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Effect of seed priming with zinc sulfate on yield and quality parameters of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh

Munish Sharma and DK Parmar

Abstract
In order to evaluate the effect of seed priming with zinc sulfate on yield and quality parameters of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh, an experiment was conducted under mid hill conditions of Himachal Pradesh. The 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). 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. Whereas, the quality of fresh pea pods (TSS) and protein content of pea and maize grains were not influenced due to treatments.

Keywords: seed priming, zinc sulfate, maize-pea, yield, quality parameters

Introduction
Zinc (Zn) is one of the vital micronutrients for plants as it has many critical functions. It acts as a cofactor for more than 300 enzymes and is also required for the production of tryptophan which is a precursor of auxin (Aravind and Prasad 2003) [4]. Zinc also plays a key role in maintaining the integrity of biological membranes, protein synthesis, photosynthesis, pollen formation and disease resistance (Alloway 2008; Hajiboland and Amirazad 2010) [3, 11]. Moreover, more than 3000 proteins contain Zn prosthetic groups in their structure (Tapiero and Tew 2003) [38].
Seed priming with Zn can improve crop emergence, stand establishment, subsequent growth, yield and quality of crops. For example, in common bean (*Phaseolus vulgaris* L.), seed priming with Zn significantly improved yield and related traits (Kaya *et al*. 2007) [22]. In barley (*Hordeum vulgare* L.), seed priming with Zn improved germination and seedling development (Ajouri *et al*. 2004) [2]. Ozturk *et al*. (2006) [31] found that Zn in newly-developed radicles and coleoptiles during seed germination was much higher (up to 200 mg kg-1) thus highlighting the involvement of Zn in physiological processes during early seedling development, possibly in protein synthesis, cell elongation membrane function and resistance to abiotic stresses (Cakmak 2000) [8]. Hence, in the present investigation, effect of seed priming with zinc sulfate on yield and quality parameters of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh was undertaken.

Material 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.

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
ii.	Soil pH	6.1
iii.	Organic carbon (g kg^{-1})	6.3
iv.	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

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.

Result and Discussion

Green pea pods, maize grains and maize equivalent yield

Effect of priming level

The data pertaining to the effect of different priming levels on fresh green pods yield of pea has been highlighted in table 4.2. 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%. The priming with 1% $ZnSO_4$, as compared to 0% $ZnSO_4$ (water soaking), 2% $ZnSO_4$ and 3% $ZnSO_4$ increased green pods yield by 6.3, 14.5 and 86.3%, respectively during 2014-15; 6.3, 14.5 and 84.3%, respectively in 2015-16 and 6.3, 14.6 and 85.3%, respectively for the pooled yield.

The data pertaining to the effect of priming levels on maize grain yield has been provided in table 2. The data revealed that different priming levels 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. Priming with 2% $ZnSO_4$ increased yield as compared to priming with 0% $ZnSO_4$ (water soaking), 1% $ZnSO_4$ and 3% $ZnSO_4$ by 29.6, 12.1 and 67.1%, respectively in the year 2015; 29.9, 12.3 and 69.0%, respectively in 2016 and 29.9, 12.3 and 67.8%, respectively for pooled yield.

The priming levels exerted a significant effect on maize equivalent yield during both years and pooled yield (Table 4.2). The priming with 1% $ZnSO_4$ recorded highest maize equivalent yield of 238.0 q ha^{-1} in 2015, 244.2 q ha^{-1} during 2016 and 241.4 q ha^{-1} on pooling the data. The minimum maize equivalent yield was observed due to priming with 3% $ZnSO_4$ solution which was 134.1 q ha^{-1} in 2015, 138.6 q ha^{-1} in 2016 and 136.4 q ha^{-1} for pooled data. 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 2: 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	S	S	S	S	S	S	S	S	S
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

Effect of priming duration

The data showing the effect of varying priming durations on green pods yield of pea has been presented in table 4.2. The data indicated that yield of pea pods differ significantly among priming durations. The pods yield increased with increasing duration time from 4 to 12 hours and the highest yield was obtained for 12 hours, which increased yield over 8 and 4 hours duration by 6.8 and 18.7%, respectively in the year 2014-15; 6.5 and 18.1%, respectively during 2015-16 and 6.6 and 18.3%, respectively in case of pooled data.

The maize grain yield has been presented in table 4.2 and the data revealed that yield observed significant differences among duration treatments and the maximum yield was recorded for 12 hours duration time, which increased yield over 8 and 4 hours duration by 16.4 and 38.6%, respectively in 2015; 15.7 and 37.3%, respectively in 2016 and 16.2 and 38.2%, respectively in case of pooled data.

The maize equivalent yield differ significantly among varying priming durations from 4 to 12 hours (Table 4.2). The yield increased with increasing priming durations and highest maize equivalent yield was obtained for 12 hours priming duration (222.7 q ha^{-1}in 2015, 228.4 q ha^{-1}during 2016 and 225.6 q ha^{-1}pooled yield), followed by 8 hours priming (204.8 q ha^{-1} during 2015, 210.4 q ha^{-1} in 2016 and 207.6 q ha^{-1} on pooling data) and 4 hours priming duration (181.6 q ha^{-1}during 2015, 187.1 q ha^{-1} during 2016 and 184.3 q ha^{-1} in case of pooled yield).

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 (Table 4.2). On the basis of observed interaction, it was noticed that maximum green pod yield of 136.2 q ha^{-1} in 2014-15; 139.3 q ha^{-1} in 2015-16 and 137.8 q ha^{-1} in case of pooled yield, was recorded due to priming with 1% $ZnSO_4$ for 12 hours duration.

The data in table 4.2 further revealed that interaction among priming levels and their duration was positive and significant for maize grain yield during both years and pooled data. The maximum grain yield of 69.2 q ha^{-1} in 2015; 71.0 q ha^{-1} in 2016 and 70.1 q ha^{-1} 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 4.2).

Priming vs Basal $ZnSO_4$

The data presented in table 4.2 revealed that yield of fresh pea pods observed significant differences among priming and soil application of $ZnSO_4$. The observed increase in pod yield due to priming over soil applied $ZnSO_4$ was 15.6% in 2014-15; 15.3% in 2015-16 and 15.4% for pooled data.

A perusal of data in table 4.2 indicated that there was a significant effect of priming over soil application of $ZnSO_4$ during individual year and on pooling of the data. The priming treatments increased maize grain yield over soil applied $ZnSO_4$ by 21.9% in 2015; 20.5% in 2016 and 21.3% for pooled data.

The data in table 4.2 further showed that maize equivalent yield differ significantly among priming and soil applied Zn during both years and pooled data. The priming treatments recorded higher equivalent yield (203.0 qha^{-1} in 2015; 208.6 q ha^{-1} and 205.8 q ha^{-1} for pooled data) in comparison to soil application of $ZnSO_4$ (173.7 qha^{-1} in 2015; 179.2 q ha^{-1} and 176.4 q ha^{-1} for pooled data).

Control vs others

The data presented in table 4.2 demonstrated that pod yield of pea differ among treatments and control. The treatments increased yield over control by 19.5% in 2014-15; 19.2% in 2015-16 and 19.3% for pooled data.

The data in table 4.2 revealed that treatments had significantly better maize grain yield than control during individual year and on pooling of the data and the treatments increased maize grain yield over control by 26.6% in 2015; 24.9% in 2016 and 25.4% for pooled data.

The data provided in table 4.2 further showed that other treatments had significantly higher maize equivalent yield during both years and pooled yield and treatments recorded maximum maize equivalent yield of 200.8 q ha^{-1} in 2015; 206.4 q ha^{-1} in 2016 and 203.6 q ha^{-1} for pooled data in comparison to control 166.1 q ha^{-1} in 2015; 171.4 q ha^{-1} in 2016 and 168.8 q ha^{-1} for pooled data.

The higher yield obtained during the current investigation can be explained on the grounds that seed priming with micronutrients increased seed yield and this increase can be related to rapid, optimal establishment of the plants and their greater ability in using nutrient. 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) [6].

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) [32]. 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) [29, 35], chickpea (Arif *et al*. 2007) [5], maize (Harris *et al*. 2007; Imran *et al*. 2013; Mohsin *et al*. 2014) [33], barley (Rashid *et al*. 2006) [33], rice (Harris *et al*. 1999) [33], sunflower (Kahlon *et al*. 1992; Hussain *et al*. 2006) [19, 17] and pea (Golezani *et al*. 2008) [10]. 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; Musa *et al*. 1999; Harris *et al*. 2000) [33, 34, 28].

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) [36]. Working with barley, Karabal *et al*. (2003) [20] 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) [28] reported significantly higher grain yield under the molybdenum loading treatments than 0 % $ZnSO_4$ (water soaking). Arif *et al*. (2007) [5] recorded higher yield of chickpea and wheat Similarly, Khanal *et al*. (2004-05) [23, 24] 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) [34]. Maskey *et al*. (2007) [25] reported chickpea and phaseolus bean yield increased with boron and molybdenum application. Umair *et al*. (2011) [39] 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) [23, 21, 37].

Stover yield of pea and maize

Effect of priming level

A cursory look into the data presented in table 4.3 indicated that stover yield of pea was significantly influenced among different priming levels and maximum yield was recorded with 1% $ZnSO_4$ priming, which increased stover yield of pea $ZnSO_4$ in comparison to 0% $ZnSO_4$ (water soaking), 2% $ZnSO_4$ and 3% $ZnSO_4$ by 11.6, 26.1 and 119.1%, respectively during 2014-15; 11.7, 26.5 and 118.1%, respectively in 2015-16 and 11.6, 26.3 and 118.6%, respectively for pooled data.

Further the data presented in table 4.3 indicated that maize stover yield significantly varied among priming levels and the maximum stover yield was recorded for priming with 2% $ZnSO_4$ and it increased stover yield in comparison to 0% $ZnSO_4$ (water soaking), 1% $ZnSO_4$ and 3% $ZnSO_4$ priming solution by 33.5, 14.0 and 88.3%, respectively in 2015; 34.1, 14.5 and 89.3%, respectively in 2016 and 33.9, 14.2 and 88.8%, respectively for the pooled data.

Effect of priming duration

The data in relation to pea stover yield as influenced by different priming durations have been given in table 4.3. The results showed that pea stover yield varied significantly among different priming durations and maximum yield was recorded for 12 hours priming duration, which increased yield in comparison to 8 and 4 hours priming duration by 6.9 and 18.6%, respectively in the year in 2014-15; 6.6 and 18.0%, respectively during 2015-16 and 7.2 and 18.5%, respectively for 8 and 4 hours duration in case of pooled data.

The data with respect to the effect of different priming durations on maize stover yield is presented in table 4.3. The data suggests that maize stover yield was significantly different among priming durations and the maximum stover yield was recorded for 12 hours duration, which increased stover yield over priming duration of 8 and 4 hours by 17.1 and 43.6%, respectively in the year in 2015; 16.5 and 42.1%, respectively during 2016 and 16.8 and 42.7%, respectively in case of pooled data.

Interaction effect

The stover yield of pea was significantly influenced due to interaction among priming levels and their duration (Table 4.3). It was observed that priming with 1% $ZnSO_4$ for 12 hours duration recorded maximum pea stover yield of 34.1 q ha^{-1} in 2014-15; 35.7 q ha^{-1} in 2015-16 and 34.9 q ha^{-1} for pooled yield.

The interaction among priming levels and their duration was also found significant for maize stover yield and on the basis of observed interaction, it can be infer that priming with 2% $ZnSO_4$ for 12 hours duration recorded maximum stover yield of 121.8 q ha^{-1} in 2015; 125.3 q ha^{-1} in 2016 and 123.6 q ha^{-1} for pooled data. (Table 4.3)

Priming vs Basal $ZnSO_4$

An examination of data presented in table 4.3 indicated that priming exhibited a significant effect on pea stover yield than soil application of $ZnSO_4$, and priming increased stover yield in comparison to soil applied $ZnSO_4$ by 22.1% in 2014-15; 22.0% in 2015-16 and 22.1% for pooled data.

An examination of data presented in table 4.3 showed that the effect of priming was found to be significantly superior to soil application of $ZnSO_4$ and priming treatments increased maize stover yield over Zn application in soil by 22.8% in 2015; 21.9% in 2016 and 22.3% for pooled data.

Control vs others

The priming treatments produced higher stover yield than control and treated plots observed an increase in yield over control to the tune of 24.4% in 2014-15, 23.5% in 2015-16 and 23.6% for pooled data (Table 4.3).

The data presented in table 4.3 further demonstrated that treatments significantly influenced maize stover yield in comparison to control and maize stover yield due to treatments was highest as much as 28.1% in 2015; 26.9% in 2016 and 27.4% for pooled data.

Zinc plays critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activates and thus their importance in achieving higher yields (Zeidan *et al*. 2010) [40]. These results endorse the finding of Rashid *et al*. (2000) [33], who reported that priming treatment significantly increased total biomass and dry weight as compared to control. Higher straw yield due to seed priming with Zinc enhanced the photosynthesis process and translocation of the photosynthesis, which resulted in enhanced enzymatic activity and other biological activity. The results are in close agreement with Chhibba *et al*. (2007) [9] and Meena *et al*. (2013) [26], who observed increased rice straw yield for priming as compared to no soaking. In barley seed priming with zinc caused marked increase in accumulation of dry matter in barley (Ajouri *et al*. 2004) [2]. Arif *et al*. (2007) [5] also reported that seed priming in Zinc solution had pronounced effect on dry matter yield of wheat and chickpea.

The increase in biological yield might be due to better early seedling growth and plant nutrition as report by Zhang *et al*. (2009) [41]. These results also coincide with the finding of Badiri *et al*. (2014) [6], who reported that total biomass significantly increased due to seed priming with Zn, Fe, Mn. Mehri *et al*. (2015) also observed that priming methods and time increased biological yield of soybean. Abdolrahmani *et al*. (2010) stated that in Zn-deficient soils, plants of Zn-rich seeds produced higher dry matter and absorbed Zn with higher efficiencies at the later growth stages. Arif *et al*. (2007) [5] also reported that seed priming in Zinc solution significantly affected biological yield of wheat and chickpea. According to them, the increase in biological yield might be due to better early seedling growth and plant nutrition as report by Zhang *et al*. (2009) [41].

Table 3: Effect of priming levels and their duration on stover yields (q ha^{-1})

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	27.7	53.2	29.1	54.9	28.4	54.0
1% $ZnSO_4$	30.9	62.3	32.5	64.3	31.7	63.3
2% $ZnSO_4$	24.5	71.0	25.7	73.6	25.1	72.3
3% $ZnSO_4$	14.1	37.7	14.9	38.8	14.5	38.3
LSD (P=0.05)	1.1	5.4	1.3	6.1	1.2	5.8
B. Priming Duration						
4 hours	22.1	45.9	23.3	47.7	22.7	46.8
8 hours	24.5	56.3	25.8	58.2	25.1	57.2
12 hours	26.2	65.9	27.5	67.8	26.9	66.8
LSD (P=0.05)	1.0	4.7	1.1	5.3	1.1	5.0
Interaction A × B	2.0	9.4	2.2	10.6	2.1	10.0
Soil application vs priming						
Soil application	19.9	45.6	20.9	47.5	20.4	46.6
Priming	24.3	56.0	25.5	57.9	24.9	57.0
LSD (P=0.05)	1.5	6.9	1.6	7.8	1.5	7.3
Control vs Others						
Control	19.3	43.1	20.4	45.0	19.9	44.1
Others	24.0	55.2	25.2	57.1	24.6	56.2
LSD (P=0.05)	1.5	6.9	1.6	7.8	1.5	7.3

Effect of priming levels and their duration on quality of crop produce

Total soluble solids (TSS) in fresh pea grains

Effect of seed priming level

The data with respect to total soluble sugar (TSS) of pea grains in fresh pods, as influenced by different priming levels has been reported in table 4.4. The data indicated that TSS content was significantly different among priming treatments and highest TSS was recorded for priming with 1% $ZnSO_4$ followed by 0% $ZnSO_4$ (water soaking), which increased its content over 2% $ZnSO_4$ and 3% $ZnSO_4$ by 5.5, 13.9 and 26.9%, respectively in the year 2014-15; 5.9, 13.3 and 26.8%, respectively in 2015-16 and 5.7, 13.6 and 26.8%, respectively for pooled data.

Effect of priming duration

The data with respect to effect of different priming durations on TSS has been provided in table 4.4. The data demonstrated that TSS of pea grains differ significantly under variable priming durations and increased with increasing duration from 4 to 12 hours. The maximum TSS was recorded for 12 hours duration and increased TSS over 8 and 12 hours duration by 13.8 and 6.1%, respectively in 2014-15; 13.8 and 7.4%, respectively in 2015-16 and 13.8 and 6.8%, respectively for pooled TSS.

Interaction effect

The interaction of priming levels and their duration did not significantly influenced TSS content of pea grains during both years and pooling the data (Table 4).

Priming vs Basal $ZnSO_4$

An examination of data presented in table 4.4 indicated that priming had significantly higher TSS as compared to soil application of $ZnSO_4$ and priming increased TSS over Zn applied in soil by 6.0% in 2014-15; 5.0% in 2015-16 and 5.5% for pooled data.

Control vs others

The data in table 4.4 further showed that control treatments recorded low TSS in comparison to other treatments and the increase posed by treatments over control was 8.4% in 2014-15; 7.0% in 2015-16 and 7.6% for pooled data.

Table 4: Effect of priming levels and their duration on TSS content (^{0}brix) of fresh pea pods

Treatments	2014-15 Pea	2015-16 Pea	Pooled
A. Priming Level			
0% Zn (water soaking)	16.8	17.1	16.9
1% $ZnSO_4$	17.7	18.1	17.9
2% $ZnSO_4$	15.6	16.0	15.8
3% $ZnSO_4$	14.0	14.3	14.1
LSD (P=0.05)	0.3	0.4	0.3
B. Priming Duration			
4 hours	15.0	15.3	15.2
8 hours	16.1	16.3	16.2
12 hours	17.0	17.5	17.3
LSD (P=0.05)	0.3	0.3	0.3
Interaction A × B	NS	NS	NS
Soil application vs priming			
Soil application	15.1	15.6	15.3
Priming	16.0	16.4	16.2
LSD (P=0.05)	0.4	0.5	0.4
Control vs Others			
Control	14.7	15.2	15.0
Others	15.9	16.3	16.1
LSD (P=0.05)	0.4	0.5	0.4

Crude protein in pea and maize grains

Effect of priming level

The data presented in table 4.5 indicated that different priming levels did not influence protein content of pea grains at harvest. The protein content among varing priming levels ranged from 11.2 to 11.3%, 11.4 to 11.5% and 11.3 to 11.4%, in 2014-15, 2015-16 and pooled data, respectively.

The data presented in table 4.5 further revealed that different priming levels had no significant effect on protein content of maize grains at harvest. The protein content with in various priming levels ranged from 10.4 to 10.4%, 10.6 to 10.8% and 10.5 to 10.6% in 2015, 2016 and pooled data, respectively.

Effect of priming duration

The data presented in table 4.5 demonstrated that there was no significant effect of priming durations on protein content of pea at harvest. The protein content of pea grains varied from 11.2 to 11.2%, 11.4 to 11.5% and 11.3 to 11.4% during 2014-15, 2015-16 and pooled data, respectively.

The data provided in table 4.5 further showed no differences among priming durations with respect to protein content of maize grains. The protein content of maize among different priming durations varied from 10.4 to 10.4%, 10.7 to 10.7% and 10.5 to 10.6 in the year 2015, 2016 and pooled data, respectively.

Interaction effect

The data in table 4.5 indicated that protein content of pea and maize grains at harvest was not influenced due to interaction among priming levels and their duration during both years and on pooling the data.

Priming vs Basal $ZnSO_4$

The data suggested that protein contents of pea and maize grains under priming and soil applied $ZnSO_4$ were statistically similar during individual year and on pooling data (Table 4.5).

Control vs others

The data in table 4.5 indicated that other treatments and control had statistically similar protein content at harvest of pea and maize crop.

The non-significant effect of priming on produce quality of pea and maize crop are similar to the results reported by Hoang Truc (2015) [16], who reported that seed priming with Zinc and Iron did not influence quality of wheat. Similar results were also obtained by Nazir *et al*. (2000) [30], who observed that seed treatment with micronutrients did not play any significant role in the improvement of grain protein content of wheat. These results are also in line with the findings of Bosewell and Worthington (1971) [7].

Table 5: Effect of priming levels and their duration on protein content (%) of pea and maize grains

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	11.19	10.38	11.43	10.61	11.31	10.49
1% $ZnSO_4$	11.20	10.39	11.45	10.76	11.33	10.58
2% $ZnSO_4$	11.22	10.41	11.45	10.76	11.34	10.59
3% $ZnSO_4$	11.26	10.45	11.49	10.80	11.38	10.63
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
B. Priming Duration						
4 hours	11.18	10.37	11.43	10.72	11.31	10.54
8 hours	11.22	10.41	11.45	10.73	11.34	10.57
12 hours	11.25	10.44	11.48	10.76	11.36	10.60
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction A × B	NS	NS	NS	NS	NS	NS
Soil application vs priming						
Soil application	11.10	10.29	11.35	10.67	11.23	10.48
Priming	11.22	10.41	11.45	10.74	11.34	10.57
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Control vs Others						
Control	11.04	10.23	11.29	10.60	11.17	10.42
Others	11.21	10.40	11.45	10.73	11.33	10.56
LSD (P=0.05)	NS	NS	NS	NS	NS	NS

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