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Nutrient Priming in Different Maize Cultivars and Evaluation of Vigour Improvement Under Controlled Conditions

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Abstract. Laboratory and pot experiments were conducted to study the effect of seed priming on vigour and germination characteristics of different maize cultivars during the year 2011. The seeds of four maize cultivars *viz*. EV 7004Q, Islamabad Gold, Rakaposhi and Sohan-3 were primed using 0% P (dry seeded control), 0.6% P and 1.2% P solutions of KH_2PO_4 for 16 h. The experiment was laid out in Complete Randomized Design (CRD) having three replicates. All the seed priming treatments significantly improved the plant vigour in terms of enhanced germination percentage, reduced mean germination time (MGT), improved root, shoot lengths and dry matter production. Among the four cultivars of maize the Islamabad Gold performed best followed by Sohan-3. Highest germination (94.57%) and vigour index (VI) of 431.66 was observed in Islamabad Gold where 1.2% P applied compared to dry seeded control. Nutrient seed priming may be used to improve germination vigour and crop stand establishment under field conditions leading to good yield targets in maize under rainfed conditions.

Keywords: genotype, maize, priming, phosphorous, vigour index

Introduction

The water needed for germination is limited, in arid and semi-arid environments and consequently, successful crop establishment depends on the rapid and uniform germination of the seed as well as on the ability to germinate under scarce moisture availability (Windauer, *et al*., 2007). However, if the stress effect can be alleviated at the germination stage, chances for attaining a good crop with economic yield production would be high (Ashraf *et al*., 2001).

To face the current demand for high standards in the agricultural market, the need for enhanced seed quality has become a priority (Paparella *et al*., 2015). Improved seed invigoration treatments (seed priming) are being used to reduce the germination time, to get synchronized germination, improved germination rate, and improved seedling stand in many horticultural (Rudrapal and Nakamura, 1998; Bradford *et al*. 1990) and field crops like wheat and maize (Basra *et al*., 2002). With an improved nutrient supply, nutrient priming has been suggested as a novel technique that unites the positive effects of hydropriming (Al Mudaris and Jutzi, 1999).

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Poor farmers in marginal areas are particularly unconvincing to meet the P requirements of their crops resource. Even when farmers use fertilizers, the properties of many tropical soils are such that recovery rates particularly for P, are very low.

Amelioration of P deficiency with cost intensive fertilizers is not a viable option for many resource-poor farmers. Treating or priming the seeds with small amounts of nutrients before sowing has been shown to partially overcome nutrient immobilisation problem in soils and to increase nutrient use efficiency (Miraj *et al*., 2013) as well as ameliorated germination and plant vigour. Seed priming with concentrating limiting plant nutrients around or within the seed may be an attractive solution to overcome poor establishment and P and Zn deficiencies (Asgedom and Becker, 2001). Priming with dilute P solutions has proved to be particularly effective in promoting rapid seedling growth and seedling performance is known to be related to seed P content (Derrick and Ryan, 1998) Rapid and uniform field emergence is also an essential prerequisite to reach the yield potential, quality and ultimately profit in crops.

Greater seed P content enables seedlings to establish faster and ultimately to produce plants with higher yields. In the present study nutrient priming has been evaluated in four maize varieties under controlled laboratory and pot experiments for vigour enhancement in terms of germination percentage, mean germination time (days), vigour index, root/shoot ratio and dry matter production. Improved germination and vigour may lead to better crop stand and yield ultimately under field conditions in dry farming.

Materials and Methods

Seeds of four maize varieties were obtained from National Agricultural Research Centre (NARC), Islamabad. The seeds were sterilized by using 30% sodium hypochlorite for 5 min and then washed three times with sterilized water. Seeds were primed in aerated solutions (1:5 w/v) for 5 h at 25 ± 2 °C of KH_2PO_4 at room temperature for duration of 16 h (already determined for maximum absorption). After soaking, seeds were given three surface washings with distilled water (Khan *et al*., 1992) and re-dried under shade, near to original weight with forced air. The seeds were then sealed in polythene bags and stored in refrigerator till further use (Basra *et al*., 2002). The primed seeds were set to germinate in an incubator at 27 °C.

Three replicates of 25 seeds from each variety and priming treatment were germinated between double layered, moistened paper towels (International Seed Asso. Test, 2003). Starting on the first day of imbibitions, counts of germinating seeds were made at 12 h intervals as far maximum germination was attained.

Mean germination time (MGT) was calculated according to the equation of Ellis and Roberts (1981) as under:

$$MGT = \frac{\Sigma Dn}{\Sigma n}$$

where:

n = the number of seeds, which were germinated on day D and

D = the number of days counted from the beginning of germination.

The seedling vigour index was calculated according to following formula (Islam *et al*., 2009).

$$VI = \frac{\text{seedling length (cm)}}{\text{germination percent}} \times 100$$

The seedlings shoot and root length was also recorded and their respective oven dried weights (taken at 70 °C for 24 h) were calculated.

Pot experiment. In pot study five seeds from each treatment were sown and kept under shade, replicated for three times. After two weeks the crop harvested from the pots and data recorded. Shoot and root length of three randomly selected seedlings was measured using transparent ruler from each pot after the seedlings were separated carefully from their roots. Then, shoot and root fresh weight was measured immediately. To determine the dry weight of these seedlings, the separated shoots and roots were dried to 70 °C for 12 h and then weighed (Ahmadvand *et al*., 2012).

Statistical analysis. The data collected for various characteristics were subjected to Analysis of Variance in MSTAT-C software (MSTATC, East Lansing, Mich) and the means obtained were compared by Duncan Multiple Range Test (DMRT) at 5% level of significance (Steel *et al*., 1997).

Results and Discussion

Germination parameters. *Germination (%).* All treatments have significant effect on germination percentage of all the cultivars of maize compared to the control. However the highest germination percentage (80.09%) was observed in Islamabad Gold. Results of interaction between treatment and varieties showed significance as Islamabad Gold with 1.2% P was significantly higher (94.57%) as compared to the control (Table 1). Higher germination percentage in this variety may be due to effect of phosphorus on metabolic activities of seed. These findings are in line with Arif *et al*. (2005) who reported that seed priming enhanced germination which may be attributed to repair processes, a build-up of germination metabolites or osmotic adjustments during priming treatment and could be the completion of "Lag phase" of germination during priming of seeds (Bakht *et al*., 2011). Shah *et al*. (2011) applied P @ 1%, during priming of *Abelmoschus esculentus* (okra) seeds in the form of SSP and concluded that phosphorus seed priming resulted in early germination and produced more yield than un-primed and water primed seeds.

Mean germination time (Mgt). The results depicted that there was significant effect of seed priming on mean germination time (days) of all the cultivars. All the priming treatments reduced mean germination time in maize cultivars as compared to control (Table 2). The interaction showed that lowest MGT (3.45 days) was observed in Islamabad Gold followed by Sohan-3 (3.51 days) when primed with 0.6% P. Faster germination due to seed priming has also been reported by Giri and Schillinger (2003) and Snapp *et al*. (2008). Similarly Harris and Jones (1997) showed 50% reduced germination time of rice cultivars from West Africa after water priming for 12-24 h. The adequate concentration of phosphorus in seeds is critical for seed germination and successful seedling growth (Lott *et al*., 2000). Priming affected the seed germination by early DNA replication and repair, increased RNA and protein synthesis and greater ATP availability (Varier *et al*., 2010). Priming enhanced the germination percentage of many field crops reported by Yari *et al*. (2010).

Table 1. Effect of different phosphorus treatments on germination percentage of maize cultivars

Treatments	Cultivars			
	EV 7004Q	Islamabad Gold	Rakaposhi	Sohan-3
0% P	71.20	68.93	71.63	68.93
0.6% P	73.07	76.77	75.63	84.60
1.2% P	74.07	94.57	72.07	70.50
Mean	73.11b	80.09a	73.11b	74.68b

*Means of same category following by different letters are significantly different at $p \leq 0.05$ using LSD test.

Table 2. Effect of different phosphorus treatments on mean germination time (days) of maize cultivars

Treatments	Cultivars			
	EV 7004Q	Islamabad Gold	Rakaposhi	Sohan-3
0% P	4.6	3.82	3.79	4.3
0.6% P	3.56	3.45	3.74	3.51
1.2% P	3.85	3.69	3.66	3.59
Varietal mean	4.00a	3.65b	3.73ab	3.80b

*Means of same category following by different letters are significantly different at $p \leq 0.05$ using LSD test.

Vigour index (Vi). The data revealed that all the P application doses as seed priming performed well as there was significant increase in vigour index (VI) of all the maize cultivars (Table 3). The application of P @ 0.6% significantly increased the VI compared to control where dry seeds were used. The data also revealed that the application of P @ 0.6 % resulted highest vigour index in Islamabad Gold under controlled conditions. Increased P content both inside the seeds and on the seed surfaces leads to better establishment of seedlings (Ros *et al*., 2000) and in turn increased vigour index. The early vigour of seedlings was ascertained by promotion of the formation of photosynthetic pigments and improved rates of photosynthesis (Zelonka *et al*., 2005).

Growth parameters. All the priming treatments improved the seedlings root as well as shoot lengths when compared to dry seeded control (Table 4). The results showed that there was significant effect of phosphorous priming on root/shoot length under controlled conditions. The highest root/shoot length was achieved in Islamabad Gold (40.33 cm and 20.67 cm) where 1.2% P has been applied. There was an increase of 37.9% observed as compared to dry seeded control. The maize varieties Islamabad Gold and Sohan-3 were at par while EV 7004Q and Rakaposhi showed similar results.

Table 3. Effect of different phosphorus treatment on vigour index (VI) of maize cultivars

Treatments	Cultivars			
	EV 7004Q	Islamabad Gold	Rakaposhi	Sohan-3
0% P	396.44	190.96	356.17	349.01
0.6% P	333.68	425.76	362.99	423.83
1.2% P	257.95	431.66	354.54	319.35
Mean	329.36a	349.46a	357.90a	364.06a

*Means of same category following by different letters are significantly different at $p \leq 0.05$ using LSD test.

The data revealed that seed priming affected the root dry matter significantly. Seed priming increased the root dry matter from 0.68 g to 0.83 g which is about 30% compared to control. The interaction data showed that Islamabad Gold performed well when P applied at the rate of 1.2%. The interaction of seed priming and varieties showed that Islamabad Gold showed increased dry matter shoot compared to control. Faster emergence rate after priming may be explained by an increased rate of cell division in the root tips as previously found for wheat (*Triticum aestivum*) (Basra *et al*., 2002) and fine rice (*Oryza sativa*) (Basra *et al*., 2003). The increase in DM yield may be due to better seedling growth and more emergence/m^2 compared with control (Azimzadeh and Koocheki, 1999).

Table 4. Effect of different seed treatment with phosphorus on shoot length, root length, shoot dry weight and root dry weight of maize cultivars

Treatments	Maize cultivars	Shoot length (cm)	Root length (cm)	Shoot dry matter (g)	Root dry matter (g)
0% P	Islamabad Gold	29.33c	16.33b	0.36c	0.42d
	EV 7004Q	31.66bc	16.00b	0.46bc	0.77bcd
	Sohan-3	30.66c	14.66b	0.50bc	0.72bcd
	Rakaposhi	30.33c	15.66b	0.55abc	0.77bcd
Mean		30.50b	15.66a	0.47a	0.67b
0.6% P	Islamabad Gold	29.00c	14.66b	0.49bc	0.71cd
	EV 7004Q	32.33bc	15.33b	0.53abc	0.69cd
	Sohan-3	35.00b	18.00ab	0.67ab	1.15ab
	Rakaposhi	29.66c	15.66b	0.49bc	1.00abc
Mean		31.50ab	15.91a	0.55a	0.89a
1.2% P	Islamabad Gold	40.33a	20.66a	0.72a	1.41a
	EV 7004Q	31.00c	15.33b	0.42c	0.50d
	Sohan-3	30.66c	15.00b	0.52abc	0.61cd
	Rakaposhi	29.33c	15.33b	0.50abc	0.79bcd
Mean		32.83a	16.58a	0.54a	0.83ab

*Means of same category following by different letters are significantly different at $p \leq 0.05$ using LSD test.

Conclusion

It is concluded from this study that seed priming improved the seedlings vigour of all the maize cultivars under controlled conditions. Islamabad Gold performed best when P applied @ 1.2% in the form of KH_2PO_4. Phosphorous enrichment of maize seeds through seed priming might be viable option for getting good crop stand and yield under field conditions. There is also possibility in further studies, to prepare 1.2% P solution by using available salts at commercial level at low cost as KH_2PO_4 salt is not feasible for poor farmers in Pakistan.

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