International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 15, No. 1, p. 155-161, 2019

INNSPUB

RESEARCH PAPER OPEN ACCESS

Yield improvement of direct sown rice on raised beds using different priming techniques in salt affected soils

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Key words: Rice; direct seeding; priming techniques; beds; salinity.

http://dx.doi.org/10.12692/ijb/15.1.155-161 Article published on July 06, 2019

Abstract

The principal method for rice establishment is transplanting, however, water scarcity and labor shortage limited the transplanting method and required an alternative approach. One of the most pragmatic and economical approach is the direct seeding of rice in an aerobic condition, but problems associated with direct seeding rice are weed infestation, uneven crop stand and poor germination and these problems are further exacerbated in saline conditions. To overcome these problems, seed priming is an effective and economical technology for uniform emergence and establishment of seedlings, improved robustness and enhanced yields. So, a three years experiment was conducted from 2016 to 2018 to investigate the yield enhancement of direct sown rice with different seed priming agents using raised bed sowing method in salt affected soil. Treatments included in the study were: T_1, KH_2PO_4 (2 %), T_2, $ZnSO_4$ (2 %), T_3, SSP (1 %), T_4, $MgSO_4$ (2 %), T_5, SSP + Urea (1% each). Experimental designed was RCBD with three replications. Seeds of rice cultivar (KSK-133) were soaked for 12 hours in respective osmopriming agents according to treatments plan. Three seeds per hill were sown by dibbling maintaining P x P and R x R distance of 30 cm. Yield and yield determining attributes of rice crop were recorded at harvesting. Results of our study showed that yield and yield determining attributes of direct sown rice were significantly influenced by all the seed priming agents, particularly seed priming with SSP solutions proved more superior as compared to other treatments and produced maximum paddy yield of direct sown rice. Therefore, it is suggested that seed priming with SSP solution can be an effective strategy to increase the yield of direct sown rice in salt affected soil which is easily and readily available source of phosphorus to poor farmers.

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Introduction

More than half of the world population used the rice as staple food (Seck *et al.,* 2012) and transplanting is a principal method for rice establishment. Nevertheless, water scarcity and labor shortage limited the transplanting method and required an alternative approach. One of the most pragmatic and economical approach is the direct seeding of rice in an aerobic condition. However, problems associated with direct seeding rice are weed infestation, uneven crop stand and poor germination (Du and Tuong, 2002) and these problems are further exacerbated in saline conditions. So, to overcome these problems, seed priming is an effective technology for uniform emergence and establishment of seedlings, improved robustness and enhanced yields (Harris *et al.,* 2007; Farooq *et al.,* 2008). Seed priming involves a partial hydration of seeds which initiates germination (Farooq *et al.,* 2006). Osmo priming is an approach in which seed is soaked in different inorganic salts (Farooq *et al.,* 2008) which improve the physiological and metabolic process of seed (Shehab *et al.,* 2010). Ruttanaruangboworn *et al.* (2017) assessed the seed priming effects of two levels of KNO_3 (1.0 and 2.0%) on two direct sown rice cultivars. They stated that priming the seed with 1.0% KNO_3 for 28 hours improved the germination rate and vigor of rice seedling. Similarly, in another study, Rehman *et al.* (2015) evaluated the effects of different seed priming agents on direct sown rice. Treatments were; T_1= (water soaking), T_2= KCl (2.2%), T_3= moringa leaf extracts (3.3%) T_4= $CaCl_2$ (2.2%). They stated that tillering, paddy yield and different grain quality parameters were highest in moringa leaf extracts and $CaCl_2$ which can be effectively used to enhance the performance of direct seeded rice. Farooq *et al.* (2010) examined the effects of different priming techniques on metabolic process during growth and seedling emergence of rice. Different treatments comprised were; T_1= Control T_2= Pre-germination T_3= hydropriming T_4= $CaCl_2$, T_5= KCl, T_6= Ascorbate priming, T_6= Hardening. They concluded that $CaCl_2$ was the most effective seed priming agents to enhance amylase activity, reducing sugars content and increased the seedling emergence. Seed priming effects of different phosphate solutions on maize was studied by Miraj *et al.* (2010). They used six treatments i.e. T_1=Non primed (control), T_2= (water soaked), T_3=KH_2PO_4 (1% P), T_4=SSP (1% P), T_5= DAP (1% P), T_6= SSP (1% P +20 g L^{-1} KOH). They described that yield and yield determining parameters of maize were increased with phosphorus priming agents and SSP + 20 g L^{-1} KOH and KH_2PO_4 were at par for improving the biomass and grain yield of maize crop. Shah *et al.* (2019) studied the seed priming effect of different solution of single super phosphate (0.5%, 1%, 1.5% and 2%) on two cultivars of okra. They concluded that seed priming with 0.5 % phosphorus solution proved more superior in improving the agronomic parameters like germination percentage, plant height, leaves per plant, pod yield and 100 seed weight of okra cultivar "Sabz Pari". Teshome *et al.* (2018) elucidated the performance of three seed priming agents i.e. water, 9 g urea L^{-1}, and 0.2 g $ZnSO_4$ L^{-1} on six cultivars of sorghum. They stated that seed priming with $ZnSO_4$ followed by urea significantly improved the germination%, growth and vigor of sorghum seedling in laboratory conditions. Anosheh *et al.* (2011) studied the response of four maize hybrids to seed priming under salt and drought stress. They used water (control), urea and KNO_3 as priming agents. They reported that seed priming with urea and KNO_3 alleviated drought and salt stress and increased the germination%, germination rate and shoot length of maize plant as compared to control. So, keeping the above facts in consideration, a study was designed to investigate the effects of different osmopriming agents on yield and yield contributing factors of direct sown rice in salt affected soil.

Materials and methods

A three years experiment was conducted from (2016 to 2018) at Soil Salinity Research Institute, Pindi Bhattian, to investigate the yield enhancement of direct sown rice with different seed priming agents using raised bed sowing method in salt affected soil. A salt affected field with EC_e, 5.52 (dS m^{-1}), pH_s, 8.81, and SAR, 38.42 $(mmol\ L^{-1})^{1/2}$ was selected, levelled and prepared. Treatments included in the study were:

T_1, KH_2PO_4 (2 %), T_2, $ZnSO_4$ (2 %), T_3, SSP (1 %) T_4, $MgSO_4$ (2 %), T_5, SSP + Urea (1% each). The experimental designed was RCBD with three replications. seeds of rice cultivar (KSK-133) were soaked for 12 hours in respective osmopriming agents according to treatments plan.

Three seeds per hill were sown by dibbling maintaining P x P and R x R distance of 30 cm. Fertilizers at the rate of (150-90-60 NPK kg ha^{-1}) was applied to rice.

All the plant protection and agronomic practices were employed uniformly. Yield and yield determining attributes of rice crop were recorded at harvesting of the crop. The collected crop data was statistically analyzed. The treatment mean comparison was made using Least Significant Difference Test @ 5% Probability (Steel *et al.,* 1997).

Results

Plant height

Results displayed in (Table 1) showed that the plant height of rice crop was significantly affected by priming techniques. Mean value of three seasons showed that maximum plant height (136.34 cm) was observed with seed priming of single super phosphate (1%) followed by single super phosphate + urea 1% (each) and both treatments were statistically significant ($p < 0.05$) from each other.

On the other hand, minimum plant height of 124.55 cm was observed in seed priming of zinc sulphate (2%).

Table 1. Effect of priming techniques on plant height (cm).

Treatment	2016	2017	2018	MEAN
T_1= KH_2PO_4 (2 %)	129.00 BC	131.00 B	129.33 B	129.78 D
T_2= $ZnSO_4$ (2 %)	124.00 C	125.33 C	124.33 C	124.55 E
T_3= SSP (1 %)	135.67 A	137.67 A	135.67 A	136.34 A
T_4= $MgSO_4$ (2 %)	130.00 AB	132.33 B	130.33 B	130.89 C
T_5= SSP + Urea (1% each)	132.67 AB	134.67 AB	133.33 AB	133.56 B

Means sharing the same letters are statistically similar at $P \leq 0.05$.

No. of tillers (m^{-2})

Average value data in Table 2 exhibited that seed priming also significantly influenced the number of tillers and maximum number of tillers (236.45) were recorded when single super phosphate (1%) was used as seed priming agents, followed by single super phosphate + urea 1% (each). Minimum number of tillers (221.11) were recorded when zinc sulphate (2%) was used as priming agents.

Table 2. Effect of priming techniques on number of tillers (m^{-2}).

Treatment	2016	2017	2018	MEAN
T_1= KH_2PO_4 (2 %)	227.00 B	231.67 AB	227.33 C	228.67 C
T_2= $ZnSO_4$ (2 %)	219.67 C	222.33 C	221.33 D	221.11 D
T_3= SSP (1 %)	234.67 A	238.00 A	236.67 A	236.45 A
T_4= $MgSO_4$ (2 %)	228.00 B	231.00 B	230.00 BC	229.67 C
T_5= SSP + Urea (1% each)	231.33 AB	232.33 AB	233.33 AB	232.33 B

Means sharing the same letters are statistically similar at $P \leq 0.05$.

No. of spikelets panicle^{-1}

Results regarding number of spikelets (Table 3) indicated maximum number of spikelets (217.33) were produced when rice seeds were primed with single super phosphate (1%) however, at the same time it was statistically ($p < 0.05$) non-significant from single super phosphate + urea 1% (each) and $MgSO_4$(2%). While minimum number of spikelets (207.00) were produced when rice seeds were primed with zinc sulphate (2%).

Paddy yield (t ha^{-1})

Pooled data of three seasons showed that seed priming technologies had remarkable effect on paddy yield of rice crop (Table 4). Among all the seed priming agents used, single super phosphate (1%) proved more efficient and produced maximum paddy yield of 5.19 t ha^{-1} which was statistically significant from all other seed priming agents. At the same time zinc sulphate (2%) recorded minimum paddy yield of 4.40 t ha^{-1}.

Table 3. Effect of priming techniques on number of spikelets panicle^{-1}.

Treatment	2016	2017	2018	MEAN
T_1= KH_2PO_4 (2 %)	210.33 A	212.33 AB	212.67 AB	211.78 B
T_2= $ZnSO_4$ (2 %)	201.33 B	209.33 B	210.33 B	207.00 C
T_3= SSP (1 %)	215.33 A	218.00 A	218.67 A	217.33 A
T_4= $MgSO_4$ (2 %)	213.33 A	215.33 AB	216.33 AB	215.00 A
T_5= SSP + Urea (1% each)	215.00 A	217.67 A	218.00 A	216.89 A

Means sharing the same letters are statistically similar at $P \leq 0.05$.

Straw yield (t ha^{-1})

Seed priming techniques also had noticeable effect on straw yield of rice crop (Table 5). Maximum paddy yield (12.99 t ha^{-1}) was recorded with single super phosphate (1%) followed by single super phosphate + urea 1% (each) and minimum paddy yield (10.13 t ha^{-1}) was produced by zinc sulphate (2%).

Table 4. Effect of priming techniques on paddy yield (t ha^{-1}).

Treatment	2016	2017	2018	MEAN
T_1= KH_2PO_4 (2 %)	4.71 CD	4.61 CD	4.26 C	4.52 D
T_2= $ZnSO_4$ (2 %)	4.63 D	4.53 D	4.06 D	4.40 E
T_3= SSP (1 %)	5.34 A	5.23 A	5.00 A	5.19 A
T_4= $MgSO_4$ (2 %)	4.93 BC	4.83 BC	4.48 B	4.74 C
T_5= SSP + Urea (1% each)	5.02 B	4.92 B	4.60 B	4.84 B

Means sharing the same letters are statistically similar at $P \leq 0.05$.

1000 grain weight (gm)

Pooled data of three seasons revealed that maximum 1000 grain weight (33.88 gm) was documented with single super phosphate (1%) followed by $MgSO_4$ (2%) and single super phosphate + urea 1% (each). Whereas minimum 1000 grain (29.44 gm) was recorded by zinc sulphate (2%).

Discussion

Seed priming technique was proposed in 1973 by Heydecker (1973). It is a technique which can improve the seed germination and emerge of seedlings and vigor especially under environmental stress conditions (Savvides *et al.,* 2016; Amirnia and Ghiyasi, 2016). Germination stage is most sensitive stages to salinity in plant life cycle (Ashraf *et al.,* 1986). After treatment with some priming agents, plants seed show improved resistance to salt stress (Ruan *et al.,* 2003) and germination is also improved under stress conditions because seed priming stimulate the activity of antioxidants enzyme like SOD, POD and CAT and increased the levels of soluble sugars and proline (Yan, 2015).

Result of the current study depicted that seed priming with different osmo priming agents had the significant affects on rice growth in term of plant height and number of tillers. Maximum plant height, numbers of tillers and spikelets per panicle was observed, when single super phosphate (1%) was used as seed priming agents, followed by single super phosphate + urea 1% (each).

Table 5. Effect of priming techniques on straw yield (t ha^{-1}).

Treatment	2016	2017	2018	MEAN
T_1= KH_2PO_4 (2 %)	10.43 AB	11.00 B	10.06 B	10.49 D
T_2= $ZnSO_4$ (2 %)	10.00 B	10.73 B	9.66 B	10.13 E
T_3= SSP (1 %)	12.66 A	13.66 A	12.66 A	12.99 A
T_4= $MgSO_4$ (2 %)	10.96 AB	11.46 AB	10.86 AB	11.09 C
T_5= SSP + Urea (1% each)	11.42 AB	12.01 AB	11.16 AB	11.53 B

Means sharing the same letters are statistically similar at $P \leq 0.05$.

This increased in growth parameters of rice crop could be justified by the fact that phosphorus plays a significant role in plant growth and its deficiency has detrimental effects on photosynthetic activity (Usuda and Shimogawara, 1992). Previously it has been reported that phosphorus deficiency decreased the rate of regeneration of ribulose 1, 5-bisphosphate along with the content and activity of ribulose 1, 5-bisphosphate carboxylase which ultimately negatively affect the photosynthetic activity (Jacob and Lawlor, 2003). Our results are in accordance with the previous findings of Arif, *et al.* (2005) who stated that priming with 1% P + 2% Zn increased the shoot fresh weight of maize plant. Positive response of seed priming has also been described by Ali *et al.* (2008) who stated that seed priming of wheat seeds with 0.3 % phosphorus solution improved the number of grains $spike^{-1}$. Improved performance of osmoprimed seed may be explained by the fact that priming attribute in metabolic repair processes, osmotic adjustment during treatment or accumulates the germination metabolites (Haghpanah *et al.,* 2009).

Table 6. Effect of priming techniques on 1000 grain weight (gm).

T_1= KH_2PO_4 (2 %)	2016	2017	2018	MEAN
T_2= $ZnSO_4$ (2 %)	23.66 C	25.00 C	25.00 C	24.55 D
T_3= SSP (1 %)	28.66 B	29.66 B	30.00 B	29.44 C
T_4= $MgSO_4$ (2 %)	33.00 A	34.66 A	34.00 A	33.88 A
T_5= SSP + Urea (1% each)	30.33 B	31.33 AB	31.66 AB	31.11 B
T_1= KH_2PO_4 (2 %)	29.66 B	31.66 AB	30.66 AB	30.66 B

Means sharing the same letters are statistically similar at $P \leq 0.05$.

Results of our studies revealed that different seed priming agents also positively affected the paddy and straw yield and yield attributes like number of sipkelets per panicle and 1000 grain weight. This increased in yield and yield attributing factors was due to fact that priming enhances the seed metabolism and more protein is synthesized which has direct role in increasing the seed performance and hence yield (Varier *et al.,* 2010). Our findings are in agreement with results of Rehman *et al,* (2011) who reported that priming with $CaCl_2$ produced maximum number of productive tillers in direct sown rice. Improve yield with osmo priming was due to better nutrition, chlorophyll stability index, improved assimilatory system and root volume making direct seeded rice adaptive to low soil water content (Rehman *et al.,* 2015). Improved paddy/ straw and 1000 grain weight with SSP seems to be the possible role of phosphorus affecting assimilatory process and improving plant water status and hence grain yield (Haloi *et al,* 2006). Similarly, dry matter yield of wheat improved with priming and maximum dry matter yield of wheat was achieved when seed were primed with 0.2% P_2O_5 solution (Khalil *et al.,* 2010) which reinforced the findings of current study. Iqbal and Chauhan (2003) also reported an increase of 94 % over control in straw yield of maize by seed priming.

Conclusion

So, the findings of our study suggest that seed priming with different osmo priming agents should be employed in direct seeded rice particularly seed priming with SSP solutions proved more superior over other treatments. Seed priming with SSP solution can be an effective strategy to increase the yield of direct sown rice in salt affected soil which is easily and readily available source of phosphorus to poor farmers.

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