Madras Agric. J., 87(1-3): 40 - 43 January - March 2000
https://doi.org/10.29321/MAJ.10.A00412

Long term fertiliser experiment - an index of yield and soil sustainability

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Abstract : In the field experiment conducted since 1972, crops numbering to 66 have been grown in a fingermillet - maize - cowpea (fodder) cropping sequence, it was observed that there was a build up in the organic carbon content of the soil. The build up was maximum for the combined application of farmyard manure and optimum NPK (100%). Maximum sustained yield was obtained for the application of 100% NPK + FYM at 10 t ha^{-1}. A combined application of inorganic fertiliser and organic manures therefore is suggested as a means of sustaining the productivity of crops. Regarding the fertility of the soil, the available N status has maintained, P status has been enhanced and there is a marked depletion in K status. *(**Key words :** Inorganic, Organic, Fertilizers, Manures, Soil fertility)*

Maintaining and improving soil fertility for sustainable agriculture will become more crucial in the future because of the increasing complexity of nutritional problems and environment related issues. Under intensive cultivation, two to three crops are being produced per year and the grain production of 10-14 Mg ha^{-1} yr^{-1} is being achieved year after year (Prasad, 1983). These intensive cropping systems remove about 554 to 932 kg of NPK per hectare per year (Grewal and Singh, 1989). Increased application of chemical fertiliser has been the major input in achieving high production levels in intensive cropping systems. The inclusion of organics as one of the components in the package is vital. With the introduction of high yielding varieties demanding high amounts of fertiliser, the need for monitoring depletion of soil fertility was increasingly felt and the All India Co-ordinated Research Project on Long Term Fertilizer Experiments were launched by the Indian Council of Agricultural Research, New Delhi at selected centres located in eleven major agroclimatic regions of the country. Coimbatore is one of the centres representing medium black soil (Vertic Ustropept). An investigation was taken up to evaluate the impact of continuous cropping and fertilisation on organic carbon content and their contribution to crop yield, total N and available nutrients.

Materials and Methods

The experimental site is located at 11°N, 77°E, 426.7m above mean seal level and has a semi arid tropical climate with a dry season from January to June and a wet season upto December. Mean temperature varies from 31°C (May - June) to 21°C (December - January). The soil of the experimental site is fine, montmorillonitic, isohyperthemic Vertic Ustropept. Texturally it is a sandy clay loam with a pH of 8.2, EC 0.2 dSm^{-1}, organic carbon 3.0 g kg^{-1} availalable N 80, available P 4.9, available K 362 mg kg^{-1}.

There are 10 treatment each replicated four times in a randomised block design. The treatments were as follows:

T_1 - 50% NPK
T_2 - 100% NPK
T_3 - 150% NPK
T_4 - 100% NPK + Hand Weeding (HW)
T_5 - 100% NPK + $ZnSO_4$ at 25 kg ha^{-1}
T_6 - 100% NP
T_7 - 100% ND
T_8 - 100% NPK + FYM at 10 t ha^{-1}
T_9 - 100% NPK (-S)
T_{10} - Control

The 100 per cent NPK dose, based on soil testing of initial soil was 90, 45 and 17.5; 135, 67.5 and 35; and 25, 50 and 0kg ha^{-1} of N, P_2O_5 and K_2O for finger millet, maize and cowpea (fodder) respectively. The fertilisers used are urea, single super phosphate, diammonium phosphate (for T_9 only), muriate of potash and zinc sulphate. The application of FYM (contained 0.96, 0.48 and 0.42 per cent % of N, P and K respectively) was done only once a year at the time of planting of finger millet. The crops were raised following recommended package of practices. The whole plot or randomly selected area of each treatment was harvested and yields were recorded. The soil sample collected after the harvest of crops were analysed for available nutrients as per the standard procedures (Jackson, 1973) and the data analysed statistically.

Results and Discussion

Continuous use of FYM along with recommended NPK increased the organic carbon content of the soil by 0.34 per cent over a period of 24 years (Table 1). Continuous intensive cultivation has increased the organic carbon by 0.14 per cent even in control. The increase was by 0.21 per cent in 100 per cent NPK application.

The total N content in the soil was maintained for the application of 100 per cent NPK and 100 per cent NPK + FYM, with a definite decline in N reserve level in control. The magnitude of build up in soil reserve N is the highest for 100 per cent NPK + FYM application.

Significant increases in yield from control via 50 per cent NPK, 100 per cent NPK and upto 150 per cent NPK were seen in both the crops over years (Table 2). However, the magnitude of increase from optimal NPK (100 per cent NPK) to high input level (150 per cent NPK) were smaller than the increase from control to sub-optimal (50 per cent NPK) and from sub-optimal to optimal NPK. Significantly higher yields in finger millet and maize were recorded in 100% NPK + FYM treatment as compared to 100 per cent NPK treatment. On an average, the yield increase due to the former treatment was 81 per cent in fingermillet and 114 per cent in maize. The available nutrient contents of the soil were found to be higher in the treatment where 100 percent NPK was applied in combination with FYM at 10 t ha^{-1} (Table 3). There was a build up in the Olsen-P status of the soil whereas a definite depletion occured in NH_4O Ac-K levels. However, the available N content of the soil was maintained over a period of 2.5 decades under an intensive continuous cultivation system.

The build up in soil organic carbon content due to continuous intensive cropping had earlier been reported. Significant build up in the organic matter content of the soil due to continuous addition of inorganic fertilizers has been reported by Bhardwaj and Omanwar (1994). Control recorded the least organic carbon content which might be due to the minimum quantum of residues added to the soil. The increased addition of biomass by way of roots and crop residues over the years would have contributed to the build up of organic carbon in soil. The consistent higher crop yields over years, leaving a higher quantum of biomass residues in the soil might have resulted in a higher organic carbon content in the soil. Despite the organic C build up, the total N concentration also showed a similar trend. The highest N content registered in NPK + FYM was due to the direct effect of 100 per cent optimal NPK added for every crop besides the 10 t of FYM being applied to the finger millet crop in the sequence. This 10 t of FYM supplies an additional dose of 50 kg of N ha^{-1} per annum since the average N content of FYM is around 0.5 per cent. Combination of organic with inorganic has the added advantage of improvements in the microbial activity, stabilisation of soil structure and associated benefits. Besides the N released is reported to get incorporated in the soil humic material thereby accounting for higher total N content of soil. Besides the direct effect of nutrient addition, the organic manures are also reported to contribute by chelating the soil nitrogen and thereby conserving it from losses.

The permanent manurial experiments conducted all over India during the period from 1885 - 1995 have shown that neither the organic manures alone nor the mineral N, P and K fertilisers could achieve the yield substantially at a high order under intensive farming where the nutrient turn over in the soil plant system was quite large. Only an integrated usage of organic manures and chemical fertilisers has been found to be promising not only in maintaining higher productivity but also in possessing maximum stability in crop production (Nambiar and Abrol, 1989). The integrated application of 100 per cent NPK along with FYM at 10 t ha^{-1} recorded the highest yield in all the cropping cycles. Addition of FYM had directly added an appreciable amount of major nutrients besides micronutrients to the soil which would contribute to the enhanced yield. The improved physical properties like waterholding capacity, moisture retention (Bhriguvanshi, 1988) would have provided a desirable soil condition for the root development, enhancing nutrient uptake, crop growth and yield. The increased availability of all the three major nutrients recorded in addition to the granular and spongy soil conditions favourable for higher biological activity could have naturally resulted in better crop growth.

The available N content of the soil increased over the initial value under 100% NPK+FYM treatment which was due to higher organic carbon content of soil. Besides FYM@10t ha^{-1} on an average had added around 50 kg N every year. Consequently, the crop yield and biomass addition were higher resulting in marked improvements in the organic carbon and total N content of soil. The favourable soil conditions under FYM addition might have helped in the mineralisation of soil N leading to the build up of higher available N.

A build up in the available P status of the soil over the initial value recorded in 1972, occured in 100% NPK+FYM. The FYM being a direct source of P might have solubilized the native P in the soil through release of various organic acids. The carbondioxide released during decomposition of organic matter formed carbonic acid, solubilising certain primary minerals (Tandon, 1988). A significant reduction in available P content of soil observed in unfertilized control was due to the crop removal in the absence of external sources of P.

Though, depletion in NH_4OAc - K status of soil occurred, addition of FYM along with inorganic K has increased the available K status of the soil. This was due to the additional K being added through the FYM and also could be due to minimised losses of K through leaching by fixing the K ions in the cation exchange sites due to organic manure addition (Aravind, 1987).

Based on the results generated over a period of twenty four years, for a fixed rotation of fingermillet - maize - cowpea in a medium black soil under irrigated intensive cultivation conditions, a fertiliser dosage of 100 per cent of optimal NPK in combination with 10 t of FYM (once in the sequence) has been found to be the optimum dose for higher harvest of these crops and sustainable soil fertility.

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(Received : February 2000 ; Revised : November 2000)

Table - 1. Soil organic carbon content (%) and total N (ppm) over years

S. No.	Treatments	Year				
		1972	1981	1987	1992	1996
		Organic Carbon				
1.	Control	0.30	0.32	0.43	0.31	0.44
2.	100%NPK	0.30	0.36	0.45	0.51	0.51
3.	100% NPK + FYM	0.36	0.44	0.52	0.56	0.64
	CD (0.05)	NS	0.026	0.014	0.047	0.053
		Total N				
1.	Control	428	352	330	305	271
2.	100%NPK	428	416	482	512	494
3.	100% NPK + FYM	428	539	594	622	597
	CD (0.05)	NS	37	34	30	42

Table - 2. Effect of FYM incorporation on yield of crops (kg ha^{-1})

S. No	Treatments	Year				
		1972	1981	1987	1992	1996
				Maize		
1.	NPK_0	468	358	988	735	670
2.	NPK_{50}	2187	1315	2963	2720	2740
3.	NPK_{100}	2731	1393	4713	3163	3255
4.	NPK_{150}	2553	1795	5650	3109	3290
5.	NPK_{100}+FYM	2997	1628	5600	3369	3398
	CD (0.05)	574	180	738	216	249
				Fingermillet		
1.	NPK_0	1641	975	863	860	1513
2.	NPK_{50}	2439	3188	2887	2475	3562
3.	NPK_{100}	2710	3538	3900	3225	3875
4.	NPK_{150}	3116	3423	3675	3518	4125
5.	NPK_{100}+FYM	2986	4306	4800	3888	4731
	CD (0.05)	506	105	552	233	938

Table - 3. Available status of Nutrients in soil over years (kg ha^{-1})

S. No.	Treatments	Year				
		1972	1981	1987	1992	1996
				$KMnO_4$-N		
1.	Control	178	169	175	160	157
2.	100%NPK		207	188	170	171
3.	100% NPK + FYM		226	200	190	197
	CD (0.05)	NS	25	4.8	7.8	10.7
				Olsen's-P		
1.	Control	11.0	3.64	4.34	3.25	3.68
2.	100%NPK		9.38	9.45	9.82	8.58
3.	100% NPK + FYM		21.28	19.95	16.52	20.12
	CD (0.05)	NS	2.84	2.06	1.50	1.08
				NH_4OAc-K		
1.	Control	810	742	642	468	525
2.	100%NPK		634	637	555	535
3.	100% NPK + FYM		765	724	581	545
	CD (0.05)	NS	123	50.5	NS	15.4