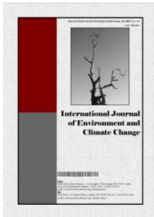

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Yield Attributes and Yields of Hybrid Maize (*Zea mays* L.) and Lathyrus (*Lathyrus sativus* L.) in Sequence as Influenced by Seed Priming under Rainfed Situation

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SB, KJ and RM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SB and KJ managed the analyses of the study. Authors KM and AM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Maize *(Zea mays* L.) is one of the most versatile crop grown throughout the tropical as well as temperate regions of the world. On the other hand, the lathyrus or grass pea or chickling pea is also called '*khesari'* and is a very hardy crop that thrives well under adverse climatic conditions. It can fix biological nitrogen in their roots through symbiotic relationship with *Rhizobium leguminoseram*. The field experiment was conducted on seed priming of hybrid maize and lathyrus at Central Research Farm, BCKV, Nadia under new alluvial zone of West Bengal, India in Randomized Complete Block Design (RCBD) with 3 replications during *kharif* season of 2016 and 2017 and rabi season of 2016-17 and 2017-18. Experimental results reveal that seed priming methods significantly influenced the germination, growth parameters, yield attributes and yield of hybrid maize-lathyrus grown in sequence under rainfed situation. Seed priming with $ZnSO_4$ @ 0.5% for 12 hours recorded the highest number of grains per cob (319.9) and highest plant height

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(262.10 cm) at harvest of hybrid maize. Grain yield and stover yield of hybrid maize showed positive and highly significant (P = 0.01) with each other (r = 0.945). The maximum number of pods per plant (50.28) was observed in seed priming with $ZnSO_4$ @ 0.5% for 12 hours and was statistically at par with seed priming with KNO_3 @ 0.5% for 12 hours (48.33) in case of lathyrus. Number of pods/ plants showed positive and highly significant (P = 0.01) correlation with grain yield (r = 0.986) of lathyrus. On the basis of pooled values of 2 years of experimentation, seed priming with $ZnSO_4$ @ 0.5% for 12 hours could be recommended due to higher yield (7.94 t ha^{-1} of *kharif* hybrid maize and 1682 kg ha^{-1} of lathyrus) and higher net return (Rs.69,904/-ha^{-1} for maize, Rs.40,327/- ha^{-1} for lathyrus) as well as highest B:C ratio (2.74 of *kharif* hybrid maize and 2.94 of lathyrus) for maize-lathyrus in sequence under rainfed situation.

Keywords: Correlation studies; hybrid maize; lathyrus; rainfed condition; seed priming and yield.

1. INTRODUCTION

The first green revolution has paid dividends through impressive agricultural growth, in the past four decades. Challenges have surfaced in the recent years with ever-increasing food demand due to increasing populations, degradation of natural resources, and changing climatic conditions. Cereal crops (rice, wheat and maize) and pulses (lentil, lathyrus, and chickpea) grown in different cropping system, contribute bulk of the food in South Asia.

Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice. Maize is one of the most versatile crops grown throughout the tropical as well as temperate regions of the world [1]. In India, maize was grown in area of 8,691 hectare, with production of 21,806 tones and productivity of 2505 kg ha^{-1} while in West Bengal the area, production and productivity were 156 thousand hectare, 720 thousand tones and 4615 kg ha^{-1} respectively in the year 2015-16 [2]. In addition to staple crop for human being and quality feed for animals, maize serves as a basic raw material for production of starch, oil, protein, alcoholic beverages, food sweeteners and more recently bio-fuel. Being a potential crop in India, maize occupies important place as food (25%), animal feed (12%), poultry feed (49 %), industrial products mainly starch (12%) and 1% each in brewery and seed [3]. Though the yield potential of our present varieties is high enough, but it has not been explored fully due to some production constraints. Among the limiting factors; proper level and ratio of fertilizer, irrigation management, plant protection and proper seed germination and also proper seedlings establishment at the time of sowing are of prime importance [4].

Lathyrus (*Lathyrus sativus*) is believed to be one of the first cultivated plants probably. There is no alternative to lathyrus at present since it is a very hardy crop that tolerates adverse environmental conditions such as drought and excessive soil moisture. The crop produces yields with little or no inputs such as fertilizer and chemicals. Presently it occupies 0.45 million ha area with annual production of 0.31 million tonnes in India. The average productivity is about 698 kg ha^{-1}. The area of lathyrus lies in the states of Chhattisgarh, Maharashtra, Madhya Pradesh, Bihar, Odisha and West Bengal. The dried seeds of lathyrus contain 31.9% protein, 53.9% carbohydrates, 0.9% oil and 3.2% ash. Even there is a limited scope for agronomic manipulation under rice-*utera* system although it has potential for increasing cropping intensity in considerable areas.

Good crop stand establishment is essential for the efficient use of water and light, and a uniform stand is a pre-requisite for cropping success. Seeds that germinate quickly produce viable seedlings that are not dependent on rapidly declining moisture in the soil that may occur in rainfed systems. Soaking seeds in water before sowing gives the germinating seeds a head start and speeds up seed establishment with a corresponding increase in survival rates and yields. Seed priming helps in mobilisation of seed food reserves to the developing embryo during germination. Storage products such as carbohydrates, amino acids, fatty acids, and inorganic nutrients are mobilised in germinating seed at varying rates. Seed priming (pre-sowing seed soaking) is an important low-cost technology to obtain better plant stand and higher crop yield. Pre-sowing soaking of seeds with KH_2PO_4, Na_2HPO_4, $ZnSO_4$ etc. or simple water was earlier reported to improve seed germination, seedling vigor, and root growth early in the season, resulting in good establishment, better drought tolerance and more yield of crop plants. Seed priming operation may be a viable option in improving crop establishment and yield, particularly in rainfed, late sown and water-stress situations. Hence, the present investigation was taken up to identify a suitable seed priming method to enhance hybrid maize and lathyrus productivity on maize-lathyrus in sequence under rainfed situation.

2. MATERIALS AND METHODS

The field experiment was carried out at Central Research Farm (CRF) of Bidhan Chandra Krishi Viswavidyalaya (BCKV) at Gayeshpur, Nadia, West Bengal during *kharif* season of 2016 and 2017 and rabi season of 2016-17 and 2017-2018. The experiment field represented a humid and sub-tropical condition and typical medium land of New Alluvial Zone of West Bengal. The research station is situated at 23^{O}N latitude and 89^{O}E longitude and the elevation of 9.75 m above the mean sea level (approximately). The experimental site falls under sub-tropical sub-humid climate. The average rainfall is 1450 mm, 75 % of which is received during June to September. The temperature begins to rise from end of February reaching towards April-May. The relative humidity remains high during June to October. During the crop growth period average maximum temperature ranged between 28.03 - 33.67 ^{o}C and minimum temperature varied between 19.34 - 24.04 ^{o}C. The average maximum relative humidity varied from 95 to 98.0 % and minimum relative humidity varied from 50.0 - 92.0 %. The average of two-year total rainfall during the crop growing period was recorded 122.4 mm. The topography of land is medium land and the soil was sandy clay loam in texture belonged to the order inceptisol and having pH ranges from 6.9-7.1. Soil having N: 196.5 kg/ha, P: 47.2 kg/ha, K: 198.4 kg/ha and organic carbon 0.51 %. Soil of this zone is mostly fertile, deep and almost neutral in reaction developed from recent alluvium of the river Ganges.

This experiment was laid out in Randomized Block Design (RBD) with 9 different treatment of seed priming *i.e*.,T_1- seed priming with water for 6 hrs., T_2 - seed priming with water for 12 hrs., T_3 - seed priming with $ZnSO_4$ @ 0.5 % for 6 hrs., T_4- seed priming with $ZnSO_4$ @ 0.5 % for 12 hrs., T_5 - seed priming with KNO_3 @ 0.5 % for 6 hrs., T_6 - seed priming with KNO_3 @ 0.5% for 12 hrs., T_7 - seed priming with KH_2PO_4 @ 0.5% for 6 hrs., T_8 - seed priming with KH_2PO_4 @ 0.5% for 12 hrs., and T_9 - control (no priming) and each treatment was replicated 3 times with the hybrid maize (variety: NISHA-3503) during *kharif* season of 2016 and 2017 followed by lathyrus (variety: Prateek) during Rabi season of 2016-17 and 2017-2018**.** Observation on yield attributing characters *e.g.* number of cobs/plant, number of cobs/m^2, number of grain/cob, cob length, cob girth, and no. of row per cob, grain yield and stover yield of maize and yield attributing character and seed yield of lathyrus were recorded at certain intervals. Statistical analysis was done for determining the standard error of mean (S. Em±) and the value of CD (Critical difference) at 5% level of significance using methodology as stated in Gomez and Gomez [5].

3. RESULTS AND DISCUSSION

3.1 Effect of Seed Priming on Yield Attributes of Hybrid Maize

3.1.1 Number of cobs per plant and cobs per m^2

The highest numbers of cobs per plant (2.67) and numbers of cobs per m^2 (11.67) were recorded from the treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours (Table 1). It was statistically at par with the treatment T_6 *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours for no. of cob per m^2 (11.33) and treatment T_8 *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours for no. of cobs per m^2 (10.67). The lowest no. of cobs per plant and no. of cobs per m^2 (9.67) were obtained from the treatment T_9 *i.e.* no seed priming (control).

3.1.2 Number of grains per cob

The highest no. of grain per cob (319.9) at harvest was recorded from the treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours (Table 1). It was statistically at par with the treatment T_6 *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours for no. of grain per cob (314.6) and treatment T_8 *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours for no. of grain per cob (310.4). The lowest no. of grain per cob (280.4) at harvest was recorded from the treatment T_9 *i.e.* no seed priming (Control). The highest no of grain per cob was recorded from seed priming with $ZnSO_4$@ 0.5% for 12 hours and medium value of no. of grain per cob was recorded from seed priming with KNO_3 and KH_2PO_4 @ 0.5% for 12 hours, respectively. These results are in conformity with the findings of Miraj et al. [6] who reported that no. of grain per cob increased when maize seed was primed with KH_2PO_4 solution.

3.1.3 Cob length, cob girth and number of rows per cob

In general cob length, cob girth, and no. of row per cob were significantly increasing at harvesting stage. The highest cob length (dehusked: 27.57 cm and husked: 17.27 cm), cob girth (4.7 cm) and no. of row per cob (13.53) at harvest was recorded from the treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours (Table 1). Cob length (husked), cob girth, and no. of row per cob were statistically at par with the treatment T_6 *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours (17.2 cm, 4.5 cm, and 12.8 at harvest, respectively) except cob length (dehusked: 25.83 cm at harvest) and treatment T_8 *i.e.* seed priming with KH_2PO_4 @ 0.5 % for 12 hours (17.03 cm, 4.07 cm and 12.83 at harvest, respectively) except cob length (dehusked:25.73 cm at harvest).

The lowest cob length (dehusked: 23.83 cm and husked: 14.77 cm), cob girth (2.93 cm), and no. of row per cob (11.27) were recorded from the treatment T_9 *i.e*. no seed priming (control).

3.1.4 Effect of seed priming on grain, stover yield and harvest index of hybrid maize

The land productivity in terms of grain yield of hybrid maize was significantly influenced by the different seed priming practices in the new alluvial soils of West Bengal. The highest grain yield (7.94 t ha^{-1}), stover yield (16.23 t ha^{-1}) and harvest index (HI) (34.52) was obtained from the treatment T_4 *i.e*. seed priming with $ZnSO_4$ @ 0.5% for 12 hours (Table 2). It was statistically at par with the treatment T_6 *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours for grain yield (7.68 t ha^{-1}), stover yield (15.93 t ha^{-1}) and harvest index (33.27) and treatment T_8 *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours for grain yield (7.45 t ha^{-1}), stover yield (15.54 t ha^{-1}) and harvest index (33.11). The lowest grain yield (5.85 t ha^{-1}), stover yield (11.32 t ha^{-1}) and harvest index (30.59) were obtained from the treatment T_9 *i.e*. no seed priming (control). The highest grain yield, stover yield and harvest index was recorded from T_4 treatment (*i.e*. seed priming with $ZnSO_4$ @ 0.5% for 12 hours). This might be due to seed priming with inorganic salts like, $ZnSO_4$, KNO_3 and KH_2PO_4 may significantly alter the activity of enzyme in germinating seeds. Seed priming enhance the activity of dehydrogenase and α-amylase. Such increase in enzyme activity has direct or indirect effect on subsequent seed germination, growth and development. It helps in mobilisation of seed food reserves to the developing embryo during germination. Storage products such as carbohydrates, amino acids, fatty acids and inorganic nutrients are mobilised in germinating seed at varying rates. The general purpose of seed priming is to hydrate partially the seed to a point where germination processes are initiated but not completed. Most priming treatments involve imbibing seed with restricted amounts of water to allow sufficient hydration and advance of metabolic processes but preventing the protrusion of the radicle. Treated seeds usually would exhibit rapid germination when absorb water under field conditions [7]. At slightly more negative water potentials, the amino acid proline begins to accumulate sharply; sometimes building up to levels of 1 percent of tissue dry weight [8]. Free proline accumulation has been suggested to be an indicator of drought resistance [9].

3.1.5 Correlation studies among yield and yield attributes of hybrid maize

The statistical association or correlation analysis is congruous in this experiment because they can indicate a predictive relationship between several variables that can be exploited in practice. To evaluate the strength of relationship between yield attributes and yield of maize under different priming practices, this bivariate exploration is necessary. Correlation between yield and yield components were computed and the results are presented in (Table 3). It was observed that number of cobs/plant positive and highly significant (P=0.01) correlation with grain yield (r = 0.834), number of grain/cob (r = 0.807), cob length (r = 0.814) and also positive significant (P = 0.05) correlation with stover yield (r = 0.705). Number of grains/ cobs showed positive and highly significant (P = 0.01) correlation with grain yield (r = 0.970), strover yield (r = 0.960), and also positive significant with (P = 0.05) cob length (r = 0.689). Cob length showed positively significant with grain yield (r = 0.629), stover yield (r = 0.588), number of grain/cob (r = 0.689) and number of cob/plant (r = 0.814). Grain yield and stover yield showed positive and highly significant (P = 0.01) with each other (r = 0.945). [10] reported positive correlations (P=0.01) among yield, yield components.

Table 1. Effect of different seed priming methods on plant height and yield attributes of hybrid maize grown during *kharif* season (Pooled value of 2 years)

Treatments	Plant height (cm) at harvest	Number of cobs/plant	Number of cobs/m^2	Number of grain/cob	Test weight (g)	Cob length (dehusked) (cm)	Cob length (husked) (cm)	Cob girth (cm)	Number of row/cob
T_1	219.6	1.00	10.0	286.6	212.2	26.47	15.27	3.40	12.13
T_2	230.1	1.00	10.0	289.2	214.3	24.63	16.57	3.73	12.27
T_3	241.4	1.00	10.3	306.5	215.0	25.53	16.93	3.70	11.60
T_4	262.1	2.67	11.7	319.9	216.2	27.57	17.27	4.70	13.53
T_5	235.7	1.00	10.3	300.3	215.0	25.47	16.73	3.57	12.53
T_6	246.8	1.67	11.3	314.6	215.7	25.83	17.20	4.50	12.80
T_7	234.6	1.00	10.0	295.7	215.0	25.13	16.87	3.77	11.87
T_8	246.2	1.33	10.6	310.4	215.5	25.73	17.03	4.07	12.83
T_9	217.3	0.67	9.6	280.4	211.4	23.83	14.77	2.93	11.27
S. Em (±)	6.67	0.21	0.39	4.18	1.99	0.55	0.30	0.31	0.37
CD (0.05)	20.16	0.64	1.18	12.64	NS	1.68	0.90	0.95	1.12

[T_1-seed priming with water for 6 hours; T_2- seed priming with water for 12 hours; T_3- seed priming with $ZnSO_4$ @ 0.5% for 6 hours; T_4- seed priming with $ZnSO_4$ @ 0.5% for 12 hours; T_5- seed priming with KNO_3 @ 0.5% for 6 hours; T_6- seed priming with KNO_3 @ 0.5% @ for 12 hours; T_7- seed priming with KH_2PO_4 @ 0.5% for 6 hours; T_8- seed priming with KH_2PO_4 @ 0.5% for 12 hours; T_9- control (no priming)]

Table 2. Effect of different seed priming methods on grain yield (t/ha), Stover yield (t/ha) and harvest index of hybrid maize grown during kharif season (Pooled value of 2 years)

Treatments	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index
T_1	6.03	12.24	31.10
T_2	6.67	13.69	31.42
T_3	7.01	15.05	32.81
T_4	7.94	16.23	34.52
T_5	6.73	14.84	32.43
T_6	7.68	15.93	33.27
T_7	6.47	14.24	32.06
T_8	7.45	15.54	33.11
T_9	5.85	11.32	30.59
S.E(m) (±)	0.31	0.18	0.45
CD (0.05)	0.93	0.54	1.37

[T_1-seed priming with water for 6 hours; T_2- seed priming with water for 12 hours; T_3- seed priming with $ZnSO_4$ @ 0.5% for 6 hours; T_4- seed priming with $ZnSO_4$ @ 0.5% for 12 hours; T_5- seed priming with KNO_3 @ 0.5% for 6 hours; T_6- seed priming with KNO_3 @ 0.5% @ for 12 hours; T_7- seed priming with KH_2PO_4 @ 0.5% for 6 hours; T_8- seed priming with KH_2PO_4 @ 0.5% for 12 hours; T_9- control (no priming)]

3.1.6 Effect of seed priming on yield attributes of lathyrus

The pod length, no. of pods per plant, number of seeds per pod and test weight of lathyrus grown during rabi season, 2016-17 and 2017-2018 were recorded at 110 DAS *i.e.* at harvest stage (Table 4).

3.1.7 Pod length and number of pods per plant

Pod length is associated character of yield attributes. Pod length was not significantly influenced by the different seed priming methods as it depends on genetic traits. The maximum value of pod length (2.69 cm) was observed in treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours followed by treatment T_6 (2.67 cm) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours and treatment T_8 (2.66 cm) *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours (Table 4). The lowest value of pod length (2.51 cm) was obtained in treatment T_9 *i.e.* no seed priming (control). Number of pods per plant was significantly influenced by the different seed priming methods. A maximum no. of pods per plant (50.28) was observed in treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours was statistically at par with treatment T_6 (48.33) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours and treatment T_8 (46.83) *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours. The lowest value of no. of pods per plant (30.67) was obtained in treatment T_9 *i.e.* no seed priming (control).

3.1.8 Number of seeds per pod and test weight (1000-seed weight)

Number of seeds per pod was significantly influenced by the different seed priming methods and it also follow the same trends as pod length and no. of pods per plant. A maximum no. of seeds per pod (3.29) was observed in treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours and it was statistically at par with treatment T_6 (3.15) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours and treatment T_8 (2.94) *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours. The lowest value of number of seeds per pod (1.72) was obtained in treatment T_9 *i.e.* no seed priming (control) (Table 4).

Boldness or plumpness in terms of test-weight (g) was not significantly influenced by the different seed priming methods as it depends on genetic traits (Table 4). However, the maximum value of test weight (51.67 g) was observed in treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours followed by treatment T_6 (50.24 g) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours and treatment T_8 (48.02 g) *i.e.* seed priming with KH_2PO_4 @ 0.5% for 12 hours. The lowest value of test weight (40.71 g) was obtained in treatment T_9 *i.e.* no seed priming (control).

Table 3. Correlation coefficient analysis of yield and yield contributing characters in hybrid maize during kharif season

	No. of cobs/plant	No. of grain/cob	Cob length (cm)	Grain yield (t/ha)	Stover yield (t/ha)
No. of cobs/plant	1	.807**	.814**	.834**	.705*
No. of grain/cob	.807**	1	.689*	.970**	.960**
Cob length (cm)	.814**	.689*	1	0.629	0.588
Grain yield (t/ha)	.834**	.970**	0.629	1	.945**
Stover yield (t/ha)	.705*	.960**	0.588	.945**	1

(and ** indicates correlation is significant at 5.0 and 1.0 % level of significance, respectively)*

The highest pod length, no. of pods per plant, no. of seeds per pod and test weight was recorded from seed priming with $ZnSO_4$ @ 0.5% for 12 hours and moderate pod length (cm), no. of pods per plant, no. of seeds per pod and test weight (g) was recorded from seed priming with KNO_3 and KH_2PO_4 @ 0.5% for 12 hours respectively. This might be due to the different significant effect of various inorganic salts like $ZnSO_4$, KNO_3 and KH_2PO_4 which enhances germination ability and speed among seed lots with different initial vigour levels. The speed and uniformity of seed germination are prominent parameters especially for field crop seeds to compete with weed seeds. It also reduced the negative effect of a lower temperature and non-optimal humidity conditions in the germination media on the germination rate. Drought and salinity stresses increased SOD activity. Activity of SOD was the highest under KNO_3 seed priming, but no significant difference was observed between the water and the urea priming [11]. By applying hydro-priming on seeds increased radicle length and stem growth of *Lathyrus sativus* L. [12]. Seed priming enhance many of the metabolic processes involved with the early phases of germination, and it has been noted that seedlings from primed seeds emerge faster, grow more vigorously, and perform better in adverse conditions such as salinity, drought and temperature [7,13] and it was also suggested that the adverse and depressive effects of salinity stress on germination can be alleviated by various seed priming treatments.

3.1.9 Effect of seed priming on seed, stover yield and harvest Index of lathyrus

The seed yield, stover yield and harvest index of lathyrus grown during rabi season, 2016-17 and 2017-2018 were recorded at 110 DAS *i.e.* at harvesting stage (Table 4).

Seed yield was significantly influenced by the different seed priming methods (Table 4). Yield variation due to priming varies from 1058 kg/ha to 1641 kg/ha and the yield increase was the tune of 58.97 % over control. The highest seed yield (1682 kg/ha) was observed in treatment T_4*i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours and it was statistically at par with treatment T_6 (1641 kg/ha) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours. The lowest value of seed yield (1058 kg/ha) was obtained in treatment T_9 *i.e.* no seed priming (control).

Stover yield was significantly influenced by the different seed priming methods. The highest stover yield (2232 kg/ha) was observed in treatment T_4*i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours. The lowest value of stover yield (1508 kg/ha) was obtained in treatment T_9*i.e.* no seed priming (control).

Harvest index (HI) was significantly influenced by the different seed priming methods. The maximum value of harvest index (44.4) was observed in treatment T_4*i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours and it was statistically at par with treatment T_6 (43.97) *i.e.* seed priming with KNO_3 @ 0.5% for 12 hours. The lowest value of harvest index (38.49) was obtained in treatment T_9*i.e.* no seed priming (control) (Table 4).

The highest seed yield, stover yield and harvest index was recorded from seed priming with $ZnSO_4$ @ 0.5% for 12 hours and moderate seed yield, stover yield and harvest index was recorded from seed priming with KNO_3 and KH_2PO_4 @ 0.5% for 12 hours, respectively. 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 plant.

Table 4. Effect of different seed priming methods on yield attributes and yield of lathyrus grown during rabi season (Pooled value of 2 years)

Treatments	Pod length (cm)	No of pods/plant	No of seeds/pod	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index
T_1	2.54	33.26	2.21	42.28	1125	1635	39.72
T_2	2.58	34.67	2.34	44.34	1230	1760	41.14
T_3	2.64	45.67	2.49	47.12	1486	1977	42.35
T_4	2.69	50.28	3.29	51.67	1682	2232	44.40
T_5	2.62	43.92	2.47	46.84	1457	1937	42.19
T_6	2.67	48.33	3.15	50.24	1641	2092	43.97
T_7	2.61	36.67	2.41	45.57	1335	1865	41.71
T_8	2.66	46.83	2.94	48.02	1587	2067	43.43
T_9	2.51	30.67	1.72	40.71	1058	1508	38.49
S.Em (±)	0.23	2.81	0.25	3.62	18.0	24.7	0.26
CD (0.05)	NS	8.49	0.75	NS	54.4	74.7	0.78

[T_1-seed priming with water for 6 hours; T_2- seed priming with water for 12 hours; T_3- seed priming with $ZnSO_4$ @ 0.5% for 6 hours; T_4- seed priming with $ZnSO_4$ @ 0.5% for 12 hours; T_5- seed priming with KNO_3 @ 0.5% for 6 hours; T_6- seed priming with KNO_3 @ 0.5% @ for 12 hours; T_7- seed priming with KH_2PO_4 @ 0.5% for 6 hours; T_8- seed priming with KH_2PO_4 @ 0.5% for 12 hours; T_9- control (no priming)]

Table 5. Correlation coefficient analysis of yield and yield contributing characters in lathyrus during rabi season

	Pod length (cm)	No of pods/plant	No of seeds/pod	Seed yield (kg/ha)	Straw yield (kg/ha)
Pod length (cm)	1	.961**	.946**	.989**	.996**
No of pods/plant	.961**	1	.907**	.986**	.965**
No of seeds/pod	.946**	.907**	1	.942**	.955**
Seed yield (kg/ha)	.989**	.986**	.942**	1	.988**
Straw yield (kg/ha)	.996**	.965**	.955**	.988**	1

(and ** indicates correlation is significant at 5.0 and 1.0% level of significance, respectively)*

Table 6. Effect of different seed priming methods on system production economics of hybrid maize-lathyrus in sequence (Pooled value of 2 years)

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1	58897	124544	65647	2.11
T_2	59425	137225	77800	2.31
T_3	60118	151179	91061	2.51
T_4	60875	171106	110231	2.81
T_5	61475	146281	84806	2.38
T_6	62430	163905	101475	2.62
T_7	64125	138330	74206	2.15
T_8	64974	156491	91517	2.41
T_9	58050	119523	61472	2.05

[T_1-seed priming with water for 6 hours; T_2- seed priming with water for 12 hours; T_3- seed priming with $ZnSO_4$ @ 0.5% for 6 hours; T_4- seed priming with $ZnSO_4$ @ 0.5% for 12 hours; T_5- seed priming with KNO_3 @ 0.5% for 6 hours; T_6- seed priming with KNO_3 @ 0.5% @ for 12 hours; T_7- seed priming with KH_2PO_4 @ 0.5% for 6 hours; T_8- seed priming with KH_2PO_4 @ 0.5% for 12 hours; T_9- control(no priming)]

Seed priming increase cell division and seedling roots which cause an increase in plant height [14]. The principal of seed priming is based on seed imbibitions behavior, so the water/nutrient uptake of seeds is an important process in the germination and growth of seeds. The imbibitions of seeds can be divided in to three phases namely imbibition phase, activation phase and growth phase. Seed priming using osmoticum / osmopriming or nutria-priming normally reduces the time of imbibitions phase and prolongs activation phase, as the major metabolic events take place before radical emergence [15]. This metabolic change includes repair of DNA and the enhanced synthesis of RNA and protein and increased in the respiratory activity of seeds [16]. These results are in conformity with the findings of [17] and they reported that seed and stover yield increased when lathyrus seed was primed with seed priming chemicals.

3.1.10 Correlation studies among yield and yield attributes of lathyrus

To evaluate the strength of relationship between yield attributes and yield of lathyrus under different priming practices, this bivariate exploration is necessary. Correlation between yield and yield components were computed and the results are presented in Table 5. It was observed that pod length positive and highly significant (P=0.01) correlation with seed yield (r = 0.989), number of pods/ plant (r = 0.961), number of seeds/pods (r = 0.946) and also strover yield (r = 0.996). Number of pods/ plants showed positive and highly significant (P =0.01) correlation with grain yield (r = 0.986), strover yield (r = 0.965), and number of seeds/ pod (r = 0.907). Number of seeds/ pods showed positive and highly significant (P = 0.01) with grain yield (r = 0.942) and strover yield (r = 0.955). Seed yield and strover yield also show positive and highly significant (P = 0.01) with each other (r = 0.988).

3.1.11 System production economics of hybrid maize-lathyrus in sequence

More acceptability of any research finding among small and marginal farmers depends on its economic viability. It includes cost of production, gross monetary return (GMR), net monetary return (NMR)/net profit and benefit-cost ratio (BCR) of the system. It is the most important factor for adopting the cultivation practice of a particular crop sequence in a specific zone. Based on the market value of the produce, the gross monetary return (Rs. ha^{-1}) of the treatment variable were calculated and from the calculation, it might be thus possible to evaluate for economic consideration for the adoption of suitable agro-techniques for the benefit of the rural sector of the zone as a whole.

From (Table 6), it was observed that the highest gross return (Rs.171106/- per ha) was obtained from the treatment T_4 *i.e.* seed priming with $ZnSO_4$ @ 0.5% for 12 hours and followed by treatment T_6 *i.e*. seed priming with KNO_3 @ 0.5% for 12 hours (Rs. 163905/- per ha) of hybrid maize-lathyrus in sequence. The highest net monetary return (Rs.110231/-per ha) was obtained from the treatment T_4 *i.e*. seed priming with $ZnSO_4$ @ 0.5% for 12 hours and followed by treatment T_6*i.e*. seed priming with KNO_3 @ 0.5% for 12 hours (Rs. 101475/- per ha). Regarding the benefit-cost ratio, the highest values (2.81) for hybrid maize-lathyrus in sequence was obtained from the treatment T_4 *i.e*. Seed priming with $ZnSO_4$ @ 0.5% for 12 hours, closely followed by the treatment T_6 *i.e*. seed priming with KNO_3 @ 0.5% for 12 hours (2.62). The lowest BCR value (2.05) was obtained from the treatment T_9 *i.e*. no seed priming (Control) (Table 6).

4. CONCLUSION

The seed priming methods significantly influenced the germination, yield attributes and yield of hybrid maize-lathyrus grown in sequence under rainfed situation. Considering pooled values of two years experimentation and based on the results obtained in the present study, it may be concluded that seed priming with $ZnSO_4$ @ 0.5% for 12 hours could be recommended due to better yield attributes and higher yield, higher net return and higher value of the benefit-cost ratio for hybrid maize-lathyrus in sequence under rainfed situation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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