E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(7): 259-262
Received: 02-05-2024
Accepted: 08-06-2024

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Productivity and balance sheet of potassium in soil as affected by nutrient management under pearlmillet-mustard cropping system

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i7Sd.1043

Abstract
The present investigation aimed to see the effect of different nutrient combination with or without farmyard manure on productivity, potassium uptake and its balance sheet in alluvial soil under pearl millet-mustard cropping system. The investigations revealed that the maximum economic yield of both crops obtained in 100% NPK + 10 t FYM ha^{-1} Yr^{-1} treatment (2174.3 and 2236.8 kg ha^{-1} in pearl millet and mustard, respectively) which was statistically at par with 150% NPK and 100% NPK + 25 kg $ZnSO_4$ ha^{-1} Yr^{-1} treatments. Application of either 150% NPK or 100% NPK+ 10 t FYM ha^{-1} Yr^{-1} showed statistically at par K-uptake by grain and stover of both crops under study which was significantly higher as compared to 100% NPK treatments. A declining trend (-3.8 to 27.0 kg ha^{-1}) was observed either without K (Control, 100% N & 100% NP) or less amount-K (50 & 75% NPK) applied treatment as compared to initial level of available K status which indicates considerable mining of available K in these treatments under pearlmillet-mustard cropping system.

Keywords: Balance sheet, farmyard manure, nutrient combination, K – uptake, pearlmillet- mustard

Introduction
Potassium (K) is an essential, major plant nutrient with numerous functions and is often taken up in large quantities by crops under intensive cropping and its uptake is in many crops almost equal to nitrogen. Thus, severe depletion of K in soils under long term continuous cropping without supplemental K, leads to minimal exchangeable K. In this scenario, the K requirement of crop(s) is met from the reserve K fraction (Srinivasarao *et al*. 2007) [9]. Pearl millet – mustard cropping system got popularized during last several years under limited and assured irrigated condition, in alluvial soil region (Typic Haplusleptts/Ustocrepts) of Northern Madhya Pradesh. Pearl millet and mustard both are high K demanding crops and requires a large amount of K to complete its life cycle. In the absence of external K application, soil K weathering is the major source for meeting the K requirement. Therefore, optimum K release from the soil to meet crop K needs is particularly important at critical plant growth stage of crop. As most farmers apply N and P regularly, yield under high rainfall depletes soil K reserves more than those with poor rainfall. As a general practice some of the farmers apply variable amounts of farm yard manure (FYM) along with imbalanced fertilizers omitting K and other nutrients. Depletion of soil K reserves is a strong constraint in enhancing and sustaining productivity of a K -demanding crops. In- sufficient K supplementation, K removal exceeds the K input, and hence the resulting negative K balance leads to severe depletion of the K reserves (Subba Rao *et al.* 2010) [10]. With these considerations, the present study was carried out for investigate trends in yields, uptake and K balance in pearl millet – mustard cropping system under different nutrient management practices.

Materials and Methods
Present study was carried out at Rajmata Vijayraje Sciendia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh during *Kharif* 2020 & 2021 and *Rabi* 2020-21 & 2021-22. The experimental soil was alluvial, sandy clay loam in nature and belonging to Inceptisol, hyperthermic family of

Typic Ustochrept. The mean initial soil available N, P and K were 206.4, 12.2 and 209.4 kg ha^{-1}, respectively. Mean value of initial soil pH of 7.87, EC 0.36 dSm^{-1} and Organic carbon 4.26 g kg^{-1}. The recommended N, P and K dose, was 80 kg N, 40 kg P_2O_5 and 20 kg K_2O ha^{-1} for pearl millet as well as mustard. The sources of N, P and K used were urea, single superphosphate and muriate of potash. Under farm yard manure treatments it was applied @ 10 t ha^{-1} yr^{-1} only before sowing of pearl millet crop during *Kharif* season. The Hybrid (F1) Pearl millet and NRCHB-101 variety of mustard was used in present experiments. After harvest, the ground grain and stover samples were digested with nitric-perchloric (9:4) di-acid mixture for the analysis of potassium was estimated with flame photometer (Jackson, 1973) [5]. The uptake of potassium was calculated with their content and yields of respective parts of the crops. The surface soil samples were collected after the harvest of mustard during 2021-22 with the help of a tube auger (stainless steel) from each plot. Exchangeable-K was extracted by neutral ammonium acetate (1N) extraction in 1:5 ratio as described by Black (1965) [3]. Soil K balance was computed by assessing K inputs into soil through different sources and outputs through crop K removal, assuming negligible loss by erosion or leaching.

Results and Discussion

Crop productivity

The pooled data on grain yield of pearlmillet and mustard are presented in table 1. The lowest grain yields of pearl millet and mustard 865.6 and 763.3 kg ha^{-1}, respectively were recorded in control. Application of 100% NPK recorded significantly higher grain yield of pearlmillet and mustard over potassium free i.e. 100% N and 100% NP treatments. 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. Yield improvement in yield due to potassium was also reported by Khare and Dixit (2011) [6]. Maximum grain yield obtained in 100% NPK + FYM treatment (2174.3 and 2236.8 kg ha^{-1} in pearl millet and mustard, respectively) was significantly higher than other treatments except 150% NPK and 100% NPK + 25 kg $ZnSO_4$ ha^{-1} Yr^{-1} treatments. The application of organic manure (10 t FYM ha^{-1} yr^{-1}) along with NPK dose (50, 75 and 100% NPK) was observed to be beneficial in enhancing the crop productivity of pearl millet and mustard over their respective NPK alone (Table 1). The beneficial effect of FYM clubbing may be due to additionnal nutrient supply from its decomposition, enhanced mobilization of nutrients from the soil, activation of beneficial soil biological activities through which nutrient availability was increased as well as improved physical condition of soil which provided the plant a good food hold to grow and develop. The similar beneficial effects of FYM along with NPK have been reported by Tiwari *et al.* (2002) [11].

Potassium uptake

Total K uptake varied from 29.62 to 68.33 kg ha^{-1} in pearl millet and 27.87 to 72.66 kg ha^{-1}in mustard, respectively. In case of pearlmillet - mustard cropping system total K-uptake ranged from 57.49 to 140.00 kg $ha^{-1}$and The highest grand total K uptake (140.00 kg ha^{-1}) was found in 150% NPK closely followed by 100% NPK + FYM (138.95 kg ha^{-1}) treatment and both treatments were statistically at par among them and the lowest uptake was observed in control plots in both the crops. It is clear from table-2 that application of 100% NPK showed significantly higher K -uptake by grain and stover of both crops as compared to 100% N, 100% NP, 50% NPK and 75% NPK treatments. Application of either 150% NPK or 100% NPK+ 10 t FYM ha^{-1} Yr^{-1} showed statistically at par K-uptake by grain and stover of both crops under study which was significantly higher as compared to 100% NPK treatments. This might be due to more availability of potassium through balanced levels of applied nutrients. Total uptake of K increased with their application to the crop because of increased availability of potassium through their respective sources and higher biomass yield. Integration of FYM with NPK was beneficial in enhancing the uptake of potassium over sole use of NPK treatment. This may be because of the fact that use of nutrients at different levels with FYM increased the K content which could be due to additional supply of these nutrients through organic matter and improvement in the soil physical, biological and chemical condition for better nutrient availability and plant growth. Findings are corroborated with those reported by Bhadauria, *et al.* (2016) [1].

Potassium input and output balance

Balance sheet of potassium (kg ha^{-1}) was calculated on the basis of mean values of potassium in soil (before and after harvest) as well as K uptake by pearlmillet - mustard cropping sequences. The perusal of data (Table-3) revealed a declining trend (-3.8 to 27.0 kg ha^{-1}) was observed either without K (Control, 100% N & 100% NP) or less amount-K (50 & 75% NPK) applied treatment as compared to its initial level (209.4 kg ha^{-1}) of available K status which indicates considerable mining of available K under pearlmillet-mustard cropping system. Maximum decline (-27.0 kg ha^{-1}) was observed in 100% NP followed by (-21.2 kg ha^{-1}) in 100% N treatment. The magnitude of decline decreased with increasing levels of NPK application. Among the inorganic fertilizers, continuous application of N, NP adversely affected the available K content of the soil, which may be attributed to non application of potassic fertilizer, which also resulted in nutrient imbalance in the soil. Continuous omission of K in pearl millet- mustard caused mining of its native pools also resulted reduction in yield (Dwivedi *et al.*; 2007) [4]. Highest available K status (256.0 kg ha^{-1}) of soil was found in the treatment 100% NPK+ 10t FYM ha^{-1} Yr^{-1}followed by75% NPK+ 10t FYM ha^{-1} Yr^{-1} (241.8 kg ha^{-1}). Bhattacharyya *et al.* (2008) [2] opined that organic matter might have caused reduction in K fixation and consequentially increased available K content due to interaction of organic matter with clay, besides the direct addition to the available K pools of soil. The similar observations of FYM along with NPK have been reported by Singh and Wanjari, (2012) [8].

Table 1: Crop Productivity of pearlmillet-mustard cropping system as influenced by different treatments (Mean data of two years)

Tr. No	Treatments	Pearlmillet		Mustard	
		Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	Control	865.6	2248.2	763.3	2081.5
T_2	100% N	1246.3	2933.8	1104.2	2869.4
T_3	100% NP	1631.7	3657.3	1447.0	3225.5
T_4	50% NPK	1339.1	3111.8	1287.9	2928.1
T_5	75% NPK	1604.2	3519.1	1613.7	3475.5
T_6	100% NPK	1912.9	4000.3	2072.0	4208.5
T_7	50% NPK+ 10t FYM ha^{-1} Yr^{-1}	1850.4	4166.1	1784.1	3625.1
T_8	75% NPK+ 10t FYM ha^{-1} Yr^{-1}	2039.8	4384.6	2034.2	4009.6
T_9	100% NPK+ 10t FYM ha^{-1} Yr^{-1}	2174.3	4388.4	2236.8	4308.9
T_{10}	100% NPK + 25 kg $ZnSO_4$ ha^{-1} Yr^{-1}	2079.6	4308.9	2164.8	4235.0
T_{11}	100% NPK + 40 Kg $FeSO_4$ ha^{-1} Yr^{-1}	2032.3	4331.6	2127.0	4219.8
T_{12}	150% NPK	2102.3	4413.0	2159.2	4460.4
	C. D. (0.05 P)	95.1	239.5	98.2	256.7

Table 2: Potassium uptake by pearlmillet-mustard cropping system as influenced by different treatments (Mean data of two years)

Tr. No	Treatments	K-Uptake (kg ha^{-1})						
		Pearlmillet			Mustard			Pearlmillet-mustard
		Grain	Stover	Total	Seed	Stover	Total	G. Total
T_1	Control	5.45	24.18	29.62	4.62	23.25	27.87	57.49
T_2	100% N	7.90	31.89	39.78	6.88	33.12	40.00	79.78
T_3	100% NP	10.41	39.77	50.17	9.23	37.84	47.07	97.24
T_4	50% NPK	8.77	34.87	43.64	8.35	34.87	43.22	86.86
T_5	75% NPK	10.75	40.25	51.01	10.84	43.06	53.90	104.91
T_6	100% NPK	13.28	46.85	60.13	14.13	53.31	67.44	127.57
T_7	50% NPK+ 10t FYM ha^{-1} Yr^{-1}	12.52	48.05	60.57	11.89	44.42	56.31	116.88
T_8	75% NPK+ 10t FYM ha^{-1} Yr^{-1}	14.19	51.99	66.18	13.75	49.47	63.22	129.40
T_9	100% NPK+ 10t FYM ha^{-1} Yr^{-1}	15.34	52.99	68.33	15.76	54.87	70.62	138.95
T_{10}	100% NPK + 25 kg $ZnSO_4$ ha^{-1} Yr^{-1}	14.28	50.29	64.58	14.79	53.54	68.33	132.91
T_{11}	100% NPK + 40 Kg $FeSO_4$ ha^{-1} Yr^{-1}	13.91	50.45	64.36	14.40	52.89	67.29	131.65
T_{12}	150% NPK	14.76	52.57	67.34	15.06	57.60	72.66	140.00
	C. D. (0.05 P)	0.71	2.90	3.36	0.70	3.37	3.71	5.69

Table 3: Balance sheet of potassium (kg ha^{-1}) in pearlmillet - mustard cropping system as influenced by different treatments (Mean data of two years)

Tr. No	Treatments	Value of potassium (kg ha^{-1}) under pearlmillet - mustard cropping sequence						
		Initial available K status (kg ha^{-1})	Added K (kg ha^{-1})	K uptake (kg ha^{-1})	Expected balance in soil (kg ha^{-1})	Available K in soil after harvest (kg ha^{-1})	Apparent loss or gain (kg ha^{-1})	Net loss or gain (kg ha^{-1}) over initial status
		A	B	C	D=A+B-C	E	F=E-D	G=E-A
T_1	Control	209.4	0.00	57.5	151.90	196.2	44.30	-13.2
T_2	100% N	209.4	0.00	79.8	129.60	188.2	58.60	-21.2
T_3	100% NP	209.4	0.00	97.2	112.20	182.4	70.20	-27.0
T_4	50% NPK	209.4	16.60	86.9	139.10	197.8	58.70	-11.6
T_5	75% NPK	209.4	24.89	104.9	129.39	205.6	76.21	-3.8
T_6	100% NPK	209.4	33.19	127.6	114.99	214.2	99.21	4.8
T_7	50% NPK+ 10t FYM ha^{-1} Yr^{-1}	209.4	68.60	116.9	161.10	226.4	65.30	17.0
T_8	75% NPK+ 10t FYM ha^{-1} Yr^{-1}	209.4	76.89	129.4	156.89	241.8	84.91	32.4
T_9	100% NPK+ 10t FYM ha^{-1} Yr^{-1}	209.4	85.19	138.9	155.69	256.0	100.31	46.6
T_{10}	100% NPK + 25 kg $ZnSO_4$ ha^{-1} Yr^{-1}	209.4	33.19	132.9	109.69	210.2	100.51	0.8
T_{11}	100% NPK+40 Kg $FeSO_4$ ha^{-1} Yr^{-1}	209.4	33.19	131.6	110.99	211.2	100.21	1.8
T_{12}	150% NPK	209.4	49.79	140	119.19	222.4	103.21	13.0

FYM contain 0.52% K

Conclusion

From the results obtained under present study indicate that the integration of FYM with different levels of NPK increased the productivity and K-uptake in pearl millet and mustard over NPK alone treatments. Application of nutrients either without K (Control, 100% N & 100% NP) or less amount-K (50 & 75% NPK) resulted considerable mining of available -K from reserves pools towards a relook at the existing recommendation for under pearlmillet-mustard cropping system.

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