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Effect of various integrated management practices on growth and yield of pearl millet crop grown on typic haplustepts soils of Gwalior region in Madhya Pradesh

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Abstract
Pearl millet is a major cereal crop in northwestern India. The crop is grown in very harsh, arid, dry climatic areas having high temperature and low and erratic rainfall. Its use as food is declining but its use as cattle feed; poultry feed and source of starch in the alcohol industry is increasing. Its fodder is an important source of animal feed particularly in dry months when alternative sources of feed are not available. Field experiment was conducted during 2014-16 at the Research Farm of College of Agriculture, Gwalior, Madhya Pradesh. The experimental soil is alluvial, sandy clay loam in texture. Eight treatments were tested in a randomized block design with three replications. The treatments were RDF (Recommended dose of fertilizer), RDF + Azotobacter + PSB, RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB, RDF + 1 gm Ammo. Molybdate/ kg seed + Azotobacter + PSB, RDF + 5 kg borax/ha + Azotobacter + PSB RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB, RDF +$ZnSO_4$ @ 25 kg/ha + FeSO4 @ 40 kg/ha, RDF + 5t FYM/ha + Azotobacter + PSB. Plant height ranged from213.7 to 248.7cm. Maximum plant height (248.7cm) was noted under treatment RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha. Maximum ear head length (34.4cm) was recorded with RDF + 5 t FYM/ha + Azotobacter + PSB treatments. Grain yield varied from 3193 to 3750 kg/ha under different treatments and the magnitude of increase in yield due to various INM treatments was 4.29 -17.44 % over RDF treatments. Integrations of FYM (5 t /ha) with recommended dose of fertilizers and bio fertilizers (Azotobacter + PSB) produced significantly higher grain yield of pearl millet over T_2 (RDF + Azotobacter + PSB) treatment. Among different micronutrients, application of $ZnSO_4$ and $FeSO_4$ gavesignifianr response in terms of grain yield of pearl millet. Application of FYM @ 5 t/ha or $ZnSO_4$ with RDF + Azotobacter+ PSB gave significant increase in N & K content in grain and stover compared to that only RDF + Azotobacter + PSB (T_2) treatment. integration of FYM (5 t /ha) with recommended dose of fertilizers and bio fertilizers (T_8) recorded significantly higher N, P & K status in soil compared to only RDF(T_1) and RDF + Azotobacter + PSB (T_2) treatments. Supplementation of FYM with NPK and biofertilizers was beneficial in enhancing the uptake of nutrients by the pearl millet over NPK only. The maximum net return (Rs 18273/ha) obtained from RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha (T_7) closely followed by (Rs 18137/ha) and (Rs 18025/ha) by T_3 (RDF+ $ZnSO_4$ @ 25 kg/ha + *Azotobacter* + PSB) and T_8 (RDF + 5 t FYM/ha + Azotobacter + PSB) treatments. The maximum B:C. ratio (2.27) was obtained from T_3 (RDF+ $ZnSO_4$ @ 25 kg/ha + *Azotobacter* + PSB).

Keywords: management practices, nutrientuptake, micronutrient and biofertilizer

Introduction
Pearl millet is a common crop grown in *Kharif* by marginal and small farmers in alluvial soil region of northern Madhya Pradesh under Pearl millet – mustard and Pearl millet –wheat cropping systems. Under intensive cultivation, there are reports of reduction in yield even due to constant use of NPK fertilizers. The reduction in the yield is generally traced due to deficiency of micronutrients. The micronutrient deficiencies which were sparse and sporadic initially are now widespread because the ability of the plants to enhance yield is dependent on the availability of adequate and balanced quantity of plant nutrients because cultivation of high yielding varieties of crop coupled with intensive cropping system has depleted the soil fertility, resulting in multi-nutrient deficiencies in soil-plant system.
Soil research results of the last decade show that at the present time, among micronutrients, Zn deficiency is the most detrimental to effective crop yield. Other important micronutrients that

increase crop yield (most to least effect) are Fe, B, Mn, Cu, and Mo. In the case of calcareous soils, the conventional notion that micronutrients increase crop yield by 15%-30% is an underestimated range. Micronutrients are very much essential for the growth, development and reproduction of plants. Different crops require varied quantities of micronutrients in their different stages of growth. Thus, they become more important as regards to increase and conserve fertility and productivity of soil. There are reports of reduction in yield even due to constant use of NPK fertilizers. The reduction in the yield is generally traced due to deficiency of secondary nutrients and micronutrients. The decline in nutrient use efficiency is particularly attributes to increase incidence of deficiency of zinc and boron in many parts of the country.

Bio-fertilizers are microbial culture, which make availability of certain plant nutrients to crops by various actions. *Azotobacter* fixes atmospheric nitrogen while certain bacteria/ fungal culture help in phosphate solublization of both native and applied sparingly soluble phosphate. Looking to the rising price of chemical fertilizers, microbial cultures can provide an eco-friendly viable support to small and marginal farmers by partly replacing inorganic fertilizers use in crop production.

The higher yield of crop depends mainly on the availability of adequate plant nutrients. The availability of nutrients has been depleted due to intensive cultivation and imbalance use of fertilizer, consequently the deficiency symptoms major and micronutrients are fast appearing on crop plants. This shows the magnitude of the problem. This is the true especially of the aim of sustainable agriculture. As such there is need to supply to plant the entire essential nutrient to the soil by way of an integrated approach. The integrated nutrient supply through inorganic and organic sources will not only meet out the nutrient requirement of crop, but shall also save the soil health.

Material and Methods

Field experiment was conducted during 2014-16 at the Research Farm of College of Agriculture, Gwalior, Madhya Pradesh. The experimental soil is alluvial, sandy clay loam in texture having 55.6 % sand, 23.8% silt and 20.6 % clay. Eight treatments were tested in a randomized block design with three replications. The treatments were RDF (Recommended dose of fertilizer), RDF + Azotobacter + PSB, RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB, RDF + 1 gm Ammo. Molybdate/ kg seed + Azotobacter + PSB, RDF + 5 kg borax/ha + Azotobacter + PSB RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB, RDF +$ZnSO_4$ @ 25 kg/ha + FeSO4 @ 40 kg/ha, RDF + 5t FYM/ha + Azotobacter + PSB. Representative soil samples of surface soil (0-15 cm depth) were collected from each plot before sowing and after harvest of Wheat crop with the help of soil auger for determination of physico-chemical properties of experimental site. As per treatment FYM was added @ 5 tonnes /ha. before sowing of pearl millet. The seeds were treated with *Azotobacter* and PSB both @ 10 g/kg seed as per treatment, micronutrients (i.e. Zn, Fe, B & Mo) were applied in the form of zinc sulphate @ 25 kg/ha, $FeSO_4$ @ 40 kg/ha, 5 kg borax/ha and 1 gm Ammo. Molybdate/ kg seed, respectively. The data recorded was statistically analyzed in a randomized block design according to analysis of variance for judging the effect of different treatments on various attributes of pearl millet.

Result and Discussion

Grain, and stover, yield and harvest index

Plant height was recorded in the range of 213.7 to 248.7cm under different treatments. Maximum plant height (248.7cm) was noted under (RDF +$ZnSO_4$ @ 25 kg/ha + FeSO4 @ 40 kg/ha) which is significantly higher over RDF, RDF +Azotobacter +PSB and RDF+Azb+ammo, molybdate and at par to other treatments. Height being 245.2, 240.2 and 238.1 cm.) whereas, minimum plant height (213.7 cm) was found under RDF treatment (T_1). Length of ear head ranged from 25.7 to 34.4 cm under different treatments. Maximum ear head length (34.4cm) was recorded with T_8 (RDF + 5 t FYM/ha + Azotobacter + PSB) treatment, which is significantly higher over T_1, T_2, T_4 and T_5treatments but statistically at par with T_3, T_6 & T_7 treatments with the length of ear head 31.8, 31.9 & 32.3 cm. Minimum ear head length (25.7 cm) was under RDF treatment (Table 1).

Maximum test weight (12.83 g) was under T_7 treatment. However, test weight obtained in this treatment was statistically at par with RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB, RDF + 5 kg borax/ha + Azotobacter + PSB, RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB and RDF + 5 t FYM/ha + Azotobacter + PSB treatments. Whereas minimum test weight (9.37 g) was in (RDF).

Table 1: Effect of different INM treatments on plant height (cm) of pearl millet

Treat No.	Treatments	Plant height (cm)	Length of ear head (cm)	Test weight (g)	Length of ear head (cm)
T_1	RDF (Recommended dose of fertilizer)	213.7	25.7	9.37	25.7
T_2	RDF + Azotobacter + PSB	223.1	28.8	9.40	28.8
T_3	RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB	240.2	31.8	12.28	31.8
T_4	RDF + 1 gm Ammo. Molybdate/ kg seed + Azotobacter + PSB	231.6	29.2	10.63	29.2
T_5	RDF + 5 kg borax/ha + Azotobacter + PSB	234.7	30.1	12.06	30.1
T_6	RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB	238.1	31.9	12.02	31.9
T_7	RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha	248.7	32.3	12.83	32.3
T_8	RDF + 5 t FYM/ha + Azotobacter + PSB	245.2	34.4	12.44	34.4
SEm (±)		3.9	0.9	0.28	0.9
C. D. (5%)		12.2	2.8	0.88	2.8

Yield parameter

Grain yield varied from 31.9 to 37.5 qha^{-1} under different treatments and the magnitude of increase in yield due to various INM treatments was 4.29 -17.44 % over RDF treatments. Integrations of FYM (5tha^{-1}) with recommended dose of fertilizers and bio fertilizers (Azotobacter + PSB) produced significantly higher grain yield of pearl millet over RDF + Azotobacter + PSB treatment. Among different micronutrients, application of $ZnSO_4$ and $FeSO_4$ gave signifiant response in terms of grain yield of pearl millet. Maximum stover yield (81.8 qha^{-1}) was observed under treatment RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha followed by treatment RDF + 5 t FYM/ha + Azotobacter + PSB with the yield of 80.9tha^{-1}. Harvest index ranged from 31.03 to 31.96 % under different treatments and it is statistically at par from each others. Application of FYM @ 5 t/ha or $ZnSO_4$ with RDF + Azotobacter+ PSB (Table-2).

Table 2: Effect of different INM treatments on grain, stover yield (kg/ha) and harvest index (%) of pearl millet

Treat. No.	Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	H. I. (%)
T_1	RDF (Recommended dose of fertilizer)	3193	7039	31.20
T_2	RDF + Azotobacter + PSB	3330	7343	31.19
T_3	RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB	3580	7624	31.96
T_4	RDF + 1 gm Ammo. Molybdate/ kg seed + Azotobacter + PSB	3358	7476	30.99
T_5	RDF + 5 kg borax/ha + Azotobacter + PSB	3374	7500	31.03
T_6	RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB	3523	7694	31.41
T_7	RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha	3750	8175	31.45
T_8	RDF + 5 t FYM/ha + Azotobacter + PSB	3693	8092	31.34
SEm (±)		79	123	0.66
C. D. (5%)		248	388	NS

Content and Uptake of nutrients

Integrations of nutrients (RDF + 5 t FYM/ha + Azotobacter + PSB) influenced the NPK content significantly which could be due to additional supply of these nutrients through FYM and improvement in the soil physical condition for better plant growth which ultimately led to higher NPK content. Increase in NPK contents with the application of FYM and bio fertilizers were also reported by Meena and Gautam (2005) [8] and Yadav *et al.* (2013) [13]. The application of $ZnSO_4$ and $FeSO_4$ with recommended dose of fertilizers and bio fertilizers (Azotobacter + PSB) recorded significantly higher N, P and K uptake by pearl millet over only RDF treatments, respectively. The increase in NPK uptake by crop as result of application of micronutrients might be due to the increase of enzymatic effect in the metabolic process (Mahatim-singh *et al*. 1978) [5]. Positive effect of zinc and iron application on its content and uptake by crop may be due to increase in concentration of zinc and iron in soil solution with its application resulting in more absorption of zinc and iron by plant.

The higher micronutrient removal especially that of Zn and Fe due to its application along with NPK could also be attributed to the priming effect caused by higher crop growth and consequential higher removal due to balanced fertilizations (Malewar *et al. (*2001) and Yadav *et al.* (2013)) [7, 13].

The uptake of N, P and K was the lowest in the plants which received only RDF (T_1). The lower uptake of nutrient in RDF plots is due to lower yields obtained in these lots. Supplementation of FYM with NPK and biofertilizers was beneficial in enhancing the uptake of nutrients by the pearl millet over NPK only. The increase in uptake of N, P, and K following FYM application is probably because of the improvement of soil environment, which encouraged proliferation of roots, which in turn drew more water and nutrients from larger area and also from deeper layer. Further, FYM after decomposition releases major and micronutrients, which become available to the plants and thus increase the uptake Meena and Gautam (2005) [8] also reported that the total N, P and S uptake were higher in FYM treated plots as compared to without FYM.

Table 3: NPK content in pearl millet grain and stover as influenced by various treatments

Tr. No.	Treatments	Nutrient content in grain (%)			Nutrient content in stover (%)		
		N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
T_1	RDF (Recommended dose of fertilizer)	1.58	0.343	0.722	0.617	0.132	1.30
T_2	RDF + Azotobacter + PSB	1.70	0.373	0.753	0.671	0.147	1.34
T_3	RDF+ $ZnSO_4$ @ 25 kg/ha + Azotobacter + PSB	1.78	0.365	0.787	0.723	0.156	1.47
T_4	RDF + 1 gm Ammo. Molybdate/ kg seed + Azotobacter + PSB	1.77	0.380	0.750	0.663	0.152	1.40
T_5	RDF + 5 kg borax/ha + Azotobacter + PSB	1.75	0.373	0.748	0.653	0.153	1.39
T_6	RDF + $FeSO_4$ @ 40 kg/ha + Azotobacter + PSB	1.74	0.385	0.757	0.680	0.149	1.46
T_7	RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha	1.80	0.374	0.761	0.687	0.146	1.40
T_8	RDF + 5 t FYM/ha + Azotobacter + PSB	1.84	0.430	0.807	0.750	0.177	1.51
SEm (±)		0.02	0.009	0.012	0.013	0.004	0.02
C. D. (5%)		0.07	0.028	0.038	0.042	0.013	0.07

Table 4: NPd K uptake (kg/ha) in grain, stover and total as influence by various INM treatments

Tr. No.	Treatments	N-Uptake (kg/ha)			P-Uptake (kg/ha)			K -Uptake (kg/ha)		
		Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
T_1	RDF	50.50	43.41	93.91	10.99	9.27	20.26	23.06	91.49	114.55
T_2	RDF + Azo + PSB	56.48	49.31	105.79	12.44	10.81	23.25	25.08	98.65	123.74
T_3	RDF+ $ZnSO_4$ @ 25 kg/ha + Azo + PSB	63.88	55.13	119.00	13.06	11.89	24.96	28.16	112.13	140.29
T_4	RDF + 1 gm Amm. Mo./ kg seed + Azo + PSB	59.32	49.59	108.91	12.75	11.39	24.14	25.17	104.91	130.08
T_5	RDF + 5 kg borax/ha + Azo + PSB	59.15	48.99	108.14	12.60	11.49	24.09	25.22	104.44	129.65
T_6	RDF + $FeSO_4$ @ 40 kg/ha + Azo + PSB	61.26	52.35	113.61	13.53	11.42	24.95	26.69	112.56	139.25
T_7	RDF + $ZnSO_4$@ 25 kg/ha + $FeSO_4$ @ 40 kg/ha	67.46	57.14	124.60	14.02	11.94	25.96	28.55	114.13	142.68
T_8	RDF + 5 t FYM/ha + Azo + PSB	68.08	60.72	128.80	15.89	14.35	30.23	29.82	122.21	152.03
SEm (±)		1.65	1.44	2.58	0.44	0.33	0.47	0.68	2.37	1.94
C. D. (5%)		5.21	4.55	8.15	1.38	1.04	1.48	2.14	7.47	6.12

Residual nutrient availability

Organic carbon

It is apparent from the result that the maximum increase in organic carbon content of soil was found in the T_8 treatment (RDF + 5 t FYM/ha + Azotobacter + PSB) which may be attributed to the increase in organic carbon which of crop residues particularly crop roots and direct addition of organic matter through FYM alongwith NPK doses (Kumar (2002) [4, 6].

Major nutrients (NPK)

Integration of FYM (5 t /ha) with recommended dose of fertilizers and bio fertilizers (T_8) recorded significantly higher N, P & K status in soil compared to only RDF(T_1) and RDF + Azotobacter + PSB (T_2) treatments. This increase is obvious as FYM favoured mineralization of organic sources of N in the soil. Similar result were reported by Kamat *et al.* (1982) [3] and Majumdar *et al.* (2002) [6]. The increase in available P with PSB and FYM addition might be due to release of more P from organic compounds, as well as from fixed form of P, increase in microbial population and decomposition product of humic substance. Increase in available K status as a result of FYM application may be attributed to mobilization of K from reserve pool. Chaudhary *et al.* (1981) [2] and Rao *et al.* (1999) [12] also reported similar result.

Micro nutrients

The amounts of different micronutrients (Zn, Fe, B & Mo) in soil were increased with their application and with FYM treated plots. Whereas it was depleted from initial status in only RDF treatments. Kumar *et al.* (2008) [13] also observed higher micronutrients status in soil treated with the FYM and Zn. According to Patil *et al*. (2006) that there was a build - up in Fe in the plots received $ZnSO_4$ and $FeSO_4$.

Table 5: Change in physico chemical properties of soil after harvest of pearl millet under INM treatments

Tr. No.	Treatments	pH	E C (dSm-1)	Organic carbon (%)	Avail - N (kg/ha)	Avail – P (kg/ha)	Avail - K (kg/ha)
Initial value		7.64	0.44	0.426	**169.08**	**14.02**	**194.6**
T_1	RDF (Recommended dose of fertilizer)	7.70	0.42	0.423	163.0	13.06	173.8
T_2	RDF + Azo + PSB	7.77	0.42	0.438	174.3	14.45	180.5
T_3	RDF+ $ZnSO_4$ @ 25 kg/ha + Azo + PSB	7.50	0.45	0.447	178.5	13.67	187.4
T_4	RDF + 1 gm Ammo. Mo/ kg seed + Azotobacter + PSB	7.70	0.42	0.446	179.3	14.25	184.9
T_5	RDF + 5 kg borax/ha + Azo + PSB	7.63	0.44	0.449	174.1	13.99	182.8
T_6	RDF + $FeSO_4$ @ 40 kg/ha + Azo + PSB	7.57	0.48	0.450	178.0	14.72	186.9
T_7	RDF + $ZnSO_4$@ 25 kg/ha + $FeSO_4$ @ 40 kg/ha	7.63	0.43	0.455	176.1	13.92	188.7
T_8	RDF + 5 t FYM/ha + Azo + PSB	7.40	0.40	0.464	182.1	15.33	196.1
SEm (±)		0.09	0.02	0.006	3.3	0.33	3.4
C. D. (5%)		NS	NS	0.019	10.3	1.04	10.7

Economics

The economic feasibility in terms of net monetary return and B;C ratio showed that The maximum net return (Rs 18273/ha) obtained from RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ @ 40 kg/ha (T_7) closely followed by (Rs 18137/ha) and (Rs 18025/ha) by T_3 (RDF+ $ZnSO_4$ @ 25 kg/ha + *Azotobacter* + PSB) and T_8 (RDF + 5 t FYM/ha + Azotobacter + PSB) treatments respectively. The maximum B:C ratio (2.27) was obtained from T_3 (RDF+ $ZnSO_4$ @ 25 kg/ha + *Azotobacter* + PSB).

Conclusion

integration of FYM @ 5 t/ha or application of $ZnSO_4$ @ 25 kg/ha and $FeSO_4$ @ 40 kg/ha with RDF + *Azotobacter* + PSB sustained higher productivity and uptake of nutrients by the crop and not only restored the original fertility status of soil under zinc and iron deficient soils of Madhya Pradesh, but also increased their status at harvest which may be beneficial to the next crop.

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