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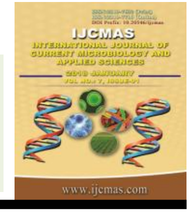

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Effect of Seed Priming on Rain-Fed Maize and Pea in a Sequence under Mid Hill Conditions of Himachal Pradesh, India

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A B S T R A C T

Seed priming techniques for maize and pea crop are not well established for rain-fed agro-climatic conditions of Himachal Pradesh. Keeping this in view, a study was carried out for two years (2014-15 and 2015-16) at the experimental farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu. Four priming levels of Zn (0% $ZnSO_4$-water soaking, 1% $ZnSO_4$, 2% $ZnSO_4$ and 3% $ZnSO_4$) and three priming durations (4 hours, 8 hours and 12 hours) were compared with basal dose of recommended NPK + $ZnSO_4$ and farmers' practice (absolute control). Seed priming with 0% $ZnSO_4$ (water soaking) resulted in higher germination of pea and maize than other priming levels. Therefore, water soaking for a period of 12 hours may be used for enhancing emergence and better seedling growth in pea and maize crop. Most of the growth characters of pea crop were improved due to priming with 1% $ZnSO_4$ for 12 hours, however such characters in maize crop were found to be better using 2% priming solution of $ZnSO_4$ for a period of 12 hours. The yield of green peas, maize equivalent yield were maximum due to priming with 1% $ZnSO_4$ for 12 hours duration, however, yield of maize grains was highest with treatment combination of 2% $ZnSO_4$ priming for 12 hours duration. It may be concluded that priming of pea seeds for 12 hours with 1% $ZnSO_4$ and that of maize seeds for 12 hours using 2% solution of $ZnSO_4$ was useful for proper germination, better crop establishment and yields enhancement.

Introduction

Maize-garden pea is most important cropping system under rain-fed conditions, being adopted by the farmers in Himachal Pradesh. However, significant yield losses in maize and pea are expected to increase with global climate change in key production areas. Water scarcity is major constraint which is beyond the control of farmers. Hence, increasing water use efficiency for enhanced drought tolerance can be achieved by involving agronomic practices like seed priming (Harris *et al.,* 2005). However, the priming technique of maize and pea crop is not well established. Although quite a good number of works have been done on seed priming of maize in abroad but under Indian condition in general and

Himachal Pradesh in particular, such works are a few. Before priming any crop seeds the knowledge of safe limits of priming concentration and duration is very important to get maximum effect.

Therefore, considering the beneficial effects of seed priming on germination and vigour which help in maintenance of optimum plant population and to obtain expected yield level, the present study was undertaken with the objectives (1) to determine appropriate concentration of zinc sulphate for seed priming of pea and maize seeds and (2) to find out the effect of seed priming with zinc on growth and yield of maize and pea

Materials and Methods

Experimental site

The experimental site was Research Farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu (31°84´ N latitude and 77°16´ E longitude), which is located at an altitude of 1090 m above mean sea level.

Climate

Agro-climatically, the study location represents zone II of Himachal Pradesh and is characterized by hot dry summers, sub humid rainy season and cool winters. The region receives an average rainfall of 873 mm per annum and major portion of rainfall (about 55%) is received during winter and dry spell are common from October to December.

Soil characteristics

The soil of the experimental site at initiation of the experiment was slightly acidic in reaction, medium in organic carbon, silty loam in texture, medium in available nitrogen and potassium and high in phosphorus and DTPA-extractable Fe, Mn, Zn and Cu. Some important initial physico-chemical characteristics of the experimental site (0-0.15 m) are provided in Table 1.

Experimental details

Field trials were conducted for two years during 2014-5 and 2015-16 taking maize and pea in a sequence. The experiment consisted of four priming levels (0 % $ZnSO_4$ -water soaking, 1% $ZnSO_4$, 2% $ZnSO_4$ and 3% $ZnSO_4$) and three priming durations (4 hr, 8 hr and 12 hr), which were compared with Recommended basal NPK + $ZnSO_4$ and farmers' practice (40% N of RDF + unprimed seed – control). The treatments were replicated thrice in a factorial RBD.

Seed priming

Four priming levels of $ZnSO_4$ namely 0 % (water soaking), 1%, 2.0% and 3%) used. The solutions of Zinc Sulfate were prepared by dissolving 10, 20 and 30 g of $ZnSO_4$ (21% Zn) per litre of distilled water to make 1%, 2.0% and 3% solution. Approximately 30 g seeds of maize and 170 g that of pea were soaked in one litre of water for 4, 8 and 12 hours. Similarly the above mentioned quantity of seeds was soaked in distilled water separately for 4, 8 and 12 hours. After soaking, the seeds were dried in shade until seed coat become dry.

Fertilizers

All the plots received recommended dose of N: P: K fertilizers and FYM (25:60:60 kg ha^{-1} + 10 t ha^{-1} for pea and 120:60:40 kg ha^{-1} + 10 t ha^{-1} for maize). The source of N, P and K fertilizer was urea, single super phosphate and muriate of potash, respectively. The whole quantity of P and K fertilizers along with FYM and half dose of N were applied at the time of maize sowing and remaining N was top dressed as two equal splits. In pea crop, whole quantity of fertilizers and FYM was applied at the time of sowing.

Results and Discussion

Germination of pea and maize seeds

Effect of priming level

The data revealed that maximum germination of pea and maize seeds was recorded in case of 0% $ZnSO_4$ (water soaking) followed by priming with 1% $ZnSO_4$. However, the priming beyond 1% $ZnSO_4$ recorded reduced germination during both years as well as on pooling the data for two years (Table 2).

Effect of priming duration

The results showed that germination of pea and maize seeds increased with increasing duration of priming from 4 to 12 hours and maximum germination was recorded for 12 hours (Table 2).

Interaction effect

The data revealed that germination of pea and maize seeds was not influenced due to interaction among priming levels and their duration, during both years and pooling the data for two years (Table 2).

Priming vs Basal $ZnSO_4$

The data indicated that priming was found significantly superior to soil application of $ZnSO_4$ and significantly increased germination of pea and maize seeds during both years and upon pooling the data (Table 2).

Control vs others

It is clear from the data that control treatment had low germination than other treatments (Table 2).

Plant stand of pea and maize crop

Effect of priming level

Population of pea and maize plants was significantly different among priming levels and highest population was observed for 0% $ZnSO_4$ (water soaking) followed by priming with 1% $ZnSO_4$, 2% $ZnSO_4$ and 3% $ZnSO_4$, indicating that increasing concentration of $ZnSO_4$ decreased plant stand (Table 3).

Effect of priming duration

The results showed that plant population of pea and maize varied significantly among varying priming durations and maximum plant population was observed for 12 hours (Table 3).

Interaction effect

The interaction among priming levels and their duration was significant for plant population of pea crop during both years and on pooled the data and priming with 1% $ZnSO_4$ for 12 hours recorded maximum plant population. The plant stand of maize crop was significantly influenced due to priming levels and their duration and it was observed that highest population was recorded using 2% priming solution of $ZnSO_4$ for a period of 12 hours (Table 3).

Priming vs Basal $ZnSO_4$

Priming exhibited a significant effect on plant stand of pea and maize crop as compared to soil application of $ZnSO_4$. The priming treatments significantly increased plant stand over soil applied $ZnSO_4$ (Table 3).

Control vs others

The findings indicated that other treatments were found superior to control and treatments had significantly higher plant stand of pea and maize when compared with control (Table 3).

Plant height of pea and maize crop

Effect of priming level

The height of pea plants varied significantly among priming levels and priming with 1% $ZnSO_4$ produced taller plants as compared to other priming levels.

The height of pea plants observed decrease with increasing concentration of $ZnSO_4$ from 1% to 3%. However, maximum height of maize plant was recorded for 2% $ZnSO_4$ and minimum for 3% $ZnSO_4$ (Table 4).

Effect of priming duration

Different priming durations exerted a significant effect on plant height of pea and maize during both years and the maximum plant height was noticed due to priming for 12 hours (Table 4).

Interaction effect

The pooled height of pea plants was significantly impacted due to interaction among treatments and taller plants were produced due to priming with 1% $ZnSO_4$ for 12 hours (Table 4). However, no such interaction was observed among treatment for plant height of pea and maize during individual year.

Table.1 Initial soil physico-chemical properties of experimental site (0-0.15 m depth)

S.No.	Soil property	Value
i.	Mechanical separates (%)	
	Sand	19.7
	Silt	62.6
	Clay	16.4
	Texture	Silty loam
i.	Soil pH	6.1
i.	Organic carbon (g kg^{-1})	6.3
v.	CEC [c mol(p^+) kg^{-1}]	11.5
v.	Available Nutrients (kg ha^{-1})	
	Nitrogen	225.8
	Phosphorus	27.8
	Potassium	169.2
vi.	DTPA extractable micronutrients (mg kg^{-1})	
	Fe	7.23
	Mn	2.28
	Zn	1.27
	Cu	1.35

Table.2 Effect of priming levels and their duration on seed germination (%) of pea and maize

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	91.2	93.2	92.0	94.0	93.6	93.6
1% $ZnSO_4$	88.7	90.7	89.3	91.4	91.0	91.0
2% $ZnSO_4$	84.3	86.3	85.7	87.7	87.0	87.0
3% $ZnSO_4$	69.0	71.0	68.8	70.8	70.9	70.9
LSD (P=0.05)	2.0	1.8	1.9	2.0	1.5	1.5
B. Priming Duration						
4 hours	80.5	82.5	81.5	83.5	83.0	83.0
8 hours	83.3	85.3	83.9	85.9	85.6	85.6
12 hours	86.2	88.2	86.5	88.5	88.3	88.3
LSD (P=0.05)	1.7	1.6	1.7	1.7	1.3	1.3
Interaction A × B	NS	NS	NS	NS	NS	NS
Soil application vs priming						
Soil application	78.0	80.0	76.5	78.5	79.3	79.3
Priming	83.3	85.3	83.9	86.0	85.6	85.6
LSD (P=0.05)	2.6	2.4	2.5	2.5	1.9	1.9
Control vs Others						
Control	74.3	76.3	73.0	75.0	75.7	75.7
Others	82.9	84.9	83.4	85.4	85.1	85.1
LSD (P=0.05)	2.6	2.3	2.5	2.5	1.9	1.9

Table.3 Effect of priming levels and their duration on plant stand of pea and maize

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	222491	78261	222505	78272	222498	78267
1% $ZnSO_4$	221720	75213	221735	75225	221727	75219
2% $ZnSO_4$	205000	74152	205014	74164	205007	74158
3% $ZnSO_4$	165000	60836	165013	60962	165007	60899
LSD (P=0.05)	371	406	358	445	346	296
B. Priming Duration						
4 hours	202980	71553	202994	71567	202987	71560
8 hours	203560	72099	203574	72095	203567	72097
12 hours	204119	72695	204132	72806	204125	72750
LSD (P=0.05)	321	352	310	385	299	256
Interaction A × B	642.6	703.7	619.2	770.3	598.6	512.7
Soil application vs priming						
Soil application	171448	55330	172667	55342	172057	55336
Priming	203553	72116	203567	72156	203560	72136
LSD (P=0.05)	473	518	456	567	441	377
Control vs Others						
Control	171325	55187	172402	55198	171863	55192
Others	201083	70824	201190	70862	201137	70843
LSD (P=0.05)	472	516	454	565	439	376

Table.4 Effect of priming levels and their duration on plant height (cm) of pea and maize

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	82.8	221.1	78.2	224.6	80.5	222.9
1% $ZnSO_4$	88.8	234.3	84.2	237.2	86.5	235.8
2% $ZnSO_4$	77.0	240.0	75.2	242.8	76.1	241.4
3% $ZnSO_4$	63.8	205.1	64.9	209.0	64.3	207.1
LSD (P=0.05)	2.9	3.8	3.1	3.6	1.9	3.5
B. Priming Duration						
4 hours	72.0	219.8	69.3	222.4	70.7	221.1
8 hours	78.2	225.0	75.6	228.8	76.9	226.9
12 hours	84.2	230.6	81.8	234.0	83.0	232.3
LSD (P=0.05)	2.5	3.3	2.7	3.1	1.6	3.0
Interaction A × B	NS	NS	NS	NS	3.3	NS
Soil application vs priming						
Soil application	73.2	216.7	71.0	221.0	72.1	218.8
Priming	78.1	225.1	75.6	228.4	76.9	226.8
LSD (P=0.05)	3.8	4.9	4.0	4.6	2.4	4.4
Control vs Others						
Control	70.7	212.0	68.3	216.7	69.5	214.3
Others	77.7	224.5	75.2	227.8	76.5	226.2
LSD (P=0.05)	3.7	4.9	3.9	4.6	2.4	4.4

Table.5 Effect of priming levels and their duration on crop yields (q ha^{-1})

Treatments	2014-15 Pea	2015 Maize	Maize equivalent yield	2015-16 Pea	2016 Maize	Maize equivalent yield	Pooled pea yield (2014-15 &2015-16)	Pooled maize yield (2015 &2016)	Pooled maize equivalent yield
A. Priming Level									
0% Zn (water soaking)	116.2	41.5	220.2	119.1	42.8	226.0	117.7	42.1	223.1
1% $ZnSO_4$	123.5	48.0	238.0	126.6	49.5	244.2	125.1	48.7	241.1
2% $ZnSO_4$	107.9	53.8	219.7	110.6	55.6	225.7	109.2	54.7	222.7
3% $ZnSO_4$	66.3	32.2	134.1	68.7	32.9	138.6	67.5	32.6	136.4
LSD (P=0.05)	4.9	4.2	7.9	5.4	4.7	8.6	5.1	4.4	8.2
B. Priming Duration									
4 hours	94.1	36.8	181.6	96.9	38.1	187.1	95.5	37.4	184.3
8 hours	104.6	43.8	204.8	107.4	45.2	210.4	106.0	44.5	207.6
12 hours	111.7	51.0	222.7	114.4	52.3	228.4	113.0	51.7	225.6
LSD (P=0.05)	4.3	3.6	6.8	4.6	4.0	7.4	4.4	3.8	7.1
Interaction A × B	8.5	7.2	13.6	9.3	8.1	14.8	8.9	7.6	14.2
Soil application vs priming									
Soil application	89.5	36.0	173.7	92.1	37.5	179.2	90.8	36.7	176.4
Priming	103.5	43.9	203.0	106.2	45.2	208.6	104.8	44.5	205.8
LSD (P=0.05)	6.3	5.3	10.0	6.8	5.9	10.9	6.5	5.6	10.4
Control vs Others									
Control	85.7	34.2	166.1	88.2	35.7	171.4	87.0	35.0	168.8
Others	102.4	43.3	200.8	105.1	44.6	206.4	103.8	43.9	203.6
LSD (P=0.05)	6.3	5.3	10.0	6.8	5.9	10.9	6.5	5.6	10.4

Priming vs Basal $ZnSO_4$

The priming was found to be significantly superior over the soil application of $ZnSO_4$ and priming treatments increased height of pea and maize plants as compared to soil application of $ZnSO_4$ (Table 4).

Control vs others

Other treatments produced significantly taller plants as compared to control and treatments over control recorded significant increase over control (Table 4).

The increased germination of pea and maize seeds recorded in the present study was a result of higher germination in the method of soaking with distilled water at varying priming durations that induces metabolic activities of germination and the resulting sugars can be used for protein synthesis during germination, which improves germination rate and uniform growth of the plants (Rouhi *et al.,* 2011). Priming enhanced seed performances are related to the repair and the build-up of nucleic acid, enhanced synthesis of protein, repair of membranes and improves antioxidant system (Hsu *et al.,* 2003). Superiority of hydro priming on germination could be due to soaking time effects rather than $ZnSO_4$ treatment suggesting toxicity of $ZnSO_4$ due to ion accumulation in the embryo (Demir *et al.,* 1990). Because, hydro primed seeds compared to $ZnSO_4$ treated seeds were allowed to imbibe water for a longer time and went through the first stage of germination without protrusion of radicle. Akinola *et al.,* (2000) reported that higher duration of exposure to seed treatment resulted in higher cumulative germination in wild sunflower. The results are in line with the findings of (Thornton and Powell 1992) in Brassica (Srinivasan *et al.,* 1999) in mustard (Diniz *et al.,* 2009) in sweet pepper, (Fujikura *et al.,* 1993) in cauliflower, (Sadeghian and Yavari 2004) in sugar beet, (Caseiro *et al.,* 2004) in onion, (Michel 1983) corn, rice and chickpea. The beneficial effects of priming with nutrients have also been successfully reported by various scientists in various crops (Shah *et al.,* 2011; Aboutalebian *et al.,* 2012; Mirshekari *et al.,* 2012; Rehman *et al.,* 2012). However, deficiency or toxicity of nutrients may damage seed or restrict germination and may also cause abnormal seedlings as reported by Louzada and Vieira (2005) in bean seeds. They observed mortality of the seedlings in bean seeds due to high applications of micronutrients. Diniz *et al.,* (2009) observed reduced percentage of germination when higher doses of micronutrients were used for priming in sweet pepper. Environmental and genetic modalities may be accounted for the variability in plant height. Additionally, vegetative and reproductive growth potential of plants is also responsible for superior plant height.

The probable reason could be that priming of seeds results in an increased seedling vigor and strength and more established root growth, which enhanced the plant competency for light, water and nutrients resulting in more established plants. Seed priming increase cell division and seedling roots which cause an increase in plant height (Singh *et al.,* 2015). Kumar *et al.,* (2002) reported that 8 hours priming of finger millet seeds in water resulted in an increased mean plant height. Similar results regarding plant height due to the seed priming with Zn solution were reported by Arif *et al.,* (2005) and Ali *et al.,* (2005). These results confirmed the findings reported by Rashid *et al.,* (2002), who illustrated that seed priming improves the plant growth and stand. Moreover, Asgedom and Becker (2001) monitored that P and Zn primed seeds showed higher vigor than unprimed seed as reflected in maximum plant height. Alam *et al.,* (2013) also reported maximum spinach plant height when seeds were soaked for 24 hour using SSP+Na_2CO_3 solution.

Green pea pods, maize grains and maize equivalent yield

Effect of priming level

It is clear from the data that there was a remarkable influence of different priming levels on green pods yield of pea. The priming with 1% $ZnSO_4$ gave maximum yield followed by 0% $ZnSO_4$ (water soaking), but yield further declined with increasing priming concentration of $ZnSO_4$ from 2% to 3%. Different priming levels also significantly influenced grain yield of maize and the maximum increase was recorded for priming with 2% $ZnSO_4$ followed by 1% $ZnSO_4$ and 0% $ZnSO_4$ (water soaking), whereas, minimum yield was recorded with 3% $ZnSO_4$ priming solution. The priming levels exerted a significant effect on maize equivalent yield during both years and pooled yield and priming with 1% $ZnSO_4$ recorded highest maize equivalent yield. The minimum maize equivalent yield was observed due to priming with 3% $ZnSO_4$ solution. The maize equivalent yield obtained under 2% $ZnSO_4$ and 0 % $ZnSO_4$ (water soaking) was statistically equal during both years and on pooling the data (Table 5).

Effect of priming duration

Yield of pea pods and maize grains differ significantly among priming durations and the highest yield was obtained for 12 hours as compared to 8 and 4 hours duration (Table 5).

Interaction effect

The green pod yield of pea during individual year and for pooled data was significantly influenced due to interaction among priming levels and their duration. On the basis of observed interaction, it was noticed that maximum green pod yield was recorded due to priming with 1% $ZnSO_4$ for 12 hours duration. However, maximum grain yield of maize was recorded with 2% $ZnSO_4$ solution for 12 hours duration. The interaction among treatments was also found significant with respect to maize equivalent yield during both years as well as on pooling the data and highest yield was obtained with a treatment combination of 1% $ZnSO_4$ priming for 12 hours duration (Table 5).

Priming vs Basal $ZnSO_4$

The yield of fresh pea pods, maize grains and maize equivalent yield observed significant differences among priming and soil application of $ZnSO_4$ and highest yield was found under priming treatments (Table 5).

Control vs others

Other treatments had significantly higher fresh pea pods, maize grains and maize equivalent yield than control during both years and pooled yield (Table 5).

The primed seed emerge fast and more uniform and seedling grown more vigorously, leading to a wide range of phonological and yield related benefits. Therefore, better use of nutritional resources due to early emergence of plants can eventually result in higher seed yield of cereal crops (Badiri *et al.,* 2014). Higher yield of pea and maize due to Zn priming is attributed to the enhanced synthesis of carbohydrates and their transport to the site of grain production (Pedda- Babu *et al.,* 2007). Similar results were also reported by various researchers due to Zinc seed priming on grain yield of wheat (Nazir *et al.,* 2000; Harris *et al.,* 2005; Aboutalebian *et al.,* 2012), chickpea (Arif *et al.,* 2007), maize (Harris *et al.,* 2007; Imran *et al.,* 2013;

Mohsin *et al.,* 2014), barley (Rashid *et al.,* 2006), rice (Harris *et al.,* 1999), sunflower (Kahlon *et al.,* 1992; Hussain *et al.,* 2006) and pea (Golezani *et al.,* 2008). Nutrient priming has been shown to improve crop stand establishment, which can reportedly improve drought tolerance, reduce pest damage, increase crop yield (Harris *et al.,* 1999; Mussa *et al.,* 1999; Harris *et al.,* 2000). Considering the concentration of $ZnSO_4$ used in this study, it is expected that the higher Zn concentration used was completely absorbed by the seeds, this level probably exerted toxic effects, thereby reducing their performance due to interruption of cell division and development Reid *et al.,* (2004). Working with barley, Karabal *et al.,* (2003) observed that exposure of barley seedlings to B solutions at higher concentrations caused damage to membranes, thereby increasing membrane permeability and the malondialdehyde content of the cell, which is an important marker of oxidative stress. Johansen *et al.,* (2007) reported significantly higher grain yield under the molybdenum loading treatments than 0 % $ZnSO_4$ (water soaking). Arif *et al.,* (2007) recorded higher yield of chickpea and wheat Similarly, Khanal *et al.,* (2004-05) recorded higher mungbean yield under sodium molybdate loading than 0 % $ZnSO_4$ (water soaking). 0 % $ZnSO_4$ (water soaking) (8 hour) of mungbean seed produced higher grain yield than control (Rashid *et al.,* 2004).

Maskey *et al.,* (2007) reported chickpea and phaseolus bean yield increased with boron and molybdenum application. Umair *et al.,* (2011) found similar effect on seed yield of mungbean under dry seed, hydro-priming and molybdenum loading treatments. Increased sucrose synthase and glutamine synthetase activities in primed chickpeas nodule enhanced nodule biomass, metabolic activity, seed fill and better yield (Kaur *et al.,* 2006; Khan *et al.,* 2008; Subedi and Yadav, 2013).

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