Impact of seed priming and seed rate on productivity and economic profitability of wheat (*Triticum aestivum* L.)

Abstract

In order to achieve optimal plant growth, the lifecycle of plants encounters various critical stage such as uneven seed germination, induce early flowering, poor and early seedling growth, poor root establishment which ultimately results in low crop yield. Keeping in view of the hypothesis of seed priming improves seedling emergence, reduces seedling emergence time, reduces seed dormancy, expands root growth, enhances nutrient uptake, resulted in better yield and yield contributing characters of plants, a field experiment was planned during Rabi season to figure out the effect of seed priming and seed rate on the yield performance of wheat. The experiment was laid out in factorial randomized block design which replicated thrice. The treatments included four seed priming methods (P1: no seed priming, P2: water seed priming, P3: 1% KNO3 seed priming, P4: 1% CaCl2 seed priming) and three seed rates (S1: 100 kg ha-1, S2: 125 kg ha-1, S3: 150 kg ha-1) using the wheat variety HD-2967. The result revealed that the yield and yield attributes of wheat were significantly influenced by the priming techniques. Seed priming with 1% $CaCl_2$ solution increased grain yield (3977 kg ha^{-1}), number of ear head (275.61 m^{-2}), length of ear head (11.29 cm), number of grains per ear head (46.17) and test weight (41.11 g) and was found to be statistically at par with seed priming with 1% KNO_3, but significantly superior over seed priming with water and dry seeding. Different seed rate significantly influenced grain and straw yield and yield contributing characters of wheat. The higher grain yield (3959 kg ha^{-1}), straw yield (5095 kg ha^{-1}) and no. of ear head (287.83) was obtained with the seed rate@150 kg/ha followed by 125 and 100 kg ha^{-1} of seed rate.

Key words: *Productivity, Profitability, Seed priming, Seed rate, Wheat*

Introduction

Wheat (*Triticum aestivum* L.) is the one of the most staple food crops for rabi season grown in India as well as in the state Bihar. It is an annual, hexaploidy (2n = 6X= 42) crop, belongs to the family Poaceae (Gramineae). "Being the most predominant cultivated cereal crop of the world, wheat ranks first (30%) followed by rice (27%) and maize (25%) among the cereal crops. Wheat production of our country is 109.59 million tons from 29.65-million-hectare area with productivity of 3.47 t ha^{-1} (Directorate of Economics and Statistics of India, 2021-22). Globally, India is the second largest producer of wheat contributing 12% in area and 11.9% in production, next to Chaina. In India, U.P ranks first in area and production while Punjab ranks first in productivity. In Bihar, area under wheat cultivation is 2.22 m ha with production 6.34 m ton having average yield of 2855 kg ha^{-1}" (USDA 2021-22). Agronomic practices, particularly seed rate, play an indispensable role in maintaining optimum plant population and for realizing higher yield. The blanket recommendation of seed rates is not suitable for all varieties and in all agro-ecosystems. Hence, proper seed rate is a must to provide optimum space and proper availability of moisture and nutrients which certainly will help for better growth and development of a crop. If plant density is above the optimum, the plant development might be poor because of competition for nutrients, light and space. On the other hand, if it is below optimum, at that point the nutrients, space and light won't be used to their full degree, subsequently coming about into poor yield. Yield increase to some extent increases linearly with the increase in plant population until the light penetration in crop canopy becomes a limiting factor. Hence, seed rate must be standardized when different seed priming's has been used.

"By overcoming the germination limits under both favourable and unfavourable conditions, pre-sowing seed treatments i.e. seed priming, offer a potential solution to poor seedling establishment and boost vigour. But in adverse circumstances, such as the current low temperature in wheat, the effectiveness of seed priming is more noticeable (Farooq et al., 2008). The germination, seedling emergence, growth, and yield characteristics of the crop are all enhanced by the seed priming approach". [31] In direct seeded rice, seed priming with KCl or $CaCl_2$ enhanced seedling development, stand establishment, and yield performance (Farooq et al., 2006). In wheat grown in late seeding conditions, $CaCl_2$ priming has also likely resulted in vigorous seedling growth, emergence, and yield performance (Farooq et al., 2008). The radicle length, plumule length, and root vigour of seedlings were enhanced by priming seeds of normal or low vigour: shoot to ratio and fresh weight (Kausar et al., 2009). According to Moosavi et al. (2009), primed seeds considerably increased the percentage of germination, germination speed, root length, and seed vigour. Seeds with low vigour that were primed performed better during germination (Bray, 1995). The best methods for increasing seed vigour and improving stand establishment were hydro priming, priming with growth regulators, and priming with different calcium and potassium salts (Basra et al., 2003). Osmo-primed wheat in late conditions had the highest number of productive tillers per unit area, biological yield, grain yield, and harvest index (Sattar et al., 2010). Prior research has demonstrated that, in comparison to non-primed crops, primed crops demonstrated quicker and more consistent emergence, strong stand establishment, and improved performance even in stressed environments. Thus, the current study was carried out to access the impact of seed priming and seed rate for enhancing nutrient uptake, growth and performance of wheat.

Materials and Methods

The experiment was carried during *rabi* seasons of 2020 and 2021, to evaluate the effect of seed priming and seed rate on growth and nutrient uptake of wheat (var. HD-2967) crop. The experimental plot had uniform topography. The experimental site is situated in the Middle Gangetic plain locale of Agro-climatic Zone III (A) in Bihar (latitude-25°23'N, longitude-87°07'E at an elevation of 37.19 meters above mean ocean level). The climatic condition of this place is tropical to subtropical and somewhat semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. The soil of the trial plot was Gangetic alluvial in its origin. The field experiment was laid out in factorial randomized block design replicated thrice. Altogether, there were 12 treatment combinations consisting of four seed priming; P_1-no seed priming (dry seed), P_2- seed priming with water, P_3- seed priming with 1% KNO_3, P_4- seed priming with 1% $CaCl_2$ and three seed rates S_1- seed rate @100 kg ha^{-1}, S_2- seed rate @ 125 kg ha^{-1} and S_3- seed rate @ 150 kg ha^{-1}. Seed of wheat was primed with 1% KNO_3 and 1% $CaCl_2$ solutions and also in water for hours. Non-primed seed was included as a control treatment.

Yields and Yield attributes:

The numbers of ear head bearing tillers, length of ear head, Number of grains per ear head were counted at maturity from randomly selected 0.25 m^{-2} areas at five locations in net plot area. It was recorded in the same way as the tiller numbers were recorded during progressive growth period. Hence, after threshing and weighing, a random sample of grains was taken from each plot and one-thousand grain were counted at random with the help of mechanical seed counter and the weight (g) was taken as test weight.

Harvested bundles of wheat plants from each net plot were threshed and winnowed separately. After cleaning, the grain as well as the straw were dried plot wise and consequently the samples were taken from each plot to determine the moisture content with the help of moisture meter. Then the weight of both grain as well as straw were recorded separately at 12 per cent moisture before being subjected to its statistical analysis. The net plot yield was then finally converted into kg ha^{-1}.

Harvest index was calculated by dividing economic (grain) yield by the total biological (grain + straw) yield and expressed as percentage:

$$H.I. = \frac{\text{Economic yield (grain yield) kg ha}^{-1}}{\text{Biological yield (grain + straw yield) kg ha}^{-1}} X\ 100$$

Economic Analysis: The common cost of cultivation was worked out by considering all the expenses based on the prevailing market prices incurred during the cultivation process. Grain and straw yield were separately compared to its current market price, and the values were summarised to achieve gross returns. Net returns were calculated by subtracting total cost of cultivation from gross return. The return per rupee investment or benefit: cost ratio was calculated by dividing the net return by the total cost of cultivation.

$$\text{Benefit: Cost ratio} = \frac{\text{Net return}}{\text{Total cost of cultivation}}$$

Result and Discussion

After two years of experimentation, it was observed that Seed priming with 1% CaCl2 (P4) had the highest number of ear head m-2 (275.61), the longest ear heads (11.29 cm), the highest number of grains per ear heads (46.17) and the highest 1000 grain weight of (41.11 g) however, had no any statistical differentiation with other two seed priming i/e. seed priming with water (P2) and seed priming with 1% KNO_3 (P3). Although the lowest values were obtained under the unprimed treatment (Table 1). Seed rate did not influence the various yield attributes significantly. Seed rate@150 kg/ha had the highest number of ear heads m^{-2} (287.33), however, maximum length of ear heads (10.96 cm) and maximum number of grains per ear heads (44.75) were found under the seed rate@125 kg/ha.

Significantly the highest grain yield (3977 kg/ha) was recorded in P_4 treatment i.e., seed priming with 1% $CaCl_2$ which was statistically at par with value (3935 kg/ha) realized under P_3 i.e., seed priming with 1% KNO_3. However, it was statistically superior with P_1 and P_2 i.e., unprimed (3627 kg/ha) and seed priming with water (3688 kg/ha), respectively. Likewise, the highest straw yield (5334 kg/ha) was recorded in P_4 treatment i.e., seed priming with 1% $CaCl_2$ which was statistically at par with value (5262 kg/ha) realized under P_3 i.e., seed priming with

1% KNO_3. However, it was statistically superior with P_1 and P_2 i.e., unprimed (4897 kg/ha) and seed priming with water (4980 kg/ha), respectively. So far as seed rate is concerned, significantly the highest grain yield of 3959 kg/ha as well as straw yield of 5317 kg/ha was obtained from seed rate@150 kg/ha which was statistically at par with value (grain yield 3885 kg/ha and straw yield 5229 kg/ha) realized under S_2 i.e., seed rate@125 kg/ha (Table 2). However, it was statistically superior with S_1 i.e., seed rate@100 kg/ha. However, their interaction (P X S) did not reach the level of significance. Significantly the highest biological yield (9311 kg/ha) was recorded in P_4 treatment i.e., seed priming with 1% $CaCl_2$ which was statistically at par with value (9198 kg/ha) realized under P_3 i.e., seed priming with 1% KNO_3. However, it was statistically superior with P_1 and P_2 i.e., unprimed (8525 kg/ha) and seed priming with water (8668 kg/ha), respectively. Similarly, the highest biological yield of 9276 kg/ha was obtained from seed rate@150 kg/ha which was statistically at par with value (9115 kg/ha) realized under S_2 i.e., seed rate@125 kg/ha. However, it was statistically superior with S_1 i.e., seed rate@100 kg/ha. A perusal of ANOVA table revealed that the differences due to seed priming and seed rate did not significantly influence the harvest index. Even their interaction effects did not create any significant difference in this regard. However maximum numerical value of harvest index 42.80 was recorded in P_3 i.e., seed priming with 1% KNO_3 and lowest value of harvest index 42.54 was obtained at P_1 i.e., unprimed. Moreover, numerically the highest harvest index of 42.68 was recorded in case of seed rate@150 kg/ha. It was followed by seed rate@100 kg/ha (42.66) and the lowest numerical value of harvest index (42.63) was noted in seed rate@125 kg/ha. This is because of the fact that in primed seeds, the nutrients can easily be accessed by germinating seeds for its growth and vigour (Farooq et al., 2021). Studies proved that seed priming had a positive impact on various plant species specially to endure the environmental stress (Bukhari et al., 2021). It aids the plant to elevate antioxidant enzyme activity and osmolytes and to build up the resistance to abiotic and non-abiotic stresses (Sattar et al., 2021). Moreover, the seed priming with $CaCl_2$ or KNO_3 improved the root growth to enhance the nutrient uptake and hastened the overall plant growth during the early stage of the crop (Farooq et al., 2021; Malko et al., 2022; Saha et al., 2022)

Significantly the highest net return of 64735 Rs. /ha was recorded under application of seed priming with 1% $CaCl_2$, which was statistically at par with the value realized under P_2 (59956 Rs. / ha) and P_3 (61567 Rs. / ha) i.e., seed priming with water and seed priming with 1% KNO_3, respectively. However, it was statistically superior with the value obtained under P_1 (59431 Rs. / ha) i.e., unprimed (Table 3). Similar trend was observed under benefit cost ratio, where, the highest benefit cost ratio (1.87) was recorded under P_4 i.e., seed priming with 1% $CaCl_2$ which was statistically at par with P_1 (1.83) and P_2 (1.84) i.e., unprimed and seed priming with water, respectively. However, it was statistically superior with the value realized under P_3 (1.28) i.e., seed priming with 1% KNO_3. Among all the seed rate, maximum net return of 64244 Rs. /ha was recorded from seed rate@150 kg/ha which was statistically at par with the seed rate@125 kg/ha 63289 (Rs. /ha) The lowest net returns of 56733 Rs/ha was recorded from seed rate@100 kg/ha. The cost-effective seed priming techniques strengthen the plants and enhance drought resistance through increased photosynthesis pigments, antioxidant defense, osmotic adjustments as well as membrane integrity (Saha et al., 2022).

Conclusions:

We experienced from the experimental results that the priming method as pre-germinative enhancement technique significantly improved the productivity as well as profitability of wheat. Seed priming with 1% $CaCl_2$ resulted in better seedling emergence, uniform stand establishment, earlier flowering and, ultimately, better crop yields with good economic returns. Besides, the indiscriminate use of seeding rates not only increases production costs but usually decrease wheat grain yield. Therefore, the priming methods along with proper seed rate have the large potential for further enhancement in wheat production. The priming methods adopted should be simple and affordable for its easy spread and adaptability to the farmers.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Details of the AI usage are given below:

1.

2.

3.

Table 1: Effect of seed priming and seed rate on yield attributes of wheat

Treatments		Yield attributing characters			
		No. of ear head/m^2	Length of ear head (cm)	No. of grains/ ear head	1000 grain weight (g)
P_1	Unprimed	261.94	10.11	42.11	37.22
P_2	Seed priming with water	270.06	10.22	42.56	38.11
P_3	Seed priming with 1% KNO_3	274.61	10.94	45.22	40.89
P_4	Seed priming with 1% $CaCl_2$	275.61	11.29	46.17	41.11
SEm±		3.09	0.30	1.05	1.08
CD (P = 0.05)		9.08	0.89	3.08	3.17
Treatments					
S_1	Seed rate@100 kg/ha	248.25	10.30	43.33	40.08
S_2	Seed rate@125 kg/ha	275.58	10.96	44.75	39.25
S_3	Seed rate@150 kg/ha	287.83	10.67	43.96	38.67
SEm±		2.68	0.26	0.91	0.93
CD (P=0.05)		7.86	NS	NS	NS
P X V		NS	NS	NS	NS

Table 2: Effect of seed priming and seed rate on grain yield, straw yield, biological yield and harvest index of wheat

Treatments		Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
P_1	Unprimed	3627	4897	8525	42.54
P_2	Seed priming with water	3688	4980	8668	42.55
P_3	Seed priming with 1% KNO_3	3935	5262	9198	42.80
P_4	Seed priming with 1% $CaCl_2$	3977	5334	9311	42.72
SEm±		79	108	187	0.07
CD (P = 0.05)		233	316	548	NS
Treatments					
S_1	Seed rate@100 kg/ha	3577	4808	8385	42.66
S_2	Seed rate@125 kg/ha	3885	5229	9115	42.63
S_3	Seed rate@150 kg/ha	3959	5317	9276	42.68
SEm±		68	93	162	0.06
CD (P=0.05)		201	274	475	NS
P X V		NS	NS	NS	NS

Table 3: Effect of seed priming and seed rate on economics of wheat.

Treatments		Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
P_1	Unprimed	32405	91836	59431	1.83
P_2	Seed priming with water	32680	92636	59956	1.84
P_3	Seed priming with 1% KNO_3	36645	98212	61567	1.68
P_4	Seed priming with 1% $CaCl_2$	34655	99390	64735	1.87
SEm±		-	1631	1631	0.03
CD (P = 0.05)		-	4784	4784	0.11
Treatments					
S_1	Seed rate@100 kg/ha	33096	89830	56733	1.72
S_2	Seed rate@125 kg/ha	34096	97386	63289	1.86
S_3	Seed rate@150 kg/ha	35096	99340	64244	1.84
SEm±		-	1412	1412	0.03
CD (P=0.05)		-	4143	4143	0.09
P X V		NS	NS	NS	NS

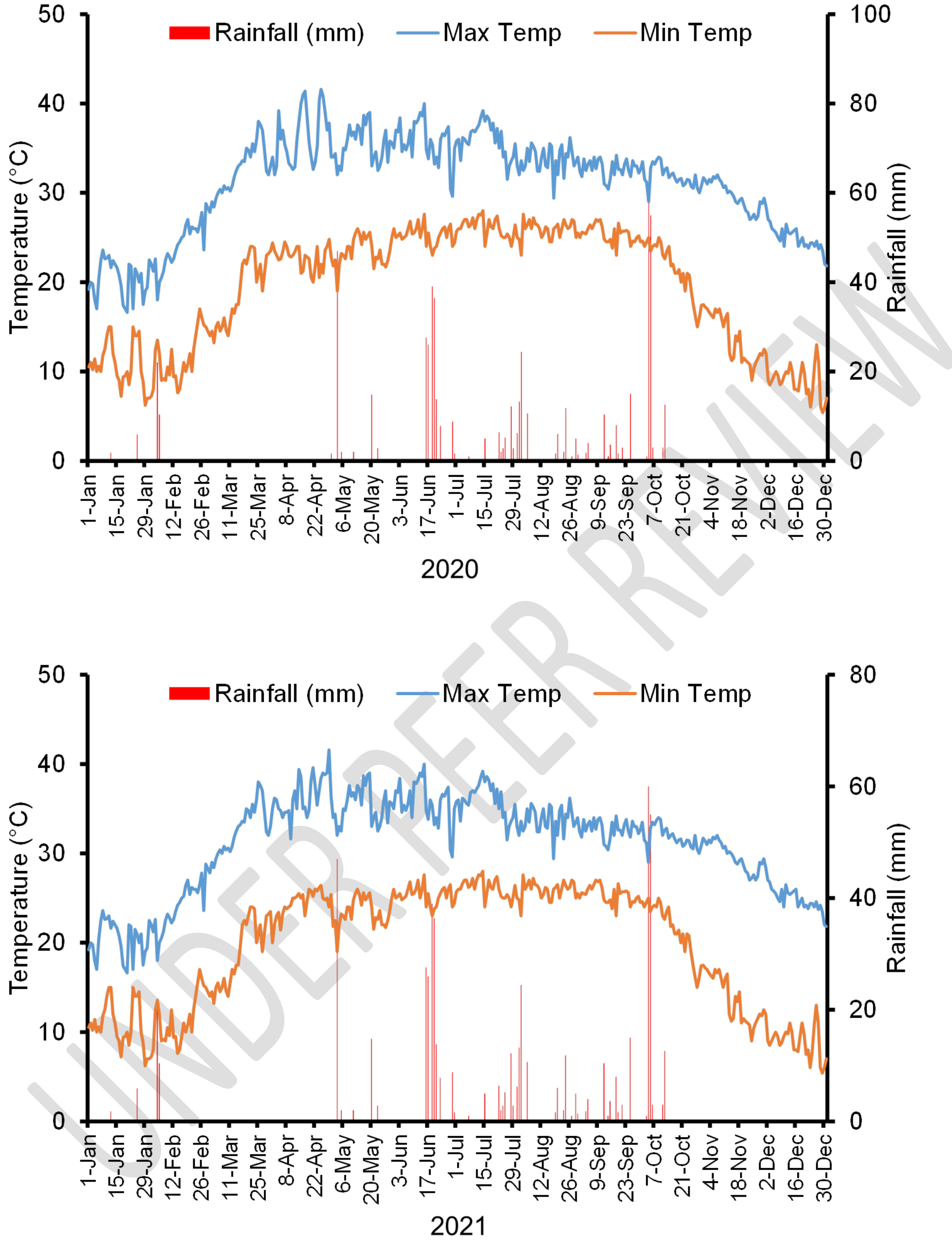

Figure 1. Meteorological data during Experimental Years 2020-2021

N

R_3	R_2	R_1
T_4-WS (100 kg/ha)	**T_{10}- SP 1%$CaCl_2$ (100 kg/ha)**	**T_1- DS (100 kg/ha)**
T_5- WS (125 kg/ha)	**T_{11}- SP 1%$CaCl_2$ (125 kg/ha)**	**T_2- DS (125 kg/ha)**
T_6- WS (150 kg/ha)	**T_{12}- SP 1%$CaCl_2$ (150 kg/ha)**	**T_3- DS (150 kg/ha)**
T_7- SP 1%KNO_3 (100 kg/ha)	**T_1- DS (100 kg/ha)**	**T_4-WS (100 kg/ha)**
	Irrigation Channel	
T_8- SP 1%KNO_3 (125 kg/ha)	**T_2- DS (125 kg/ha)**	**T_5- WS (125 kg/ha)**
T_9- SP 1%KNO_3 (150 kg/ha)	**T_3- DS (150 kg/ha)**	**T_6- WS (150 kg/ha)**
T_{10}- SP 1%$CaCl_2$ (100 kg/ha)	**T_4-WS (100 kg/ha)**	**T_7- SP 1%KNO_3 (100 kg/ha)**
T_{11}- SP 1%$CaCl_2$ (125 kg/ha)	**T_5- WS (125 kg/ha)**	**T_8- SP 1%KNO_3 (125 kg/ha)**
	Irrigation Channel	
T_{12}- SP 1%$CaCl_2$ (150 kg/ha)	**T_6- WS (150 kg/ha)**	**T_9- SP 1%KNO_3 (150 kg/ha)**
T_1- DS (100 kg/ha)	**T_7- SP 1%KNO_3 (100 kg/ha)**	**T_{10}- SP 1%$CaCl_2$ (100 kg/ha)**
T_2- DS (125 kg/ha)	**T_8- SP 1%KNO_3 (125 kg/ha)**	**T_{11}- SP 1%$CaCl_2$ (125 kg/ha)**
T_3- DS (150 kg/ha)	**T_9- SP 1%KNO_3 (150 kg/ha)**	**T_{12}- SP 1%$CaCl_2$ (150 kg/ha)**

1.8 m

8 m

Figure 2. - Layout plan of the experimental design of single plots

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