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Balance sheet of N and P in hybrid pearl millet (*Pennisetum glaucum* L.) as influenced by sources and application methods

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Abstract
The present investigation were carried out during kharif 2021 and 2022 at RVSKVV, College of Agriculture, Gwalior (M.P.), India with 12 treatments and three replication in Randomized Block Design. Result indicated that the 100% NP applied treatments recorded significantly higher uptake of N & P as compared to 50 and 75% NP treatments. Maximum uptake of these nutrients was noted with integration of chemical, organic and bio fertilizers (i.e. 75% NP + Seed treatment by *Azotobacter* + PSB + 5 t VC/ha) treatment which was significantly higher with 100% NP, 75% NP + 5 t VC/ha and 75% NP + 1% Foliar spray of Urea Phosphate (17:44:0) at 30-35 DAS treatments. integration of bio fertilizers (*Azotobacter* + PSB) + vermicompost with chemical fertilizers recorded higher available –N and P status in soil after harvest of the crop. Under balance sheet, maximum balance of available –N and P in soil after harvest of the crop was also found with integration of chemical, organic and bio fertilizers treatment (i.e.75% NP + Seed treatment by *Azotobacter* + PSB + 5 t VC/ha) whereas minimum in control.

Keywords: *Azotobacter*, balance sheet, pearl millet, PSB and urea phosphate

Introduction
Crop cultivation without judicious use of nutrients may adversely affect the sustainability of agriculture system. Continuous growing of hybrid pearlmillet in pearlmillet-mustard/wheat cropping sequence which is popular in Gwalior Chambal and adjoining area can deplete soil fertility if nutrient management is not given due attention. Chemical fertilizers are essential inputs for modern (i.e. hybrid) crop production to fulfill nutrient demand of crop. With increase in production and productivity of crops the nutrient demand has also increased markedly shifting the nutrient balance towards the negative side in most of the Indian soils (Tandon, 2007) [12]. Therefore, a quantitative knowledge of nutrient depletion from soils may be helpful in selecting appropriate nutrient management strategies. Soils release 5-9 kg P_2O_5 ha^{-1} $year^{-1}$ without any use of fertilizer (Edwards *et al*., 2015) [3], therefore, mobilizing large non available P through use of organic manures and bio-fertilizers by devising suitable integrated nutrient management (INM) modules can be a right answer to P related problems in India. Appropriate nutrient management strategies must be adopted in hybrid pearl millet for maintaining soil fertility. Therefore, the present study was conducted to evaluate various nutrient management strategies i.e. different sources (organic, inorganic and bio) and method (soil, foliar and seed) of nitrogen and phosphorus for obtaining a good crop response without disturbing the soil nutrient balance.

Methods and Materials
Present study were carried out at the latitude of 26°.13' North and longitude 76°.14' east during *kharif* 2021 and 2022 with 12 treatments namely $T_{1:}$ 0% NP, $T_{2:}$ 50% NP, $T_{3:}$ 75% NP, $T_{4:}$ 100% NP, $T_{5:}$ 50% NP + 1% Foliar spray of 17:44:0 at 30-35 DAS, $T_{6:}$ 75% NP + 1% Foliar spray of 17:44:0 at 30-35 DAS, $T_{7:}$ 50% NP + 5 t VC/ha, $T_{8:}$ 75% NP + 5 t VC/ha, $T_{9:}$ 50% NP + Seed treatment by *Azotobacter* + PSB, $T_{10:}$ 75% NP + Seed treatment by *Azotobacter* + PSB, T_{11}: 50% NP + Seed treatment by *Azotobacter* + PSB + 5 t VC/ha and $T_{12:}$ 75% NP Seed

treatment by *Azotobacter* + PSB + 5 t VC/ha were replicated thrice under Randomized Block Design. The experimental soil was alluvial and sandy clay loam in texture and normal to soil pH having low organic carbon (0.406%) and available N, P, & K were 187.5, 13.84 & 202.4 kg ha^{-1}, respectively. The hybrid pearl millet (86M90) were sown on mid of July in both the years. As per treatment vermin compost (V C) was added @5 tonnes ha^{-1} before sowing of crop and *Azotobacter* and PSB were applied trrough seed treatment at the time of sowing. The recommended dose of fertilizer (100% NPK) for pearl millet were applied 80:40:20: $N:P_2O_5$: K_2O kg ha^{-1}. In all treatments recommended dose of potassium were applied as basal through muriate of potash and 50 per cent of nitrogen and entire dose of P_2O_5 through urea and di-ammonium phosphate were also applied at the time of sowing and remaining 50 per cent of nitrogen was top dressed through urea at 30 -35 days after sowing. Weed removal by hands weeding and the required plant population was maintained. Harvesting of crop was done at maturity and proper drying of grain; this was followed by recording of grain and stover yield. The ground grain and stover samples were digested with di-acid mixture of nitric-perchloric (9:4) for the analysis of phosphorus. Nitrogen was determined by KEL PLUS nitrogen estimation system and phosphorus by vanadomolybdate yellow colour method (Jackson, 1973) [6]. The uptake of nutrients was calculated with their content and yields of respective parts of pearl millet. Available soil nitrogen and phosphorus before sowing and at crop harvest was determined by standard methods. Nutrient balance sheets were prepared on the basis of initial nutrient status, nutrients added, soil nutrient status at crop harvest, total crop nutrient uptake and calculation of unaccounted nutrient losses. Data were statistically analysed during each year of study and on pooled basis deploying standard procedure for analysis of variance (ANOVA) of randomized block design (Gomez and Gomez, 1984) [4].

Results and Discussion

Yield and uptake

There was a significant response in grain and stover yield due to different NP applied treatments as compared to control. Grain and stover yield varied from 1222 to 2987 and 3333 to 6469 kg ha^{-1} under different treatments and the magnitude of increase in grain yield due to various treatments was 51.0 to 144.4% over control (Table 1). Application of 100% NP recorded significantly higher grain yield of pearl millet by 40.7 and 21.4 percent over 50% NP and 75% NP treatments, respectively. This might be attributed to the adequate and balanced supply nutrition to plants which might have created a favorable influence on the plant growth and development, which ultimately depicted in higher yield. This could be attributed to effective utilization of nutrients through the extensive root system developed by crop plants under adequate NP application (Jain and Dahama, 2005 and Tomar *et al*. 2018). The additional either 1% foliar application of 17:44:0 or seed treatment through *Azotobacter* and PSB with 75% NP recorded at par grain yield and total uptake of N and P by pearl millet as compared to 100% NP treatment. Whereas additional application of 5 t vermicompost ha^{-1} with 75% NP recorded significantly higher grain and stover yield as we'll as total uptake of N and P as compared to 100% NP treatment. Maximum grain (2987 kgha^{-1}), Stover (6469 kg ha^{-1}) yield and total uptake of N (101.71 kg ha^{-1}) & P (23.21 kg ha^{-1}) crop was recorded with 75% NP + *Azotobacter* + PSB + 5 t VC ha^{-1} which was significantly higher over rest of other treatments under study (Table -1). This may be attributed to higher availability of nutrients in chemical fertilizer, vermicompost and bio-fertilizer applied treatments that increased the availability of both the native and applied nutrients which gave adequate supply of nutrients throughout the entire growth period of crop ultimately diverted more energy under sink source relationship which helped in producing more yields and higher nutrient uptake. The present findings are in close agreement with the results obtained by Narolia and Poonia (2011) [10], Rinku *et al.*, (2014) [11], and Divya *et al.*, (2017) [2] in pearl millet crop.

Nutrient balance in soil

Available - N balance

The results (Table-2) showed that the apparent N balance in soil remained negative in joint application of chemical fertilizers and vermicompost (Table 2). Though, the net N balance in soil was higher under treatment in which application of N by integration of organic, chemical, and bio fertilizers. Among the treatments, 50% NP + *Azotobacter* + PSB + 5 t VC ha^{-1} had minimum apparent N loss from soil (-1.82 kg ha^{-1}) whereas, 75% NP + 5 t VC ha^{-1} recorded the maximum N loss (-17.04 kg ha^{-1}). Increase in NP dose from 50 to 100% recommended level reduced net N loss in soil. The difference in net N gain between 75 and 100% NP dose was 6.2 kg ha^{-1}. More N under higher nutrient doses and integrated application increased available N in soil which ultimately helped in increasing net N balance of soil. In terms of depletion and buildup in available –N, over initial status, all the treatments showed buildup in available –N after harvest of crop as compared to initial status except control and 50% and 75%NP applied alone or with additional foliar application of 1% (17:44:0) water soluble NPK fertilizers. This might be attributed to the adequate and lower addition of N in soil as compared to nutrient uptake by crop from soil. The findings of Math *et al*. (2016) [9] and Kumar (2009) also confirm these results.

Available-P Balance

Pooled crop P uptake (C values) registered a significant variation among the treatments. Integration of either 50 or 75% NP with Vermicompost + bio-fertilizers, alone or with combination also registered significant variations in pooled C values. The results showed that the apparent P balance in soil remained negative in joint application of chemical fertilizers and vermicompost (Table 2). Though, the net P balance in soil was higher under treatment in which application of P by integration of organic, chemical, and bio fertilizers. Among the treatments, 50% NP + *Azotobacter* + PSB + 5 t VC ha^{-1} had minimum apparent P loss from soil (-15.43 kg ha^{-1}) whereas, 75% NP + 5 t VC ha^{-1} recorded the maximum P loss (-19.31 kg ha^{-1}). Increase in NP dose from 50 to 100% recommended level reduced net P loss in soil. More P under higher nutrient doses and integrated application increased available P in soil which ultimately helped in increasing net P balance of soil. In terms of depletion and buildup in available –P, over initial status, all chemical fertilizer applied treatments show depletion over initial status. This can be ascribed to significant variations in pooled grain and stover yield between nutrient treatments having 50, 75 and 100% NP. On the other side all the integrated treatments i.e combined application of inorganic with either organic or bio fertilizer alone or with combination showed buildup in available –P after harvest of crop as compared to initial status. This might be due to the fact that organic compounds in soil increase P availability to plants due to formation of organophosphate complexes, replacement of $H_2PO_4^-$ions on adsorption sites by other anions and more mineralized organic P relative to inorganic P. Concentration of bio-available P in soil is very low but PSB can potentially enhance P availability to crop plants through mineralization of organic P and dissolution of precipitated P through release of organic acids and assimilation of labile P in microbial biomass which prevents P from being adsorbed/fixed (Chen *et al*., 2006) [1].

Table 1: Yield and uptake of N & P by pearl millet as influenced by different sources and application methods (Pooled data of two years)

Tr. No.	Treatments	Yield (kg ha^{-1})		N-Uptake (kg ha^{-1})			P-Uptake (kg ha^{-1})		
		Grain	Stover	Grain	Stover	Total	Grain	Stover	Total
T_1	0% NP	1222	3333	16.82	19.79	36.61	4.02	3.97	7.99
T_2	50% NP	1845	4908	28.36	31.12	59.48	6.73	6.58	13.31
T_3	75% NP	2138	5413	34.73	36.66	71.39	8.26	7.73	16.00
T_4	100% NP	2595	5747	45.59	42.01	87.61	10.87	8.95	19.83
T_5	50% NP + 1% F. S. of 17 :44:0 at 30-35 DAS	2141	5917	35.21	40.63	75.84	8.53	8.51	17.05
T_6	75% NP + 1% F. S. of 17:44:0 at 30-35 DAS	2497	6139	42.66	42.79	85.45	10.28	9.29	19.56
T_7	50% NP + 5 t VC/ha	2524	5939	44.20	43.11	87.31	10.57	9.40	19.97
T_8	75% NP + 5 t VC/ha	2750	6152	49.36	45.40	94.76	11.92	9.96	21.87
T_9	50% NP + *Azotobacter* + PSB	2202	5751	36.84	40.58	77.42	8.80	8.69	17.49
T_{10}	75% NP + *Azotobacter* + PSB	2435	5894	41.68	41.62	83.29	9.98	9.03	19.01
T_{11}	50% NP + *Azotobacter* + PSB + 5 t VC/ha	2778	6213	48.87	45.65	94.52	11.61	9.79	21.40
T_{12}	75% NP + *Azotobacter* + PSB + 5 t VC/ha	2987	6469	53.68	48.03	101.71	12.75	10.46	23.21
	SEm = + -	53	86	1.08	0.68	1.33	0.24	0.17	0.33
	C.D. at 5%	152	247	3.10	1.95	3.84	0.70	0.50	0.96

Table 2: Balance sheet of N in soil as influenced by different doses, sources and method of nitrogen application (Pooled data of two years)

Tr. No.	Treatments	Initial available N status (kg/ha)	Added N (kg/ha)	N uptake (kg/ha)	Expected balance in soil (kg/ha)	Available N in soil after harvest (kg/ha)	Apparent loss or gain (kg/ha)	Net loss or gain (kg/ha)
		A	B	C	D= A + B- C	E	F= E-D	G = E-A
T_1	0% NP	187.5	0	36.61	150.89	180.4	29.51	-7.1
T_2	50% NP	187.5	40	59.48	168.02	183.8	15.78	-3.7
T_3	75% NP	187.5	60	71.39	176.11	186.2	10.09	-1.3
T_4	100% NP	187.5	80	87.61	179.89	192.4	12.51	4.9
T_5	50% NP + 1% F. S. of 17:44:0 at 30-35 DAS	187.5	40	75.84	151.66	182.6	30.94	-4.9
T_6	75% NP + 1% F. S.of 17:44:0 at 30-35 DAS	187.5	60	85.45	162.05	184.6	22.55	-2.9
T_7	50% NP + 5 t VC/ha	187.5	104	87.31	204.19	195.2	-8.99	7.7
T_8	75% NP + 5 t VC/ha	187.5	124	94.76	216.74	199.7	-17.04	12.2
T_9	50% NP + *Azotobacter* + PSB	187.5	40	77.42	150.08	190.4	40.32	2.9
T_{10}	75% NP + *Azotobacter* + PSB	187.5	60	83.29	164.21	192.8	28.59	5.3
T_{11}	50% NP + *Azotobacter* + PSB + 5 t VC/ha	187.5	104	94.52	196.98	198.8	1.82	11.3
T_{12}	75% NP + *Azotobacter* + PSB + 5 t VC/ha	187.5	124	101.71	209.79	204.6	-5.19	17.1

Vermicompost (VC) contain (1.28 % N, 0.65 % P, 0.83 % K and 12.4:1 C: N ratio)

Table 3: Balance sheet of P in soil as influenced by different doses, sources and method of nitrogen application (Pooled data of two years)

Tr. No.	Treatments	Initial available P status (kg/ha)	Added P (kg/ha)	P uptake (kg/ha)	Expected balance in soil (kg/ha)	Available P in soil after harvest (kg/ha)	Apparent loss or gain (kg/ha)	Net loss or gain (kg/ha)
		A	**B**	**C**	**D= A + B- C**	**E**	**F= E-D**	**G = E-A**
T_1	0% NP	13.84	0	7.99	5.85	11.26	5.41	-2.58
T_2	50% NP	13.84	8.73	13.31	9.26	12.44	3.18	-1.40
T_3	75% NP	13.84	13.10	16.00	10.94	12.96	2.02	-0.88
T_4	100% NP	13.84	17.47	19.83	11.48	13.12	1.64	-0.72
T_5	50% NP + 1% F. S. of 17 :44:0 at 30-35 DAS	13.84	13.10	17.05	9.89	12.76	2.87	-1.08
T_6	75% NP + 1% F. S.of 17:44:0 at 30-35 DAS	13.84	17.47	19.56	11.75	13.48	1.73	-0.36
T_7	50% NP + 5 t VC/ha	13.84	41.23	19.97	35.10	16.36	-18.74	2.52
T_8	75% NP + 5 t VC/ha	13.84	45.60	21.87	37.57	18.26	-19.31	4.42
T_9	50% NP + *Azotobacter* + PSB	13.84	8.73	17.49	5.08	14.76	9.68	0.92
T_{10}	75% NP + *Azotobacter* + PSB	13.84	13.10	19.01	7.93	17.52	9.59	3.68
T_{11}	50% NP + *Azotobacter* + PSB + 5 t VC/ha	13.84	41.23	21.40	33.67	18.24	-15.43	4.40
T_{12}	75% NP + *Azotobacter* + PSB + 5 t VC/ha	13.84	45.60	23.21	36.23	19.32	-16.91	5.48

Vermicompost (VC) contain (1.28 % N, 0.65 % P, 0.83 % K and 12.4:1 C: N ratio)

Conclusion
From present study, it could be concluded that application of vermicompost @ 5 tonnes/ha with 75 per cent of NP and inoculation of seed by *Azotobacter* and PSB gave higher yield and take more nutrients from soil as uptake and also show positive balance in soil after harvest of the crop which may be beneficial for sustainability of the crop production.

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