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Growth and productivity of succeeding pearl millet (*Pennisetum glaucum*) influenced by residual phosphorus, zinc and zinc solubilizer

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Abstract
Two year field experiment was conducted at Rajasthan Agriculture Research Institute, Durgapura, during rainy seasons of 2016 and 2017 in split plot design with three replications to study the growth, productivity and economics of fenugreek - pearl millet cropping system by using four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) and six treatments of zinc and zinc solubilizer [0, 2.5 and 5.0 kg Zn/ha, zinc solubilizer (*Bacillus endophyticus*), 2.5 kg Zn/ha + zinc solubilizer & 5 kg Zn/ha + zinc solubilizer) applied to fenugreek. Results revealed that all growth and yield attributes of pearl millet were increase up to 40 kg P_2O_5/ha while, plant height, dry matter and yield increased up to 60 kg P_2O_5/ha. The residual effects of 60 kg P_2O_5/ha and 5 kg Zn/ha + zinc solubilizer applied to fenugreek increased grain yield of pearl millet by 52 and 46%, respectively. The highest growth and yield contributing characters obtained with 5 kg Zn/ha + zinc solubilizer was at par with 2.5 kg Zn/ha + zinc solubilizer. The net returns and B: C ratios were also highest in 60 kg P_2O_5/ha and 5 kg Zn/ha + zinc solubilizer applied treatments.

Keywords: growth characters, pearl millet, phosphorus, yield characters, zinc and zinc solubilizer

Introduction
In India, pearl millet is one of the important millet crops which flourishes well even under adverse conditions. It is nutritious and palatable and adapted to drought and poor soil fertility, but responds well to good management and higher fertility levels. Phosphorus (P) is an essential nutrient for growth and development of plant. Phosphorus plays a very important role in photosynthesis, respiration, energy storage, cell division and other metabolic activities in plantlets. and also it is very important for seed germination and root formation for plant growth and development (Hrinathan *et al*., 2016) [3].

Zinc play indispensable role in various plant physiological processes such as photosynthesis, protein and sugar synthesis, fertility and production of seeds, growth regulation and disease immune system (Khinchi *et al*., 2017) [4]. A greater part of soil phosphorus and zinc are in the form of insoluble phosphates and cannot be utilized by the plants. To increase the availability of zinc for plants, zinc solublizer use to solubilize the fixed unavailable zinc into available form and that residue fertilizer can be utilize by succeeding crop. Therefore, an attempt was made to increase the productivity of pearl millet with different residual phosphorous and zinc levels.

Materials and Methods
Experimental details
The experiment was conducted at research farm of Rajasthan Agriculture Research Institute-Durgapura (SKNAU, Jobner) during the rainy seasons of the years 2016 and 2017. The soil was loamy sand, low in available nitrogen and phosphorous, medium in potassium and low in zinc content (139.2, 26.6, 182 kg/ha and 0.37 ppm) during 2015-16 and (134.2, 24.5, 180 kg/ha and 0.35 ppm) during 2015-16, respectively in 0-30 cm soil depth. The soil pH was 8.3 and 8.1 and per cent organic carbon content was 0.17 and 0.14 % with respective years. Treatments comprised of twenty four treatment combinations consisting of four phosphorous levels (0, 20, 40 and 60 kg P_2O_5/ha) as main plot treatments and six zinc treatments (0, 2.5, 5.0 kg Zn/ha, zinc solubilizer (*Bacillus endophyticus*), 2.5 kg Zn/ha + zinc solubilizer and 5 kg

Zn/ha + zinc solubilizer) as sub plot treatments were tested in split plot design with three replications. A uniform dose of 20 kg N/ha along with phosphorous and zinc as per treatment were drilled through diammonium phosphate and zinc sulphate (21%), respectively. To compensate the sulphur obtained from different levels of zinc compensatory dose of sulphur applied through elemental sulphur. To assess the residual effect of phosphorous and zinc treatments applied to preceding crop, succeeding crop of pearl millet (var. RHB 177) was raised, during *kharif* seasons of 2016 and 2017 in same lay out and was sown on 18 July 2016 and 20 July 2017, respectively. Recommended dose of nitrogen (90 kg/ ha) was applied to pearl millet in two splits, half as basal and remaining as top dress at 30 days after sowing and no other nutrient was applied. Not a major insect/disease was observed during the life cycle of fenugreek in the experiment, but weeds were manually controlled twice (30 and 58 days after sowing). Economics of treatments were worked out using market price of inputs and minimum support price of outputs.

Environmental conditions

The total number of rainy days (32 days) was higher, during 2016 as compared to, during 2017 (24 days). Besides, the total amount of rainfall received, during 2016 (402.8 mm) was higher in amount and relatively well distributed than that of obtained, during 2017 (348.4 mm), as it is evidenced by dry spells of 7 days occurred for three times, during 2016, however, during 2017 these dry spells received for five times. Similarly, evaporation rate was also lower, during ear emergence stage of crop growth, during 2016 as compared to, during 2017. Onset of rainfall, its amount and distribution with favorable temperature and better atmospheric humidity greatly influenced the performance of the pearl millet to a great extent, thus productivity levels were higher during 2016.

Result and Discussion

Growth attributes

Residual effect of different levels of phosphorous significantly increase the plant height, total dry matter/plant, number of total and effective tillers/plant, ear length and test weight of succeeding pearl millet recorded at harvest. The highest values of all growth attributes were obtained with 60 kg P_2O_5 /ha applied to fenugreek crop that was also significantly superior over rest of the treatments in plant height and plant dry matter accumulation, during both the years. While, number of total tillers /plant, during both the years significantly improved only up to 40 kg P_2O_5 /ha. The residual effect of 20 kg P_2O_5 /ha was statistically similar with control in plant height, plant dry matter, during both the years. Cereals respond nitrogen and phosphorus to a great extent and increased availability of these nutrients in soil led to higher uptake of these nutrients which had a favourable effect on the growth of pearl millet. Higher availability of phosphorous to the succeeding crop might be partly due to accumulated phosphorous in the soil applied preceding crop and partly due to the fact that crop seldom absorb more than 20 % of fertilizer phosphorous, during the first cropping season after application as reported by Tandon (1987) [7] and residual phosphorous may be utilized by succeeding crop.

Residual effect of zinc significantly increased the plant height, plant dry matter accumulation and total tillers /plant of succeeding pearl millet, during both the years, except zinc solubilizer, during 2016 in plant height, during both the years, in plant dry matter accumulation and total tillers/plant similarly, residual effect of 2.5 kg Zn /ha, during 2017, in total tillers /plant could not produce any significant impact and remained at par to control. The highest increase in all growth attributes were obtained with the residual effect of 5 kg Zn /ha + zinc solubilizer. During 2016, effect of that treatment was significantly superior over rest of the treatments, followed by 5 kg Zn/ha in increasing the plant height and plant dry matter accumulation. Residual effect of 5.0 kg Zn/ha was significantly better over zinc solubilizer and 2.5 kg Zn/ha but at par with that of 2.5 kg Zn/ha + zinc solubilizer, however, effect of zinc solubilizer was also statistically at par with that effect of 2.5 kg Zn/ha, during both the years in plant height and during 2016, in plant dry matter accumulation. During 2017, plant dry matter accumulation and during 2016, total tillers plant^{-1} residual effect of 5 kg Zn/ha, was statistically at par with 2.5 kg Zn/ha + zinc solubilizer, 5 kg Zn/ha + zinc solubilizer and 2.5 kg Zn/ha, however, during 2017, residual effect of 5 kg Zn/ha + zinc solubilizer remained at par with 5 kg Zn/ha and 2.5 kg Zn/ha + zinc solubilizer in increasing the total tillers /plant. Significant improvement in growth attributes of this may also be ascribed to the auxin metabolism and increased photosynthetic rate and also due to increased starch, protein nitrogen, soluble protein and specific activity of carbonic anhydrase, specific activities of acid phosphatase and ribonuclease in leaves and pods by residues of zinc.

Yield attributes and yield

Number of effective tillers /plant and ear length, during both the years and test weight, during 2016, significantly improved up to 40 kg P_2O_5/ha, however, during 2017, test weight increased only up to 20 kg P_2O_5/ha. The residual effect of 20 kg P_2O_5/ha was statistically similar with control, during 2016 in test weight. However, grain, stover and biological yields were significantly influenced up to 60 kg P_2O_5/ha, during both the years. The increase in yields of pearl millet owing to residual effects of phosphorous levels might be due to the fact that phosphorus application increased symbiotic root nodulation of fenugreek that promoted microbial activities promoting mineralization in soil that resulted in relatively higher availability and better absorption of these nutrients by the plant, ultimately leading to increased yield. The extensive and high volume of extracting roots pearl millet is one of the most efficient crop in this respect which can extract this residual phosphorous for its nourishment. These increased photosynthates tend to move towards yield contributing characters and after partitioning these photosynthates will results in increased yield attributes and yield.

The residual effect of zinc treatments significantly influenced all yield attributes and yield of pearl millet, over control except zinc solubilizer, during both the years in all yield attributes and stover and biological yields and also effect of 2.5 kg Zn/ha, during both the years, in number of effective tillers plant^{-1} and during 2016 in test weight. The highest number of effective tillers plant^{-1}, length of ear was recorded with the residual effect of 5 kg Zn/ha + zinc solubilizer followed by 2.5 kg Zn/ha + zinc solubilizer and 5 kg Zn/ha, during both the years (Table 1&2). Residual effect of 5.0 kg Zn/ha was significantly superior over control and zinc solubilizer but statistically at par with that of 2.5 kg Zn/ha + zinc solubilizer and 5 kg Zn/ha + zinc solubilizer, during both the years, in number of effective tillers/plant, length of ear and during 2016 in test weight. Residual effect of 2.5 kg Zn/ha was significantly better over control and statistically at par with that of 5.0 kg Zn/ha, during 2016, however, it was also at par with 2.5 kg Zn/ha + zinc solubilizer, during 2017,

in number of effective tillers/plant. The residual effect of 5 kg Zn/ha was significantly better than that of 2.5 kg Zn/ha and zinc solublizer but found as at par with that of 2.5 kg Zn/ha + zinc solublizer, during both the years in grain and stover yield and during 2017 in biological yield, however, during 2016, in biological yield residual effect of 2.5 kg Zn/ha + zinc solubilizer statistically at par with that of 2.5 kg Zn/ha and 5 kg Zn/ha. The residual effect of zinc solublizer was also at par with 2.5 kg Zn/ha in grain yield. In dry land areas zinc application increases absorption of minerals by roots (Singh *et al*., 2017) [6]. Nourishment with zinc helps in improving nitrogen content of plant through biological nitrogen fixation (BNF) though, nitrogen appears to be synergistic with zinc, which may leads to increase in many physiological and molecular activities which in turn improve yield attributing characters (Cakmak *et al*., 2010) [2]. A very small part of applied zinc may be utilized by the field crops and such fraction remains between 0.3 to 3.5 % (Abid *et al*., 2013)*et alo*, consequently a larger amount of applied zinc remain in soil but in unavailable form. Thus to utilize this fraction of zinc is of paramount importance. Solubilizers solubilize that fixed zinc through their acid production action and increased microbial activity in the soil led to higher uptake of these nutrients which had a favorable effect on succeeding crop.

Table 1: Residual effect of phosphorous and zinc fertilization on growth and yield attributes of pearl millet

Treatments	Plant height (cm)		Dry matter (g/plant)		Total tillers/plant		Effective tillers/plant		Ear length (cm)		Test weight (g)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Phosphorous (P_2O_5 kg/ha)												
0.0	167.8	161.4	38.2	33.6	3.43	3.30	3.26	3.13	19.97	19.26	5.81	5.70
20	171.7	167.1	42.5	36.0	3.68	3.58	3.58	3.33	20.73	20.07	6.01	5.94
40	188.9	180.4	52.7	44.4	4.13	3.90	3.97	3.82	21.94	21.37	6.28	6.15
60	201.4	192.1	59.2	48.6	4.30	4.13	4.17	4.03	22.10	21.54	6.49	6.23
SEm±	2.8	2.8	1.7	0.8	0.08	0.07	0.06	0.08	0.32	0.31	0.07	0.06
CD (P=0.05)	9.6	9.5	5.8	2.7	0.29	0.24	0.21	0.29	1.10	1.08	0.25	0.21
Zinc levels (kg/ha)												
0.0	167.8	154.9	41.2	34.8	3.49	3.34	3.36	3.23	20.08	19.37	5.94	5.88
2.5	177.4	167.9	46.0	39.7	3.83	3.61	3.63	3.48	21.03	20.40	6.09	5.98
5.0	188.2	183.4	51.3	42.9	4.05	3.89	3.86	3.67	21.55	20.95	6.22	6.05
Zinc solubilizer	175.2	165.9	43.9	36.8	3.63	3.51	3.54	3.41	20.40	19.72	6.03	5.96
2.5 + Zinc solubilizer	186.6	183.7	50.2	43.6	4.09	3.94	3.96	3.72	21.78	21.20	6.27	6.08
5.0 + Zinc solubilizer	199.5	195.6	56.3	46.0	4.24	4.09	4.11	3.94	22.27	21.72	6.33	6.09
SEm±	2.9	3.0	1.5	1.2	0.11	0.10	0.09	0.10	0.50	0.49	0.09	0.07
CD (P=0.05)	8.4	8.7	4.4	3.5	0.30	0.28	0.25	0.28	1.43	1.39	0.24	NS

Table 2: Residual effect of phosphorous and zinc fertilization on yields (q/ha) and harvest index of pearl millet

Treatments	Grain yield		Stover yield		Biological yield		Harvest index		Benefit : Cost ratio	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Phosphorous (P_2O_5 kg/ha)										
0.0	16.66	14.84	44.10	36.04	60.77	50.89	27.93	29.40	2.32	1.63
20	18.56	16.34	47.99	40.30	66.55	56.64	28.12	28.89	2.69	1.95
40	22.52	19.58	55.29	48.11	77.81	67.70	29.00	29.21	3.35	2.53
60	25.69	22.30	61.53	53.04	87.22	75.35	29.46	29.64	3.90	2.95
SEm±	0.46	0.41	0.96	0.85	1.64	1.50	1.16	0.95		
CD (P=0.05)	1.58	1.43	3.31	2.95	5.67	5.19	NS	NS		
Zinc levels (kg/ha)										
0.0	17.54	15.01	46.76	38.43	64.30	53.45	27.69	28.21	2.55	1.77
2.5	19.55	16.99	50.67	41.88	70.22	58.87	27.93	29.02	2.90	2.07
5.0	22.23	19.89	55.65	46.48	77.88	66.36	28.62	30.10	3.28	2.44
Zinc solubilizer	19.17	16.40	47.93	39.17	67.11	55.57	29.12	29.75	2.74	1.91
2.5 + Zinc solubilizer	21.61	18.87	53.11	47.68	74.72	66.54	28.83	28.46	3.18	2.46
5.0 + Zinc solubilizer	25.06	22.44	59.25	52.63	84.31	75.07	29.58	30.16	3.75	2.95
SEm±	0.53	0.44	1.54	1.32	1.92	1.61	1.11	1.09		
CD (P=0.05)	1.53	1.26	4.39	3.78	5.48	4.60	NS	NS		

Cost of cultivation = 13825 and 14825 during 2016 and 2017, respectively

Economics

Application of 60 kg P_2O_5/ha and 5 kg Zn/ha + zinc solubilizer gave the highest net monetary returns (Fig 2) and benefit: cost ratios. Consequently application of 60 kg P_2O_5/ha and 5 kg Zn/ha + zinc solubilizer is recommended for increasing the residual pearl millet productivity and fetching high returns.

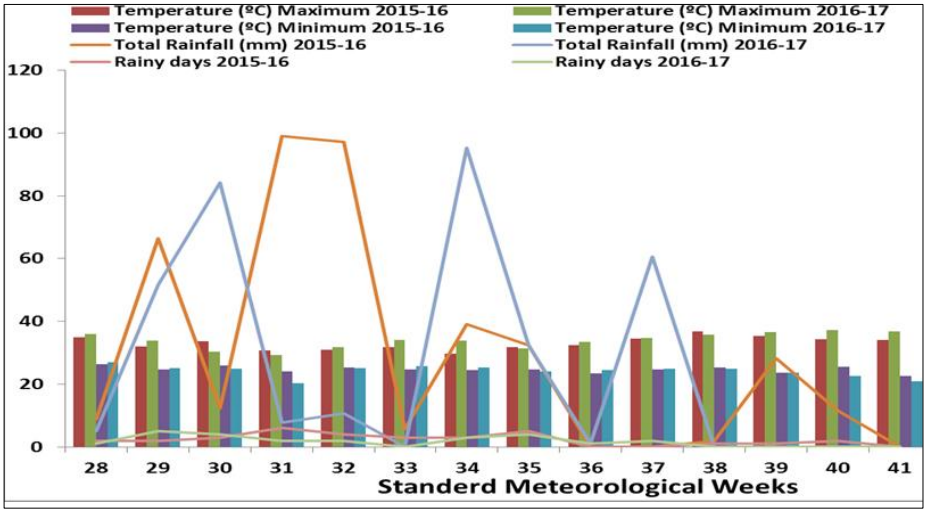

Fig 1: Mean weekly weather parameters for *kharif* crop season (Pearl millet)

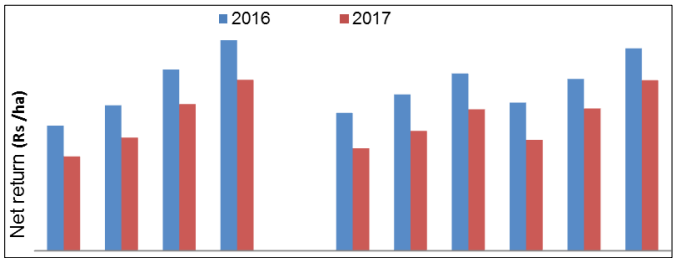

Fig 2: Effect of phosphorous and zinc fertilization on net returns of Pearl millet

Conclusion

Residual effect of 60 kg P_2O_5/ha and 5.0 kg Zn/ha + zinc solubilizer were significantly effective in improving growth and yield attributes and yield of succeeding pearl millet. Application of 60 kg P_2O_5/ha and 5.0 kg Zn/ha + zinc solubilizer resulted in the highest net returns and B:C ratio when applied to fenugreek in fenugreek - pearl millet cropping system.

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