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Effect of Continuous Fertilization on Yield and Nutrient Uptake by Maize and Sunflower in Red Calcareous Soil (*Typic Haplustalf*) under Permanent Manurial Experiment

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The Permanent Manurial Experiment (PME) of Tamil Nadu Agricultural University Coimbatore was started in the year 1909 and continuously being maintained in order to investigate the effect of continuous NPK fertilization either singly or in combination of two or more with or without organic manures on yield and nutrient uptake by crops. Since 2008 maize- sunflower cropping sequence is being followed under irrigated conditions. The treatment consists of 18 treatments as non replicated plots with plot size of 100 m_2. The results obtained in experimental crops of 2011 and 2012 revealed that continuous application of 100 % recommended dose of N,P_2O_5 and K_2O along with farm yard manure @ 12.5 t ha^{-1} (INM practice) recorded the highest grain yield of 9179 kg ha_{-1} in maize and seed yield of 1461 kg ha_{-1} in sunflower. The highest stover yield in maize was recorded in application of FYM on nitrogen equivalent basis followed by application of poultry manure on nitrogen equivalent basis and INM practice whereas INM practice recorded the highest stalk yield in sunflower. However total uptake of NPK by both the crops was found to be high in INM practice. When compared to balanced NPK fertilization, skipping of any one or two of fertilizer nutrients reduced the yield and nutrient uptake remarkably. Continuous application of organic manure alone also not produced marked increase in yield and uptake as well as imbalanced fertilization. Organic carbon, available nitrogen and potassium status was also recorded high in INM practice for both the crops. In case of available phosphorus, higher P recorded in INM practice and the highest P recorded in the treatment that receiving application of poultry manure on nitrogen equivalent basis irrespective of the crops.

Key words: Fertilization, manuring, maize, sunflower, yield, uptake, soil properties.
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The Permanent Manurial Experiment of Tamil Nadu Agricultural University (TNAU) remains successfull among a few of permanent manurial experiments, which are being continued for more than 100 years in India and abroad. The famous Broadbalk field experiment at Rothamsted in England is a well known example of long-term experiments in which the effect of continued application of organic manures and inorganic fertilizers to the same plot year after year has been studied for the past one century and more.

The earliest long-term experiments called Permanent Manurial Experiments were started at Rothamsted Experimental Station, Harpenden, Herts, England between 1843 and 1856 by J.B. Lawes and J.H. Gilbert and are known as 'Rothamsted Classical Experiments'. These experiments were neither replicated nor randomized. These experiments have been continued for more than 150 years and have yielded most valuable information for adoption of an efficient

approach for managing the crops and cropping system.

Based on the Rothamsted model a series of long-term fertilizer experiments were established in the beginning of the 20th century at different locations in India. These locations were at Kanpur (Uttar Pradesh), Pusa (Bihar) and Coimbatore (Tamil Nadu) and started in 1885, 1908 and 1909 respectively. The principal aim of these experiments was to evaluate the long -term effect of inorganic and organic manuring on crop production and soil health.

Materials and Methods

The Permanent Manurial Experiment (PME) of Tamil Nadu Agricultural University, Coimbatore has been initiated in the year 1909. It is the oldest one having historical importance in India as it has crossed 100 years of continuous experimentation. The PME is located at the prominent central area, which having Agricultural Student Hostels, Teachers Hostel and TNAU Cafeteria around, so that every scientist and student can have a gaze on the

experimental performance every year. The experimental soil (Palathurai soil series) is red sandy loam in texture and is taxonomically grouped under *Typic Haplustalf***.** The initial soil was non saline and alkaline in pH. Experimental soil was found to be low in available nitrogen, low in available phosphorus and high in available potassium. Since 2008 maize-sunflower cropping sequence has been adopted. Maize (Hybrid-NK 6240) and sunflower (Hybrid - Sunbred 275 PR (ARENA)) crops were raised between August to December 2011 (Moonsoon season) and February-May 2012 (Summer season) respectively. They are eighteen treatments in PME as non replicated plots with plot size of 100 m_2 . Treatments were; T_1-Control (unmanured and unfertilized), T_2-N alone, T_3-NK alone, T_4- NP alone, T_5-NPK, T_6-PK alone, T_7-K alone, T_8-P alone, T_9-NPK blanket, T_{10}-100 % NPK + FYM, T_{11}-Farmer's practice, T_{12}-No manure no crop,T_{13}-STCR – IPNS, T_{14}-Farm yard manure on nitrogen equivalent basis, T_{15}-Poultry manure on nitrogen equivalent basis, T_{16}- Residue mulching, T_{17}- FYM every year for both the crops and T_{18}-FYM every even year for both the crops.

The blanket recommendation of N,P_2O_5&K_2O (100% NPK) @ 250:75:75 kg ha^{-1} for maize hybrid and 60:90:60 kg ha^{-1} for sunflower hybrid was applied as per the treatments. Fertilizers *viz*., urea, single super phosphate (SSP) and muriate of potash (MOP) were used as source of fertilizers for both the crops. For maize hybrid, twenty five per cent of nitrogen (N), hundred percent of P_2O_5 and K_2O were applied at basal; remaining fifty and twenty five per cent of N as urea was top dressed at 25 and 45 days after sowing (DAS) respectively. In case of sunflower hybrid, entire dose of fertilizer nutrients was applied at basal. For INM treatment FYM @ 12.5 t ha^{-1} was applied at 20 days before sowing of the both crops. The same level of FYM was applied for every year and every even year treatment. Based on the N content in FYM (0.56 %) and poultry manures (2.18 %), organic manures were added at 100% nitrogen equivalent basis. For farmers practice, 125 kg diammonium phosphate (DAP) ha^{-1} was applied basally and then 125 kg urea ha^{-1} and 125 kg MOP ha^{-1} were applied at 25 DAS and 125 kg urea ha^{-1} was applied at 45 DAS. In the STCR-IPNS treatment, for a targeted yield @ 8 t ha^{-1} for maize hybrid and 1.5 t ha^{-1} for sunflower hybrid, fertilizer requirements were calculated.

Grain and stover yields were recorded and expressed in kg ha^{-1}. Soil and plant samples were collected subjected to chemical analysis. The grain and stover samples were analyzed for N by microkjeldhal digestion and distillation method (Bremner and Mulvaney, 1982), for P by triple acid extraction and vanadomolybdo phosphoric yellow color method (Jackson, 1973) and for K by triple acid extraction and flame photometry (Piper, 1966). Based on the uptake use efficiency of fertilizer nutrients was worked out separately for N, P & K as nitrogen use efficiency (NUE), phosphorus use efficiency (PUE) and potassium use efficiency (KUE) by using apparent nutrient recovery (ANR) formula as given below:

$$\text{ANR (\%)} = \frac{\text{(Uptake in treated plot (kg ha}^{-1}\text{) – uptake in control plot (kg ha}^{-1}\text{))}}{\text{Level of fertilizer nutrient applied (kg ha}^{-1}\text{)}} \times 100$$

Soil pH and EC were determined in soil : water (1 : 2.5 ratio) suspension by potentionmetric and conductometry methods respectively (Jackson, 1973). Organic carbon was estimated by chromic acid wet digestion method (Walkley and Black, 1934). Available N in soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P by Colorimetry method (Olsen *et al*., 1954) and available K by Neutral Normal Ammonium Acetate method (Stanford and English, 1949).

Results and Discussion

Grain and stover yield

The grain yield of maize and seed yield of sunflower varied from 1087 to 9179 kg ha^{-1} and 640 to 1641 kg ha^{-1} respectively (Table 1). Among the eighteen treatments, relatively higher grain yield (9179 kg ha^{-1} in maize and 1641 kg ha^{-1} in sunflower) was recorded in the treatment receiving 100%NPK + FYM @ 12.5 t ha^{-1} (INM practice-T_{10}) when compared to other treatments which might be due to the sustained fertility by the continuous addition of nutrients both in organic and inorganic forms. The T_{10} proved its superiority by recording 18.8% increase in grain yield of maize and 9.9 % in seed yield of sunflower over 100% NPK (T_5). Application of FYM acts as source for growth and multiplication of microorganisms which would have helped to mineralise the nutrients from organic form to inorganic form. Further, yield increase in INM might be due to greater utilization of nutrients from soil which would have ultimately increased the yield of both the crops (Dakshinamoorthy *et al*., 2005).

Omission of N in PK alone (T_6), NP in K alone (T_7) and NK in P alone (T_8) did not record marked increase in the grain yield of maize and sunflower when compared to 100% NPK. Continuous manuring such as residue mulching (T_{16}), application of FYM on every year (T_{17}) and even year (T_{18}) also recorded the comparable yield with T_6, T_7 and T_8. Insufficient and unbalanced application of nutrients either in organic and inorganic forms might be the reason for decline in yield of the both crops. Application of N alone had a noticeable increase in grain yield when compared to T_1, T_6, T_7, T_8, T_{16}, T_{17} and T_{18} which might be due to relatively higher response of maize and sunflower to N and its role in protein formation, constituent of chlorophyll and involved in carbohydrate utilization which resulted in higher grain yield.

Table 1. Continuous fertilization and manuring on yield, uptake and apparent nutrient recovery of maize and sunflower

Treatment	Maize hybrid (2011)								Sunflower hybrid (2012)							
	Yield (kg ha^{-1})		Total uptake (kg ha^{-1})			Apparent nutrient recovery (%)			Yield (kg ha^{-1})		Total uptake (kg ha^{-1})			Apparent nutrient recovery (%)		
	Grain	Stover	N	P	K	N	P	K	Seed	Stalk	N	P	K	N	P	K
T_1	1087	5918	50.1	7.2	83.6	-	-	-	640	1486	26.7	6.4	53.4	-	-	-
T_2	3140	7609	96.0	15.4	123.3	18.3	-	-	906	1534	32.9	8.0	56.4	10.3	-	-
T_3	5918	7246	122.5	19.1	143.2	29.0	-	79.5	1123	2029	47.4	11.1	77.8	34.4	-	40.6
T_4	6522	6401	128.2	19.8	138.4	31.3	16.7	-	1256	2500	57.1	13.3	96.3	50.6	7.6	-
T_5	7729	12560	189.3	26.6	228.8	55.7	25.8	193.5	1329	4481	80.3	18.6	167.7	89.2	13.5	190.6
T_6	2174	7005	68.1	11.5	106.6	-	5.7	30.6	886	2174	39.3	9.4	78.8	-	3.3	42.3
T_7	1812	4831	48.8	9.0	75.7	-	-	-10.6	749	1630	30.2	7.3	58.7	-	-	8.9
T_8	1691	5435	53.2	8.9	83.3	-	2.2	-	707	1932	32.3	7.7	68.9	-	1.4	-
T_9	7488	13647	182.6	29.4	243.9	53.0	29.5	213.6	1341	4650	76.8	18.0	169.3	83.4	12.8	193.3
T_{10}	9179	12802	237.6	34.3	255.6	75.0	36.1	229.2	1461	5217	95.0	21.9	197.8	113.8	17.2	240.7
T_{11}	6643	8333	135.1	23.4	162.1	61.8	28.2	104.6	821	3152	51.9	12.1	115.9	18.3	9.8	104.2
T_{12}	-	-	-	-	-	-	-	-			-	-	-	-	-	-
T_{13}	6522	12560	197.0	28.3	226.4	58.8	28.0	190.3	1316	5145	90.6	20.9	194.3	106.4	16.0	234.9
T_{14}	6280	16546	175.1	31.5	264.2	-	-	-	845	4943	63.8	14.9	172.6	-	-	-
T_{15}	7246	14614	181.9	34.0	249.0	-	-	-	930	4771	67.1	15.7	169.9	-	-	-
T_{16}	2415	9541	92.0	13.8	140.9	-	-	-	833	2633	44.3	10.4	95.6	-	-	-
T_{17}	2959	6039	79.6	11.6	102.2	-	-	-	725	2192	37.8	8.9	79.9	-	-	-
T_{18}	2234	3925	54.2	10.0	68.7	-	-	-	779	1944	36.7	8.7	71.7	-	-	-

Stover yield of maize varied from 3925 to 16546 kg ha^{-1} and stalk yield of sunflower from 1486 to 5217 kg ha^{-1} (Table 1). Application of FYM on N equivalent basis (T_{14}) recorded the highest stover yield (16546 kg ha^{-1}) of maize followed by application of PM on N equivalent basis (T_{15}) and INM practice (T_{10}). In the case of sunflower the highest stalk yield (5217 kg ha^{-1}) was registered in the INM practice (T_{10}). Higher dry matter production coupled with greater utilization of nutrients might be attributed to higher stover and stalk yield of both the crops in the above said treatment than other treatments. Application of FYM and PM on N equivalent basis, INM practice and STCR-IPNS approach released adequate amount of nutrients at right time resulted in higher stover and stalk yield of both the crops when compared to other treatments. Imbalanced and organic manure alone applied plots did not result in better stover and stalk yield when compared to 100 % NPK and INM practice. The lowest yield of 3925 kg ha^{-1} in maize and 1486 kg ha^{-1} in sunflower was recorded in application of FYM on every even year (T_{18}) and control (T_1) respectively. The stover and stalk yield in T_8 & T_{10} was found to be low in both the crops which might be due to insufficient nutrient supply to the plants by intensive cropping without addition of external source of fertilizers and manures.

Total uptake of nutrients

Similar to yield of both the crops, total uptake of NPK was also influenced by treatments (Table 1). Application of NPK alone or in combination with FYM showed higher uptake of nutrients than control (T_1), N alone (T_2), PK alone (T_6), K alone (T_7), P alone (T_8), application of FYM on every year (T_{17}) and even year (T_{18}). Higher total NP uptake by maize and NPK uptake by sunflower was observed in INM treatment than other treatments. An increased biomass coupled with higher nutrients content in the produce resulted in higher nutrient uptake by both the crops. The increase in the uptake under INM may be ascribed to more availability of these nutrients from the added fertilizers and also to the solubilizing action of organic acids produced during the decomposition of FYM thus rendering more release of nutrients from the soil (Vipin Kumar and Prasad, 2008). Total K uptake by maize hybrid was recorded the highest in application of FYM on N equivalent basis (T_{14}) whereas FYM application on every even year basis (T_{18}) recorded the lowest. Higher uptake of nutrients could be attributed to the increased stover yield in FYM applied on N equivalent basis. Addition of FYM increasing the availability of nutrients and in turn would have increased the uptake and yield of hybrid maize (Singh *et al*., 2011). Uptake of nutrients was lower in the plots receiving neither fertilizer nor manure plot due to absence of external source of essential major nutrient supply to the plants. Hence, the lower nutrient uptake might be due to lower grain and stover yield of both the crops in control plot.

Apparent nutrient recovery

Apparent nutrient recovery was found to be high under INM practice in both the crops (Table 1). Increased concentration in plant tissues correspondingly resulted in greater uptake, which finally yielded the higher fertilizer use efficiency of nutrients (Sunil Sharma *et al*., 2012). In NUE calculation N contributed by FYM for N uptake was not deducted which might be the reason for greater NUE noticed in INM. The PUE under INM practice was very high due to the addition of FYM with inorganic fertilizers. The highest KUE was recorded in INM treatment which might be due to addition of FYM @ 10 t ha^{-1} + 100% NPK as well as the luxury consumption of K from the soil K supply.

Organic carbon and available nutrients in post harvest soil of maize and sunflower

The INM practice (T_{10}) recorded the highest organic carbon value of 0.67 in post harvest soil of maize and 0.61 % in sunflower (Table 2). This is in conformity with the finding of Rajshree *et al.* (2005) who reported that application of FYM increased organic carbon which would stimulate the growth and activity of micro organisms. The results also revealed that continuous addition of FYM with or without inorganic fertilizers registered the comparable values with each other than inorganic fertilization. Control (T_1) and N alone (T_2) treatments recorded the least organic carbon in both the crops probably due to low dry matter production and hence low return of crop residues to the soil.

Available N varied from 156 to 241 and 148 to 224 kg ha^{-1} in post harvest soil of maize and sunflower respectively (Table 2). The highest value of 241 kg ha^{-1} in maize and 224 kg ha^{-1} in sunflower was noticed in INM practice (T_{10}) which recording 49 and 95 kg ha^{-1} increase in maize and 20 and 76 kg ha^{-1} increase in sunflower than 100% NPK (T_5) and control (T_1) respectively. Continuous and steady release of N from both inorganic fertilizers and FYM to the soil solution increased the concentration of N and made them available for plant growth (Deshmukh *et al*., 2005). Invariably in both the crops the lowest value was noticed in control. Continuous removal by crops without external addition of fertilizers and FYM over a period of time resulted decline in soil available N.

Table 2. Continuous fertilization and manuring on organic carbon and available nutrient status in post harvest soil of maize and sunflower

Treatment	Maize hybrid (2011)				Sunflower hybrid (2012)			
	Org. carbon (%)	Aval. N (kg ha^{-1})	Aval. P (kg ha^{-1})	Aval. K (kg ha^{-1})	Org. carbon (%)	Aval. N (kg ha^{-1})	Aval. P (kg ha^{-1})	Aval. K (kg ha^{-1})
T_1	0.50	156	9.47	349	0.28	148	7.78	318
T_2	0.52	182	12.51	422	0.48	193	8.38	327
T_3	0.53	171	14.65	545	0.54	154	11.58	543
T_4	0.57	176	19.31	403	0.45	196	12.97	324
T_5	0.59	202	20.93	561	0.45	204	13.37	573
T_6	0.59	160	19.68	604	0.43	154	14.57	633
T_7	0.52	176	13.05	580	0.48	182	11.98	651
T_8	0.53	157	19.56	527	0.48	188	18.76	368
T_9	0.56	210	20.97	597	0.57	204	13.37	585
T_{10}	0.67	251	24.98	720	0.63	224	21.56	696
T_{11}	0.55	168	14.35	437	0.48	185	8.78	501
T_{12}	0.52	156	14.10	408	0.48	188	8.58	424
T_{13}	0.65	241	23.16	691	0.63	221	18.76	670
T_{14}	0.61	207	30.34	704	0.63	216	21.36	672
T_{15}	0.60	202	32.92	681	0.54	224	31.54	626
T_{16}	0.59	179	19.63	526	0.63	230	11.98	487
T_{17}	0.63	210	23.41	534	0.61	241	29.14	402
T_{18}	0.65	176	19.42	520	0.61	244	16.37	449

Available P recorded the highest (32.92 kg ha^{-1} in maize and 31.54 kg ha^{-1} in sunflower in the treatment that received application of poultry manure on N equivalent basis (T_{15}) followed by INM and STCR practice (Table 2). Higher amount of P released during the decomposition of PM when applied continuously on N equivalent basis which resulted in higher build up of available P than other treatments. Higher availability of P in T_{15} may be attributed to the solubilisation of P by the organic acids released from the organic manures, reduction of P fixation in the soil due to chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu and also due to enhanced microbial activity (Sathya, 2010). Continuous addition of N alone (T_2), NK (T_3) and K alone (T_7) resulted in lower P than 100% NPK (T_5&T_9) and INM practice (T_{10}).

The highest value of available K 720 kg ha^{-1} in maize and 696 kg ha^{-1} in sunflower was observed in INM practice (T_{10}) followed by STCR –IPNS (Table 2). The increase in the availability of K through addition of FYM may be due to the decomposition of organic matter and release of nutrients. The beneficial effect of FYM on the available K is also due to the reduction of K fixation and release of K due to interaction of clay with organic matter (Kamble and Kathmale, 2012). The decreased availability of K in N (T_2), NP alone (T_4), P alone (T_8) and control (T_1) may be attributed to the higher uptake of K by crops resulting in depletion of K in the absence of K addition. This finding was in corroboration with Sindhu Prudvinath (2012).

Conclusion

From the PME results, it can be concluded that the highest yield and uptake of nutrients by crops with sustainable soil fertility was achieved with the application of 100% NPK along with FYM. Hence application 100% NPK along with FYM @ 12.5 t ha^{-1} can be recommended to get higher yield of both the crops under maize-sunflower cropping sequence in *Typic Haplustalf*.

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