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A study on the maturity of grain in Sorghum

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Introduction The importance of sorghum as a major food and fodder crop of India demands it efficient management. In this crop, as in many other cereals the date of flowering is much more definite than ripening. It is desirable to know when exactly the crop becomes fit for harvest, steering clear of immature grains and poor germination on the one hand and loss of grain by leaving the crop too long in the field, on the other. If the date of maturity could be fixed definitely as so many days after flowering the crop could be harvested earlier and the straw would also be secured in a greener and more palatable state. Being an exposed grain, sorghum gets discoloured if any rain is received after the dough stage. This reduces its market value. Moreover, if heavy rains are received at the time the grains are in the 'wax' stage, they are liable to germinate *in situ*, which means a loss in the yield also.

Thus a knowledge of the exact date of maturity would help to prevent an unnecesrary delay in harvest. This paper presents the results of a preliminary study on the ripening of sorghum grain.

Previous work Not much work seems to have been done on the relative germination capacity of seeds gathered at different stages of maturity. The only work worth mentioning is that of Hermann, E. M. and Hermann, W. (1939)[1] on the crested wheat-grass *Agropyron cristatum* (L) (Gaertn). Being a forage crop the yield of grain was not taken into consideration in their study. The shattering stage of grain in this grass occurs about 48 days after flowering. The seeds harvested 21 days after flowering were able to germinate; but vigorous seedlings were secured only when the seed was harvested after the 'hard dough stage' (30 days after flowering). Thus these workers established the fact that seed of this grass could be collected without disadvantage 30 days after flowering; i. e., nearly three weeks before it shows any signs of shattering.

In a study of the effect of immature seed on the growth of the progeny it is also pertinent to know if the size of the seeds has any influence on the growth of the succeeding crop For nearly 300 years botanists have studied the effect of 'seed size on the succeeding crop and Oexemann (1942)[2] has summarised all the previous work on this aspect. During this century many of the earlier investigators like Delassus (1911), Cummings (1914), Schmidt (1924) and Kiesselbach (1924) have reported that plants raised from heavier seeds show a more vigorous growth and give higher yields. Later investigators, like Golinska (1929), Kotowski (1929), Vansel-low (1933) and Rohmeder (1939) have found however that the seed-weight

* Ramasastrulu Munagala Prize Essay 1943—44.

factor was significant only during the early stages of plant growth and i the growing season was long enough, this early superiority might even dis appear entirely. Oexemann, in certain dicotyledonous plants, reduced the seed size in one set by removing half a cotyledon and in a second set by removing a full cotyledon, thus reducing the reserve food material to three fourths and half of the normal. He has confirmed that plants from lighter seeds are poorer in their early stages of growth but under favourable green-house conditions the seedlings pull up later on and there was practically no difference by the time the plants reach the mature stage

Material and method It is obvious, that for a study of the maturation of grains the material should be a standard variety of the tract, with the longest possible duration. A long duration is necessary to give the maximum chance for the seedlings from immature seeds to make up the early superiority of the seedlings from more mature grains. The *Periamanjal cholam* strain A. S. 29 of the Millet Breeding Station, Coimbatore was chosen for this study, as it is the most popular variety of the tract, with a long duration of nearly 130 days. The botanical group to which this variety belongs is *Sorghum durra var, Coimbatoricum*.[3]

The first step in this study was to find out at what particular stage of maturity the seeds were capable of germinating. One thousand spikelets were marked with pieces of white thread, in a bulk crop of A. S. 29 on the 5th November, 1940. This date was chosen as representing the flowering date of the bulk. From the next day onwards 20 spikelets were removed daily in two groups of 10 each. The first set was kept on germination trays immediately and the other dried well, preserved in screw-topped bottles and tested for germination seven months later i e., at the time of sowing the succeeding *Periamanjal cholam* crop No germination was observed in seeds collected earlier than 14 days after flowering, even after seven months of storage.

In the second year, 1941, one hundred plants in a bulk crop of the same strain which flowered on November 2nd, were marked for study. In the light of the previous year's experience; five earheads were harvested on the 12th day after flowering. Every succeeding fourth day, a batch of five more was harvested till the 44th day after flowering, when the crop as a whole was considered ripe, as judged by the brittle nature of the grain. All the spikelets in the sorghum panicle do not flower on the same day. The flowering commences at the top of the panicle and it takes seven days for it to reach the base.[4] The plant is said to have flowered when the anthesis has reached the middle region of the panicle. It will thus be seen that a four- day interval between each harvest would be the optimum, when the units of harvest are ear-heads as it is in actual field practice.

These ear-heads were sun-dried and utilised for recording characters like grain size, grain weight, persistence of glumes etc. Germination tests were also made on seeds from these earheads after storage for different

periods viz. one month, seven months, twelve months, nineteen months and twenty-four months after harvest.

The seeds were also grown in pots and the leaf measurements of the seedlings were recorded. The pots were all of the same size (15" in diameter and 7" in height) filled with the same soil mixture and watered similarly.

From these germination tests, the stages which had good germinating capacity under soil were sown in the next season under replicated row yield tests on the field. The stage at which the seedlings from seed collected at various stages of maturity tended to be similar was found out from the leaf measurements. This was sought to be confirmed under the field conditions also by thinning out and weighing 10 seedlings at that time from all the variants and analysing them statistically.

In the adult plants the date of flowering, the plant height, number of internodes, the length and breadth of the fourth leaf and the diameter of the fourth internode were recorded and analysed statistically.

It was possible to distinguish the following six stages in the period intervening between flowering and the complete ripening of the sorghum grain.

Heads harvested on the

4th and 8th day	—	Pre-milk stage.
12th and 16th day	—	Early milk stage.
20th and 24th day	—	Late milk stage.
28th and 32nd day	—	Dough stage.
36th and 40th day	—	Wax stage.
44th day after flowering		Horny stage.

Results The results obtained are presented in the following tables.

Table I shows that even after thorough drying and a resting period of seven months (corresponding to the normal interval between two successive crops of *Periamanjal cholam*) a minimum development period of fourteen days after flowering is required for the seeds to be able to germinate.

In the next year, 1941, the date of general flowering of the *Periamanjal cholam* crop (A. S. 29) was 2—11—1941. Ear-heads were collected every fourth day, commencing from the 12th day after flowering up to the 44th day. The differences noticeable on the colour, size, weight, volume, percentage of grain with glumes and other characters in the grains harvested at different stages of maturity are appended in Tables II, III and IV. The size of each grain was determined by vernier calipers. The weight was taken in grammes for samples of 100 grains each. The volume was found by immersing 100 grains in liquid paraffin. The increase in size of the grain with the progress in maturity can be seen clearly from the photograph.

TABLE 1 Stages of maturity at which the seeds are capable of germination.
(Ten seeds were kept in each group for germination on moist blotting paper)
Season—1940 November

Number of days after flowering	Percentage of germination	
	Immediately after harvest	Seven months after harvest
1—13	...	...
14	...	10
15	...	...
16	...	20
17	...	10
18	...	30
19	...	50
20	10	60
21	10	80
22	...	60
23	20	80
24	10	60
25	10	70
26	10	70
27	20	90
28	10	80
29	20	80
30	20	80
31	10	90
32	20	80
33	20	90
34	20	80
35	20	70
36	30	90
37	30	80
38	30	90
39	40	70
40	50	80
41	50	00
42	40	90
43	50	90
44	60	80

TABLE II Details of grain harvested at different stages of maturity.

Seeds collected. (No. of days after flowering)	Maturity stage	Size of grain (mm)			Average of 100 grains		Colour and fullness of grain	Dry glume colour	Adherence of glume to the grain	Percentage of grain with glumes adhering	Remarks
		Length	Breadth	Thickness	Weight (gms)	Volume (c. c.)					
12	Early Milk	3·6	2·7	1·7	0·77	0·5	Pale yellow wrinkled	Straw	Does not separate at all	100	Average of five readings.
16	,,	3·8	2·8	1.9	1·18	0·8				100	
20	Late Milk	4·2	3·3	2·0	1·70	1·3	Good yellow slightly wrinkled	Light blackish purple	Gets separated with [illegible]	23	
24	,,	4·5	·5	2·4	2·29	1·7		Blackish purple		14	
28	Dough	4·6	3·6	2·5	2·54	1·9	Good yellow full grain	,,	Gets threshed easily	7	
32	,,	4·7	3·6	2·6	2·75	2·1	Yellow with brown wash full grain	,,		7	
36	Wax.	4·8	3·8	2·7	2·96	2·3		,,		7	
40	,,	5·0	4·0	2·9	3·30	2·4		,,		6	
44	Horny	5·0	4·0	2·9	3·28	2·4		,,		7	
Are the differences significant		Yes	Yes	Yes	Yes	Yes				Yes	
Critical difference at 5% level		0·1	0·1	0·2	0·08	0·1				2	

TABLE III. The germination capacities of seeds collected at different stages of maturity. (Harvested on November & December 1941).

Seeds collected (days after flowering)	Maturity stage.	Percentage of germination.					Remarks.
		January 1942 (1 month)	June 1942 (7 months)	December 1942 (12 months)	June 1943 (19 months)	December 1943 (24 months)	
12	Early milk	9	39	22	17	12	Average of five replications
16		11	76	58	32	30	
20	Late milk	39	88	90	93	80	
24		38	91	92	95	87	
28	Dough	42	96	95	80	83	
32		49	95	90	83	89	
36	Wax	48	94	89	86	82	
40		51	94	90	87	82	
44	Horny	56	94	92	86	84	
Are the differences significant.			Yes		Yes.		
Critical difference at 5% level.			4		5		

TABLE IV The results of germination tests of seed stored for seven months and nineteen months.

Period of storage	Seeds collected Days after Flowering	Maturity stage	In germination trays (Average of 5 tests) No. of days after setting up the test												In pots Number of days after sowing									
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
Seven months	12	Early milk	...	...	2	2	6	6	8	6	8	1	...	...	...	...	...	...	1	...	...	4	...	...
	16	"	...	...	...	1	2	12	16	21	12	8	4	...	...	...	...	...	2	1	2	...	...	...
	20	Late milk	...	31	3	3	1	...	...	...	...	...	...	...	...	...	...	61	...	...	...	...	...	...
	24	"	...	83	6	1	1	...	...	...	...	...	...	...	...	...	...	60	6	...	...	...	...	...
	28	Dough	...	95	1	...	...	...	...	...	...	...	...	...	...	...	...	84	...	...	...	...	...	...
	32	"	...	94	1	...	...	...	...	...	...	...	...	...	...	...	...	82	...	...	...	...	...	...
	36	Wax	...	92	2	...	...	...	...	...	...	...	...	...	...	...	...	85	...	...	...	...	...	...
	40	"	...	93	1	...	...	...	...	...	...	...	...	...	...	...	...	86	...	...	...	...	...	...
	44	Horny	...	92	2	...	...	...	...	...	...	...	...	...	...	...	...	81	...	...	...	...	...	...
Nineteen months	12	Early milk	...	...	2	2	5	2	2	1	1	...	1	1	...	...	...	...	...	...	...	...	...	...
	16	"	...	...	2	3	2	5	10	5	3	1	...	1	...	...	...	...	...	...	...	...	...	...
	20	Late milk	...	74	17	2	...	...	...	...	...	...	...	...	...	...	...	55	13	...	...	...	...	...
	24	"	...	73	18	4	...	...	...	...	...	...	...	...	...	...	...	56	12	...	...	...	...	...
	28	Dough	...	80	6	3	...	...	...	...	...	...	...	...	...	...	...	74	...	...	...	...	...	...
	32	"	...	81	1	1	...	...	...	...	...	...	...	...	...	...	...	74	...	...	...	...	...	...
	36	Wax	...	82	2	2	...	...	...	...	...	...	...	...	...	...	...	75	...	...	...	...	...	...
	40	"	...	83	2	2	...	...	...	...	...	...	...	...	...	...	...	73	...	...	...	...	...	...
	44	Horny	...	81	3	2	...	...	...	...	...	...	...	...	...	...	...	70	...	...	...	...	...	...

Conclusion:— The less mature seeds tend to be delayed in germination in trays and also fail to sprout well when sown in pots.

Leaf measurements were taken on plants grown in pots under controlled conditions and the data are given in the following table (Table V). The figures are averages of ten measurements in each case.

TABLE V (Measurements in centimeters).

Seeds collected (No. of days after flowering)	First leaf		Second leaf		Third leaf		Fourth leaf		Fifth leaf	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
20	1·2	0·6	3·0	0·6	6·3	0·7	11·9	1·0	26·2	1·6
24	1·5	0·6	4·2	0·7	8·4	0·7	15·3	1·0	26·5	1·6
28	1·9	0·7	4·7	0·6	8·9	0·6	14·6	1·0	25·9	1·6
32	2·0	0·7	4·9	0·7	9·1	0·8	15·1	0·9	25·9	1·5
36	2·0	0·7	4·8	0·6	9·0	0·7	15·8	1·0	27·3	1·6
40	1·9	0·7	5·0	0·6	8·8	0·7	15·9	1·0	26·8	1·6
44	2·0	0·7	4·9	0·6	9·0	0·7	14·9	1·0	26·9	1·6
Are the differences significant	Yes	No	Yes	No	Yes	No.	Yes	No	No	No
Critical difference at 5% level	0·2		0·3		0·4		1·1			

The table shows that the differences in the breadth of leaves are not significant. In length, the differences are significant up to the stage when the fifth leaf is put forth i. e., when the seedlings are seventeen days old. After this stage, the differences in leaf length also tend to get obliterated.

Having known from the observations of the first year, that seeds from ear-heads harvested on the 12th and 16th days after flowering do not germinate well under natural conditions, these two stages were omitted in the replicated row yield trials of 1942 Main. A suitable field was chosen and seeds were sown under rain-fed conditions in five replications of randomised rows—each 18 links long and 2 links apart. When the seedlings were 21 days old, 10 seedlings from each replication were weighed and the data analysed statistically to confirm the results observed in pot-sown seedlings

TABLE VI Weight of seedlings — 21 days old

	Seeds collected — (Days after flowering)						
	20	24	28	32	36	40	44
Average weight of 10 seedlings (gm.)	27·2	26·0	28·0	28·0	26·4	26·0	26·6
Expressed as % of control (44 days)	102	98	105	105	99	98	100

Conclusion: The differences in weight of seedlings are not statistically significant.

When the plants were mature the crop was harvested. The dry weight of grain and straw were recorded and analysed statistically. The results are given below.

TABLE VII Yields of grain and straw

Yield expressed as percentage of control (44 days)	Seeds collected — (Days after flowering) 20	24	28	32	36	40	44
Grain	104	100	103	101	104	104	100
Straw	97	98	101	99	98	97	100

Conclusion: The differences in yields of grain and straw are not statistically significant.

All the plants flowered on the same day — 85 days after sowing. The measurements of vegetative characters indicating the vigour of the adult plants are given in the following table (Table VIII)

Table VIII

Particulars	Seeds collected — (Days after flowering) 20	24	28	32	36	40	44
Height (cm)	300	305	305	300	305	305	305
No. of leaves	14	14	14	14	14	14	14
Fourth leaf { Length, cm.	75·3	72 0	76·5	73·4	75·0	76·7	73·5
Fourth leaf { Breadth, cm.	9·0	8·6	9 0	8 6	8·7	8·6	8·7
Fourth internode (Diameter, cm.)	1·3	1·3	1·3	1·3	1·3	1·3	1·3
Panicle { Length, cm.	20·0	21·0	19 8	20·3	21 0	20·6	20·2
Panicle { Breadth, cm.	8·5	8·5	8·7	8 9	8 9	9·0	8·6

Conclusion: The differences in all the above mentioned characters are not statistically significant.

Discussion Grains harvested on the 12th and 16th days after flowering are useless for seed purposes as they fail to germinate under field conditions (Table IV). Seeds collected on the 20th and 24th days after flowering have a slightly poor germination and the seedlings are small and deficient in vigour (Tables V and VI) but they are able to give a normal crop ultimately (Tables VII and VIII). Seeds from the 28th day onwards have a normal germination and a normal yield (Tables IV, VII and VIII).

This experience is in line with the results reported by Hermann on *Agropyron cristatum*, which gave a normal crop from the seeds gathered at any stage beyond the 30th day after flowering, although the interval between flowering and full ripening was as much as 48 days.

Oexemann's (1942) work on a variety of other crops helps us to interpret the results of our experiments to a certain extent. Sorghum seeds collected on the 20th and 24th days produce smaller seedlings (Table V) than seeds collected later on, indicating that the food reserve in the seeds is not quite adequate. But if optimum conditions are given for growth this early set back can be made up by the time the seedlings are three weeks old and the plants are able subsequently to produce a normal crop.

Seeds harvested from the 28th day onwards are normal for the purpose of propagating the species. From the 28th to the 40th day it is merely an

addition of reserve food material, which is useful to man but is more or less superfluous (Tables VII and VIII) to the seedlings of the succeeding generation.

The wild sorghums, untouched by human influence serve to corroborate this conclusion. The grains which are small in these wild sorghums are shed along with the spikelets at the dough stage itself but these seeds are able to produce normal plants under natural conditions

Table II shows that by the time the seeds attain the "wax" stage i. e., (40 days after flowering) they have completed their development and subsequently the process seems to be merely one of dehydration. Therefore there can be no disadvantage in harvesting the ear-heads at this stage, although they may require some further drying to facilitate easy threshing.

From the Table IV it will be seen that only 80 to 90 per cent of the seeds which germinate on blotting paper by the third day are capable of sprouting under field conditions. In the less mature seeds the germination is delayad and the bulk of the seeds germinate from the fourth to twelfth day, when tested in germination trays. Seeds with such delayed germination seldom sprout when sown in the field.

There is also a slight indication that even the fully mature seeds tend to have a delayed germination, when stored for more than a year.

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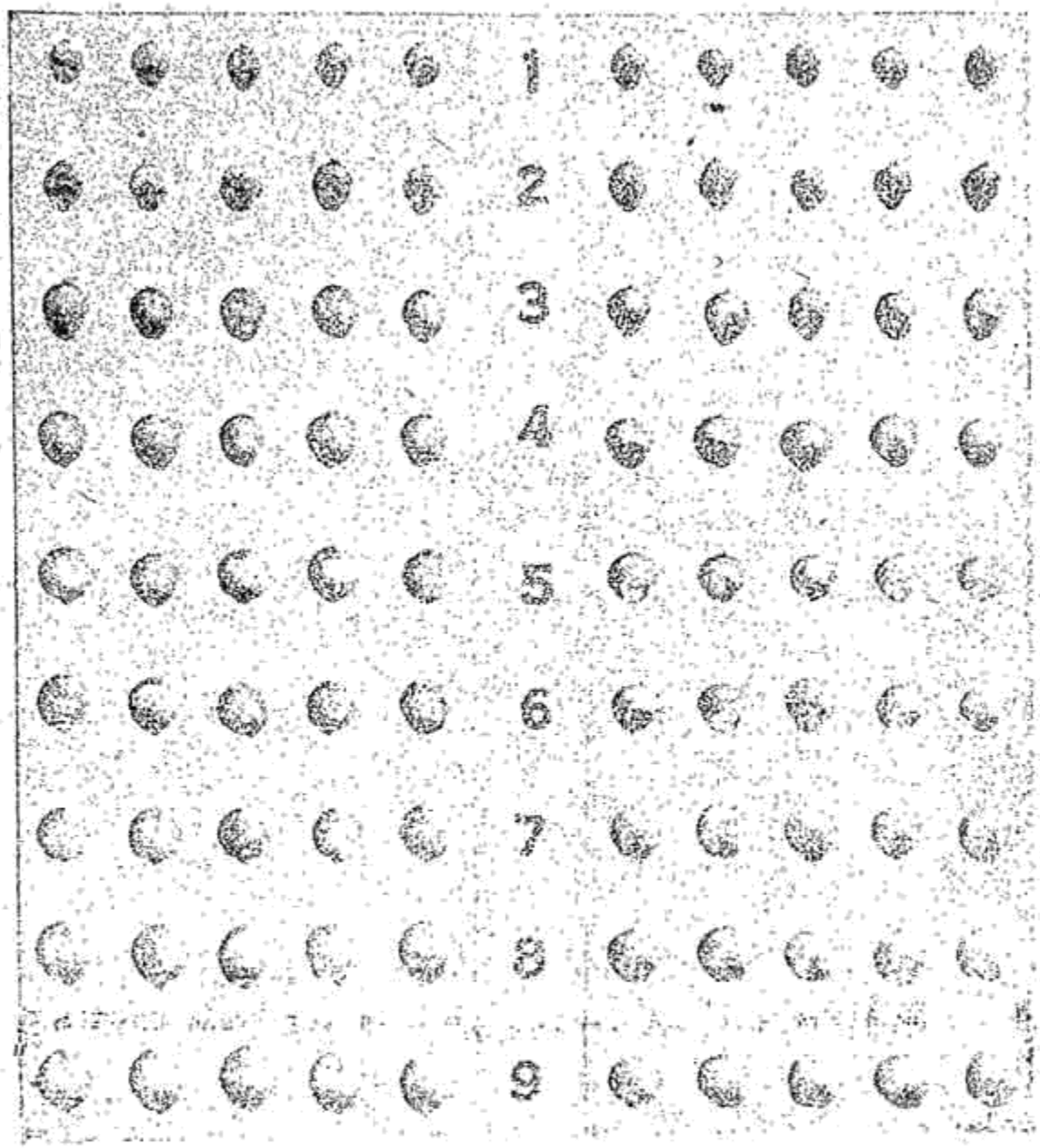
Summary A study was made on the germination and growth of *Periamanjal cholam* plants (*Sorghum durra var. Coimbatoricum*) raised from seeds collected at different stages of maturity. From the results obtained it is possible to distinguish six distinct stages in the process of maturation, from the fertilised ovary up to the ripe grain. These stages are briefly described below.

(a) *The Pre-milk stage* This comprises heads harvested up to the eighth day after flowering. Such seeds do not have any germinating capacity.

(b) *The Early-milk stage* succeeds the pre-milk stage and extends to the sixteenth day after flowering. The seeds collected during this stage are able to germinate on trays. When tested on blotting paper they are rather slow in germination and under field conditions they have a poor sprouting ability.

(c) *The late-milk stage* extends from the sixteenth up to the 24th day after flowering and seeds of this stage have a slight delay on the tray and only 60 per cent of the seeds sprout under field conditions as against 80 per cent with fully ripe grains. The seedlings are rather deficient in vigour during the early stages but pull up later on. Under field conditions the growth becomes quite normal by the time the seedlings are 21 days old.

SORGHUM GRAINS AT DIFFERENT STAGES OF MATURITY



X 1½

Endosperm side. *Embryo side.*

1. Grains gathered on the 12th day after flowering
2. " " on the 16th day " "
3. " " on the 20th day " "
4. " " on the 24th day " "
5. " " on the 28th day " "
6. " " on the 32nd day " "
7. " " on the 36th day " "
8. " " on the 40th day " "
9. " " on the 44th day " "

(d) *The dough stage* extends up to the 32nd day after flowering. By the time this stage is reached the development of the embryo is complete and sufficient reserve food material is stored in the seed for the normal development of the seedlings. For seed purposes the crop could be harvested without any disadvantage as early as 28 days after flowering.

(e) *The wax stage* extends from the 32nd day up to the 40th day after flowering and during the first half of this stage the grains continue to increase in size and weight. The increase in size ceases before the end of the wax stage. Even for grain purposes the crop can be harvested on the 40th day after flowering.

(f) *The horny stage* is the stage which extends from the 40th day to the 44th day and in ordinary field practice the earliest harvest is done only by the end of this stage. It is not necessary to wait until this stage for harvesting a sorghum crop.

The germination tests conducted during this experiment give us some interesting results, that the more immature seeds have a tendency for delayed germination on trays and these seeds lack the vigour to sprout up over the soil.

Conclusion Seeds of *periamanjal cholam (S. durra var.* Coimbatoricum) are able to germinate well and produce normal plants when harvested as early as 28 days after flowering. For grain purposes ear-heads can be harvested at the wax stage itself (40 days after flowering), about a week earlier than the usual time of harvest.

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