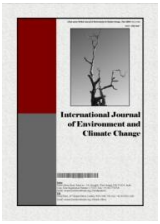

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# Pattern of Capsule and Seed Development in Sesame (*Sesamum indicum* L.) as Influenced by Seed Priming

**Utpal Biswas[1*], Rupa Das[1] and Amitava Dutta[1]**

*[1]Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia (W.B.)-741252, India.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. Author UB managed the work, wrote the paper and performed the statistical analysis. Author RD helped author UB during the experiment. Author AD planned the experiment and guided as and when required. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** To study the influence of seed priming on the pattern of capsule and seed development in sesame.
**Place and Duration of Study:** The field experiment was conducted during the pre kharif seasons of 2017-2018 and 2018-2019 in sesame variety Savitri at AB Block farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India.
**Methodology:** Experiment was laid out in split plot design with 3 replications. Ten schedules of seed priming *viz* $T_1$ ($KNO_3$ @ 10 mM), $T_2$ ($KNO_3$ @ 20 mM), $T_3$ ($KNO_3$ @ 50 mM), $T_4$ ($KH_2PO_4$ @ 50 mM), $T_5$ ($KH_2PO_4$ @ 100 mM),$T_6$ ($KH_2PO_4$ @ 200 mM), $T_7$ [Polyethylene glycol (PEG) 6000 @ -0.4 MPa], $T_8$ [Polyethylene glycol (PEG) 6000 @ -0.3 MPa], $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa], $T_{10}$ Distilled water (Hydro priming) along with control $T_{11}$ (Dry seed) were taken as main plot treatment and stage of harvest was considered as sub plot treatment. The pattern of capsule and seed development was studied at 10 days after anthesis (DAA), 20 days after anthesis (DAA), 30 days after anthesis (DAA), 40 days after anthesis (DAA) and 50 days after anthesis (DAA)

**Corresponding author: E-mail: biswasutpal70@gmail.com;*

interval. Ten plants from each replication and in each treatment were selected at random to record data on morphological and physiological characters.
**Results:** Fresh capsule length, fresh capsule breadth, fresh capsule weight, fresh seed weight and dry seed weight showed a steady increase up to 40 days after anthesis (DAA) then decreased slowly up to maturity.
**Conclusion:** Considering seed yield and quality parameters, $T_7$ [Polyethylene glycol (PEG) 6000 @ -0.4 MPa] and $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa] appears to be ideal among the treatments for quality seed production in sesame.

*Keywords: Capsule development; priming; seed development; seed quality.*

## 1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is the earliest domesticated plant of India and an important edible oilseed crop cultivated throughout the world. India ranks second in sesame production and first in area by contributing 23.2% and 13.1% of the world production and area respectively [1]. In India the crop is cultivated on 15.80 lakh hectares with 7.55 lakh tonnes of production and a productivity of 478 kg $ha^{-1}$ (2017-2018). In West Bengal during 2016-2017 sesame was grown in 2.32 lakh hectares area with 2.18 lakh tonnes of production and a productivity of 933 kg $ha^{-1}$ [Source: Ministry of Agriculture and Farmers Welfare, Government of India (ON1704)].

There is an increasing domestic and international demand of sesame due to its excellent medicinal and cooking qualities. The productivity can be enhanced through proper crop management practices as well as improving the seed quality. High quality seed is essential for better field establishment and productivity of sesame. The indeterminate growth habit of sesame and shattering of capsule during maturity hampers the seed quality. If plants are harvested too early then the quality of seed is reduced by the inclusion of immature seed from near the top of the plants. If plants are harvested too late then yield may be reduced by loss of seed due to earliest maturity capsules. Seeds attain maximum quality when the crop is in physiological maturity stage. Seed maturation refers to the morphological, physiological and functional changes that occur from the time of fertilization until the mature seeds are ready to harvest. Tracing the sequence of seed development and fixing the time for maturity have more practical utility in getting higher quality seeds. Lack of optimum plant population resulting from poor germination and seedling vigour is a major problem affecting the productivity of sesame [2]. Seed priming is an excellent technique which enhances uniform germination, increased vigour and establish crop at early growth stage. The advantage of seed priming in reducing the germination time and improving emergence uniformity is well established. This technique generally enhances pre-germination metabolic activity prior to emergence of radical and plant performance which influence in capsule and seed development. Therefore the present investigation aims at maximize yield of quality seed and to assess seed maturity in relation to capsule maturity.

## 2. MATERIALS AND METHODS

The field experiment was conducted during the pre kharif seasons of 2017-2018 and 2018-2019 in sesame variety Savitri at AB Block farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani (23.5° North Latitude and 89.0° East Longitude with an altitude of 9.75 m above the mean sea level) in West Bengal. After ploughing for a good seed bed preparation, fertilizers were applied @ N: $P_2O_5$:$K_2O$ @ 40:40:40 kg/ha as basal and another 40 kg N was applied at 30 days after sowing. Seeds were sown at a row spacing of 30 cm and 15 days after sowing thinning was done, maintaining plant to plant spacing of 10 cm. The recommended agronomic practices and plant protection measures were adopted for raising a good crop. Experiment was laid out in split plot design with 3 replications. Ten schedules of seed priming *viz* $T_1$ ($KNO_3$ @ 10 mM), $T_2$ ($KNO_3$ @ 20 mM), $T_3$ ($KNO_3$ @ 50 mM), $T_4$ ($KH_2PO_4$ @ 50 mM), $T_5$ ($KH_2PO_4$ @ 100 mM),$T_6$ ($KH_2PO_4$ @ 200 mM), $T_7$ [Polyethylene glycol (PEG) 6000 @ -0.4 MPa], $T_8$ [Polyethylene glycol (PEG) 6000 @ -0.3 MPa], $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa], $T_{10}$ Distilled water (Hydro priming) along with control $T_{11}$ (Dry seed) were taken as main plot treatment and stage of harvest was considered as sub plot treatment. The pattern of capsule and seed development was studied at 10 days after anthesis (DAA), 20 days after anthesis (DAA), 30 days after anthesis (DAA), 40

days after anthesis (DAA) and 50 days after anthesis (DAA). Ten plants from each replication and in each treatment were selected at random to record data on morphological and physiological characters. Before sowing seeds were soaked for 6 hours in priming solution then washed with distilled water and dried to original moisture at room temperature. The seed quality characters were estimated at the laboratory of department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia by following the method as prescribed by ISTA. Data on various characters were analysed by analysis of variance [3] and OPSTAT software programme [4].

## 3. RESULTS AND DISCUSSION

### 3.1 Capsule and Seed Development

Fresh capsule length, fresh capsule breadth, fresh capsule weight, fresh seed weight and dry seed weight are important parameters for seed quality and yield of sesame. Sesame seeds and capsule expanded together during early development. Thomas [5] claims that morphologically and biochemically, the most dramatic events of seed development occur during maturation. During maturation, the developing seed increases considerably in volume and mass due to significant cell expansion and the accumulation and storage of proteins, lipids and carbohydrates [6,7,8]. Data presented in Table 1 revealed that Fresh capsule length recorded a significant variation among the treatments, stage of growth as well as interaction between them. Among the treatments $T_1$ ($KNO_3$ @ 10 mM) recorded maximum fresh capsule length during both the years. Maximum fresh capsule length was recorded at 40 days after anthesis (DAA) though it was continuously increased upto 40 days after anthesis (DAA), there after slightly reduced at 50 days after anthesis (DAA). The fresh capsule breadth increased up to 40 days after anthesis (DAA) reached their maximum values and then decreased slowly up to maturity. Maximum fresh capsule breadth was observed at 40 days after anthesis (DAA) and among the treatments $T_2$ ($KNO_3$ @ 20 mM) recorded maximum value during both the years. Fresh capsule breadth followed significant variation among the treatments, stage of growth and interaction between treatments and stage of growth during both the years. The characters fresh capsule weight, fresh seed weight, dry seed weight showed a rapid initial increase up to 40 days after anthesis (DAA) and reached the maximum value followed by gradual decrease up to maturity during both the years. Throughout the course of development the seeds undergo changes in both fresh and dry weight and in moisture content. Between 10 and 30 DAA, both fresh and dry weights increase very rapidly. In developing seeds fresh weight continues to increase slowly between 30 and 40 DAA. This enhancement was a result of dry mass accumulation. During this period reserve material accumulation occurs with such intensity that fresh weight goes on increasing in spite of the decrease in water content which has already begun. Among the treatments $T_7$ [Polyethylene glycol (PEG) 6000 @ -0.4 MPa] followed by $T_6$ ($KH_2PO_4$ @ 200 mM) recorded maximum value and reached maximum value at 40 days after anthesis (DAA) then decreased slowly at 50 days after anthesis (DAA) during both the years. Fresh capsule weight, fresh seed weight and dry seed weight were recorded significant variation among the treatments, stage of capsule development as well as interaction between them during both the years.

This indicated that the physiological maturity in sesame as measured by attainment of maximum dry seed weight, have reached between 40 and 50 days after anthesis (DAA). A similar study in sesame was reported by Monalisa et al. [9], where physiological maturity of sesame seeds attained between 35 to 42 days after anthesis where the dry matter, germination and vigour at their maximum value.

### 3.2 Physiological Parameters

The seed quality parameters of harvested seed from 10 days after anthesis (DAA) to 50 days after anthesis (DAA) at 10 days interval were assessed in the laboratory. Up to 20 days after anthesis (DAA) there was no germination of the seed. From 30 days after anthesis (DAA) up to 50 days after anthesis (DAA), there was progressive increase of germination percentage (Table 2). Freshly harvested sesame seeds were capable of germinating during 30 DAA but germinating capacity is very low. Analysis of variance indicated that germination percentage recorded a significant variation among the treatments as well as under stage of growth; but interaction between treatments and stage of growth, recorded non significant variation during both the years. In this study treatment agent, PEG 6000 showed higher germination percentage than that of control.

**Table 1. Effect of seed priming chemicals on morphological parameters**

| | Fresh capsule length (mm) | | | Fresh capsule breadth (mm) | | | Fresh capsule weight (mg capsule$^{-1}$) | | | Fresh seed weight (mg seed$^{-1}$) | | | Dry seed weight (mg seed$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment (T)** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** |
| $T_1$ | 27.54 | 27.89 | 27.72 | 8.09 | 8.22 | 8.16 | 695.67 | 674.47 | 685.07 | 3.30 | 3.26 | 3.28 | 2.18 | 2.17 | 2.18 |
| $T_2$ | 27.07 | 27.06 | 27.07 | 8.33 | 8.25 | 8.29 | 717.20 | 737.27 | 727.24 | 3.36 | 3.33 | 3.35 | 2.23 | 2.22 | 2.23 |
| $T_3$ | 25.95 | 25.68 | 25.82 | 7.48 | 7.47 | 7.48 | 693.27 | 683.27 | 688.27 | 3.33 | 3.31 | 3.32 | 2.23 | 2.21 | 2.22 |
| $T_4$ | 27.28 | 27.11 | 27.20 | 8.09 | 8.07 | 8.08 | 694.47 | 701.67 | 698.07 | 3.26 | 3.29 | 3.28 | 2.13 | 2.18 | 2.16 |
| $T_5$ | 27.21 | 27.16 | 27.19 | 7.96 | 8.01 | 7.99 | 742.80 | 744.47 | 743.64 | 3.38 | 3.36 | 3.37 | 2.22 | 2.24 | 2.23 |
| $T_6$ | 26.91 | 26.96 | 26.94 | 7.48 | 7.40 | 7.44 | 735.47 | 753.93 | 744.70 | 3.34 | 3.37 | 3.36 | 2.20 | 2.24 | 2.22 |
| $T_7$ | 26.36 | 26.55 | 26.46 | 7.89 | 7.81 | 7.85 | 764.27 | 772.20 | 768.24 | 3.42 | 3.41 | 3.42 | 2.25 | 2.27 | 2.26 |
| $T_8$ | 25.87 | 25.79 | 25.83 | 7.70 | 7.55 | 7.63 | 712.93 | 705.33 | 709.13 | 3.30 | 3.34 | 3.32 | 2.18 | 2.23 | 2.21 |
| $T_9$ | 25.82 | 25.81 | 25.82 | 7.80 | 7.62 | 7.71 | 727.13 | 745.53 | 736.33 | 3.36 | 3.34 | 3.35 | 2.23 | 2.21 | 2.22 |
| $T_{10}$ | 26.59 | 26.76 | 26.68 | 7.66 | 7.64 | 7.65 | 672.13 | 664.53 | 668.33 | 3.23 | 3.24 | 3.24 | 2.15 | 2.15 | 2.15 |
| $T_{11}$ | 26.42 | 26.44 | 26.43 | 7.48 | 7.33 | 7.41 | 660.33 | 669.20 | 664.77 | 3.23 | 3.18 | 3.21 | 2.14 | 2.12 | 2.13 |
| SEm (±) | 0.13 | 0.08 | | 0.06 | 0.07 | | 8.92 | 8.44 | | 0.03 | 0.01 | | 0.01 | 0.01 | |
| CD at 5% | 0.40 | 0.23 | | 0.18 | 0.20 | | 25.03 | 23.70 | | 0.07 | 0.04 | | 0.03 | 0.03 | |
| **Stage of crop (S)** | | | | | | | | | | | | | | | |
| 10 DAA | 25.81 | 25.83 | 25.82 | 6.99 | 6.99 | 6.99 | 610.52 | 606.06 | 608.29 | 3.08 | 3.05 | 3.07 | 1.21 | 1.21 | 1.21 |
| 20 DAA | 26.68 | 26.65 | 26.67 | 7.97 | 7.79 | 7.88 | 659.15 | 658.39 | 658.77 | 3.22 | 3.17 | 3.20 | 1.40 | 1.39 | 1.40 |
| 30 DAA | 26.87 | 27.08 | 26.98 | 8.05 | 7.90 | 7.98 | 719.67 | 741.73 | 730.70 | 3.40 | 3.39 | 3.40 | 2.34 | 2.31 | 2.33 |
| 40 DAA | 27.15 | 27.13 | 27.14 | 8.18 | 8.19 | 8.19 | 785.39 | 786.30 | 785.85 | 3.52 | 3.58 | 3.55 | 3.12 | 3.17 | 3.15 |
| 50 DAA | 26.67 | 26.59 | 26.63 | 7.88 | 7.94 | 7.91 | 777.85 | 776.55 | 777.20 | 3.37 | 3.37 | 3.37 | 2.90 | 2.94 | 2.92 |
| SEm (±) | 0.09 | 0.06 | | 0.05 | 0.04 | | 6.01 | 5.69 | | 0.02 | 0.01 | | 0.01 | 0.01 | |
| CD at 5% | 0.26 | 0.17 | | 0.15 | 0.11 | | 16.87 | 15.98 | | 0.05 | 0.03 | | 0.02 | 0.02 | |
| **Interaction (T×S)** | | | | | | | | | | | | | | | |
| SEm (±) | 0.30 | 0.17 | | 0.13 | 0.15 | | 19.94 | 18.88 | | 0.06 | 0.03 | | 0.02 | 0.02 | |
| CD at 5% | 0.87 | 0.58 | | 0.50 | 0.36 | | 55.97 | NS | | 0.16 | 0.09 | | 0.06 | 0.07 | |

**Table 2. Effect of seed priming chemicals on physiological parameters**

| | Seed germination (%) | | | Root length (cm) | | | Shoot length (cm) | | | Vigour index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment (T)** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** | **1st year** | **2nd year** | **Mean** |
| $T_1$ | 58.3 | 59.00 | 58.65 | 8.18 | 8.18 | 8.18 | 2.94 | 2.95 | 2.95 | 660.57 | 668.70 | 664.64 |
| $T_2$ | 55.3 | 55.79 | 55.55 | 7.38 | 7.66 | 7.52 | 2.80 | 2.77 | 2.79 | 576.38 | 593.28 | 584.83 |
| $T_3$ | 59.4 | 60.93 | 60.17 | 8.48 | 8.64 | 8.56 | 2.83 | 2.99 | 2.91 | 701.60 | 732.44 | 717.02 |
| $T_4$ | 56.7 | 58.37 | 57.54 | 7.95 | 8.15 | 8.05 | 3.01 | 3.23 | 3.12 | 632.57 | 679.05 | 655.81 |
| $T_5$ | 53.4 | 54.07 | 53.74 | 8.68 | 8.61 | 8.65 | 2.63 | 2.67 | 2.65 | 623.66 | 630.16 | 626.91 |
| $T_6$ | 55.8 | 57.32 | 56.56 | 7.45 | 7.77 | 7.61 | 2.91 | 3.03 | 2.97 | 606.76 | 645.04 | 625.90 |
| $T_7$ | 58.1 | 59.31 | 58.71 | 7.79 | 7.89 | 7.84 | 2.75 | 2.81 | 2.78 | 629.21 | 652.24 | 640.73 |
| $T_8$ | 56.9 | 57.94 | 57.42 | 8.21 | 8.27 | 8.24 | 2.73 | 2.70 | 2.72 | 641.88 | 651.22 | 646.55 |
| $T_9$ | 61.1 | 61.66 | 61.38 | 8.17 | 8.26 | 8.22 | 2.96 | 3.19 | 3.08 | 707.08 | 734.71 | 720.90 |
| $T_{10}$ | 52.6 | 54.23 | 53.42 | 8.12 | 7.80 | 7.96 | 2.72 | 2.67 | 2.70 | 602.96 | 590.15 | 596.56 |
| $T_{11}$ | 51.4 | 53.13 | 52.27 | 7.64 | 7.56 | 7.60 | 2.76 | 2.49 | 2.63 | 569.58 | 558.66 | 564.12 |
| SEm (±) | 1.81 | 1.44 | | 0.25 | 0.13 | | 0.15 | 0.11 | | 24.64 | 20.10 | |
| CD at 5% | 5.12 | 4.08 | | 0.72 | 0.35 | | NS | 0.32 | | 69.76 | 56.92 | |
| **Stage of crop (S)** | | | | | | | | | | | | |
| 10 DAA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 DAA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 DAA | 16.69 | 17.36 | 17.03 | 7.12 | 7.37 | 7.25 | 2.65 | 2.67 | 2.66 | 163.21 | 174.86 | 169.04 |
| 40 DAA | 66.21 | 67.82 | 67.02 | 8.29 | 8.19 | 8.24 | 2.83 | 2.89 | 2.86 | 736.62 | 751.90 | 744.26 |
| 50 DAA | 85.91 | 87.12 | 86.52 | 8.60 | 8.66 | 8.63 | 2.99 | 3.03 | 3.01 | 996.24 | 1019.34 | 1007.79 |
| SEm (±) | 0.94 | 0.75 | | 0.13 | 0.07 | | 0.08 | 0.06 | | 12.87 | 10.50 | |
| CD at 5% | 2.67 | 2.13 | | 0.37 | 0.19 | | 0.22 | 0.17 | | 36.43 | 29.73 | |
| **Interaction (T×S)** | | | | | | | | | | | | |
| SEm (±) | 3.13 | 2.49 | | 0.44 | 0.22 | | 0.26 | 0.20 | | 42.67 | 34.81 | |
| CD at 5% | NS | NS | | NS | NS | | NS | NS | | NS | NS | |

Haigh and Barlow [10] said ion concentration accumulation in osmotic priming seed would be in proportion to the time of treatment agent which would decrease metabolic mechanism of seed. Among the treatments $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa] recorded maximum germination percentage on different seed development stage during both the years. The ability of seeds to germinate is related to developmental stage (time from anthesis), degree of desiccation and rate of the imposed drying treatment [11]. Root length, shoot length and vigour index values were taken from 30 days after anthesis (DAA) to 50 days after anthesis (DAA) as germination of seed was attained at 30 days after anthesis (DAA). Root length recorded significant variation among the treatments as well as stage of growth during both the years but they followed non significant variation under interaction between treatments and stage of growth during both the years. Among the treatments $T_5$ ($KH_2PO_4$ @ 100 mM) during first year and $T_3$ ($KNO_3$ @ 50 mM) followed by $T_5$ ($KH_2PO_4$ @ 100 mM) during second year recorded maximum root length. Over the two years maximum root length was observed in $T_5$ ($KH_2PO_4$ @ 100 mM). Among the treatments, shoot length recorded non significant variation during first year but there was significant variation during second years. Different stage of growth recorded significant variation during both the years. Interaction between treatments and stage of growth recorded non significant variation during first year and second year for shoot length. $T_4$ recorded maximum shoot length under different treatment as well as mean value during both the years. Vigour index followed significant variation under treatments as well as stage of growth but interaction between treatments and stage of growth followed non significant variation during both the years. Vigour index was maximum in $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa] under different treatments as well as mean value during both the years. The improvement in seed germination and vigour were associated with dry matter accumulation in the developing seeds. Root length shoot length and vigour index value was maximum at 50 days after anthesis during both the years.

In a similar study Rajasekaran et al. [12] reported that although germination of seed attained after 15 days after anthesis (DAA), the maximum germination percentage was observed at 25 days after anthesis (DAA).

The root length, shoot length and vigour index showed similar trends of improvement like germination in present investigation. The results of the study suggested that physiological maturity of sesame seed attained at 50 days after anthesis (DAA) where germination and vigour were at maximum value.

## 4. CONCLUSION

It can be concluded that physiological maturity of sesame seeds attained between 40 to 50 days after anthesis (DAA) where the dry matter, germination and vigour were at their maximum value. Considering the boldness of capsule and seed $T_7$ [Polyethylene glycol (PEG) 6000 @ -0.4 MPa] followed by $T_2$ ($KNO_3$ @ 10 mM) appears to be the most favourable for capsule and seed development among the treatments. For seed quality parameters $T_9$ [Polyethylene glycol (PEG) 6000 @ -0.2 MPa] followed by $T_3$ ($KNO_3$ @ 50 mM) emerges to be encouraging for quality seed production in sesame.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Lizabeli Kithan, Rajesh Singh. Effect of nipping, crop geometry and different levels of nitrogen on the growth and yield of sesame (*Sesamum indicum* L.). Journal of Pharmacognosy and Phytochemistry. 2017;64:1089-1092.
2. Mura SS, Panda D, Mukherjee A, Pramanik K. Effect of pre-sowing treatment of growth regulators and agrochemicals on germination, dry matter accumulation, chlorophyll content and yield of sesame (*Sesamum indicum* L.). Int. J. Bio-res. 2015;89:49-57.
3. Panse VG, Sukhatme PV. Statistical methods for agricultural Research. ICAR, New Delhi; 1985.
4. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC, Pannu RS. Statistical software package for agricultural research workers. D.S. Hooda, R.C. Hasija (Eds.), Recent Advances in Information Theory, Statistics & Computer Applications, Department of Mathematics Statistics, CCS HAU, Hisar. 1998;139-143.
5. Thomas TL. Gene expression during plant embryogenesis and germination: An overview. The Plant Cell. 1993;5(10): 1401–1410.

6. Long SR, Dale RMK, Sussex IM. Maturation and germination of *Phaseolus vulgaris* embryonic axes in culture. Planta. 1981;153(1):405–415.
7. Bechtel DB, Gaines RL, Pomeranz Y. Protein secretion in wheat endosperm – formation of the matrix protein. Cereal Chemistry. 1982;59(5):336–342.
8. Rosenberg LA, Rinne RW. Moisture loss as a prerequisite for seedling growth in soybean seeds (*Glycine max*. L. Merr.). J. Exp. Bot. 1986;37(184):1663–1674.
9. Monalisa SP, Swain SK, Chiranjeevi, Kulkarni C, Behera M. Seed development and maturation in sesame (CV. Prachi) as influenced by growing seasons. JPP. 2018; 7(2):804-806.
10. Haigh AM, Barlow EWR. Germination and priming of tomato, carrot, onion and sorghum seeds in a range of osmotica. J Am Soc Hortic Sci. 1987;112:202-208.
11. Gosling PG, Butler RA, Black M, Chapman JM. The onset of germination ability in developing wheat. J. Exp. Bot. 1981; 32(128):621–627.
12. Rajasekaran R, Balamurugan P, Reshama C, Raja K. Studies on physiological maturity in Niger (*Guizotia abyssinical* Lf, cass) cv. Paiyur1. Seed Tech News. 2002; 32(1):137.



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