

## SEED PRIMING EFFECTS ON SEED QUALITY, STAND ESTABLISHMENT AND YIELD OF DIRECT SEEDED CROPS: A REVIEW

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### Abstract

Seed priming can be employed to reduce the duration of germination, to synchronize germination, to improve germination rate and to improve field stand of low-quality seeds. Seed priming helps to develop the embryo before germination with increasing  $\alpha$ -amylase activity, and the content of fructose and glucose, and with reducing sucrose content. Total sugar content of primed seed was higher than non-primed seeds. Germination of soybean seed lot stored for 16 months improved by priming treatment from 10.0 to 50.5%. Priming treatment of soybean seeds stored more than 12 months also reduced  $T_{50}$  by 0.3 to 1.0 days. Rapid and uniform emergence increases the stand establishment which influences better growth tend to better yield. Priming influences the emergence of seedling and stand establishment and it has a subsequence impact on yield and yield attributes. In general, plant population at harvest was closely related with emergence percentage of seed and plant population was positively correlated with seed yield.

**Keywords:** Seed priming, osmoconditioning, Hydropriming, growth regulator, stand establishment, yield

### Introduction

There is a growing realization that poor stand establishment is a major constraint of direct seeded crop production in marginal farm level. Fields without a reasonable number of well-spaced, vigorous plants cannot be expected to produce good yield. There are many reasons for poor stand establishment in tropical and sub-tropical crops: inappropriate seedbed preparation (Joshi, 1987), low quality seed, untimely sowing (Oosterom *et al.*, 1996), poor sowing technique, inadequate soil moisture (Gurmu and Naylor, 1991, Harris, 1996) adverse soil properties such as a propensity to form surface crusts (Soman *et al.*, 1992) and high temperature (Peacock *et al.*, 1993). Conditions after sowing had a large influence on emergence and seedling vigor which are important determinant of successful establishment.

Delayed germination, and poor seedling stand are often serious problems in direct seeding in dry fields, especially when seeds are sown early in the season. During this time soil moisture is low so seeds germinate slowly with no uniformity in individual seeds. Early

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development of roots in deeper soil can uptake more water thereby escaping drought damage to some degree. Seed priming, a pre-sowing treatment involving partial hydration and subsequent re-drying, enhances seed germination rate, uniformity, and seedling vigor, particularly under suboptimal environmental conditions (Anwar *et al.*, 2021, Zhang *et al.*, 2025). This physiological technique optimizes pre-germinative metabolic processes, leading to faster and more synchronous emergence, which is critical for robust crop stand establishment (Mondal and Bose, 2021). In germinating seeds, the major reserved food is starch, which is broken down by amylases induced or activated in the scutellum. Priming can alter the  $\alpha$ -amylase activity and sugar content of the seeds which influence the rate and speed of germination. Mukasa *et al.* (2003) indicated that priming shortened the average germination period and seedlings of primed seeds emerged significantly faster in the field than did the seedlings of the non-primed seeds of sugar beet. Reducing both the time taken between sowing and germination, and that of first and last seed of a batch to germinate could be of great agronomic benefit. Therefore, it is necessary to develop techniques for seeds to tolerate drought conditions, more stand and uniform germination. Pre-planting treatments of seeds or seed priming such as osmoconditioning, matricconditioning, hardening, humidification or soaking, and growth regulator can be employed to reduce the duration of germination, to synchronize germination, and to improve germination rate in the laboratory and field emergence rate.

Considering the above views this paper is the synthesis of the determining the application possibility of priming treatment in direct seeded crops to improve stand establishment and to assess the subsequent impact of priming on yield.

## **Materials and methods**

Given its profound impact on agricultural productivity, especially in staple crops like rice, a systematic review of the diverse priming agents and their mechanistic actions is warranted (MacDonald and Mohan, 2025). During preparation of this review paper various books, journals, symposium, proceedings, reports, publications, etc. related to seed priming have been reviewed taking the library facilities of Bangladesh Institute of Nuclear Agriculture, Bangladesh Agricultural University and other related institutions and through internet. Data has been collected from secondary resources and this paper is being prepared by using these secondary data and findings.

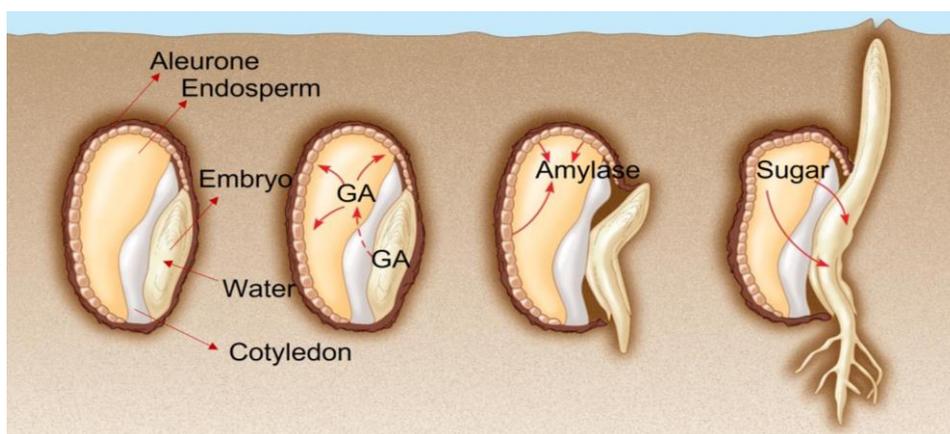
## **Results and discussion**

### **Seed priming**

Seed priming is the technique in which seeds are allowed to imbibe sufficient water to enable the early events in the germination process to occur, but not sufficient to permit radicle emergence through the seed coat (Heydecker, 1973/74). Seed priming reduces the

duration of germination, synchronizes germination, improves germination rate and finally improves field stand. Different techniques are used for priming like osmoconditioning, matricconditioning, hardening, humidification or soaking into water and preplant seed treatments by different growth regulators (Roknuzzaman and Haque, 2022). Different materials are used for priming likes; polyethylene glycol (PEG),  $\text{CaCl}_2$ ,  $\text{NaCl}$ ,  $\text{KCl}$ ,  $\text{KNO}_3$ , growth regulators ( $\text{GA}_3$ , ABA, kinetin etc.). Invigoration mechanism of different priming agents differ greatly depending upon the concentration and duration of seed priming. For example, priming agent  $\text{CaO}_2$  is believed to release oxygen to seed under anaerobic conditions and reduce anaerobic damage (Copeland and Mc Donald, 1995). Priming agents  $\text{KCl}$  and  $\text{CaCl}_2$  enhanced seed vigor of rice and improved stand establishment of rice in flooded condition (Ruan *et al.*, 2002).

Seed priming influences water imbibition. After water is imbibed, the embryo releases a hormone (giberellic acid) as a signal to the aleurone which then synthesizes and secretes  $\alpha$ -amylase and other digestive enzymes that hydrolyze stored foods in the endosperm, producing small, soluble molecules. Nutrients absorbed from the endosperm by the cotyledon are consumed during growth of the embryo into a seedling (Fig. 1).



**Fig. 1.** Early events in germination process and mobilization of nutrient during germination. Source: Hamayoun *et al.* (2023).

Preplant treatments of seed or seed priming can be employed to reduce the duration of germination, to synchronize germination, to improve germination rate and to improve field stand of low quality seeds (Khan, 1992). The priming of seeds in a proper polyethylene glycol (PEG) solution improved the overall germination rate, uniform germination and reduced the time to germination, particularly in many vegetable crops of which germination rate of normal seeds was relatively low (Drew and Dearman, 1993). Also, similar priming effects were observed in high quality field crop seeds planted under adverse environmental conditions such as sub-optimal temperatures or inadequate soil moisture conditions.

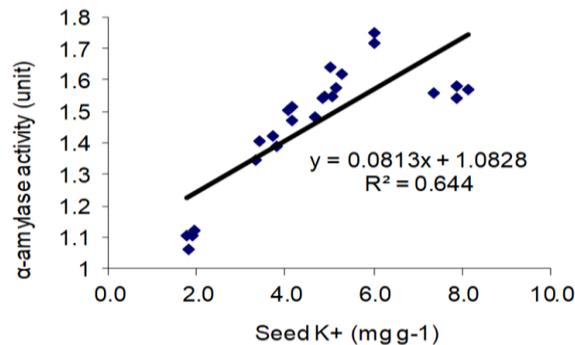
### Total sugars and $\alpha$ -amylase activity of seed

Seed priming helps to develop the embryo before germination with increasing  $\alpha$ -amylase activity, and the content of fructose and glucose, and with reducing sucrose content (Lee and Kim, 1999). As osmoconditioning of rice seeds are advanced, large compound starch grains in the endosperm are disintegrated into tiny starch granules, and small holes were found in the tiny starch granules and many of cavities are developed between embryo and endosperm. The radicle and plumule of seeds treated with properly osmoconditioning were developed faster than those of the control seeds (Lee and Kim, 1999). Lee and Kim (2000) conducted an experiment to know the total sugars,  $\alpha$ -amylase activity and germination after priming of normal and aged rice seeds and observed that total sugar content of primed seed was higher than non-primed seeds. Sugar content of normal seeds was also much higher than that of aged seeds (Table 1). Lee and Kim (2000) reported increased  $\alpha$ -amylase activity which might be attributed to prime induced proper hydration during imbibition. This may be further illustrated by drawing relationship between seed  $K^+$  and  $\alpha$ -amylase activity of rice seeds (Fig. 2). There was a positive correlation between seed  $K^+$  concentration and  $\alpha$ -amylase activity (Roknuzzaman *et al.*, 2016). The positive relationships of seed  $K^+$  with  $\alpha$ -amylase activity suggested that seed priming profoundly enhanced the endogenous seed  $K^+$  and led to the increased activity of  $\alpha$ -amylase in converting starch to reducing sugar (Farooq *et al.*, 2006).

**Table 1. Total sugar content and  $\alpha$ -amylase activity of differently primed rice seeds**

Seed	Priming	Total sugar (mg/g seed)	$\alpha$ -amylase activity (Unit)
Normal	Control	20.7 b	9.5 ab
	Osmoconditioning*	23.1 a	10.4 a
Aged	Control	16.9 d	5.6 d
	Osmoconditioning*	18.3 cd	7.2 cd
	Hardening**	18.9 c	8.9 abc

\*Priming into -0.6 MPa PEG 8000 solution for 4 days at 15<sup>0</sup>C, \*\* Three times of the water soaking for 24 hours and drying. Means within a column followed by the same letter are not significantly different by the DMRT at 5% level of significance (Lee and Kim, 2000).



**Fig. 2.** Relationship between seed  $K^+$  and  $\alpha$ -amylase activity in seeds of direct seeded aus rice. Source: Roknuzzaman *et al.* (2016).

In normal seeds, the total sugar content of germinating seeds with the osmoconditioning was significantly higher than that of the control and  $\alpha$ -amylase activity of it was slightly higher compared with the control seeds. Relationships between  $\alpha$ -amylase activity and total sugars or germination rate are shown in Fig. 3. There were highly significant positive correlation between  $\alpha$ -amylase activity and total sugar or germination rate at 17°C and 25°C.

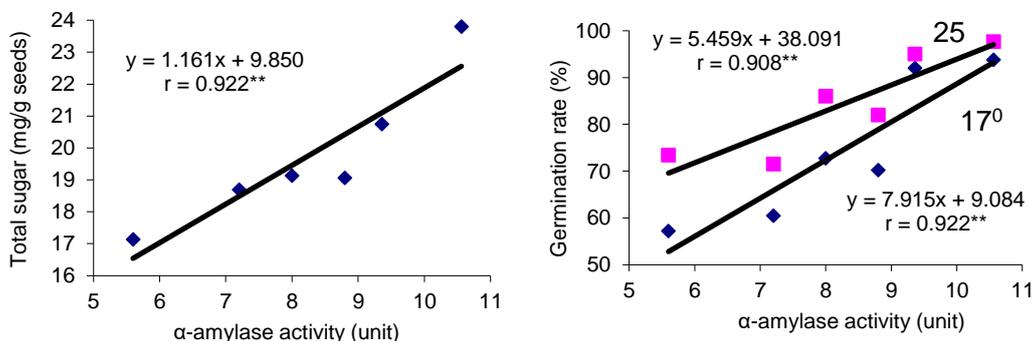


Fig. 3. Relationships between  $\alpha$ -amylase activity and total sugar content or germination rate of rice seeds at 17°C and 25°C. **Source:** Lee and Kim, 2000.

### Germination

Priming treatments improved emergence percentage, mean emergence time, and uniformity of emergence. The improvements are attributed to priming-induced quantitative changes in biochemical activities including greater amylase activity, increasing free sugars and DNA during seed germination (Sung and Chang, 1993). Osmoconditioning with 20-25% PEG offered an effective means for raising germination percentage and vigor index in deteriorated peanut seeds (Fu *et al.*, 1988). Priming ameliorated aging induces membrane disruption and leakage of UV absorbing substances and improves seedling vigor (Pandey, 1988). Park *et al.*, (1999) conducted an experiment to determine the effect of priming on the germination ability and seedling emergence of aged soybean seeds in lab and field conditions where, artificial or natural procedure for seed aging was applied. The aged seeds were osmoconditioned in -1.1 MPa PEG 8000 solution for 3 days at 25°C and air dried. They observed that germination of soybean seeds stored under room temperature decreased gradually as storage duration proceeded and decreased rapidly after 6 months (Table 2). Priming treatment increased germination percentages of soybean seeds stored for more than 12 months. Germination of soybean seed lot stored for 16 months improved by priming treatment from 10.0 to 50.5%. Priming treatment also improved seed vigor shown as  $T_{50}$ . Priming treatment of soybean seeds stored more than 12 months also reduced  $T_{50}$  by 0.3 to 1.0 days. Sarmin *et al.*, 2025 reported that the effectiveness of specific priming agents, particularly  $ZnSO_4$ ,  $KCl$ , and  $CaCl_2$ , enhances seed performance and early seedling

development, offering a promising strategy for optimising winter rice cultivation. Similar results also found by Roknuzzaman *et al.* (2016); Roknuzzaman and Haque, (2022) in rice.

**Table 2. Effect of priming treatment on the germinability of soybean seeds stored for 16 months under room temperature**

Storage duration (months)	Germination (%)		T <sub>50</sub> (days)		
	Unprimed	Primed	Unprimed (A)	Primed (B)	B-A
0	98.0a	96.0a	0.9	0.7	-0.2
3	99.5a	98.0a	0.6	0.8	0.2
6	87.5b	93.0a	1.1	0.8	-0.3
9	81.0b	86.5b	1.2	0.6	-0.6
12	72.5c	86.5b	1.2	0.6	-0.6
14	50.0d	78.5c	1.6	0.6	-1.0
16	10.0e	50.5d	1.9	1.6	-0.3

Source: Park *et al.*, 1999.

If rice seeds subject to excess soil moisture before emergence due to rain and the seeds tend to decay under the soil due to lack of oxygen. Under the excess soil moisture conditions, the emergence rate of rice seeds sown directly in dry field varies from 0-90% depending on soil moisture, temperature and varieties and emergence may be delayed 27-34 days after sowing (Lee and Myung, 1994). However, if rice seedlings emerge rapidly before raining, they can escape the excess moisture damage because oxygen is transported from the leaves to the roots through the aerenchyma tissue. Lack of soil moisture may also cause poor emergence of direct seeded rice. Early development of roots in deeper soil can uptake more water thereby escaping drought damage to some degree. Seed priming is an effective technique for rapid, uniform seed germination of various crops (Hurly *et al.*, 1991). Lee *et al.* (1998) conducted an experiment to find out the priming effects of rice seeds on the seedling establishment and early emergence under different soil moisture conditions and different temperature. They observed that germination and emergence rates of primed seeds were higher than those of unprimed seeds by 5-34% depending on soil moistures and temperatures. At 17°C germination and emergence rates of primed seeds were the lowest at 60% and increased up to 100% field capacity and then decreased with further higher soil moistures. However, germination and emergence rates of unprimed seeds at 17°C and those of both primes and unprimed seeds at 25°C were the lowest at the soil moisture of 60% and higher at 80% field capacity, then decreased with further higher soil moistures (Fig. 4). Generally, priming effects on germination and emergence rates were greater at too lower or higher soil moistures compared with at optimum soil moisture of 80% field capacity.

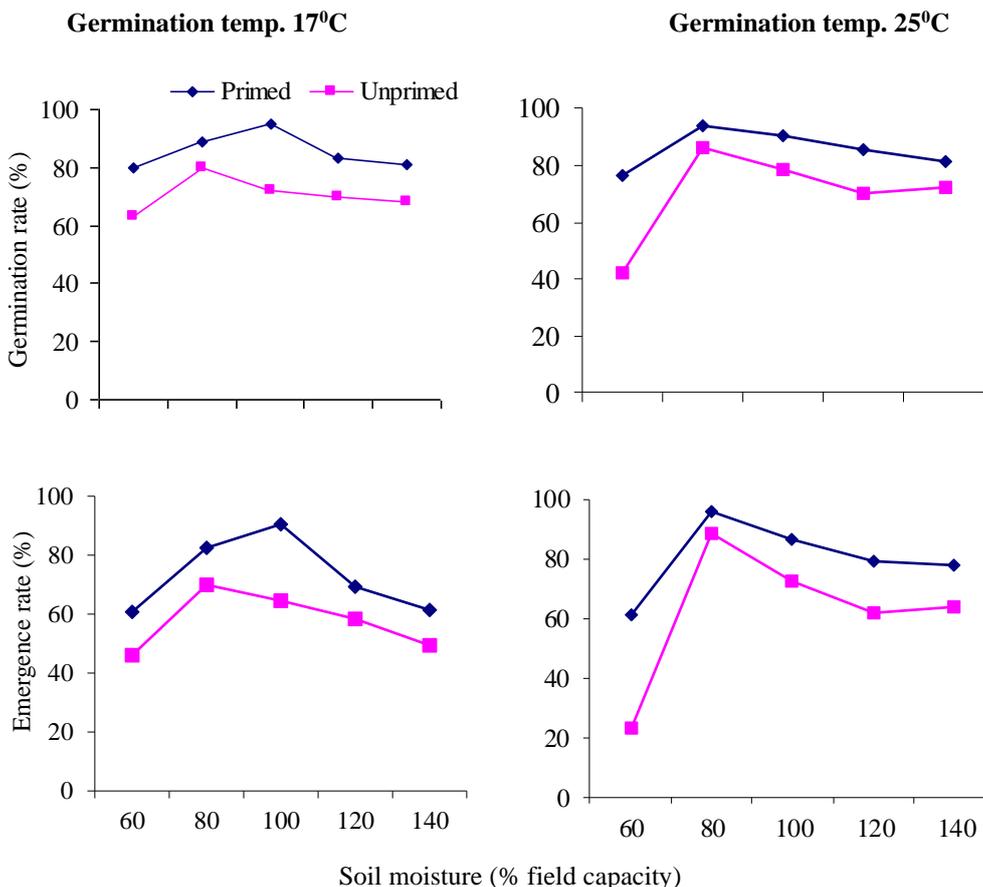


Fig. 4. Mean germination and emergence rate of primed and unprimed rice seeds at different soil moistures and temperature. Source: Lee *et al.* (1998).

### Seedling characteristics

Seed priming improves seedling establishment in rice under adverse soil conditions (low and high soil moistures) (Lee *et al.*, 1998). Qin and Zheng (1994) found that rice seeds primed in PEG solutions had significantly higher vigor and greater resistance to imbibitional chilling injury than non-primed seeds. Ruan *et al.* (2002) conducted an experiment to investigate the influence of priming on germination of rice seeds and seedling establishment and seedling vigor in flooded soil. The authors used different chemicals as priming agent like CaCl<sub>2</sub>, NaCl, PEG, and different ppm of GA<sub>3</sub> and observed that all priming treatments significantly improved rice seedling establishment in flooded soil as compared with the control (Table 3). Priming also significantly enhanced seedling vigor index and leaf score of rice seedling and accelerated the emergence.

**Table 3. Effects of priming on emergence and seedling characteristics under greenhouse condition of rice seeds (Zhenongda 454)**

Priming solutions	Seedling establishment	Seedling vigor	Leaf score	Speed of emergence	Shoot dry weight	Shoot height
	(%)	index		(%)	(mg seedling <sup>-1</sup> )	(cm)
None	70.5b	6.68 b	2.39b	78.61b	10.33d	11.48cd
CaCl <sub>2</sub> ,	79.5a	8.08 a	3.01a	98.17 a	12.21ab	12.17bc
CaCl <sub>2</sub> ,+ NaCl	76.0a	7.53 a	2.86a	94.15 a	11.19bcd	11.32cd
CaCl <sub>2</sub> ,+ NaCl+10 ppm GA <sub>3</sub>	76.0a	7.70 a	2.84a	96.77 a	12.12abc	12.22bc
CaCl <sub>2</sub> ,+ NaCl+100 ppm GA <sub>3</sub>	78.5a	7.98 a	2.83a	96.20 a	12.43ab	12.69b
CaCl <sub>2</sub> ,+ NaCl+1000 ppm GA <sub>3</sub>	80.0a	7.81 a	2.76a	91.18 a	13.12a	16.84a
PEG	79.5a	7.84 a	2.89a	91.06 a	10.80cd	11.01d

Source: Ruan *et al.*, 2002.

### Growth

Growth and development of plants depend on their genetic constitution and the environment but some management practices may alter some extent. Field stand have also some effects on growth. Rapid and uniform emergence increases the stand establishment which influences better growth in rice (Roknuzzaman and Haque, 2022). The rapid and uniform emergence of the seedlings attribute to better growth of mungbean (Hopper *et al.*, 1979; Gan *et al.*, 1992, Saha, 2005), sorghum (Harris, 1996) and maize, rice and chickpea (Harris *et al.*, 1999). Misra and Dwivedi (1980) conducted two experiments in different two years to investigate the effects of pre-sowing seed treatments on growth and dry-matter accumulation in 12 wheat varieties under rainfed condition. They treated the seeds by potassium and distilled water. The authors observed that pre-sowing seed treatments brought about significant differences in plant height, number of tillers, number of green leaves, leaf area, dry weight of shoot/plant during both the years (Table 4). Seed treatment with potassium and distilled water produced significantly more plant height, enhanced tiller production, green leaf number, leaf area over the control.

**Table 4. Effect of seed treatments on growth of wheat**

Treatment	Plant height (cm)		Number of tillers/plant		Leaf numbers/plant		Leaf area/plant (cm <sup>2</sup> )	
	1 <sup>st</sup> year	2 <sup>nd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year
	Control	86.1	73.0	2.6	1.9	8.0	5.1	122.0
Soaking in water	88.9	76.6	3.0	2.3	8.9	6.0	137.0	97.0
Soaking in 2.5% KCl	92.2	80.3	3.3	2.7	9.8	6.9	151.0	111.0
CD 5%	0.3	0.4	0.1	0.2	0.1	0.1	1.4	1.3

Source: Misra and Dwivedi, 1980.

Saha, (2005) conducted an experiment to evaluate the pre-sowing hydration effects on mungbean seed in respect of stand establishment and yield performance 4 hours and 8 hours water soaking were used as priming treatments. It was reported that seed priming produced

more vigorous plants compared to control (Fig. 5). Among the treatments 4 hours seed priming produced the highest total dry matter all over the growing period.

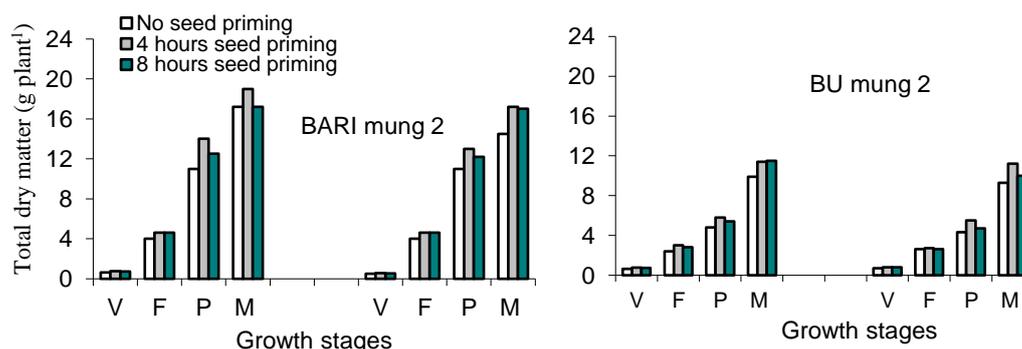


Fig. 5. Total dry matter per plant at vegetative (V), flowering (F), pod development (P), and maturity (M) stages of plants grown from normal and aged seeds of mungbean varieties at different priming duration. Source: Saha, (2005).

### Yield and yield attributes

Germination phase is of prime importance in the growth cycle of plants as it determines the stand establishment and final yield of the crop (Roknuzzaman and Haque 2022). Germination indices and emergence indices exhibited highly positive significant relationship between stand establishment and ultimately seed yield of mungbean (Roknuzzaman *et al.*, 2008). Priming influences the emergence of seedling and stand establishment and it has a subsequent impact on yield and yield attributes (Roknuzzaman and Haque 2022). Hosen *et al.*, 2023 observed that osmopriming influenced yield attributes and yield of wheat. Saha (2005) reported that priming caused significant variation in yield of mungbean. Among the priming levels, 4 hours seed priming produced significantly larger number of plants, pods/plant, longer pod compared with other treatments, priming for 8 hours and seed without priming. The author also reported that in general, plant population at harvest was closely related with emergence percentage of seed ( $r=0.64$ ) and plant population was positively correlated with seed yield ( $r= 0.52$ ).

**Table 5. Yield and yield attributes of mungbean varieties at variable priming level of seeds**

Priming level	Population/m <sup>2</sup>	Pods/plant	Pod length (cm)	Seed/pod	Seed size (mg)	Seed yield (Kg/ha)
No seed priming	25.83	19.65	7.45	9.79	46.06	1382.25
4 hrs. seed priming	27.33	22.35	7.75	10.08	64.00	1585.42
8 hrs. seed priming	24.50	21.02	7.68	9.81	46.06	1430.30
LSD <sub>(0.05)</sub>	1.38	1.23	0.22	NS	NS	112.30

Source: Saha (2005).

## **Conclusions**

Growth and development of plants depend on their genetic constitution and the environment but some management practices may alter some extent. Seed priming helps to develop the embryo before germination with increasing  $\alpha$ -amylase activity, and the content of fructose and glucose, and with reducing sucrose content. Priming treatments can improve emergence percentage, mean emergence time, and uniformity of emergence and seed vigor. Seed priming helps early development of roots in deeper soil which can uptake more water thereby escaping drought damage to some degree. Rapid and uniform emergence increases the stand establishment which influences better growth. Pre-sowing seed treatments brought about significant differences in growth, yield attributes and final yield of the crop.

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