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Effect of nutrient management on yield, uptake of nutrients and soil fertility under pearl millet (*Pennisetum glaucum*)- wheat (*Triticum aestivum*) crop sequence

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ABSTRACT

Field experiments were conducted on farmer's field at Panwari village of Agra district (U.P.) during 2012-13 and 2013-14 to assess the effect of nutrient management in pearl millet-wheat cropping system for higher productivity. The seven treatments were laid out in randomized block design in fixed plots. In pearl millet and wheat, treatments comprised farmer fertilizer practice, different levels of NPK fertilizers and omission of N, P and K. Pearl millet grain yield varied from 2.96 t ha^{-1} under farmer fertilizer practice to as high as 4.59 t ha^{-1} under 100% recommended dose of NPK (100 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1}). Increasing levels of NPK from 50 to 100% NPK significantly increased the yields of both the crops. Application of 100% NPK resulted in 55.0 and 63.9 per cent increase over FFP in pearl millet and wheat yields, respectively. The mean reductions in the grain yield of pearl millet due to N, P and K omission were 44.0, 3.3 and 12.0%, respectively. The corresponding mean figures for yield reduction in wheat grain were 49.0, 7.8 and 9.7 per cent. The quality of produce of both the crops, in terms of protein content, improved significantly with increasing levels of NPK and maximum values were recorded under 100% NPK. The uptake of N, P and K by the crops was significantly reduced in the respective nutrient omission treatments. The uptake of these nutrients by pearl millet and wheat was more drastically reduced in the N omission treatment. The higher uptake of N, P and K by these crops was recorded under 100% NPK. The soil fertility parameters viz, organic carbon and available nutrients (NPK) content in soil showed significant improvement with the application of 100% NPK applied in pearl millet and wheat compared to FFP and omission treatments. Thus, the optimum dose of NPK fertilizer is necessary for sustaining soil fertility and productivity of the crops.

Keywords: Nutrient management, pearl millet-wheat, nutrient uptake, yield

INTRODUCTION

Pearl millet (Pennisetum glaucum)- wheat (*Triticum aestivum L*) is one of the most prevalent cropping sequences followed in a substantial area of Agra region of western Uttar Pradesh. This crop sequence having high nutrients demand is grown in a mono culture fashion over decades. Both these crops are heavy nutrient feeders and their intensive cropping leads to large withdrawal of plant nutrients from soil thereby accentuating the problem of nutrient disorders and affecting crop yields. Therefore, soil fertility management is of utmost importance. Thus, balanced application of NPK for maintenance and enhancement of soil productivity in pearl millet-wheat crop sequence is a challenging issue. Balanced fertilization is the key to increase use efficiency of applied nutrients. A balanced fertilization programme does more than simply replacing the amount of any nutrient removed by the crop. It ensures that fertilizers are applied in adequate amounts and correct ratios for optimum plant growth, sustenance of soil and crop productivity. Crop production in this area is confined primarily to the application of nitrogen and phosphorus fertilizers. Very little or no potassium is being applied by the farmers and thus most of it comes from K reserves of the soil and continuous cropping without K application has been reported to cause considerable drain of K. After N, K has been reported to be absorbed in large amount than any other nutrient. Nutrient limited yields are determined from plots in which the nutrient of interest is not added (Singh 2016). Therefore, it is necessary to supply them through fertilizers. However, the fertilizers applied are either insufficient or imbalanced and not based on soil supplying capacity. Initiatives are made in recent years through nutrient omission approaches to arrive at the soil and fertilizer contributions to the crops performance and finally arrive of site specific nutrient management recommendations for sustainable yield. Keeping the above facts in view, field experiments were conducted to

assess the effect of nutrient addition and omissions on productivity and uptake of nutrients of pearl-millet-wheat crop sequence in alluvial soils of Agra region.

MATERIALS AND METHODS

The field experiments were conducted at Panwari village of Agra district (Uttar Pradesh) for two consecutive years (2012-14). The area is characterized by a semi-arid climate, hot summer with maximum temperature of 45°-2°C, mean minimum temperature of around 3°+-2°C. The average annual rainfall in the study area is 650mm of which about 80% is received during Kharif season from July to September and rest during the rabi season. The soil of the experimental field was sandy loam in texture having pH 8.1, EC 0.40 dSm^{-1}, organic carbon 3.9 g kg^{-1} and available N, P and K 145, 9.2 and 115 kg ha^{-1}, respectively. The experiment was laid out in randomized block design with three replications. The treatments were T_1 FFP for pearl millet (60 kg N ha^{-1}). T_2 50% state recommended dose of NPK, T_3 75% NPK, T_4 100% NPK (100, 60 and 40 kg K_2O ha^{-1}, respectively) T_5 100% PK-N, T_6 100% NK-P and T_7 7 100% NP-K. The same treatments were applied in wheat. T_1 FFP in wheat was 100 kg N and 40 kg P_2O_5 ha^{-1}. State recommended dose of N, P, K was 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. Urea, diammonium phosphate and muriate of potash as source of N, P and K were used. In 100% PK-N treatment, P was applied as single superphosphate. Hybrid pearl millet (Pioneer 86 M 86 was sown in the last week of June in both the years. Pearlmillet was succeeded by wheat CV PBW 502 in rabi season. Half of the nitrogen and potassium and entire quantity of P was applied as basal dressing at the time of sowing. Remaining amount of N and K was top dressed in two splits. The crops were grown by adopting all agronomic practices except fertilizer rate. The crops were harvested at maturity. The grain and straw / stover samples were analysed for their N content by modified Kjeldahl method (Jackson 1973). The P and K in di-acid extract (HNO_3 and $HClO_4$) was determined by vanadomolybdate yellow colour method and flame photometer, respectively. The treatment-wise representative surface soil samples (upto 20cm) were collected randomly from each treatment for the physicochemical analysis. The pH and electrical conductivity of soil was determined in 1:2.5 soil-water suspension (Jackson 1973), organic carbon by Walkley and Black wet digestion method (Jackson 1973), available N by alkaline permanganate method (Subbiah and Asija, 1956), available P by Olsen method (Olsen *et al.* 1954) and available K by flame photometer in neutral 1 N NH_4 OAC extract (Jackson 1973).

RESULTS AND DISCUSSION

Pearl millet

Pearl millet grain and stover yield ranged from 2.96 and 6.87 t ha^{-1} under farmer fertilizer practice (FFP) to as high as 4.59 and 10.40 t ha^{-1} with 100% NPK, respectively, on mean basis. This treatment significantly increased the grain and stover yield by 55.0 and 53.1%, respectively over FFP. This was probably owing to greater availability of nutrients and metabolites for growth and development of reproductive structures (sink) under 100% NPK which ultimately led to realization of higher productivity of crop (Dwivedi *et al.* 2011) and Kumar and Singh (2018). The reductions in the grain yield over T_4 treatment due to N, P and K omissions were 44.0, 3.3 and 12.0%, respectively.

Table 1: Effect of various treatments on yields and quality of pearl millet and wheat (mean of 2 years)

Treatment	Pearl millet			Wheat		
	Grain (t ha^{-1})	Stover (t ha^{-1})	Protein (%)	Grain (t ha^{-1})	Straw (t ha^{-1})	Protein (%)
T_1 FFP	2.96	6.87	10.6	3.44	5.39	11.0
T_2 50% RD NPK	3.40	7.58	10.8	4.15	6.47	11.1
T_3 75% NPK	4.25	10.03	11.0	5.15	8.62	11.3
T_4 100% NPK	4.59	10.40	11.2	5.64	9.17	11.8
T_5 100% PK	2.58	5.52	10.0	2.88	4.49	10.7
T_6 100% NK	4.44	10.15	11.1	5.20	8.21	11.6
T_7 100% NP	4.04	8.98	11.2	5.09	7.98	11.5
CD (P=0.05)	0.44	0.55	0.14	0.54	0.62	0.13

Nitrogen omission led to the maximum reduction of yield than any other nutrient. The next most limiting nutrient was K as its omission resulted in significant reduction in yield. The reduction in the grain and stover in the respective nutrient omissions may be due to the depletion of the indigenous soil nutrient reserves. These results corroborate the findings of Dwivedi *et al.* (2011).

Wheat

The highest grain yield (5.64 t ha^{-1}) was obtained under 100% NPK treatment, which enhanced the grain yield by 63.9% over FFP and its effect was significantly superior to rest of the treatments Ganai *et al.* (2013). The straw yield of wheat was also highest in this treatment (T_4). These results established again the inadequacy of farmer fertilizer practice in exploiting the high yield potential of modern cultivar under otherwise congenial environments (Dwivedi *et al.* 2011). The mean reductions in grain yield due to omission of N, P and K over T_4 treatment were 49.0, 7.8 and 9.7%, respectively. These findings confirm that N deficiency is a general feature of wheat in Agra region (Singh, 2016). Thus, omission of nutrients from the fertilizer schedule resulted in a marked yield loss indicating the significance of replenishment of these nutrients for achieving high yield target. On the contrary, imbalanced application of nutrients in crops led to a loss of productivity which arises from continuous exhaustion of essential nutrients from the soil. Such inference was explicitly drawn from the present investigation where farmer fertilizer practice produced lower yields (Singh, 2016).

Table 2: Effect of various treatments on uptake of N, P and K (kg ha^{-1}) by pearl millet (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 FFP	53.6	31.0	4.8	5.5	14.5	127.0
T_2 50% RD NPK	60.3	37.3	6.7	7.0	16.3	142.3
T_3 75% NPK	79.5	48.0	8.8	9.3	23.0	185.4
T_4 100% NPK	86.3	54.0	9.5	10.7	25.6	199.3
T_5 100% PK	43.0	25.0	5.0	5.3	13.9	113.5
T_6 100% NK	78.5	45.4	6.3	6.7	22.7	189.5
T_7 100% NP	73.7	44.6	8.8	9.1	18.9	168.2
CD (P=0.05)	6.80	4.61	1.10	1.62	2.47	10.00

Protein

The protein in pearl millet and wheat grain increased from 10.6 to 11.2 and 11.0 to 11.8% with T_4 treatment. The increase in protein content with NPK application may be attributed to the involvement of N in protein synthesis. The effect of various NPK levels had significantly beneficial effect on protein percentage in grain over FFP and omission of nutrients. The minimum values of protein content in both the crops were recorded under N omission treatment. Similar results were reported by Singh (2016).

Table 3: Effect of various treatments on uptake of N, P and K (kg ha^{-1}) by wheat (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1 FFP	70.5	30.3	8.5	6.7	14.6	101.2
T_2 50% RD NPK	79.2	34.3	10.0	6.9	17.0	118.6
T_3 75% NPK	103.0	43.6	12.7	8.4	22.9	139.2
T_4 100% NPK	116.1	51.0	15.1	11.7	27.0	168.0
T_5 100% PK	50.5	20.8	7.4	5.1	13.8	85.5
T_6 100% NK	109.7	48.1	10.9	7.9	23.1	149.2
T_7 100% NP	104.6	44.3	11.8	8.6	21.0	142.3
CD (P=0.05)	6.11	4.98	0.85	0.64	2.56	8.47

Uptake of Nutrients

The uptake of nutrients by these crops was significantly affected by various treatments. The mean ranges of N uptake were from 43.0 to 86.3 kg ha^{-1} in grain and 25.02 to 54.0 kg ha^{-1} in straw of pearl millet. The ranges of N uptake by wheat grain and straw were 50.5 to 116.1 kg ha^{-1} and 20.8 to 51.0 kg $ha^{-1,}$ respectively. The corresponding ranges of P uptake were from 4.8 to 9.5 to 7.4 and 15.1 kg ha^{-1}. The straw/stover portion of these crops utilized higher amounts of potassium than that of grain in all the treatments which may be attributed to greater concentration of K in straw. The K uptake in grain of pearl millet and wheat varied from 13.9 to 25.6 and 13.8 to 27.0 kg ha^{-1}, respectively. Application of 100% NPK recorded the maximum uptake of N and K by pearl millet and wheat compared with FFP. Since nutrient uptake is the outcome of the nutrient concentration and the crop output, the higher grain and straw yield of these crops resulted in higher NPK uptake. This may be attributed to increased grain and straw yield of the crops and their respective nutrient contents owing to increased availability of nutrients to the crops as a result of improved soil fertility. The results are in close conformity with the findings of Singh (2013) and Kumar *et al.* (2017). Since FFP lacked K fertilizer, the practice not only adversely affected K uptake, but also uptake of N and P, because of low yields and reduced N, P metabolism (Hussain and Kumar 2013). On the other hand NPK uptake by these crops decreased under omission of nutrients. FFP in pearl millet and wheat proved superior to no nitrogen (-N) treatment in respect of N, P and K uptake. The minimum uptake of N, P and K by pearl millet and wheat crop was noticed under no nitrogen (-N) treatment. Omission of P and K also reduced the uptake of NPK by these crops as compared to 100% NPK treatment. This might have been due to the depletion of soil available N, P and K omission plots. Nitrogen omission resulted in more severe reduction in N, P and K uptake by the crops because of strong influence of N on the dry matter accumulation. Nitrogen omission had far greater impact on K uptake, rather than K omission itself (Dwivedi *et al.* 2011, Singh, 2016).

Table 4: Effect of various treatments on physico-chemical properties of soil after harvest of wheat (mean of 2 years)

Treatment	pH	EC (dSm^{-1})	Org. C ($g\ kg^{-1}$)	Available nutrients ($kg\ ha^{-1}$)		
				N	P	K
T_1 FFP	7.9	0.40	3.64	139.6	8.6	105.2
T_2 50% RD NPK	7.9	0.40	3.66	148.8	8.8	123.2
T_3 75% NPK	7.8	0.41	3.75	157.0	9.2	138.2
T_4 100% NPK	7.8	0.42	4.16	166.4	9.5	143.0
T_5 100% PK	7.7	0.42	3.78	121.8	9.4	140.0
T_6 100% NK	7.9	0.42	4.10	164.5	7.1	141.4
T_7 100% NP	7.9	0.41	4.07	165.0	9.4	104.8
CD (P=0.05)	NS	NS	0.03	4.91	0.29	3.84

Soil Fertility

The soil pH was influenced due to various treatments but the treatment effects were not significant (Table 4). The effects of various treatment were statistically at par with each other including FFP indicating no change in soil pH with these treatments. In general, the various treatments did not influence significantly the electrical conductivity of soil. Analysis of post harvest soil revealed only a marginal improvement in organic carbon content under 100% NPK over the initial content. The organic carbon content ranged between 3.64 and 4.16 g kg^{-1} (Table 4). Organic carbon content of soil with an initial value of 3.9 g kg^{-1} increased significantly and attained a maximum value of 4.16 g kg^{-1} in the treatment that has received 100% NPK fertilizer (Singh *et al.* 2012). Increasing levels of fertilizer helped in increasing the organic carbon content, which is due to increased contribution from the biomass, as it is observed that with increasing levels of fertilizer application, the crop yield had increased.

Contribution from root stubble could also be expected to follow the same trend. Similar finding have been reported by Dwivedi *et al.* (2011). Application of NPK fertilizers increased the amount of available N, P and K in soil as compared to initial values and FFP. The maximum increase was recorded with 100% NPK addition. This increase in available N, P and K with 100% NPK application may be attributed to addition of these elements through fertilizers. The amounts of available N, P and K were significantly reduced in the respective nutrient omission treatments as compared to 100% NPK. Similar results were reported by Hussain and Kumar (2013).

It may be concluded from the results that there was significant improvement in crop yields, nutrient uptake with balanced use of NPK fertilizers (100% NPK). The yields and uptake of nutrients were significantly reduced in nutrient omission treatments over 100% NPK treatment. Nitrogen is the most limiting nutrient and its omission resulted in a drastic reduction in yields of pearl millet and wheat.

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