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Seed development and maturation in sword bean (*Canavalia gladiata* L.)

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Abstract
The experiment to trace the pattern of seed development and maturation in Sword bean conducted at the Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore revealed that the pods and seeds attained physiological maturity on 80 days after anthesis as evidenced by the maximum dry weight of the pod (183.3g) and seed (2.92g) combined with minimum moisture content of the pod (18.63%) and seed (14.77%). The change in colour of pod from green to brown and seed from green to dark red could be considered as a visible index of maturity. The seed quality parameters *viz*., germination (93%), dry weight of seed (2.92g), root length (20.87cm), shoot length (22.43cm), vigour index (4038.67), drymatter accumulation (8.11g) and protein content (14.75%) were also maximum at 80 days after anthesis.

Keywords: Sword bean, seed development, physiological maturity, drymatter accumulation

Introduction
Sword Bean (*Canvalia gladiate* L.) is underutilized vegetable crop propagated through seeds belongs to the Fabaceae family and widely distributed in South and Southeast Asia. Sword bean is self-pollinated photo-insensitive crop and climbing in nature. Flowers are white in colour. Sword bean seeds are rich in protein. Seeds are elliptical in shape with 3cm long and reddish in color.
Sword bean is a warm season crop (Li *et al.*, 2007; Huang, 2008) [18, 14] resistant to drought, pest and disease (Sagarika *et al*., 2000) [29]. It requires sufficient light and temperature for its growth and has good adaptability in all type of soil (Ma *et al.*, 2009) [19]. Since, Sword bean seeds have low fat and high protein content are being used in traditional medicine (Chen *et al*., 2001) [9]. Seeds have nutritional, medicinal and antivenom properties. It is a good source of antioxidant phenolicsn and used for treating against coughing, lower soring and pain around kidneys. (Duranti, 2006; Li *et al*., 2007) [10, 18].
Seed maturity is the crucial factor in determining the seed quality (Austin, 1972) [5] and it is a gradual preparation for germination of seeds (Bewley and Black, 1994) [7]. Quality of the seed is basically depending upon the nature of seed filling and metabolic as well as synthetic activities during seed developmental and maturation which in turn is reflected upon the germination and vigorous growth of seedlings. A study on tracing the pattern of seed development and maturation is highly essential to fix the optimum stage for seed harvest from the mother plant so as to obtain good quality seeds with assured germination and vigour. Early harvesting of crop before physiological maturity leads to reduction in yield and quality of seed and also favours development of immature seeds. Delaying of harvest after physiological maturity leads to decrease in viability and vigour and lower performance during storage. Therefore, a study on the development and maturation in Sword bean seeds involving physical, physiological parameters have to be undertaken to know about the exact time of harvest for exploiting fullest potential of germination, vigour index and seedling characters.

Materials and Methods
Sword Bean (*Canavalia gladiata.* L) seeds were obtained from Kerala Agricultural University, Thrissur formed the base material for this study. The experiment was conducted at Department of Vegetable Science, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to determine the physiological maturity of the seed. To trace the pattern of seed development and maturation, crop was raised with the spacing of 40× 30 cm with recommended agronomic practices during Rabi, 2019. Laboratory studies were conducted at Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during 2019-20.
During anthesis, large number of fully opened flowers were individually tagged and continued

up to completion of flowering. The developing pods were collected at 5 days interval from the day of anthesis (*ie*) 5 DAA to 85 DAA at five replications comprising ten pods per replication. At each interval, pod characters such as length, width, fresh weight, dry weight, pod moisture content and pod chlorophyll were recorded. Similarly, seed characters namely seed length, seed width, seed moisture content, fresh weight of seed, dry weight of the seed, seed chlorophyll and seed quality parameters such as 100 seed weight, germination percentage (ISTA,1999) [15], root length, shoot length, dry matter production, vigour index (Abdul Baki and Anderson, 1973) [1] and protein content were recorded.

For determining 100 seed weight, freshly harvested seeds taken from pod were counted in 8 replications of 100 seeds each and weighed and expressed in g. The germination test was carried out in four replicates of hundred seed in each maturation stage in germination room maintained at 25±1°c and 95±2 per cent relative humidity (RH) in sand medium as per ISTA (1999) [15]. After 14 days, normal seedling was counted (Vijay, 2020) and expressed in percentage. In each replication, 10 normal seedlings were selected and seedling lengths were measured. Dry matter production (mg per 10 seedlings) was measured by drying the seedlings in hot air oven maintained at 80±2°c for 24 h and cooled for 30 min in desiccator and weighed. Vigour index was calculated as per Abdul-Baki and Anderson (1973) [1]. Pod and seed chlorophyll content was calculated as per Arnon (1949) [3]. Protein content of seed was estimated by Ali-Khan and Youngs (1973) [2]. The data obtained from experiment were analyzed statistically by adopting the procedure described by Gomez *et al*., (1984) [11]. The percent values were transformed to angular (Arc-sine) value before analysis.

Result and Discussion

Seed maturation refers to the morphological, physiological and functional changes that occurred from the time of fertilization until the matured seed is ready for harvesting (Delouche, 1973). According to Harrington (1972) [12], physiological maturity is the stage at which the seed reaches its maximum dry weight and nutrient flow from mother plant to the seed ceases. The cessation of nutrient flow is due to breakage of vascular connection to the seed by the formation of an abscission layer at physiological maturity (Eastin *et al*., 1973). In seed production, harvesting of crop at physiological maturity determine the seed yield and quality. Harvesting at early stages results in immature and underdeveloped seeds and harvesting at later stage result in poor seed quality and seed yield. Physiological maturity indices show certain symptoms such as physical (yellowing and drying of plant, pods, change in seed coat and pod colour), physical and physiological indices (dry matter production, dry weight of seed, germination) which have been adopted for fixing physiological maturity in Sword bean.

Effect of maturation stage on pod character

In the present investigation, highly significant results were obtained for pod and seed characters. The fresh weight of pod increased with stages of development. The maximum fresh weight of the pod (233.5g) was recorded at 65 DAA and it started decreasing in later stages. The rapid pod growth at initial stages might be due to more uptake of water when the intake of carbon and nitrogen was comparatively low (Patel *et al*., 1977) [25]. Thereafter decreased drastically. This may be due to desiccation and dehydration of the pod and due to escape of nutrients and volatile substances in semi fluid state while desiccation. Initial increase in pod weight is due to rapid elongation and division. Dry weight of the pod increases steadily from 5 DAA (0.18g) and reached maximum on 80 DAA (183.83g) and it decreased during subsequent stages of development. Increase in dry weight of seed is continuous throughout the development period was observed and increase in dry weight coincides with decrease in moisture content indicating that accumulation of nutrients in developing seeds. At later stages due to reduced moisture content, respiration rate is at slower rate and caused higher dry weight at physiological maturity stages. Rao *et al*., (1978) [26] in black gram and Reshma (2001) [27] in Guinea grass also observed the similar results. The changes in pod development and maturation process might be due to development of zygote to matured seed. Pod length and pod width was maximum at 65 days after anthesis and thereafter no increase in length and width of pod was recorded (Figure 1). Similar results was reported by Arul prabhu, (1998) in pole beans.

Table 1: Influence of seed development and maturation on pod characteristics in Sword bean

Stages of pod development (Days after anthesis)	Pod length (cm)	Pod width (cm)	Fresh weight of the pod (g)	Dry weight of pod (g)	Pod moisture content (%)
5	5.6	0.5	1.6	0.18	88.67 (70.34)
10	10.1	1.1	4.7	0.68	85.52 (67.65)
15	13.5	1.4	11.6	2.23	80.63 (63.89)
20	18.6	1.7	23.5	5.40	76.95 (61.32)
25	22.4	1.9	40.8	12.37	69.71 (56.61)
30	24.4	2.0	82.6	27.34	67.21 (55.07)
35	25.7	2.1	126.0	41.55	67.02 (54.95)
40	26.4	2.1	144.5	46.84	66.74 (54.78)
45	27.5	2.2	165.5	57.74	65.12 (53.8)
50	28.5	2.2	177.5	72.31	59.24 (50.33)
55	29.1	2.2	185.4	93.16	49.76 (44.87)
60	29.6	2.3	226.3	145.97	35.51 (36.57)
65	30.1	2.5	233.5	164.96	28.45 (32.24)
70	30.1	2.5	231.8	174.54	24.80 (29.86)
75	30.1	2.5	227.2	180.88	20.36 (26.82)
80	30.1	2.5	226.0	183.83	18.63 (25.57)
85	30.0	2.5	224.8	183.83	16.50 (23.97)
Mean	24.22	2.01	137.25	81.99	54.2 (47.4)
S.Ed.	1.07	0.16	12.1	0.52	0.44
CD (P 0.05)	2.17	0.32	5.9	1.07	0.91

Figures in parentheses indicate transformed (arcsine) values

The initial loss of moisture in maturing pod is inherent phase of pod development (McIlrath *et al*., 1963). In the present study, pod moisture content was maximum on 5th day (88.67%) and it decreased during the subsequent stages of development. The loss of moisture content in pod with advancement in maturation correlated with dehydration and shrinking of pod as reported in lablab by Manohar (1970) and in soyabean by Sabir (1989) (Table 1).

Fig 1: Physiological maturity stages of pods

Pod chlorophyll content was maximum on 5th day and it decreases during subsequent stages of development. The changes in the colour of pods was observed during the stages of development is due to reduction of chlorophyll pigments which indicates the physiological maturity of seeds. The pod chlorophyll may contribute to meet the demand of developing seeds and to reduce the load of mother plant (Table 3).

Effect of maturation stage on physiological character of seeds: Seed quality parameter were influenced by different stage of maturity. The present study revealed that the seed moisture content was maximum on the 20th day (86.1%) and decreased during the subsequent stages of development due to maturation of seeds. The moisture content of seed decreased rapidly from 5 DAA to 85 DAA due to ripening and maturation of seeds. During maturation of seeds, higher dehydration was noticed (Manohar, 1970 and Natarajan *et al.*, 2008). The reduction in moisture content due to advancement of

Table 2: Influence of seed development and maturation on seed characteristics**.**

Stages of pod development (Days after anthesis)	Seed length (cm)	Seed width (cm)	Fresh weight of seed (g)	Dry weight of seed (g)	100 seed weight(g)	Protein content (%)	Moisture content of seed (%)
5	0	0	0	0	0	0	0 (0)
10	0	0	0	0	0	0	0 (0)
15	0	0	0	0	0	0	0 (0)
20	0.70	0.33	0.04	0.01	4.27	7.68 (16.09)	86.10 (68.12)
25	1.17	0.63	0.14	0.02	7.67	8.28 (16.72)	82.72 (65.46)
30	1.40	0.97	0.28	0.05	23.47	8.79 (17.25)	80.65 (63.9)
35	1.70	1.07	0.78	0.16	66.27	9.34 (17.8)	79.88 (63.35)
40	2.27	1.20	1.65	0.38	171.63	9.71 (18.16)	76.95 (61.32)
45	2.50	1.33	2.49	0.78	256.15	10.48 (18.89)	68.86 (56.1)
50	2.57	1.53	3.00	0.94	310.21	11.19 (19.54)	68.63 (55.86)
55	2.77	1.60	3.37	1.55	351.04	11.45 (19.78)	53.90 (47.24)
60	2.83	2.00	3.70	2.13	386.17	11.71 (20.01)	42.34 (40.61)
65	3.23	2.27	4.07	2.47	419.08	12.53 (20.73)	39.17 (38.74)
70	3.07	2.23	3.80	2.70	382.91	13.60 (21.64)	29.00 (32.55)

75	2.97	2.07	3.63	2.80	359.18	14.20 (22.14)	22.93 (28.61)
80	2.97	2.00	3.43	2.92	339.70	14.75 (22.52)	14.77 (22.6)
85	2.90	1.97	3.32	2.87	335.93	14.37 (22.27)	13.46 (21.52)
Mean	1.94	1.25	1.98	1.16	200.8	9.29 (17.74)	44.67 (41.94)
S.Ed.	0.05	0.05	0.06	0.04	2.11	0.16	0.86
CD (P 0.05)	0.09	0.10	0.11	0.07	4.30	0.33	1.76

Figures in parentheses indicate transformed (arcsine) values

maturity of seed might be due to desiccation and dehydration (Abdul-Baki and Anderson, 1973) [1]. The decrease in moisture content accompanied with increase in dry weight of seeds up to 85 days after anthesis indicated the continuous accumulation of food reserves in the developing seeds (Metha *et al.*, 1993). This coincides with increase in dry weight where the flow of nutrients was stopped from the mother plant to seed.

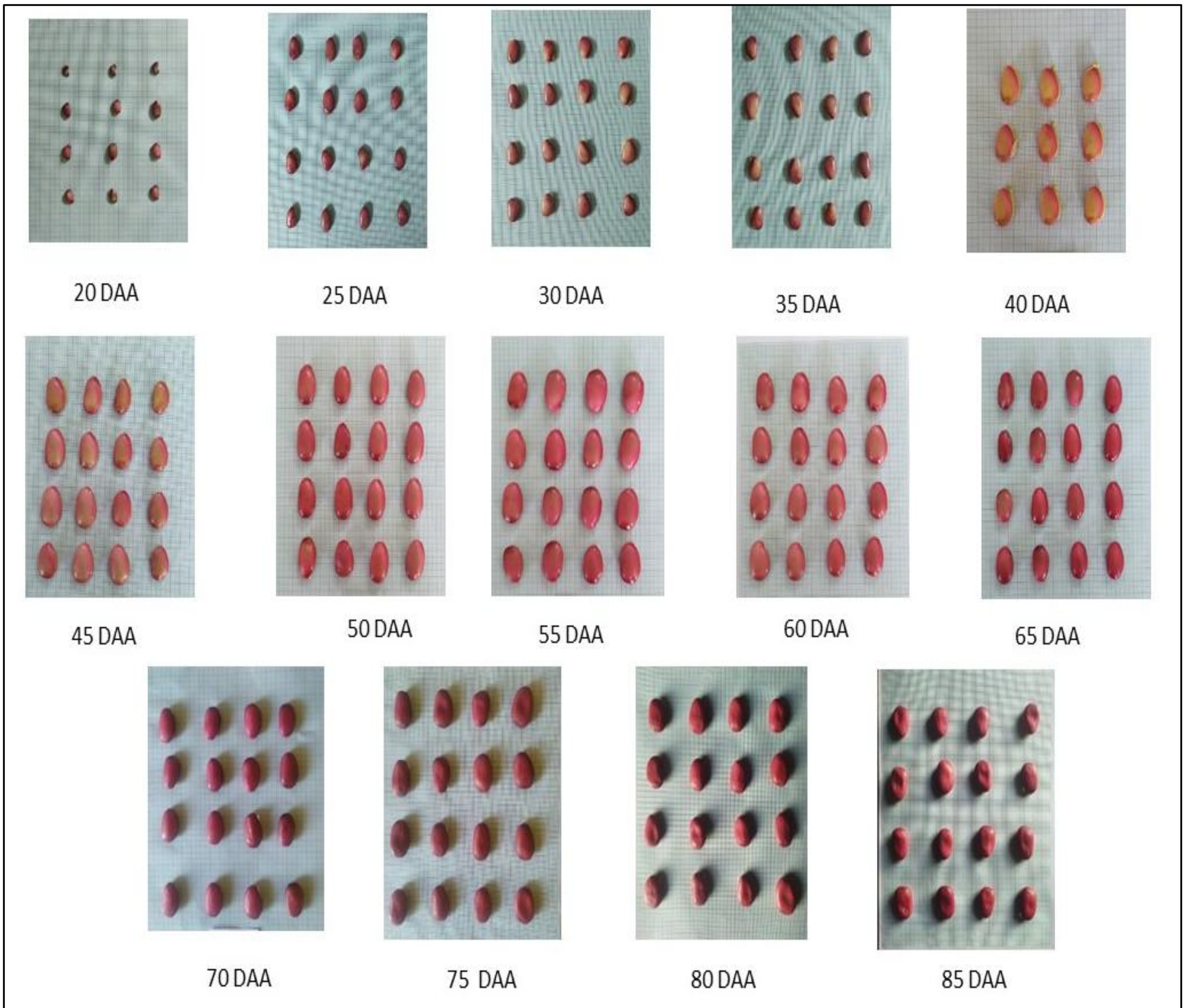

Fig 2: Physiological maturity stages of seeds

Fresh weight and 100 seed weight showed rapid increase and reaches maximum at 65 days after anthesis (4.07g and 419.08g, respectively) and there after reduction was noticed (3.32g and 335.93g respectively) at 85 days after anthesis. The reduction of moisture content of the seed are due to escape of nutrients and volatile substances in semi fluid state by drying. The loss of moisture content of seed is due to maturation of seeds. Dry weight of seed reaches maximum on the 80 days after anthesis (2.92g) and decreased thereafter. Increase in dry weight of seed is continuous throughout the development period which coincides with decrease in moisture content indicating that accumulation of nutrients in developing seeds (Mathews, 1973) [21]. Both length and breadth of seeds showed rapid increase and reaches maximum on 65 days after anthesis (3.23cm and 2.27cm) and thereafter slight reduction was noticed at 85 DAA (2.90cm and 1.97cm). Initially rapid increase in seed size is due to cell expansion and the seed is acting as sink (accumulation of dry matter). Similar reports were reported by Arul prabhu (1998) [4] in pole beans and Sundareswaran (2011) [30] in ambrette (Table 2). Seed chlorophyll content was maximum on the 5th day after anthesis and it decreased during subsequent stages of development content. The seed colour was initially green in colour and thereafter colour changes into red and finally seed became dark red in colour due to accumulation of pigments. Once the seed attained physiological maturity, the photosynthetic material reduced and there after chlorophyll content started to disappear and appearance of pigments and characteristics colour in seed (Figure 2). This was also in accordance with Surendhar (2018) [31] in tomato (Table 3).

Table 3: Pod and seed chlorophyll content

Stages of pod development (Days after anthesis)	Pod Chlorophyll A (mg)	Pod Chlorophyll B (mg)	Pod Total chlorophyll (mg)	Seed Chlorophyll A (mg)	Seed Chlorophyll B (mg)	Seed Total chlorophyll
5	0.98	0.56	1.44	0.00	0.00	0.00
10	0.93	0.53	1.37	0.00	0.00	0.00
15	0.86	0.45	1.25	0.00	0.00	0.00
20	0.82	0.42	0.97	0.46	0.35	0.22
25	0.75	0.34	0.88	0.35	0.30	0.15
30	0.67	0.28	0.85	0.23	0.19	0.10
35	0.65	0.25	0.80	0.14	0.15	0.08
40	0.64	0.24	0.72	0.07	0.09	0.07
45	0.62	0.22	0.56	0.06	0.08	0.06
50	0.42	0.17	0.44	0.06	0.07	0.05
55	0.37	0.14	0.15	0.06	0.07	0.05
60	0.16	0.09	0.05	0.05	0.06	0.03
65	0.01	0.02	0.01	0.02	0.04	0.02
70	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.46	0.22	0.56	0.09	0.08	0.05
SED	0.01	0.01	0.02	0.01	0.01	0.01
CD (P 0.05)	0.02	0.02	0.03	0.02	0.02	0.02

Germination capacity is the prime indicator of seed quality as the final produce will become seed, only on gaining capacity for regeneration. Among the physiological manifestations of the seed, germination plays a vital role in physiological maturity. In the present study, the seeds were capable of germination to an extent of 37 percent on 45 DAA and it increased with advances in maturity and reached the maximum of 93 percent at 80 days after anthesis which coincided well with the accumulation of the maximum dry weight of the seed. The increasing trend in germination percent during the developmental stages and attainment the maximum germination might be due to the accumulation of maximum dry matter associated with decrease in seed moisture. Similar increase in germination with increase in maturity was also reported by Demir and Samit (2001) in tomato.

Table 4: Influence of seed development and maturation on seedling characteristics

Stages of pod development (Days after anthesis)	Germination (%)	Root length (cm)	Shoot length (cm)	Drymatter (mg per 10 seedlings)	Vigour index
45	37 (37.22)	7.30	12.13	3.79	711.67
50	50 (45)	9.07	13.90	5.37	1148.67
55	63 (52.78)	12.27	16.83	6.57	1849.67
60	63 (52.78)	13.30	18.60	7.18	2023.00
65	73 (59)	15.00	20.10	7.49	2577.67
70	77 (61.22)	16.60	20.87	7.75	2872.67
75	80 (63.43)	18.70	21.43	7.90	3210.67
80	93 (77.71)	20.87	22.43	8.11	4038.67
85	83 (66.14)	20.20	21.33	7.93	3460.00
Mean	36.47 (37.15)	7.84	9.86	3.65	1287.81
SED	3.53	0.39	0.31	0.94	103.10
CD (P 0.05)	7.42	0.79	0.63	1.91	210.02

Figures in parentheses indicate transformed (arcsine) values

Woodstock and Comb (1964) [33] coined root and shoot length are the measure of seedling vigour as they reveal the performance of the seed under given environmental conditions. The root and shoot length of the seedlings were also increased significantly upto 80 DAA (20.87cm and 22.43cm) which was in coincidence with stages of dry weight of the seed and seed germination. This could be attributed to maximum dry matter accumulation of the seeds, which might have provided more energy in the growth process (Tupper, 1969) [32]. Dry matter production of seedlings was attributed as manifestation of the physiological efficiency dependent of seed vigour (Heydecker, 1973) [13]. Seedling dry matter reaches maximum at 80 DAA (8.11g) and thereafter dry matter production decreased slightly due to the development of inbuilt mechanism that involved in the disorganization of cell organelles in the few days after physiological maturity (Mathew, 1973) [21]. Vigour as the inherent ability of seed to survive well in wide range of condition (Hey decker, 1972). The computed vigour index values of the present study were maximum at 80 DAA (4038.67) which coincides well with germination, dry weight and seedling vigour characters which were all considered as one of the indices of seed maturation. Protein accumulation occurred continuously until maturity in developing seeds. But in present study, protein content was maximum at 80 DAA (14.75 per cent). At physiological maturity high protein accumulation may be due to the synthesis and deposition of protein in the seed. After physiological maturity protein content is decreased due to desiccation. Similar result was also reported by Arul prabhu (1998) [4] in pole beans (Table 4).

Pod colour is the visual index of seed maturation in pod and seed (Sundareswaran, 2011) [30]. In pods colour changes from green to greenish yellow to yellowish brown to brown colour, where brown colour coincides with 80 DAA the predicted day of maturation with physiological status of seed. In seeds colour changes from green to orange red to red to dark red in colour with maturation. Dark red colour coincides with 80 DAA the physiological maturity stage of the seed. As the seed matured, the integumentary vascular system was destroyed, which coincided with turning of seed coat colour as reported by Carlson (1973) [8]. Similar results in change of seed colour were also reported by Baruah and Paul (1997) [6] in okra and Sundareswaran (2011) [30] in Ambrette.

From this study, the results revealed that the physiological maturity of seeds in Sword bean could be fixed at 80 days after anthesis which coincides with maximum pod characters and seed germination, seedling length, vigour, dry matter production and protein.

Conclusion

The present study on tracing the physiological maturity of Sword bean through physical and physiological characters revealed that the Sword bean seeds could attain physiological maturity on 80 days after anthesis with maximum of dry weight (2.92mg), germination (93%), vigor index (4038.67), protein content (14.75%), root length (20.87cm), and shoot length (22.43cm).The visual indices for maturation with turning of pod colour to brown and seed to dark red colour at 80 days after anthesis. Hence for obtaining better seed quality the crop could be harvested at 80 days after anthesis.

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References

1. Abdul-Baki AA, Anderson JD. Vigour determination in soybean seed by multiple criteria. Crop Sci 1973;13:630-633.
2. Ali-Khan ST, Youngs CG. Variation in protein content of field peas. Canadian journal of Plant science 1973;53(1):37-41.
3. Arnon, Daniel I. Copper enzymes in isolated chloroplasts. Polyphenol oxidase in Beta vulgaris. Plant physiology 1949;24(1):1-8
4. Arul Prabhu. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 1998.
5. Austin RB. Effects of environment before harvesting on viability. Viability of seeds Chapman and Hall, London, 1972, 114-149.
6. Baruah GKS, Paul SR. Seed development and mutation studies in okra (*Abelmoschus esculentus*). Ann. Agric. Res 1997;18:367-368.
7. Bewley JD, Black M. Physiology and biochemistry of seeds in relation to germination. Vol. 2. Springer - Verlag. Berlin, 1994,77-94.
8. Carlson JB. Morphology. In: Soyabeans improvement, production and uses (Ed. B.E. cald well), American Society of Agronomy, 1973, 12-28.
9. Chen H *et al*. Atlas of the Traditional Vegetables in China (in Chinese). Zhejiang Science and Technology Publishing House, Zhejiang Province, China 2001;40:147-159.
10. Duranti M. Grain legume proteins and nutraceutical properties. Fitoterapia 2006;77:67-82.
11. Gomez KA, Gomez AA. Statistical procedures for agricultural research of legumes seeds of different density. Agriculture 1984;41:47-56.
12. Harrington JF. Seed storage and longevity, In: Seed biology. (Ed: T.T. Kozlowski) Academic Press. New York & London, 1972, 145-245.
13. Heydecker W. Vigour. In: Viability of seeds (Ed. E.H. Roberts), Chapman and Hall, London, 1973, 209-252.
14. Huang YF. The characteristics of French sword bean and high yield techniques of French sword bean cultivation (in Chinese). China Fruit and Vegetable 2008;1:18.
15. ISTA, International Rules for Seed Testing. Seed Sci. & Technol. Supplement Rules. 1999;27:25-30.
16. Karivaratharaju TV. Studying seed maturation aspects to fix maximum physiological maturity to achieve maximum vigour and dry weight. Tamil Nadu Agricultural University, Coimbatore, 1974.
17. Kathiravan M. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 2001.
18. Li N, Li X, Feng ZG, Masayuki Y. Chemical constituents from Canavalia gladiate (in Chinese). Journal of Shenyang Pharmaceutical University. 2007;24(11):676-678.
19. Ma DX *et al*. Sword bean. In: Cultivation of Chinese Vegetables (in Chinese) Second Ed, China Agriculture Press, Beijing China, 2009, 787-789.
20. Manohar MS. Seed development and germination studies on lablab. Indian J Hort. 1970;27(1, 2):86-92.
21. Mathews S. The effect of time of harvest on the viability and pre-emergence mortality of pea (*Pisum sativum* L.) seeds in soil. Ann. Appl. Biol 1973;73(2):211-219.
22. McIlrath WJ, Abrol YP, Heiligman F. Dehydration of seeds in intact tomato fruits. *Science*, 1963;142:1681.
23. Metha CJ, Kuhad MS, Sheoran IS, Nandwal AS. Studies on seed development and germination in chickpea cultivars. Seed Res. 1993;21:89-91.
24. Natarajan K, Srimathi P. "Studies on seed development and maturation in petunia." Reseach Journal of Agriculture and Biological Sciences. 2008;4(5):585-590.
25. Patel JS, Sharkey PJ, Atkins CA. Nutrition of developing legume fruit. Plant Physiol 1977;59:506-510.
26. Rao SP, Appa Rao S, Mukherjee RK. Indian J Agric. Res. 1978;12(3):191-194.
27. Reshma C. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 2001.
28. Sabir-Ahamed A. Studies on the production of quality seed and storage in soybean (*Glycine max* (L.) Merrill.). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 1989.
29. Sagarika E, Jansz ER, Bamboo M, Nair. Plant foods for human nutrition 2000;55:305-321.
30. Sundareswaran S, Sathish S, Vijayakumar A. Seed development and maturation studies in ambrette (*Abelmoschus moschatus* Medic.). Madras Agricultural Journal 2011;98(1-3):29-32.
31. Surendhar. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 2018.
32. Tupper CR. P hysical characteristics of cotton seed related to seedling vigour and design parameters for seed selection. Ph.D. Thesis, Texas A and M Univ. College Station, 1969.
33. Woodstock LW, Combs MF. A comparison of some possible indices of seedling vigour in corn. Proc. Assoc. Off. Seed Anal 1964;54:50-60.
34. Vijay. Msc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, 2020.