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Impact of integrated Nutrient Management on Soil, Economics, Phenology, Yield of Pearl Millet

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ABSTRACT: An experiment was conducted at Research Farm Area, Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar during *Kharif* 2022 to study the effect of integrated nutrient management on pearl millet. The experiment was conducted in randomized block design with three replications containing 12 treatments. The crop was sown on 12 July, 2022 using pearl millet hybrid 'HHB 67 improved'. Among the treatments, application of recommended dose of fertilizer (156.25:62.50 kg ha^{-1} N:P) + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX (T_{12}) took maximum number of days to reach various phenological events, had significantly higher number of effective tillers plant^{-1} (4.05), ear head length (23.37 cm), ear head girth (35.33 mm), test weight (10.90 g) and grain yield (3002 kg ha^{-1}). Maximum gross returns (₹ 83,909 ha^{-1}), net returns (₹ 25,716 ha^{-1}), B:C (1.44) and available NPK in soil after harvest was recorded in T_{12}.This crop has a great scope in agriculture and farmer's field, more focus on the production and marketing of this crop is needed.

Keywords: Pearl millet, INM, NPK, Phenology, B:C.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) is one of the most extensively cultivated cereals in the world after rice, wheat and sorghum particularly in arid and semi-arid regions. It is an important dual purpose crop grown for food and fodder. In India, it is one of the important millet crops which flourishes well even under adverse conditions of weather. It provides staple food for the poor people in a short period in the relatively dry tracts of the country.

In the present system of intensive agriculture, most of the farmers are using exhaustive high yielding varieties of the crops, which led to heavy withdrawal of nutrients from the soil during past few years and fertilizer consumption remained much below compared to removal of nutrients. This gap between nutrient removal and supply cannot be bridged by fertilizers alone. It can only be achieved through Integrated Nutrient Supply System (INSS).

Biofertilizers are one of the most important components of integrated nutrient management which are products of beneficial microorganisms that increase agricultural production by way of nutrient supply especially N and P. Biofertilizers can either fix atmospheric nitrogen for plant or can mobilize unavailable phosphorus pool which can be used by plants. These biofertilizers are inexpensive and simple to use and have no problem of environmental pollution. Their role assumes a special significance in the present context of very high costs of chemical fertilizers. Thus, judicious use of biofertilizers along with chemical and other organic sources of plant nutrients will help to sustain productivity and soil health apart from supplementing chemical fertilizers in sustainable agriculture.

Micronutrients are better applied to the foliage than to the soil. Since application rates are lower than for applying nutrients to soil, it is easier to apply the same amount of nutrients, and crops respond to nutrient applications quickly. When the roots are unable to supply the required nutrients, it is highly beneficial. Foliar spraying was suggested because people are worried about the environment and nutrient absorption through plant leaves is preferable than soil application (Bozorgi *et al*., 2011). Due to soil characteristics like high pH, lime content, or thick texture, crop roots are unable to absorb some essential minerals like zinc. In these circumstances, foliar spraying could be 6 to 20 times more effective as compared to soil application. Also, it is well known that these materials have positive effects on soil quality, productivity, and nutrient absorption as well as on soil structure, nutrient retention capacity, and bio-regulatory roles in the soil (Patil *et al*., 2017).

Increased use of fertilizers without organic recycling has not only aggravated multi-nutrient deficiencies in soil-plant-system but also detrimental to soil health and has created environmental pollution. Moreover, chemical fertilizers are becoming costlier in agriculture. However, with increasing awareness on soil health and sustainability in agriculture, organic manures and many diverse organic materials have gained importance as components of integrated plant nutrient management. Therefore, it is the right time to evaluate the feasibility and efficiency of organic sources not only for improving and building up of soil fertility but also to increase the fertilizer use efficiency. Hence present investigation was carried out to evaluate the effect of integrated nutrient management on different parameters of pearl millet.

MATERIAL AND METHODS

A. Experimental details

A field experiment was conducted in *Kharif* 2022 at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar (India). Experiment was laid out in randomized block design with a total number of 12 treatments and replicated thrice. Details of the treatments used in experiment are given in Table 1. Soil of the experimental field was low in organic matter (0.32 %) and available N (119.0 kg ha^{-1}) with medium P_2O_5 (15.8 kg ha^{-1}) and K_2O (232.0 kg ha^{-1}).

B. Crop husbandry

Pearl millet variety HHB 67 (Improved) was sown on 12th July 2022 using seed rate of 5 kg ha^{-1} with spacing of 45 × 15 cm. Seed was treated with biomix (mixture of azotobacter, azospirillum and PSB) @ 250 ml ha^{-1} in respective treatment. Two manual weeding and hoeing at 22 and 35 DAS were done to control the weeds. For the maintenance of desirable plant to plant distance (15 cm) thinning and gap filling were done at 20 DAS. One irrigation was given at 55 DAS. Crop was grown in accordance with recommendations of CCS HAU, Hisar. All the procedure as mentioned in package and practices of CCS HAU, Hisar was followed except nutrient management. Different dose of FYM, vermicompost, nitrogen, phosphorus and potassium were applied as per the treatments. The N, P and K nutrients were applied in the form of Urea, Di-ammonium Phosphate (DAP) and Single Super Phosphate (SSP). Soil application of $ZnSO_4$ and foliar spraying of 0.5% $FeSO_4$ and $ZnSO_4$ was done at 25 DAS.

C. Data collection and analysis

Phenological stages of the pearl millet in terms of number of days taken to reach at a particular phenological event were counted by regular monitoring the field. Phenological stages were determined by visual observations. Three plants from every plot is tagged for observations and that plants were used for taking the number of effective tillers $plant^{-1}$, the length of the ear head was recorded from the tagged plants. Then the average of these was taken as length of ear head, the girth (diameter) of ear in milli-meter was taken from maximum point, a random sample of grain was taken from the each plot yield. Then the 1000 grains from each sample were counted manually and their weight was recorded. Each of the plots were harvested and threshed separately. Grain yield from each plot was recorded and this was converted to grain yield in kg ha^{-1}. After the harvest of crop, the soil samples were collected from all the treatments (0- 30 cm) and brought to the laboratory of department of agronomy, college of agriculture, CCSHAU, Hisar (Hr) in polythene bags. The soil samples were dried under shade and ground with pestle and mortar and sieved through 2 mm sieve. The processed soil samples were analysed for pH, available soil N, P and K. The pH of soil was determined in 1:2.5 soil to water suspension after stirring the samples intermittently for half an hour using a pH meter (Jackson, 1967). Available nitrogen in the soil was estimated by alkaline permanganate method (Subbiah and Asija 1956). The soil was tested with alkaline $KMnO_4$ in the presence of NaOH and the ammonia released was distilled and absorbed in a known volume of boric acid and stannous mixed indicator and titrated with a standard sulphuric acid. Available phosphorus in the soil sample was extracted with Olsen's reagent. The phosphorus content in extracted solution was determined calorimetrically and the intensity of blue colour complex was measured at 660 nm wavelength with a spectrophotometer. Available potassium was determined by extracting the soil with neutral normal ammonium acetate solution and estimated using flame photometer method as outlined by Jackson (1973). The cost of cultivation and gross returns (₹ha^{-1}) of different treatments were calculated on the basis of prevailing market price considering price of grain and stover as ₹ 2350 q^{-1} and ₹190 q^{-1}, respectively. Net returns (₹ha^{-1}) was worked out by subtracting the total cost of cultivation of each treatment from the gross income of respective treatment. B:C was also worked out by dividing the gross returns with cost of cultivation. Data was subjected to statistical analysis using OP STAT software developed by CCS HAU, Hisar.

RESULTS AND DISCUSSION

A. Phenological events

Non-significant variation among different treatment regarding days taken to various phenophase was observed. Among treatment T_{12} (RDF (156.25:62.50 kg ha^{-1} N:P) + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX) took maximum days to reach emergence (2.66 days), five leaf stage (15.47 days), earhead initiation (27.33 days), 50% flowering (48.67 days) and physiological maturity (71.67 days) followed by T_{11} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS) and T_8 (RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application) at 25 DAS) (Table 1). Integrated nutrient management provide adequate environment for growth and development of plants resulting in taking more time for crop growth. Similar results were also reported by Kumar *et al.* (2014) that the control plot recorded the earliest time to 50% flowering (49.66 days) compared to 40 kg N (54.0 days) and 40 kg N + 20 kg P_2O_5 + 20 kg K_2O + 20 kg ZnO + 20 kg Gypsum (60.33 days). Gautam *et al*. (2020) also found that the application of 120 kg N and 60 kg P ha^{-1} (51.20 days) and 80 kg N and 30 kg P ha^{-1} (49.90 days) significantly delayed the days to 50% flowering in *Kharif* pearl millet when compared to the control (43.20 days).

B. Yield attributes

Nutrient management treatments had significantly affected number of tillers $plant^{-1}$, ear head length, earhead girth, test weight. The data pertaining to yield attributes given in Table 2 revealed that treatment T_{12} closely followed by T_{11}, T_{10} and T_8 recorded significantly higher number of effective tillers (4.05), ear head length (23.37 cm), ear head girth (35.33 mm), test weight (10.90 g). This may be due to better nutrition as a result of different nutrient management treatments which aided in better root growth, better proliferation and enhanced the uptake and translocation of nutrients. These results were validated by Yadav *et al*. (2014); Prashantha *et al*. (2019) in finger millet and Pandey *et al*. (2018) in pearl millet.

C. Yield

Among the nutrient management treatments significantly higher grain yield (3002 kg ha^{-1}) was recorded with treatment T_{12} (recommended dose of fertilizer + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX) and it was statistically at par with T_{11} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS) and T_8 (RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application) at 25 DAS). In terms of grain yield, Treatment T_{12} exhibited 47.7 and 7.11% increase over control and RDF, respectively. Crop production is a function of the environment and the genetic potential of the crop variety. As genetic potential of specific crop cultivar remains constant, interaction of crops and environment affects yield of various components. Increase in grain, stover and biological yield may be ascribed to better growth and development, nutrient uptake, elevated dry matter accumulation $plant^{-1}$ and its ensuing translocation to the developing ear head. These results were in conformity with Reddy *et al*. (2016); Prashantha *et al*. (2019) in finger millet.

D. Economics

Among different nutrient management with application of recommended dose of fertilizer + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX (T_{12}) had considerably maximum gross returns (₹ 83,909 ha^{-1}), net returns (₹ 25,716 ha^{-1}) and B:C (1.44) followed by T_{11} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS). Lowest gross returns, net returns and B:C reported under control showed in Table 4. In terms of gross returns, net returns and B:C Treatment T_{12} exhibited a 46.8, 364.4 & 29.7% increase compared to the control and 6.7, 9.4 & 4.3% increase over RDF, respectively. The highest gross return, net returns and B:C was associated with its higher grain yield per unit of added cost. Chaudhari *et al*. (2016) also found that the economics of fertilizer treatments resulted in higher gross and net returns over control. Considerable variation in gross returns, net returns and B:C of various nutrient management treatments in pearl millet (Ashewar *et al*., 2018).

E. Soil analysis of available NPK (kg ha^{-1}) and pH after harvest

It was apparent from the data presented in Table 4 that available NPK in soil increased with the application of various nutrient treatment combination with Biofertilizers. After pearl millet harvesting, the maximum available NPK in soil was recorded with T_{12} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX) and it was statistically at par with T_{11} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS) and T_8 (RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application) at 25 DAS) treatments where available N was recorded 123.33, 122.00, 122.00 kg ha^{-1}, P is recorded 16.18, 16.10, 16.02 kg ha^{-1} and K is reported 237.43, 237.30, 235.80 kg ha^{-1} respectively. Various nutrient treatments didn't affect the pH of soil significantly but numerically decreased it. However, the lowest soil pH (7.76) was recorded in treatment T_{12} (RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX) and it was higher under control (7.80).

Biofertilizers *viz*., Azotobacter and Azospirillum increases nitrogenase activity in the soil and fix atmospheric nitrogen that might lead to improvement in available N status of the soil. Phosphate solublizing bacteria (PSB) solublize the native and applied phosphorous via organic manures; thus enhance the availability of phosphorous in soil and reducing pH of soil. Decomposition of organic manures and resultant production of organic acid might solublize native and non exchangeable potassium and increase soil available potassium. These results are in conformity with Rekha *et al*. (2018a); Rekha *et al*. (2018b); Roy *et al*. (2018); Jakhar *et al*. (2018).

Table 1: Effect of different nutrient treatments on phenological events (days) of pearl millet.

Treatment	Emergence	Five leaf stage	Ear head initiation stage	50% flowering	Physiological maturity
T_1: Control	2.06	13.60	23.20	44.20	66.20
T_2: RDF (156.25:62.5:0) kg ha^{-1} N:P:K through inorganic source	2.55	15.40	25.00	45.67	68.33
T_3: RDF + BIOMIX	2.65	15.50	25.67	46.00	69.00
T_4: 50% RDN through inorganic source + 50% RDN through FYM + BIOMIX	2.12	14.07	23.67	44.67	67.67
T_5: 50% RDN through inorganic source + 50% RDN through Vermicompost + BIOMIX	2.21	14.17	23.90	44.90	67.90
T_6: 75% RDN inorganic source + 25% N through FYM+BIOMIX	2.34	15.07	24.27	45.27	68.27
T_7: 75% RDN inorganic source + 25% N through vermicompost + BIOMIX	2.37	15.07	24.53	45.53	68.53
T_8: RDF + 25 kg $ha^{-1}$$ZnSO_4$ (soil application)	2.52	15.27	26.33	47.33	70.33
T_9: RDF + 0.5% $ZnSO_4$ (foliar spray) at 25 DAS	2.42	15.27	25.67	46.67	69.67
T_{10}: RDF + 0.5% $FeSO_4$ (foliar spray) at 25 DAS	2.45	15.30	25.87	46.87	69.87
T_{11}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS	2.46	15.13	26.67	47.67	70.67
T_{12}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX	2.66	15.47	27.33	48.67	71.67
SEm±	0.32	0.37	1.35	1.35	1.47
C.D. 5%	NS	NS	NS	NS	NS

*BIOMIX: Azotobacter + Azospirillum + PSB

Table 2: Effect of different nutrient treatments on yield attributes and yield of pearl millet.

Treatment	Effective tillers plant^{-1}	Ear head length (cm)	Ear head girth (mm)	Test weight (g)	Grain yield (kg ha^{-1})
T_1: Control	1.37	16.60	23.67	8.10	2036.00
T_2: RDF (156.25:62.5:0) kg ha^{-1} N:P:K through inorganic source	3.02	21.30	28.33	10.00	2802.67
T_3: RDF + BIOMIX	3.03	21.40	29.67	10.03	2817.00
T_4: 50% RDN through inorganic source + 50% RDN through FYM + BIOMIX	1.57	18.77	25.33	9.10	2629.00
T_5: 50% RDN through inorganic source + 50% RDN through Vermicompost + BIOMIX	1.90	19.23	25.67	9.17	2693.00
T_6: 75% RDN inorganic source + 25% N through FYM+BIOMIX	2.72	20.07	28.00	9.43	2702.67
T_7: 75% RDN inorganic source + 25% N through vermicompost + BIOMIX	2.85	20.67	29.67	9.73	2736.00
T_8: RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application)	3.49	22.80	33.33	10.40	2895.00
T_9: RDF + 0.5% $ZnSO_4$ (foliar spray) at 25 DAS	3.06	21.57	31.00	10.03	2824.00
T_{10}: RDF + 0.5% $FeSO_4$ (foliar spray) at 25 DAS	3.39	21.90	31.30	10.20	2848.35
T_{11}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS	3.82	23.03	34.00	10.70	2991.00
T_{12}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX	4.05	23.37	35.33	10.90	3002.00
SEm±	0.29	0.47	1.26	0.23	46.65
C.D. 5%	0.86	1.39	3.74	0.68	137.72

Table 3: Effect of different treatments on gross returns (₹ha^{-1}), net returns (₹ ha^{-1}) and Benefit Cost Ratio (B:C) Pearl millet.

Treatment	Economics (₹ ha^{-1})		
	Gross Returns (₹ ha^{-1})	Net Returns (₹ ha^{-1})	B:C
T_1: Control	57140.80	5537.56	1.11
T_2: RDF (156.25:62.5:0) kg ha^{-1} N:P:K through inorganic source	78595.83	21662.33	1.38
T_3: RDF + BIOMIX	79045.00	21832.39	1.38
T_4: 50% RDN through inorganic source + 50% RDN through FYM + BIOMIX	73666.00	17947.74	1.32
T_5: 50% RDN through inorganic source + 50% RDN through Vermicompost + BIOMIX	75295.40	9025.30	1.14
T_6: 75% RDN inorganic source + 25% N through FYM+BIOMIX	75651.77	19187.57	1.34
T_7: 75% RDN inorganic source + 25% N through vermicompost + BIOMIX	76513.00	14772.88	1.24
T_8: RDF + 25 kg ha^{-1}$ZnSO_4$ (soil application)	81136.80	23225.18	1.40
T_9: RDF + 0.5% $ZnSO_4$ (foliar spray) at 25 DAS	79294.11	21940.71	1.38
T_{10}: RDF + 0.5% $FeSO_4$ (foliar spray) at 25 DAS	79939.92	22448.20	1.39
T_{11}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS	83542.90	25631.28	1.44
T_{12}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX	83909.70	25716.50	1.44

Table 4: Effect of different treatments on available NPK in soil (kg ha^{-1}) after harvest in pearl millet.

Treatment	Available NPK in Soil after harvest			Soil pH after harvest
	Available N (kg ha^{-1})	Available P_2O_5(kg ha^{-1})	Available K_2O(kg ha^{-1})	pH
T_1: Control	118.00	13.67	228.53	7.80
T_2: RDF (156.25:62.5:0) kg ha^{-1} N:P:K through inorganic source	120.33	15.62	234.70	7.77
T_3: RDF + BIOMIX	120.67	15.85	234.80	7.77
T_4: 50% RDN through inorganic source + 50% RDN through FYM + BIOMIX	118.33	14.65	229.52	7.79
T_5: 50% RDN through inorganic source + 50% RDN through Vermicompost + BIOMIX	118.67	14.85	229.77	7.79
T_6: 75% RDN inorganic source + 25% N through FYM+BIOMIX	119.33	14.92	230.23	7.78
T_7: 75% RDN inorganic source + 25% N through vermicompost + BIOMIX	119.67	15.02	231.23	7.78
T_8: RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application)	122.00	16.02	235.80	7.77
T_9: RDF + 0.5% $ZnSO_4$ (foliar spray) at 25 DAS	121.00	15.87	234.97	7.77
T_{10}: RDF + 0.5% $FeSO_4$ (foliar spray) at 25 DAS	121.33	15.88	235.27	7.77
T_{11}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 25 DAS	122.00	16.10	237.30	7.77
T_{12}: RDF + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX	123.33	16.18	237.43	7.76
SEm±	0.71	0.09	0.61	0.01
C.D. 5%	2.20	0.27	1.80	NS

CONCLUSIONS

According to the findings of the study, application of recommended dose of fertilizer (156.25:62.50 kg ha^{-1} N:P) + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + BIOMIX (T_{12}) took maximum number of days to reach various phenological events, had significantly better yield attributes, grain yield, economics and available NPK in soil after harvest. Hence, integrated nutrient management proved to be better option for sustainable soil health, higher yield and income.

FUTURE SCOPE

Soil fertility maintenance necessitates a sensible application of inorganic and organic nutrient resources. The mounting food demands of an increasing population and the need for an environment friendly approach for the sustainable agricultural advancement requires extensive consideration while tackling the issue of enhancing crop productivity. To resolve these concerns integrated nutrient management (INM) plays a crucial role, which is considered as a reassuring strategy for tackling such challenges. INM has ambidextrous capability for the progress of plant performance and resource effectiveness while also reassuring the security of the environment and resource quality. Several studies revealed that INM enriches crop yields by 8-150% compared with conventional practices, improves water-use efficiency, and the economic returns to farmers, while enhancing grain quality and soil health and sustainability. Numerous methodologies and assessments for advance enhancement of INM rapidly are also anticipated and deliberated. Solid and compelling testimony implies that INM practice could be an inventive and ecologically friendly approach for sustainable agriculture universal.

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Conflict of Interest. None.

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