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Seed development and maturation studies in Little Millet (*Panicum sumatrense* Roth ex Roem. and Schult.) cv. Co (Samai) 4

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Abstract
Minor millets are claimed to be the future foods for better health and nutrition security. Seeds obtained from the Department of millets, Tamil Nadu Agricultural University, Coimbatore formed the base material for the study. In order to study the seed development and maturation for fixing physiological maturity in little millet cv. CO (Samai) 4, was raised in the department of seed science and technology, AC&RI, Madurai. The individual panicles of bulk crop raised in the field and were tagged at the time of flower opening. The panicles were collected at 5 days intervals up to 50 days after anthesis (DAA) and subjected to the following seed quality assessments. The observations made on panicle fresh weight (g), dry weight (g) and moisture content (%). The results revealed that physiological maturity of little millet was attained on 40 day after anthesis with corresponding increase in 1000 seed weight (3.6 g) seed fresh weight (10.2 g), dry weight (4.9 g), seed germination (38%), seedling dry matter production (0.011g/ 10 seedlings), vigour index (578).

Keywords: Little millet, physiological maturity, days after anthesis, vigour index

Introduction
Little millet (*Panicum sumatrense* Roth. ex. Roem. & Schult.) is one of the important small grain crops belongs to the family Poaceae is indigenous to Indian sub-continent. The advantage of millets lies in the fact that they can be grown in infertile soil, intense heat, and scanty rainfall (Gupta *et al.*, 2014) [13]. Seed maturity is the crucial and most important factor determining the seed quality under successful seed production programme (Austin, 1972) [7]. It is understood that seed maturation is the gradual preparation for germination (Bewley and Black, 1994). The development process during seed growth and maturity interacts with the production environment to determine the planting quality of a seed. It is well established that seed quality is the highest at physiological maturity which precedes harvestable maturity. This practice would permit quick harvesting at appropriate timings, resulting in better field management (Delouche, 1973) [9]. The present investigation on seed development and maturation in Little Millet (*Panicum sumatrense* Roth ex Roem. and Schult.) cv. Co (samai) 4 was carried out.

Materials and Methods
The study was conducted with little millet seeds obtained from the Department of millets, Tamil Nadu Agricultural University, Coimbatore formed the base material for this study. The experiment was conducted at the department of seed science and technology, AC&RI, Madurai to determine the physiological maturity status of the seed. The bulk little millet crop seed was raised in the field. Individual flower heads were tagged at the time of flower opening. The panicles were collected at 5 days intervals and subjected to the following seed quality assessment. Seed moisture content, 1000 seed weight, germination percentage, drymatter production and vigour index are the observations recorded.

Seed fresh weight and Dry weight
Immediately after collection, the panicles were individually weighed in an electronic balance and the mean value was expressed in g/panicle.

Fresh panicles were dried initially under shade and then in a hot air oven maintained at 85±1 ºC for 24 h. After drying, the dry weight of panicles was taken and the mean value was expressed in g panicle^{-1}.Panicle moisture content was estimated using low constant hot air oven method at 103 ± 1 ºC for 16 ± 1 h with five grams of samples. After drying, the seed samples were placed in desiccators containing calcium chloride for 30 min and weighed. The fresh seeds extracted from panicle were counted and dried initially under shade for a day and then in a hot air oven maintained at 85±1^{0}C for 24 h. After cooling in a desiccator for 30 minutes, the dry weight of the seeds was recorded and the mean value was expressed in g seed panicle^{-1}. After extraction of seeds from panicle, the seeds were uniformly dried under shade and the thousand seed weight was arrived at by weighing the thousand seeds. The mean weight of eight samples was expressed in grams (ISTA, 1999)

Moisture content

Moisture content of seed was estimated by using high constant temperature hot air oven method in two replications (ISTA, 2010) [17]. Seed samples (5g) were weighed and ground to coarse powder using a grinding mill. The coarsely ground material kept in moisture bottle was dried in hot air oven at 130 ± 1°C for 2 h. After drying, the dried seed material was cooled in a desiccator for 30 min and weighed along with bottles. Moisture content of seeds was estimated on wet weight basis by using the following formula and expressed in percentage.

Germination test

Germination test was carried out in quadruplicate using 100 seeds each in rolled paper towel method (ISTA, 1999) in a germination room maintained at 25 ± 1ºC temperature and 96 ± 2% relative humidity (RH) with diffused light during the day. On tenth day of germination test, number of normal seedlings were counted and the average was expressed as per cent.

Shoot and Root length

Ten normal seedlings were selected randomly from the germination test and root length was measured from tip of primary root to base of shoot and mean root length was expressed in cm. Ten normal seedlings chosen for measurement of root length were used for measurement of shoot length. It was measured from tip of primary leaf to base of shoot and mean shoot length was expressed in cm.

Seedling dry matter

Ten normal seedlings chosen earlier for measuring shoot and root lengths were used to determine seedling dry weight. The seedlings kept in paper cover and dried under shade for 24 h and then in a hot air oven at 85± 1ºC for 24 hours. The average weight was expressed in gram per ten seedlings.

Vigour index

Seedling vigour index was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and was expressed in whole number. Vigour index (VI) was computed using the following formula and expressed as whole number.

Vigour Index (VI) = Germination Percentage (%) x Seedling Length (cm)

Statistical analysis

The data obtained from experiments were analyzed by the 'F' test for significance following the method Completely Randomized Design. Wherever necessary, the percent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance.

Experimental Results

Panicle length, Moisture content, Fresh and Dry weight

The differences in length of panicle due to different stages of development were highly significant. The panicle length was higher in 40 days after anthesis (DAA) (31.5 cm) and this was on par with 35 DAA (30.8 cm) which were significantly different from all other stages. The lowest panicle length was observed in 5 DAA (22.2 cm). The maximum panicle fresh weight was recorded in 40 DAA (28.0 g) and was followed by 35 DAA (27.0 g). The minimum fresh weight of panicle was observed in 5 DAA (10.3 g). The lowest panicle dry weight was found in 5 DAA (2.1 g), which increased gradually during development and reached the maximum in 40 DAA (18.4 g) and declined thereafter in 35 DAA (18.1 g).The highest panicle moisture content (79.61%) was noticed in 5 DAA which was decreased gradually and reached the lowest at 40 DAA (20.7%)

Seed moisture content, 1000 Seed weight, Fresh and Dry weight

The fresh weight of seed increased as the period of seed development increased from 15 DAA (7.6 g) to 40 DAA (10.2 g) and thereafter, significant reduction was noticed in 35 DAA (8.6 g). The panicles from first two stages of development (5 DAA and10 DAA) did not produce any seeds. The initial dry weight of seeds was 3.0 g at 15 DAA and this was gradually increased up to 4.9 g at 40 DAA whereas, the panicles from first two stages of development (5 DAA and 10 DAA) did not produce any seeds. The thousand seed weight showed a steady and significant increase over the period of seed development and maturation. The maximum thousand seed weight (3.6 g) was recorded in 40 DAA and minimum was in 15 DAA (2.1 g) whereas, the panicles from first two stages of development (5 DAA and 10 DAA) did not produce any seeds. The highest seed moisture content of 60.52 per cent was registered at 15 DAA which decreased gradually and reached the minimum at 40 DAA (20.15%). All the stages were significantly differed from each other. The panicles from first two stages of development (5 and 10 DAA) did not produce any seeds.

Table 1: Changes in panicle length (cm), fresh weight (g), dry weight (g) and moisture content (%) of panicle during seed development and maturation in little millet cv. CO (Samai) 4

Days after anthesis (DAA)	Panicle length (cm)	Panicle fresh weight (g)	Panicle dry weight (g)	Panicle moisture content (%)
5 DAA	22.2	10.3	2.1	79.6
10 DAA	24.8	12.4	5.2	58.0
15 DAA	25.5	16.8	8.1	51.8
20 DAA	26.4	18.2	10.2	43.9
25 DAA	28.6	20.9	12.1	45.6
30 DAA	29.9	23.4	15.1	30.1
35 DAA	30.8	27.0	18.1	25.5
40 DAA	31.5	28.0	18.4	20.7
45 DAA	30.7	26.9	18.1	20.1
SEd	0.56	0.31	0.31	0.75
CD (P = 0.05)	1.2**	0.67**	0.69**	1.59**

Table 2: Changes in seed and seedling quality characteristics during seed development and maturation in little millet cv. CO (Samai)

Days after anthesis (DAA)	Fresh weight of seeds (g)	Dry weight of seeds (g)	1000 seed weight (g)	Seed moisture content (%)	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling dry matter production (g 10 seedling^{-1})	Vigour Index
5 DAA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 DAA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 DAA	7.6	3.0	2.1	60.52	0.0	0.0	0.0	0.0	0.0
20 DAA	7.4	3.2	2.9	56.75	0.0	0.0	0.0	0.0	0.0
25 DAA	7.9	3.4	3.1	48.56	4 (11.53)	4.3	6.8	0.04	44
30 DAA	8.2	4.2	3.2	40.26	16 (23.57)	5.8	7.5	0.06	213
35 DAA	8.6	4.3	3.3	33.64	24 (29.33)	6.4	7.9	0.08	343
40 DAA	10.2	4.9	3.6	20.15	38 (38.05)	7.1	8.7	0.011	578
45 DAA	9.8	4.6	3.2	22.56	36 (36.87)	6.9	7.9	0.009	569
SEd	0.151	0.063	0.076	0.716	0.50	0.11	0.08	0.08	110.8
CD (P 0.05)	0.32**	0.13**	0.16**	1.51**	1.07**	0.23**	0.18**	0.18**	234.9**

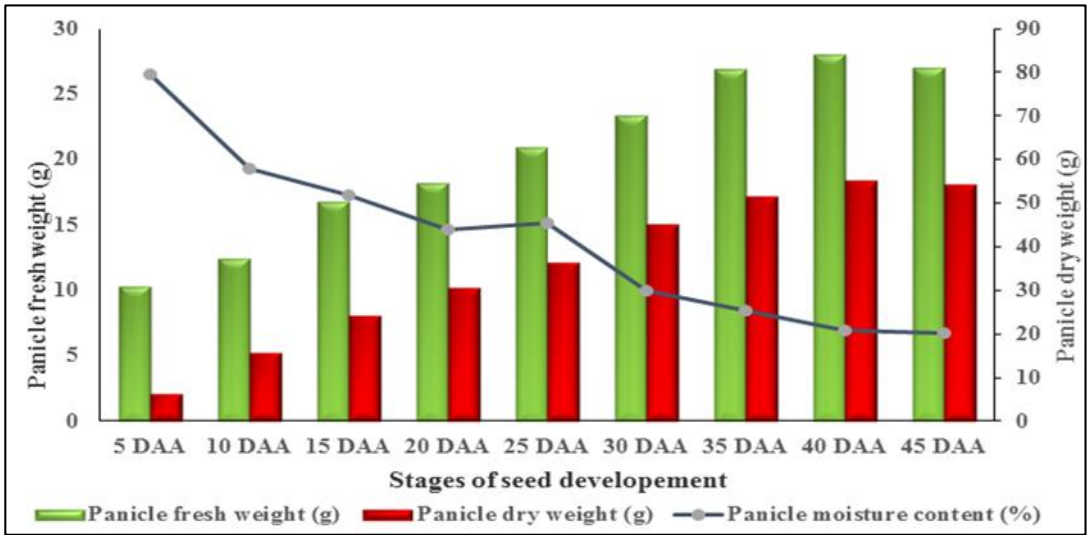

Fig 1: Changes in fresh weight (g), dry weight (g) and moisture content (%) of panicle during seed development and maturation in little millet cv. CO (Samai)

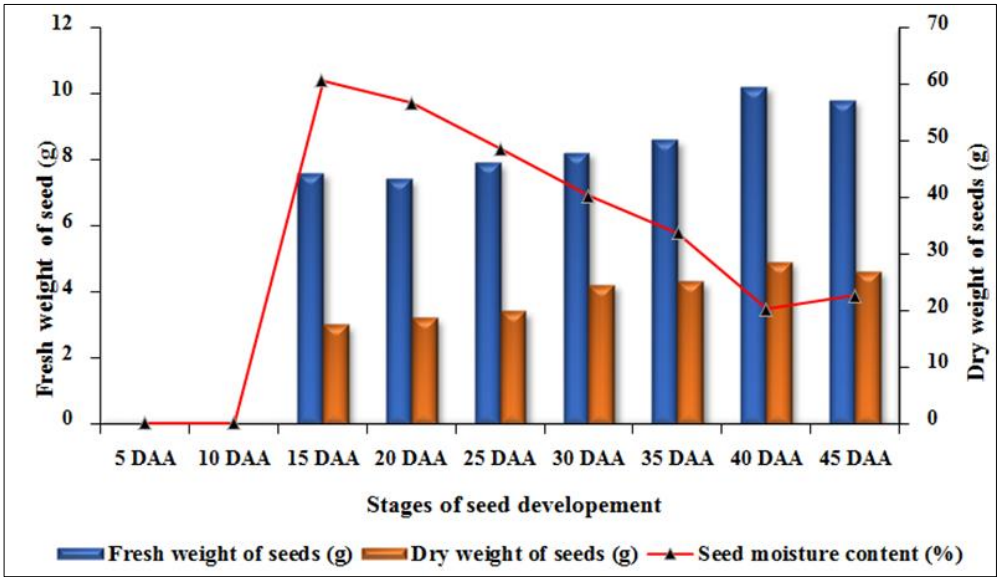

Fig 2: Changes in fresh weight (g), dry weight (g) and moisture content (%) of seed during seed development and maturation in little millet cv. CO (Samai) 4

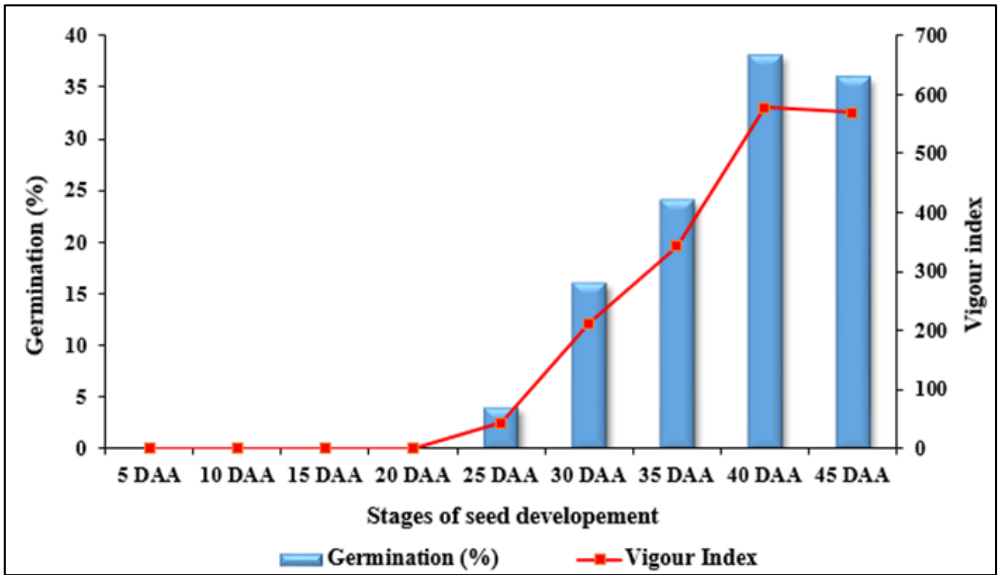

Fig 3: Changes in seed germination percentage and vigour index during seed development and maturation in little millet cv. CO (Samai) 4

Plate 1: Panicle developmental stages in little millet cv. CO (Samai) 4

Seed germination, Seedling length and Vigour

As the seed maturation stages advanced, significant increase in germination percentage was noticed. The maximum germination was observed at 40 DAA (38%) followed by 45 DAA (36%). The first sign of germination was noticed in the seed obtained at 25 DAA with 4 per cent germination. The

seeds from previous two stages of development (15 and 20 DAA) did not produce any seedlings. The longest root was produced at 40 DAA (7.1 cm), and seeds from 25 DAA stage produced the shortest root (4.3 cm) whereas, the seeds from third and fourth stages of development (15 and 20 DAA) did not produce any seedlings. The longest shoot of 8.7 cm was produced at the stage of 40 DAA and the seeds from 25 DAA produced the shortest shoot of 6.8 cm, whereas; the seeds from third and fourth stages of development (15 and 20 DAA) did not produce any seedlings. Significantly highest dry matter production by the seedling was noticed at the stage of 40 DAA (0.011 g) and followed by 45 DAA (0.09 g) which was on par with 35 DAA (0.08 g). The minimum seedling dry weight was recorded at 25 DAA (0.04 g); whereas, the seeds from third and fourth stages of development (15 and 20 DAA) did not produce any seedlings. The seedling vigour index was maximum with 578 at 40 DAA followed by 35 DAA (343). The minimum vigour index was recorded at 25 DAA (44); whereas, the seeds from third and fourth stages of development (15 and 20 DAA) did not produce any seedlings (Table.1, 2).

Discussion

In seed production, the time of harvest is a critical factor determining the seed yield and quality. The unevenness of the performance of a seed lot is due to the differential condition of the mature plant and the environment interaction, which affects seed development. Seed maturation refers to the physiological and functional changes that occur from time of anthesis until the seeds are ready for harvest. Studies on the pattern of seed development and assessment on time and indices of maturity have greater practical utility on production of quality seeds. Malarkodi and Srimathi (2007) [20] found that stages, symptoms and days for seed development and maturation vary with crops and studies on seed maturation are warranted not only for individual species but also for various locations. According to Harrington (1972) [14], physiological maturity is the stage at which the seed reaches its maximum dry weight and nutrient flow into the seed from mother plant is ceased due to breakage of vascular connection by the formation of abscission layer (Eastin *et al*., 1973) [10]. In the present study, the pattern of seed development and maturation in little millet was traced out to fix the optimum time and indices of physiological maturity for harvesting quality seeds.

In the present investigation, the observations made on the panicle characters revealed that fresh weight of panicle and seed observed a steady increase with advancement in maturity status up to 40 days and declined thereafter. The weight of panicle was also supported by the increase in morphological structure of panicle which was measured by the length of panicle. These observations attained their maximum value at 40 days after anthesis which was in increasing order up to that period. The fresh weight of developing seed increased continuously up to physiological maturity indicating the cessation of cell division during seed maturity (Noggle and Fritz, 1991) [21].

The moisture content of the panicle as well as the seed showed a steep and rapid decline from 5 DAA up to 40 DAA and subsequently showing rather a slow decrease (Fig.1). The panicle moisture content decreased much faster than the seed moisture content. The decrease in moisture content was associated with the development of seed inside the panicle as it was evident from the corresponding increase in the dry weight of seeds and the germination and vigour potential as revealed by the root length and dry matter content of seedlings. Such trend of reduction in moisture content was also reported in sorghum by Dahatonde and Adhao (1978) [8] and in pearl millet by Adib sultana *et al.* (1994) [3].

The fresh weight of seeds up to 40 days after anthesis (10.2 g) had also supported the fact that the seed development continued up to 40 days after anthesis in little millet **(fig.2)** Significant increase in 1000 seed weight up to 40 days after anthesis (3.6 g) had also supported the fact that the seed development continued up to 40 days after anthesis in little millet. This is in conformity with the finding of Javaregowda (1986) [18] in finger millet.

Seeds germinated only after 25 DAA, reaching the maximum at 40 DAA (38 per cent). It was at this stage that the dry weight of seeds was also at maximum (4.9 g). Similar increase in root length (7.1 cm) and shoot length (8.7 cm) at 45 DAA and in dry matter production (0.011 g) and vigour index values (578) at 40 DAA might be due to seeds which were provided with more energy in the growth process. Seed germination and seedling vigour were at their peak by physiological maturity at 48, 36, 52 and 44 DAA respectively in ragi, panivaragu, kuthiraivalli, thenai (Angamuthu and Karivaratharaju, 1974) [5] and at 50 DAA in italian millet (Kalavathi *et al.,* 2000).

The results of the study thus amply suggested that the physiological maturity of little millet [*Panicum sumatrense* Roth ex Roem. & Schult.] cv. CO (Samai) 4, occurred 40 days after anthesis with accumulation of maximum dry weight of panicle and seed accompanied with decrease in seed moisture content, higher germination and vigour parameters.

Conclusion

The bulk little millet [*Panicum sumatrense* Roth ex Roem. & Schult.] cv. CO (Samai) 4 crop was raised in the field. Individual panicles were tagged at the time of flower opening. The seeds were collected at 5 days intervals and subjected to the following seed quality assessment. Seed moisture content, 1000 seed weight, germination percentage, drymatter production and vigour index are the observations recorded. Studies on tracing the pattern of seed development and maturation through physical and physiological characters indicated that the seeds attained physiological maturation on 40 DAA with maximum of 1000 seed weight (3.6g), germination (38%) and vigour index (1978).

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