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Response of phosphorus, phosphate solubilizing bacteria and zinc on yield and quality of blond psyllium (*Plantago ovata* Forsk)

A. C. Shivran*, S. S. Yadav, O. P. Sharma, L. R. Yadav, B. L. Dudwal and O. P. Meena

S.K.N. Agriculture University, Jobner, Rajasthan, India 303 329

Abstract

A field experiment was carried out at S.K.N. College of Agriculture, Jobner (Rajasthan) during two consecutive *rabi* seasons. Experiment comprising 24 treatment combinations replicated three times, was laid out in split plot design with four levels of phosphorus (0, 10, 20 and 30 kg P_2O_5 ha^{-1}) and two levels of PSB inoculation (No inoculation and inoculation) in main plots and zinc (0, 2.5 and 5.0 kg Zn ha^{-1}) in sub plots. Results indicated that successive increase in levels of phosphorus up to 30 kg ha^{-1} significantly improved seeds $spike^{-1}$, seed yield (13.82 q ha^{-1}), total N and P uptake and net returns (₹ 31990 ha^{-1}). Significantly higher spikes $plant^{-1}$, spike length, straw and biological yields, husk recovery (35.01%) and Zn uptake were recorded up to 20 kg ha^{-1}. The test weight, harvest index and protein content were significantly improved only up to 10 kg ha^{-1}. Seed yield and net returns increased with 30 kg ha^{-1} phosphorus to the tune of 54.24 and 76.64% over control, 20.80 and 27.04% over 10 kg and 4.46 and 5.26% over 20 kg, respectively. PSB inoculation significantly improved spikes $plant^{-1}$, spike length, seeds $spike^{-1}$, test weight, seed (12.52 q ha^{-1}), straw and biological yields, protein, husk recovery (34.54%), swelling capacity (11.05 cc g^{-1}), total N, P and Zn uptake and net returns (₹ 28351 ha^{-1}) over no inoculation. Inoculation increased seed yield and net returns by 11.69 and 15.69% repectively. Zinc application up to 5.0 kg ha^{-1} significantly increased spikes $plant^{-1}$, seeds $spike^{-1}$, test weight, seed (13.07 q ha^{-1}), straw and biological yields, protein content, husk recovery (34.82%), total N, P and Zn uptake and net returns (₹ 29696 ha^{-1}). Spike length was improved only with 2.5 kg zinc application. Contrarily, swelling capacity was significantly decreased with 5.0 kg ha^{-1} zinc (10.80 cc g^{-1}) as compared to control (10.98 cc g^{-1}). The increase in seed yield and net returns of blond psyllium with 5.0 kg ha^{-1} zinc were 26.04 and 32.99% over control and 7.57 and 9.03% over 2.5 kg zinc application, respectively. Blond psyllium should be fertilized with 30 kg phosphorus and 5.0 kg zinc per hectare along with inoculation from phosphate solubilizing bacteria to obtain higher productivity and profitability.

Key words: Blond psyllium, phosphorus, PSB, zinc, yield, quality, nutrient uptake, net returns

Introduction

Among various medicinal and aromatic crops, *Plantago ovata* Forsk. commonly known as blond psyllium and locally isabgol, has been recently documented as a very promising crop for cultivation in semi-arid region of Rajasthan. At present, it has acquired the name "Dollar earner" in North Gujarat and South Western Rajasthan. As a whole, India commands a near monopoly in production and export of the seed and husk in the world market. It is a medicinal plant, valued for its mucilaginous rosy white husk (epicarp of seed). The seed and husk is used for medicinal purposes (Gupta, 5, Wolver *et al.,* 22, Galindo *et al.,* 3 and Aishwath and Ram, 1). Economic value of this species is related to mucilage content of the seed mainly used in medicine and industry. The husk has the property of absorbing and retaining water and therefore, it has numerous pharmaceutical uses principally as swelling dietary and potentially for lowering blood cholesterol level and in checking constipation, diarrhea and intestinal irritation. In addition to these medicinal uses, it is also used in dyeing, calico printing, in the ice-cream as a stabilizer, confectionery and cosmetic industries (Thakur *et al.,* 21). The production technologies have already been developed for the traditional areas (Maiti and Mandal, 7). However, due to high demand and assured market, this crop is spreading to other nontraditional areas of India especially Rajasthan. Therefore, it is felt necessary to study the nutritional requirement of blond psyllium when grown in sandy loam soils of semi-arid region of Rajasthan.

Phosphorus is the most important key element in the nutrition of blond psyllium second only to nitrogen required by plants (Srinivasan *et al*., 20). It is a key nutrient for higher and sustained agriculture productivity (Scervino *et al.,* 15) which limiting plant growth in many soils including present study area. Phosphorus, the master key element is known to be involved in a plethora of functions in the plant growth and metabolism (Mahdi

*Corresponding author e-mail: acs_shivran@rediffmail.com

et al., 6). Phosphorus is the least mobile element in plants and soil contrary to other macronutrients (Sharma *et al.,* 17). Plants take phosphorus in soluble form but soil phosphorus is present as insoluble phosphate form thereby not utilized by plants. Microorganisms, especially the use of phosphate solublizing bacteria (PSB) as inoculants simultaneously increases phosphorus uptake by the plant and therefore can be used as biofertilizer (Nico *et al.,* 9). PSBs have a high potential to be used for the management of phosphorus in phosphorus deficient soils as well as disease suppression (Panhwar *et al.,* 10). Its use as inoculant for agricultural improvement has been a focus of numerous researchers for a number of years (Rodriguez *et al.,* 13). Zinc is an essential element for plant that act as a metal component of various enzymes, involved in RNA metabolism and ribosomal content in plant cells, stimulation of carbohydrates, proteins synthesis, DNA formation, cell division, maintenance of membrane structure and function and sexual fertilization (Marschner, 8). It also helps the utilization of phosphorus and nitrogen in plants. Response to applied zinc for better growth and yield of several important field crops has been reported from almost all corners of the country including Rajasthan.

The information on beneficial effect of nutritional requirement of blond psyllium on economic yield and quality is rather meager. Therefore, the present investigation was undertaken to study the effect of phosphorus, inoculation and zinc on blond psyllium under semi-arid region of Rajasthan.

Materials and methods

The two-year field experiment comprising 24 treatment combinations replicated three times, was laid out in split plot design with four levels of phosphorus (0, 10, 20 and 30 kg P_2O_5 ha^{-1}) and two levels of PSB (No inoculation and inoculation) in main plots and zinc (0, 2.5 and 5.0 kg Zn ha^{-1}) in sub plots. It was conducted at S.K.N. college of Agriculture, Jobner (Rajasthan) during *rabi* seasons of 2003-04 and 2004-05 situated at latitude of 26^{0}05' N, longitude of 75^{0}20' E and at an altitude of 427 m above mean sea level. The soil of experimental field was loamy sand, low in organic carbon (0.26%), available N (129.4 kg ha^{-1}), phosphorus (19.25 kg ha^{-1}), zinc (0.41 mg kg^{-1}) and medium in potassium (152.88 kg ha^{-1}) with alkaline (pH 8.5) in reaction having 1.49 Mg/m^{3} bulk density, 2.57 Mg/m^{3} particle density, 11.80% field capacity and 4.90% permanent wilting point at the beginning of the experiment. The crop variety 'GI-2' was sown in rows 20 cm apart with seed rate of 8 kg ha^{-1}. Uniform dose of nitrogen (40 kg ha^{-1}) through urea and phosphorus and soil application of zinc as per treatments through DAP and zinc sulphate, respectively were drilled at the time of sowing. During the crop season need based cultural and plant protection operations were taken up to harvest good crop during both the years of experimentation. Five random plants were selected from each plot for taking observations on yield attributes and for yield, the net plots were harvested. To determine the swelling factor, 1 g of seed was put into beaker of 25 ml capacity and 20 ml distilled water was added. The swelling of seeds was calculated after 24 hours. Husk content in the seed was also determined according to the method suggested by Sharma and Koul (16). Nutrient uptake was calculated using the following expression: Uptake of N/P/Zn (kg ha^{-1}) = Per cent N/P/Zn in seed X Seed yield (kg ha^{-1}) + Per cent N/P/Zn in straw X Straw yield (kg ha^{-1})/100. To ascertain the economic feasibility of different treatments, economics of treatments was worked out on the basis of prevailing market prices of inputs and outputs and expressed in terms of net profit per hectare so that most remunerative treatment could be recommended. Regular analysis of variance was performed for each trait for both the seasons and the pooled analysis over seasons after testing error variance homogeneity was carried out according to the procedure outlined by Gomez and Gomez (4).

Results and discussion

Yield attributes and yield

Data (Table 1) showed that increase in phosphorus levels at 20 kg ha^{-1} recorded significantly higher spikes plant^{-1} and spike length by 37.10 and 35.27% over control and 12.50 and 12.94% over 10 kg ha^{-1}, respectively but remained at par with 30 kg ha^{-1}. The seeds spike^{-1} was significantly increased up to 30 kg ha^{-1} recording 43.45, 16.05 and 6.10% increase over control, 10 and 20 kg ha^{-1}, respectively. Whereas, significant improvement in test weight was only up to 10 kg ha^{-1} which was higher by 3.89% over control. This could be attributed to better root proliferation, higher root development, increased availability and uptake of nutrients, energy transformation and metabolic processes in plant. The beneficial effect of phosphorus on fruiting of plants and better translocation of desired metabolites to the yield contributing parts of the plant might attributed to more yield attributes. These findings are in agreement of Deo and Khandelwal (2). The seed yield of blond psyllium progressively and significantly increased up to 30 kg ha^{-1} phosphorus (13.82 q ha^{-1}) resulting to 54.24, 20.80 and 4.46% increase over

Table 1: Influence of phosphorus, phosphate solubilizing bacteria and zinc on yield attributes and yield of blond psyllium (Pooled data of 2003-04 and 2004-05)

Treatment	Spikes plant^{-1}	Spike length (cm)	Seeds spike^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Phosphorus (P_2O_5 kg ha^{-1})								
0	18.25	2.58	42.09	1.80	8.96	23.54	32.51	27.57
10	22.24	3.09	52.03	1.87	11.44	27.80	39.25	29.16
20	25.02	3.49	56.91	1.89	13.23	30.48	43.72	30.26
30	26.41	3.60	60.38	1.90	13.82	31.54	45.37	30.47
SEm±	0.39	0.06	0.81	0.01	0.15	0.65	0.65	0.52
CD (P=0.05)	1.11	0.18	2.25	0.04	0.44	1.89	1.82	1.46
Phosphate solubilizing bacteria (PSB)								
No inoculation	22.21	3.06	50.80	1.85	11.21	26.88	38.10	29.43
Inoculation	23.76	3.26	54.88	1.89	12.52	30.29	42.82	29.23
SEm±	0.27	0.05	0.57	0.01	0.11	0.48	0.53	0.46
CD (P=0.05)	0.79	0.14	1.60	0.03	0.32	1.42	1.49	NS
Zinc (Zn kg ha^{-1})								
0	21.15	3.01	48.87	1.83	10.37	25.65	36.03	28.78
2.5	23.37	3.22	53.65	1.88	12.15	28.73	40.89	29.72
5.0	24.41	3.35	56.03	1.90	13.07	30.65	43.73	29.90
SEm±	0.20	0.05	0.44	0.01	0.11	0.38	0.48	0.37
CD (P=0.05)	0.56	0.15	1.23	0.02	0.31	1.07	1.36	NS

control, 10 and 20 kg ha^{-1}, respectively. Whereas, significantly increased straw (30.48 q ha^{-1}) and biological yields (43.72 q ha^{-1}) were observed up to 20 kg ha^{-1} phosphorus having 29.48 and 34.48% higher over control and 9.64 and 11.39% over 10 kg ha^{-1}, respectively. The application of phosphorus significantly increased harvest index (29.16%) only up to 10 kg ha^{-1} and was 5.77% over control. The improvement in yield might be due to the fact that phosphorus tends to increased growth and development in terms of dry matter and yield attributes by improving nutritional environment of rhizosphere and plant system leading to higher plant metabolism and photosynthetic activity. These findings corroborate the results of Puniya *et al.*, (12) who reported increased yield of mothbean with phosphorus application.

Significantly higher spikes plant^{-1}, spike length, seeds spike^{-1} and test weight were recorded with inoculation compared to no inoculation indicating an increase of 6.98, 6.54, 8.03 and 2.16%, respectively. The higher values of yield attributes might be associated with increased availability of phosphorus due to PSB treatment which in turn played an important role in rapid cell-division and elongation in the merismatic regions, root development and proliferation and enhancing flowering and seed formation (Mahdi *et al.,* 6). PSB inoculation significantly increased seed (12.52 q ha^{-1}), straw (30.29 q ha^{-1}) and biological yields (42.82 q ha^{-1}) over on inoculation to the tune of 11.69, 12.69 and 12.39%, respectively. Harvest index remained statistically same. Since, PSB helps in reducing phosphorus fixation by its chelating effect and also solubilized the fixed phosphorus leading to more uptakes of nutrients and reflected in better yield attributes in present study ultimately leads to higher seed and straw yields. These results corroborate with the findings of Singh *et al.*, (18).

Progressive increase in zinc levels at 5.0 kg ha^{-1} recorded significantly highest spikes plant^{-1}, seeds spike^{-1} and test weight having 15.41, 14.65 and 3.83% over control and 4.45, 4.44 and 1.06% over 2.5 kg ha^{-1}, respectively. However, spike length was significantly increased by 6.98% with 2.5 kg ha^{-1} zinc over control and remained at par to 5.0 kg. Soil under investigation was deficient in zinc and role of Znic in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them resulted in better flowering and fruiting. The finding of present investigations is also supported by Sahito *et al.*, (14). Zinc application up to 5.0 kg ha^{-1} significantly increased seed (13.07 q ha^{-1}), straw (30.65 q ha^{-1}) and biological yields (43.73 q ha^{-1}). The increase in seed, straw and biological yields with application of 5.0 kg ha^{-1} zinc was 26.04, 19.49 and 21.37% over control and 7.57, 6.68 and 6.95% over 2.5 kg ha^{-1}, respectively. Zinc could not influence harvest index significantly. The positive effect of zinc with respect to plant growth and yield with its attributes is due to the fact that zinc favors the enzyme system, auxin and protein synthesis and seed production directly or indirectly (Solanki *et al,* 19). Zinc is also a main limiting plant nutrient in arid and semi-arid regions where soils are deficient in zinc. Pariari *et al.* (11) in fenugreek also recorded increased plant growth and yield with zinc application.

Quality parameters

Application of phosphorus to blond psyllium significantly influenced protein content in seed and husk recovery; however, swelling capacity remained unaffected (Table 2). Phosphorus at 10 kg ha^{-1} significantly increased protein content in seed (12.11%) to the magnitude of 2.71% over control and higher levels could not bring significant improvement. Husk recovery from seed significantly increased with phosphorus up to 20 kg ha^{-1} (35.01%) registering 8.32 and 3.18% over control and 10 kg ha^{-1}, respectively. Protein content is essentially the manifestation of nitrogen content in seed. Better and bold seed development as indicated by higher test weight in present study might be responsible for high husk recovery. Further, significantly higher protein content (12.30%), husk recovery (34.54%) and swelling capacity (11.05 cc g^{-1}) were noted with PSB indicating 3.19, 2.40 and 2.79% increase over on inoculation, respectively. The variable nitrogen availability and test weight might be responsible for these quality parameters.

Zinc application at 5.0 kg ha^{-1} significantly increased protein content (12.24%) to the tune of 2.17% over control. The husk recovery increased up to 5.0 kg ha^{-1} (34.82%) where it recorded 4.25 and 1.84% higher over control and 2.5 kg ha^{-1}, respectively. Contrarily, swelling capacity was significantly decreased with 5.0 kg ha^{-1}zinc application (10.80 cc g^{-1}) as compared to control (10.98ccg^{-1}). The increased protein content may be attributed to increased availability and uptake of nitrogen

Table 2: Influence of phosphorus, phosphate solubilizing bacteria and zinc on quality, nutrient uptake and net returns of blond psyllium (Pooled data of 2003-04 and 2004-05)

Treatment	Protein content (%)	Husk recovery (%)	Swelling capacity (cc g^{-1})	Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total Zn uptake (g ha^{-1})	Net returns (Rs ha^{-1})
Phosphorus (P_2O_5 kg ha^{-1})							
0	11.79	32.32	10.98	35.15	13.22	157.03	18110
10	12.11	33.93	10.94	44.27	17.68	186.75	25182
20	12.24	35.01	10.86	50.44	20.88	205.49	30390
30	12.36	35.26	10.82	53.06	22.27	211.04	31990
SEm±	0.08	0.25	0.10	0.78	0.35	3.36	472
CD (P=0.05)	0.27	0.72	NS	2.16	0.97	9.77	1326
Phosphate solubilizing bacteria (PSB)							
No inoculation	11.92	33.73	10.75	42.76	17.11	178.68	24507
Inoculation	12.30	34.54	11.05	49.03	19.86	204.76	28351
SEm±	0.06	0.18	0.07	0.54	0.25	3.00	335
CD (P=0.05)	0.17	0.51	0.20	1.50	0.69	8.73	935
Zinc (Zn kg ha^{-1})							
0	11.98	33.40	10.98	40.01	16.59	165.42	22330
2.5	12.11	34.19	10.92	46.39	18.68	194.08	27237
5.0	12.24	34.82	10.80	50.27	19.75	212.82	29696
SEm±	0.05	0.14	0.06	0.41	0.21	2.74	334
CD (P=0.05)	0.14	0.38	0.15	1.16	0.60	7.97	940

in seed with zinc as also reported by Solanki *et al*., (19). Higher test weight (1.90 g) in present study might contribute to more husk recovery, whereas, bold seeds may not absorb high water as indicated by reduced swelling capacity.

Nutrient uptake

Pooled data (Table 2) revealed that each successive increase in levels of phosphorus up to 30 kg ha^{-1} significantly improved total nitrogen and phosphorus uptake by the crop showing 50.95 and 68.45% increase over control, 19.85 and 25.96% over10 kg and 5.19 and 6.67% over 20 kg phosphorus, respectively. The total zinc uptake was significantly increased only up to 20 kg ha^{-1} indicating 30.86 and 10.03% over control and 10 kg ha^{-1}, respectively. Since, uptake of N, P and Zn is the function of seed and straw yield and their content, the significant increase in seed and straw yield enhanced the total uptake of N, P and Zn. These findings were also similar to Puniya *et al.,* (12).

Inoculation with PSB significantly increased total nitrogen, phosphorus and zinc uptake indicating 14.66, 16.07 and 14.60% over on inoculation, respectively. It is obvious that PSB produces organic acids which render the insoluble phosphate to soluble one and release native and applied phosphorus in root zone leading to higher uptake by the plant. Uptake of N, P and Zn by crop is accordingly to the content and their above ground biomass they produced. Since biomass produced is influenced significantly, similar trend was also repeated in case of uptake (Nico *et al.,* 9).

Further, significantly highest total nitrogen, phosphorus and zinc uptake were recorded with 5.0 kg ha^{-1}over preceding levels of zinc where it registered an increase of 25.64,19.05 and 28.65% over control and 8.36, 5.73 and 9.66% over 2.5 kg ha^{-1}, respectively. The increase in nutrient uptake with zinc application is due to treatment effect which increased nutrient content in seed and straw and yields of blond psyllium as also noted by Deo and Khandelwal (2) in mustard and Puniya *et al*., (12) in mothbean.

Net returns

The results in Table 2 further revealed that net returns from blond psyllium were progressively and significantly increased up to 30 kg ha^{-1} phosphorus (₹ 31990 ha^{-1}). Net returns from crop were significantly increased by 15.69% with PSB inoculation (₹ 28351 ha^{-1}) over no inoculation. The zinc application up to 5.0 kg ha^{-1} significantly increased net returns (₹ 29696 ha^{-1}) and these were 32.99 and 9.03% over control and 2.5 kg ha^{-1}, respectively. These increased net returns were due to the fact that the treatments with phosphorus, inoculation and zinc registered maximum economic yields and ultimately fetch higher market prices (Singh *et al.,* 18).

Conclusion

The present study indicates that application of 30 kg phosphorus and 5.0 kg zinc per hectare along with inoculation from PSB to blond psyllium is better for realizing higher productivity and profitability under phosphorus-zinc-deficient conditions in semi-arid region of Rajasthan.

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