering phase is attained. The trend of distribution of tillers in plants of different tiller classes follows a systematic course and it does not seem to vary much among the varieties under study. Under normal field conditions the percentage of functional tillers to the total tillers in a plant is almost the same irrespective of the number it produces, but this percentage is evidently a varietal character, being low in later varieties. The yield per ear and weight of grain in the different tiller classes are almost the same. Hence it follows that keeping the environment the same, any increase in the average number of tillers per plant or per unit area correspondingly goes to increase the yield of grain per plant or per unit area. As early conditions have a marked predetermining influence on after development, to obtain good yields the plant must be provided with optimum conditions for vigorous growth by the production of a large number of tillers earlier to the 'critical period.'

Ear development. The interval between the completion of tillering and commencement of ear formation seems to depend on the duration of the variety. The interval increases with the increase in duration. In the case of early varieties and in late planted crops ear formation commences even before tillering is completed. The relationship between tillering and ear formation is a useful criterion to be made use in adjusting the time of application of a fertiliser to the crop. The formation of the ear primordia commences about 24 to 31 days before the date of emergence of ear tip, the interval apparently depending on the duration of the variety. The ear completes its growth in length about a week before its date of emergence. The linear development of all the spikelets and the mechanical strengthening of the rachis, rachilla and glumes are complete by the time of its emergence.

Shoot growth. Nearly 90 per cent of the height in a mature rice shoot is attained during the month preceding flowering. Active growth of shoot starts almost with the commencement of the ear development. Elongation of the different parts of the shoot proceeds from base upwards in regular succession. A week or ten days before the emergence of the ear, the top-most internode and peduncle starts growth while those lower below would have reached their full length. Growth of all parts of the shoot stops with the commencement of general flowering, which is four to five days after the emergence of the ear tip from the shoot.

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MARKETING OF CULTIVATORS' COTTON AT TIRUPUR, MADRAS PRESIDENCY

BY S. V. DURAISWAMI, B.A., B.Sc. Ag.,

Asst. Lect rer in Agriculture, Agricultural College, Coimbatore.

(*Note*:—Investigations into the finance and marketing of cultivators' cotton in Tirupur town and in two representative villages of the tract were carried out by the author with the aid of a scholarship from the Indian Central Cotton Committee in 1932 and 1933 and two reports were submitted, the first for the town and the second for the villages. The article below is an abridgement of the first. The other, on growing, finance and marketing of cotton in the villages of the tract has been published in "Agriculture and Livestock in India" of January 1935.)

The town of Tirupur situated in the middle of Coimbatore district has grown in importance in recent years due to its cotton trade and is now one of the largest centres of cotton trade in South India. The total quantity of cotton dealt with per annum is about 80 to 100 thousand bales. Cotton grown in the surrounding area, to a radius of about 50 miles, is almost all marketed through Tirupur. Cambodia and *Karunganni* are the chief varieties disposed of, *Uppam* and *Nadan* being received in small lots. The proportion of these arriving at Tirupur may be estimated as follows:—Cambodia, 60%; *Karunganni*, 30% *Uppam* and *Nadan*, 10%. The investigation was carried out from April to July of 1932, as the marketing season at Tirupur is normally from March to August. A total of 590 sellers were examined in 90 days.

The Market Organisation. The whole of the Municipal town of Tirupur serves as a market place. Spot purchases are generally the rule though sales are also effected on the forward contract system by the town merchants. Situated in the central part of the town are about 30 commission *Mundies* or depots, the owners of which act as financiers and commission agents for the sellers of *kapas*. There is storage accomodation available in these *Mundies* and advances are