International J. Seed Spices 6(1), Jan 2016: 66-73

Growth, yield and nutrient uptake of isabgol (*Plantago ovata* Forsk) with phosphorus, PSB and zinc fertilization

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Abstract

In order to evaluate the effects of phosphorus, inoculation and zinc under semi-arid region of Rajasthan, the field experiment was carried out at SKN College of Agriculture, Jobner (Rajasthan) during two consecutive *rabi* seasons. Experiment comprising 24 treatment combinations replicated thrice, was arranged 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 in main plots and zinc (0, 2.5 and 5.0 kg Zn ha^{-1}) in sub plots. Results showed that application of phosphorus up to 30 kg ha^{-1} recorded significantly higher plant height at harvest, tillers per plant and dry matter production at 60 DAS and at harvest, seed yield (13.82 q ha^{-1}), P content in seed and straw, uptake of N in seed and P in seed and straw and net returns (₹ 31990 ha^{-1}). Significantly higher plant height at 60 DAS, straw yield, N content in seed and straw, N uptake in straw and Zn uptake in seed and straw and husk recovery were obtained up to 20 kg ha^{-1}. Contrarily, Zn content reduced significantly in seed with 30 kg and in straw with 20 kg ha^{-1} over control. PSB inoculation significantly improved plant height, tillers per plant and dry matter production at 60 DAS and at harvest, seed (12.52 q ha^{-1}) and straw yields, N and P content in seed and P and Zn content in straw; N, P and Zn uptake, protein content, husk recovery, swelling capacity and net returns (28351 ₹ ha^{-1}) over no inoculation. Zinc application up to 5.0 kg ha^{-1} significantly increased plant height, tillers per plant and dry matter production at 60 DAS and at harvest, seed (13.07 q ha^{-1}) and straw yields, N and Zn content and N, P and Zn uptake in seed and straw, protein content, husk recovery (34.82%) and net returns (29696 ₹ ha^{-1}).

Key words: Isabgol, phosphorus, PSB, nutrient uptake , yield ,zinc, growth

Introduction

Isabgol (*Plantago ovata* Forsk.) has been recently recognized as a very promising crop for cultivation in semi-arid region of Rajasthan. India has monopoly in production and export of the seed and husk of isabgol in the world market. Now a days, it has acquired the name "Dollar earner" in North Gujarat and South Western Rajasthan. It is a medicinal plant, valued for its mucilaginous rosy white husk (epicarp of seed). Economic value of this species is related to mucilage content of the seed mainly used in medicine and industry (Galindo *et al.,* 2000). The production technologies have already been developed for the traditional areas (Maiti and Mandal, 2000). However, due to high demand and assured market, this crop is spreading to other nontraditional areas of India especially Rajasthan. For that reason, it is felt necessary to study the nutritional requirement of isabgol when grown in sandy loam soils of semi-arid region of Rajasthan.

Phosphorus is the most important key element in the nutrition of isabgol second only to nitrogen required by plants (Srinivasan *et al.,* 2012). It is a key nutrient for higher and sustained agriculture productivity (Scervino *et al.*, 2011) which is limiting plant growth in many soils including area of present study. Phosphorus, the master key element is known to be involved in a plethora of functions in the plant growth and metabolism (Mahdi *et al.*, 2011). Phosphorus is the least mobile element in plants and soil contrary to other macronutrients (Sharma *et al.*, 2011). Plants take phosphorus in soluble form but soil phosphorus is present as

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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 (Singh *et al.*, 2005). 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.*, 2012). Its use as inoculants for agricultural improvement has been a focus of numerous researchers for a number of years. 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. 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. Thus, effects of these nutrient applications might be due to their critical role in crop growth, involving photosynthesis processes, respiration and other biochemical and physiological activities and their importance in attaining higher yields. Therefore, the present investigation was initiated to examine the effects of varying levels of phosphorus, PSB inoculation and zinc on isabgol under semi-arid region of Rajasthan.

Materials and methods

The field experiment was arranged 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 making 24 treatment combinations and replicated three times. 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 growth attributes and yield, the net plots were harvested. Nutrient content in seed and straw was estimated using modified Kjeldahl's method (Snell and Snell, 1949) for nitrogen, ammonium venadate molybdate yellow colour method (Richards, 1968) for phosphorus and atomic absorption spectrophotometer (Lindsay and Norwell, 1978) for zinc. Nutrient uptake was calculated using the following expression:

Uptake of N/P/Zn (kg ha^{-1}) = Per cent N/P/Zn in seed /straw X Seed/straw yield (kg ha^{-1}) /100.

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 (1986). 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.

Results and discussion

Growth attributes and yield

Growth and yield of isabgol was significantly influenced with application of varying levels of phosphorus, PSB and zinc application (Table 1). Phosphorus application up to 30 kg ha^{-1} recorded significantly higher plant height at harvest, tillers per plant and dry matter production at 60 DAS and at harvest in pooled data analysis. The plant height at 60 DAS was significantly increased only up to 20 kg ha^{-1} This could be attributed to better root proliferation, higher root development, increased availability and uptake of nutrients, energy transformation and metabolic processes in plant. These findings are in agreement of Deo and Khandelwal (2009). The seed yield of isabgol 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 control, 10 and 20 kg ha^{-1}, respectively. Whereas, significantly increased straw yield (31.54 q ha^{-1}) was observed in population 30 kg ha^{-1} & 20kg population compare to control, 10 kg ha^{-1}, respectively. The improvement in yield might be due to the fact that phosphorus tends to increased growth and development 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*., (2014) who reported increased yield of mothbean with phosphorus application.

Significantly higher plant height, tillers per plant and dry matter production at 60 DAS and at harvest were recorded with inoculation compared to no inoculation. The higher values of growth 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 (Mahdi *et al.*, 2011). PSB inoculation significantly increased seed (12.52 q ha^{-1}) and straw yields (30.29 q ha^{-1}) over on inoculation to the tune of 11.69 and 12.69%, respectively. 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 growth attributes in present study ultimately leads to higher seed and straw yields. These results corroborate with the findings of Singh *et al.*, (2014).

Progressive increase in zinc levels at 5.0 kg ha^{-1} recorded significantly highest plant height, tillers per plant and dry matter production at 60 DAS and at harvest. Soil under investigation was deficient in zinc and the favourable influence of applied zinc on these growth parameters may be ascribed to catalystic or stimulatory effect of zinc on most of the physiological and metabolic processes of the plant. Zinc also acts as a metal activator and is an essential component of enzymes such as proteinase and peptidase. It is also required for the synthesis of tryptophan, a precursor of IAA that acts as a growth promoting substance. Sahito *et al.* (2014) also support the finding of present investigation**.** Zinc application up to 5.0 kg ha^{-1} significantly increased seed (13.07 q ha^{-1}) and straw yields (30.65 q ha^{-1}). The increase in seed and straw yields with application of 5.0 kg ha^{-1} zinc was 26.04 and 19.49% over control and 7.57 and 6.68% over 2.5 kg ha^{-1}, respectively. The positive effect of zinc with respect to plant growth and yield is due to the fact that zinc favors the enzyme system, auxin and protein synthesis and seed production directly or indirectly (Solanki1 *et al.*, 2010). Zinc has catalytic, co catalytic and structural functions. Zinc is also a main limiting plant nutrient in arid and semi-arid regions where soils are deficient in zinc. Pariari *et al.*, (2009) also recorded increased plant growth and yield with zinc application in fenugreek.

Nutrient content and uptake

A perusal of pooled data showed that nitrogen content in seed and straw significantly increased with levels of phosphorus up to 20 kg ha^{-1}. However, phosphorus content in seed and straw significantly increased up to 30 kg ha^{-1} phosphorus (Table 2). Application of phosphorus might increase availability of nitrogen and phosphorus as well as high absorption by the plant consequently leading to higher content of these nutrients in seed and straw. Contrarily, zinc content reduced significantly in seed with 30 kg and in straw with 20 kg ha^{-1} phosphorus over control which might be due to hindrance/ antagonistic effect caused by increased availability of phosphorus on absorption and translocation of zinc from the roots to the above ground parts. Uptake of nitrogen in seed and phosphorus in seed and straw improved

Table 1. Influence of phosphorus, PSB and zinc on growth and yield of isabgol (Pooled data)

Treatments	Plant height (cm)		Tillers plant^{-1}		Dry matter (g plant^{-1})		Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest		
Phosphorus (P_2O_5 kg ha^{-1})								
0	16.36	27.09	2.85	2.90	1.07	3.92	8.96	23.54
10	19.34	33.76	4.08	4.30	1.23	4.52	11.44	27.80
20	20.52	38.64	4.72	4.87	1.37	4.77	13.23	30.48
30	21.16	40.98	5.02	5.13	1.46	4.99	13.82	31.54
SEm±	0.30	0.55	0.07	0.08	0.03	0.07	0.15	0.65
CD (P=0.05)	0.89	1.54	0.21	0.23	0.07	0.18	0.44	1.89
Phosphate solubilizing bacteria (PSB)								
No inoculation	19.06	33.63	3.93	4.13	1.14	4.22	11.21	26.88
Inoculation	19.66	36.60	4.37	4.46	1.42	4.88	12.52	30.29
SEm±	0.21	0.39	0.05	0.06	0.02	0.06	0.11	0.48
CD (P=0.05)	0.59	1.11	0.14	0.15	0.05	0.18	0.32	1.42
Zinc (Zn kg ha^{-1})								
0	18.79	31.71	3.77	3.99	1.10	4.22	10.37	25.65
2.5	19.38	35.77	4.25	4.35	1.31	4.63	12.15	28.73
5.0	19.88	37.89	4.48	4.57	1.44	4.80	13.07	30.65
SEm±	0.17	0.42	0.04	0.04	0.02	0.05	0.11	0.38
CD (P=0.05)	0.46	1.19	0.10	0.12	0.06	0.15	0.31	1.07

significantly up to 30 kg ha^{-1} phosphorus by 61.73, 82.12 and 60.19% over control; 23.30, 29.20 and 23.82% over10 kg and 5.59, 6.83 and 6.53% over 20 kg phosphorus, respectively. Nitrogen uptake in straw and zinc uptake in seed and straw improved significantly with 20 kg ha^{-1} phosphorus over preceding levels showing 34.55, 44.50 and 26.36% increase over control; 11.04, 14.26 and 8.52% over10 kg phosphorus, 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 uptake of N, P and Zn. These results are in agreement with those reported by Puniya *et al.*, (2014).

Inoculation with PSB significantly increased nitrogen and phosphorus content in seed and phosphorus and zinc content in straw. The inoculation of seed with PSB culture improved nutritional environment of rhizosphere; thereby enhanced availability of nutrients in soil which might increase uptake of these nutrients by the plant. Nitrogen, phosphorus and zinc uptake enhanced significantly with inoculation indicating 15.19, 15.29 and 13.78% in seed and 14.13, 16.45 and 14.58% in straw over on inoculation, respectively. Uptake of N, P and Zn by crop is accordingly to the content and their above ground biomass they produced. Since biomass produced and nutrient content are influenced significantly, similar trend was also repeated in case of uptake (Singh *et al.*, 2005).

Significantly highest nitrogen and zinc content in seed and straw were recorded with 5.0 kg ha^{-1} over preceding levels of zinc which might be due to increased zinc concentration in soil solution because the *experiment*al soil had a low status of available zinc (0.4 ppm). Contrary to it, phosphorus content reduced significantly in seed and straw with 5.0 kg ha^{-1} zinc over control which might be due to antagonistic effect of zinc and phosphorus. Further, significantly highest nitrogen, phosphorus and zinc uptake in seed and straw were recorded with 5.0 kg ha^{-1}over preceding levels of zinc where it registered an increase of 28.77, 23.37 and 35.31% in seed; 22.55, 16.40 and 26.34% in straw over control and 8.70, 6.40 and 10.84% in seed; 8.05, 5.27 and 9.22% in straw 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 isabgol as also noted by Deo and Khandelwal (2009) in mustard and Puniya *et al.,* (2014) in mothbean.

Quality

Application of varying levels of phosphorus to isabgol significantly influenced protein content in seed and husk recovery; however, swelling capacity remained unaffected (Table 3). Application of 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 N 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.

Application of zinc 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. The increased protein content may be attributed to increased availability and uptake of nitrogen in seed with zinc as also reported by Solanki *et al.,* (2010). 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.

Economics

The net returns from isabgol were significantly increased up to 30 kg ha^{-1} phosphorus (₹ 31990 ha^{-1})

Table 2. Influence of phosphorus, PSB and zinc on nutrient content and uptake of isabgol (Pooled data)

Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		Phosphorus Content (%)		Phosphorus uptake (kg ha^{-1})		Zinc Content (ppm)		Zinc uptake (g ha^{-1})	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
Phosphorus (P_2O_5 kg ha^{-1})												
0	1.88	0.77	16.91	18.23	0.556	0.350	4.98	8.24	43.41	50.17	38.92	118.11
10	1.93	0.79	22.18	22.09	0.614	0.384	7.02	10.66	43.01	49.47	49.22	137.52
20	1.95	0.80	25.90	24.53	0.642	0.407	8.49	12.39	42.51	48.96	56.24	149.25
30	1.97	0.81	27.35	25.70	0.656	0.419	9.07	13.20	41.40	48.76	57.23	153.81
SEm±	0.01	0.01	0.34	0.54	0.005	0.003	0.10	0.26	0.35	0.37	0.76	3.25
CD (P=0.05)	0.05	0.03	0.95	1.53	0.015	0.009	0.29	0.75	0.98	1.04	2.13	9.15
Phosphate solubilizing bacteria (PSB)												
No inoculation	1.91	0.79	21.39	21.36	0.607	0.384	6.80	10.31	42.17	48.86	47.30	131.37
Inoculation	1.96	0.80	24.64	24.38	0.627	0.397	7.84	12.01	42.99	49.82	53.82	150.93
SEm±	0.01	0.006	0.24	0.39	0.004	0.003	0.07	0.19	0.31	0.26	0.56	2.32
CD (P=0.05)	0.03	NS	0.68	1.09	0.012	0.007	0.20	0.53	NS	0.75	1.57	6.52
Zinc (Zn kg ha^{-1})												
0	1.91	0.78	19.88	20.13	0.624	0.395	6.46	10.12	41.01	47.90	42.53	122.89
2.5	1.93	0.79	23.55	22.83	0.617	0.390	7.49	11.19	42.72	49.48	51.92	142.15
5.0	1.95	0.80	25.60	24.67	0.610	0.385	7.97	11.78	44.02	50.65	57.55	155.26
SEm±	0.01	0.007	0.24	0.38	0.003	0.003	0.07	0.18	0.20	0.22	0.56	2.16
CD (P=0.05)	0.04	0.019	0.66	1.06	0.010	0.007	0.19	0.52	0.56	0.64	1.57	6.07

registering an increase of 76.64, 27.04 and 5.26% over control, 10 and 20 kg ha^{-1}, respectively (Table 3). 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}) with 32.99 and 9.03% improvement over control and 2.5 kg ha^{-1}, respectively. These increased net returns were because the treatments with phosphorus, inoculation and zinc registered maximum economic yield and ultimately fetch higher market prices (Singh *et al.*, 2014).

Conclusion

From this research experiment, it is recommended that application of 30 kg phosphorus and 5.0 kg zinc per hectare along with inoculation from PSB to *isabgol* is superior for obtaining higher productivity and net monetary returns in semi-arid region of Rajasthan.

Acknowledgement

The author is highly thankful to National Medicinal Plants Board, Ministry of Health and Family Welfare, Government of India for providing financial grant to the research project for conducting this investigation.

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Table 3. Influence of phosphorus, PSB and zinc on quality and economics of isabgol (Pooled data)

Treatment	Protein content (%)	Husk recovery (%)	Swelling capacity (cc g^{-1})	Net returns (Rs ha^{-1})
Phosphorus (P_2O_5 kg ha^{-1})				
0	11.79	32.32	10.98	18110
10	12.11	33.93	10.94	25182
20	12.24	35.01	10.86	30390
30	12.36	35.26	10.82	31990
SEm±	0.08	0.25	0.10	472
CD (P=0.05)	0.27	0.72	NS	1326
Phosphate solubilizing bacteria (PSB)				
No inoculation	11.92	33.73	10.75	24507
Inoculation	12.30	34.54	11.05	28351
SEm±	0.06	0.18	0.07	335
CD (P=0.05)	0.17	0.51	0.20	935
Zinc (Zn kg ha^{-1})				
0	11.98	33.40	10.98	22330
2.5	12.11	34.19	10.92	27237
5.0	12.24	34.82	10.80	29696
SEm±	0.05	0.14	0.06	334
CD (P=0.05)	0.14	0.38	0.15	940

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Received : August 2015; Revised : October 2015; Accepted : December 2015.