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Role of Seed Priming with Zinc in Improving the Hybrid Maize (*Zea mays* L.) Yield

[1]Sher Afzal, [1]Nadeem Akbar, [2]Zahoor Ahmad, [1]Qaiser Maqsood,
[1]Muhammad Aamir Iqbal and [1]Muhammad Rehan Aslam

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan
[2]Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Abstract: A field experiment was conducted to evaluate the role of seed priming with Zn in improving the performance of maize hybrids at Agronomic Research Area, University of Agriculture, Faisalabad in 2010. The two maize hybrids namely SIPRA 4444 and SP13 were tested with hydro-priming, priming with 0.5% $ZnSO_4$, priming with 1.5% $ZnSO_4$, priming with 0.5% Zn EDTA and priming with 1.5% Zn EDTA. Replicated three times the experiment was laid out in randomized complete block design with factorial arrangement. The net plot size was 3m x 6m. Observations on seed emergence, physiological parameters, grain yield and yield components were recorded in maize by following standard procedures. The data collected were analyzed statistically using Fisher's analysis of variance technique and differences among treatments means were compared by employing least significant difference (LSD) test at 5% probability level. The results of the present study revealed that priming techniques of zinc gave higher values in almost all the physiological and yield parameters. The maximum grain yield (5.35 t ha^{-1}), biological yield (16.69 t ha^{-1}) were found in priming with $ZnSO_4$ @1.5 % in maize hybrid.

Key words: Seed priming · Zinc · Yield · Maize

INTRODUCTION

Maize, being the highest yielding cereal crop in the world, is of considerable importance for countries like Pakistan, where population is rapidly increasing and has already out stripped the available food supplies. Maize is third important cereal after wheat and rice in Pakistan. Its uses are not only restricted as food and feed for livestock and poultry, maize grains are also utilized in many other industrial and commercial products. In Pakistan, it is cultivated on an area of 0.935 million hectares with an average yield of 3.26 t ha^{-1} [1].

Seed priming is usually described as pre-sowing treatments in water or in an osmotic solution that permits the seed to imbibe water to proceed to the first step of germination, but avoids radicle emergence through the seed coat. The most widely used priming treatments are osmo-priming and hydro-priming. In hydro-priming seeds are soaked in water overnight, surface drying and sowing the seeds at the same day. While in osmo-priming seeds are soaked in osmotic solution followed by drying the seed before sowing [2]. Several studies report the advantages of priming to enhance the germination and stand establishment [3, 4, 5, 6]. Research has shown that on-farm seed priming (Hydro-priming) can lead to better establishment in tropical crops such as rice, maize, sorghum, wheat and chickpea [7]. Seed priming techniques have been employed to develop resistance against several a-biotic stresses in a wide range of field crops [8-10].

Priming seeds with $ZnSO_4$ solutions increased grain yield significantly in maize, wheat and chickpea by 27%, 17% and 18% respectively across a wide range of production environments. These increases are similar to results reported for wheat (16%) and maize (26%) by Harris *et al*. [11, 12] in response to adding the recommended rates of $ZnSO_4$ to these soils. The response was similar with soil applied or by priming with a 1% $ZnSO_4$ aqueous solution. [12] However, significant yield benefits result from the priming process itself and many farmers growing various crops have found it to be a simple, low-cost and low risk technology that they could adopt easily [13].

Corresponding Author: Sher Afzal, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Various seed priming approaches have been reported to enhance the germination and seedling establishment at unfavourable temperatures. For example, soaking rice seed in various concentrations of proline, spermidine, spermine, betaine and putrescine, increased the tolerance at low temperature. Priming with $CaCl_2$ is considerd as the most effective technique in order to improve the growth of rice nursery seedling [14, 15] and stand establishment in coarse and fine rice [4, 5, 6]. Zheng *et al*. [16] also reported considerably improved low temprature tolerance in rice by priming with $CaCl_2$. In another study, Farooq *et al*. [8] stated that improved low temperature tolerance in late sown wheat by seed priming with $CaCl_2$. Naidu *et al*. [17] originate better performance of cotton under drought stress by seed treated with glycinebetaine. Priming with KCl has been found the most effective practice in enhancing the growth of rice seedlings [14, 15] and establishment of the stands in coarse rice [4-6]. Nevertheless, mechanisms of such improvisations are not understood yet.

Seed vitality or physiological status can be influenced by hydration treatments like by priming. Several studies have been made to inspect the effect of seed priming in response to enzymatic activities and low temperature tolerance in different plants like maize. Experiments show that priming reduces the optimum and higher temperature limits for germination, unlike untreated seeds [18]. The present study therefore was carried out to let slip the role of $ZnSO_4$ and $ZnSO_4$ EDTA seed treatments to improve the yield in hybrid maize.

MATERIALS AND METHODS

Experimental Site and Design: To evaluate the role of seed priming with Zinc in improving the performance of maize (*Zea mays* L.) hybrids a field experiment was conducted at the student farm, department of Agronomy, University of Agriculture Faisalabad, Pakistan and analytical work was done in the seed laboratory, department of Agronomy, University of Agriculture Faisalabad, Pakistan. The experiment was laid out in randomized complete block design with factorial arrangement (RCBD) having three replications. Seeds of two maize (*Zea mays* L.) hybrids namely ''SIPRA 4444 and SP13'' and six priming treatments such as No priming, Hydro-priming, Priming with 0.5% $ZnSO_4$, Priming with 1.5% $ZnSO_4$, Priming with 0.5% Zn EDTA and Priming with 1.5% Zn EDTA were used as experimental material.

Crop Husbandry: The crop was sown on well prepared seed beds on 4th August, 2010 by using the seed rate of 25 kg ha^{-1}. The plot contained four lines in each plot having inter-row and intra-plant spacing of 75 cm and 25 cm respectively. Plant to plant distance was achieved by thinning crop at 15 days stage. An inorganic fertilizer dose of NPK @ 200-150-125 kg ha^{-1} was applied in all treatments. Whole phosphorous, potassium and one third nitrogen was applied at the time of sowing; the other one third nitrogen was applied at first irrigation while remaining one third nitrogen was applied at second irrigation. Sources of fertilizers were DAP 9 bags, Urea 3 bags and SOP 4 bags. Hand hoeing was done at knee and tasseling stage. Application of Furadon @ 25 kg ha^{-1} was applied one month after sowing against shoot fly attack. All other cultural practices such as thinning, hoeing, irrigation and plant protection measures were kept normal and uniform for all the treatments. The crop was harvested on 5th November, 2010.

Seed Priming Protocol: For priming, maize seeds were subjected to hydro-priming, priming with 0.5% $ZnSO_4$, priming with 1.5% $ZnSO_4$, priming with 0.5% Zn EDTA and priming with 1.5% Zn EDTA for 12 h at 25±2°C. Seed weight to solution volume ratio was 1:5 (w/v) [4]. For seed priming, seeds were soaked in respective solution or water. Thereafter seeds were removed, given three surface washings and re-dried with forced air near to its original weight. Untreated seeds were used as control treatment.

Data Collection

Physiological Parameters: The experiment was visited daily. Number of emerged seeds was recorded daily according to the seedling evaluation (Handbook of Association of Official Seed Analysts) 1990. For this total number of plants in each plot was counted and divided to plot area to get germination count m^{-2}. All the leaves of five randomly selected plants from each plot were removed and a representative sample was taken, leaf length and leaf width was recorded with scale. The leaf area was calculated by multiplying leaf length and leaf width. Then leaf area per plant was worked out.

Leaf area index was calculated by dividing the leaf area to land area by the formula

$$LAI = \text{Leaf area/ Land area}$$

Leaf area duration was calculated in days by using following formula [19].

$$LAD = \frac{(LAI_1+LAI_2) \times (T_2-T_1)}{2}$$

Where; LAI1 and LAI2 are leaf area indices at times T1 and T2 respectively.

Crop Growth Rate (CGR) was calculated by the following formula [19].

$$CGR = \frac{W_2-W_1}{T_2-T_1} (g/m^2/day)$$

Where; W_2=Dry weight per m^2 land area at second harvest, W_1=Dry weight per m^2 land area at first harvest, T_2=Time corresponding to second harvest and T_1=Time corresponding to first harvest.

Net Assimilation Rate (NAR) was determined by using the formula [19].

$$NAR = \frac{TDM}{LAD} (g/m^2/day)$$

Where; TDM =Total dry matter accumulated at harvest and LAD =Final leaf area duration.

Yield Parameters: The weight of sun dried plants from each plot was recorded separately and converted into ton $hect^{-1}$. After sun drying of cobs for 15 days the cobs of each plot were shelled mechanically with maize sheller. Grains per plot were weighed by digital balance and then converted into ton $hect^{-1}$. After the separation of cobs from the maize plants the stover weight was recorded from each plot and converted into ton $hect^{-1}$.

Harvest Index (HI) was calculated by the following formula

$$HI = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Statistical Analysis: Data collected were subjected to statistical analysis by using a computer program MSTAT-C [20]. Least Significant Difference test (LSD) at 5 % probability level was applied to compare the differences among treatments` means [21].

RESULTS AND DISCUSSION

Physiological Parameters: The data regarding, physiological parameters such as germination count m^{-2}, leaf area index (LAI), lead area duration (LAD), crop growth rate (CGR) and net assimilation rate (NAR) showed that the different levels of seed priming with zinc significantly ($P \leq 0.05$) increased the germination count m^{-2}, LAI, LAD, CGR and NAR (Table 1a). The maximum value of germination count m^{-2} (5.30), LAI (5.74), LAD (181 DAS), CGR (25.43 g m^{-2} day^{-1}) and NAR (g m^{-2} day^{-1}) were recorded in the treatment where seed priming with $ZnSO_4$@ 1.5% (Table 1b) applied. While the minimum value of germination count m^{-2} (4.87), LAI (4.95), LAD (159 DAS), CGR (16.34 g m^{-2} day^{-1}) and NAR (3.72 g m^{-2} day^{-1}) were observed in control treatment where no priming with zinc applied (Table 1b).

Maize hybrids showed non.significant effect ($P \leq 0.05$) on the germination count m^{-2}, leaf area index (LAI), lead area duration (LAD), crop growth rate (CGR) and net assimilation rate (NAR) by the seed priming with zinc (Table 1a). The interaction between the different levels seed priming with different source of zinc and maize hybrids was non-significant.

The physiological parameters such as germination count m^{-2}, leaf area index (LAI), lead area duration (LAD), crop growth rate (CGR) and net assimilation rate (NAR) were increased by seed priming with different sources of zinc. Leaf area index (LAI) is the main physiological determinant of crop yield. Crop growth rate (CGR) for the varieties was slower during early vegetative phase of the crop due to lower temperature; thereafter it increased sharply. In this present study the germination count m^{-2} performed better where seed priming with $ZnSO_4$ @ 1.5% was applied than all other treatments. These results are in conformity with the findings of Shahid and Khan [22] who reported that seed priming with $ZnSO_4$ @ 1.5 % increased the seed germination as against the seeds grown without priming. Since germination depends on the viability of seed and other germination requirements i.e. sowing time, soil preparation, soil moisture and temperature of soil etc, so these must be kept in coordination to induce germination. Therefore different priming techniques created statistically significant differences among treatments. Yordanov *et al.,* [23] reported that the leaf area index (LAI), leaf area duration (LAD) and net assimilation rate (NAR) was increased in maize by priming of seeds with 1.5% $ZnSO_4$ solution. Greater leaf area index values may attribute to significant increase in leaf expansion due to good germination and growth of plants as affected by priming. Kaiser *et al.* [24] concluded that crop growth rate (CGR) was the highest with the priming of 1.5% $ZnSO_4$ solution and was the lowest where seeds were not primed.

Table 1a: Mean square value for analysis of variance for germination count m^{-2}, LAI, LAD, CGR (g m^{-2} day^{-1}) and NAR (g m^{-2} day^{-1}) of maize as affected by different levels of seed priming with zinc

SOV	D.F	Germination count m^{-2}	LAI	LAD (DAS)	CGR (g m^{-2} day^{-1})	NAR (g m^{-2} day^{-1})
Replication	2	0.3611	0.053	20.028	3.4330	0.00123
Hybrids (H)	1	0.0278^{NS}	0.0001^{NS}	26.69^{NS}	0.2550^{NS}	0.00467^{NS}
Seed priming (P)	5	38.9611*	0.545*	632.628*	38.2750*	6.43419*
H x P	5	0.1611^{NS}	0.0005^{NS}	402.361^{NS}	21.7744^{NS}	7.29712^{NS}
Error	22	3.4520	0.05345	16.876	2.4272	0.01894

*, ** = Significant at 0.05 and 0.01 levels respectively; NS= Non-significant

LAI= Leaf area index, LAD= Leaf area duration, CGR= Crop Growth rate and NAR= Net assimilation rate

Table 1b: Effect of different levels seed priming with zinc on germination count m^{-2}, LAI, LAD, CGR (g m^{-2} day^{-1}) and NAR (g m^{-2} day^{-1}) of maize

Treatments	Germination count m^{-2}	LAI	LAD (DAS)	CGR (g m^{-2} day^{-1})	NAR (g m^{-2} day^{-1})
Varieties					
SIPRA-4444	5.09	5.47	173	19.99	4.88
SP-13	5.09	5.46	172	19.82	4.86
Concentration of seed priming with Znic					
Control	4.87 c	4.95 c	159 d	16.34 c	3.72 d
Hydro-priming	5.02 b	5.25 b	162 d	17.56 c	4.19 c
Priming with 0.5% $ZnSO_4$	5.14 ab	5.64 a	170 c	19.44 b	4.41 b
Priming with 1.5% $ZnSO_4$	5.30 a	5.74 a	181 a	25.43 a	6.90 a
Priming with 0.5% Zn EDTA	5.11 ab	5.60 a	177 b	20.37 b	4.44 b
Priming with 1.5% Zn EDTA	5.13 ab	5.60 a	173 bc	20.33 b	4.56 b
Interaction					
Treatment X Varieties	NS	NS	NS	NS	NS

Data within columns followed by different latters are significantly different at $P \leq 0.05$

Table 2a: Mean square value for analysis of variance for biological yield (t ha^{-1}), grain yield (t ha^{-1}), Stover yield (t ha^{-1}) and harvest index (%) of maize as affected by different levels seed priming with zinc

SOV	D.F	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index %
Replication	2	0.0852	0.04750	0.36668	5.6016
Hybrids (H)	1	0.1035^{NS}	0.00353^{NS}	0.20250^{NS}	0.546^{NS}
Seed priming (P)	5	19.4625*	2.82944*	9.81904*	57.4771*
H x P	5	0.1683^{NS}	0.46137^{NS}	0.42717^{NS}	5.5272^{NS}
Error	22	0.6196	0.18525	0.51134	8.4110

*, ** = Significant at 0.05 and 0.01 levels respectively; NS= Non-significant

Table 2b: Effect of different levels of seed priming with zinc on biological yield (t ha^{-1}), grain yield (t ha^{-1}), Stover yield (t ha^{-1}) and harvest index (%) of maize

Treatments	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index %
Varieties				
SIPRA-4444	15.49	4.63	10.85	29.73
SP-13	15.59	4.59	11.00	29.49
Concentration of seed priming with Znic				
Control	13.21 d	3.51 c	9.69 d	26.57 c
Hydro-priming	14.68 c	3.86 c	10.81 bc	26.35 c
Priming with 0.5% $ZnSO_4$	15.84 b	4.67 b	11.16 b	29.55 b
Priming with 1.5% $ZnSO_4$	16.69 a	5.35 a	13.33 a	34.33 a
Priming with 0.5% Zn EDTA	15.49 bc	5.13 ab	10.36 bcd	30.82 b
Priming with 1.5% Zn EDTA	15.35 bc	5.12 ab	10.23 cd	30.75 b
Interaction				
Treatment X Varieties	NS	NS	NS	NS

Data within columns followed by different latters are significantly different at $P \leq 0.05$

Yield Parameters: The data regarding, the yield parameters such as biological yield, grain yield, stover yield and harvest index (HI) showed that the different levels of seed priming with different source of zinc significantly ($P \leq 0.05$) increased the biological yield, grain yield, stover yield and harvest index (HI) (Table 2a). The maximum value of biological yield (16.69 t ha^{-1}), grain yield (5.35 t ha^{-1}), stover yield (13.33 t ha^{-1}) and harvest index (HI) (34.33%) were recorded in the treatment where seed priming with $ZnSO_4$@ 1.5% (Table 2b) applied. While the minimum value of biological yield (13.21 t ha^{-1}), grain yield (3.51 t ha^{-1}), stover yield (9.69 t ha^{-1}) and harvest index (HI) (26.57%) were observed in control treatment where no priming with zinc applied (Table 2b).

Maize hybrids showed non-significant effect ($P \leq 0.05$) on the biological yield, grain yield, stover yield and harvest index (HI) by the seed priming with zinc (Table 2a). The interaction between the different levels seed priming with different source of zinc and maize hybrids was non-significant.

Priming seeds with $ZnSO_4$ solutions increased grain yield significantly in maize, wheat and chickpea by 27%, 17% and 18% respectively across a wide range of production environments. These increases are similar to results reported for wheat (16%) and maize (26%) by Harris *et al*. [8, 9] in response to adding the recommended rates of $ZnSO_4$ to these soils. The yield parameters such as biological yield, grain yield, stover yield and harvest index (HI) were increased by seed priming with different sources of zinc. The results of present study are in-line with Shahid and Khan [22] who reported that biological yield, grain yield and stover yield were increased with the priming of 1.5% $ZnSO_4$ solution in maize. These results are in conformity with the findings of Zeb and Arif [25] who reported that harvest index (%) increased when maize seeds were primed with $ZnSO_4$ solution.

CONCLUSION

By observing the overall performance, it can be concluded from this study that priming of maize seed with $ZnSO_4$ solution having concentration of 1.5% was found to be the most suitable, appropriate and economical for raising maize (*Zea mays* L.) hybrids under the prevailing conditions of Faisalabad.

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