The Andhra Agric. J 59(2): 219-224, 2012

Long Term Effect of Nutrient Application on Soil Chemical and Biological Properties and crop Productivity in Sorghum-Wheat Cropping Sequence on Vertisols

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ABSTRACT

The experiment was under taken during the year 2007-08 to study the effect of long term fertilization and manuring on soil chemical and biological properties. The dynamics of soil characteristics was studied in the ongoing long term fertilizer experiment initiated during *kharif* 1988 at Akola, Maharashtra. The experiment comprised of twelve treatments including NPK levels with and without FYM, sulphur and zinc replicated four times in randomised block design. The manure and fertilizers were given to sorghum crop every year and only fertilizers were applied to wheat crop. The soil samples from all the treatments were collected from 0-20 cm depth. The chemical and biological soil characteristics were studied. Significantly highest increase in the soil organic carbon and total nitrogen were recorded in the treatment of FYM @10 t ha^{-1} + 100% NPK. The availability of N, P, K, S, soil microbial biomass carbon, soil microbial biomass nitrogen, dehydrogenase assay and productivity of sorghum and wheat were significantly increased with the integrated application of organic manure (FYM @ 10 t ha^{-1}) and chemical fertilizer (100% NPK) over control and other fertilizer treatments in 20 years of experimentation.

Key words : Dehydrohgenase assay, Long term effect, Soil microbial biomass carbon, Soil microbial biomass nitrogen

Sorghum and wheat are the premier food grain crops in general in peninsular central India and in particular of Maharashtra. There has been a phenomenal increase in their production after mid sixties with the introduction of high yielding varieties. The heavy removal of nutrients from the soil by high yielding varieties for higher use of fertilizer made it imperative to examine the sustainability of modern intensive cropping systems based on high external inputs of fertilizers and high yielding varieties under irrigated conditions. Significance of soil fertility maintenance in sustaining crop productivity has been realized worldwide. Sustaining soil quality is the most appropriate method to ensure sufficient food to support life. Maintaining and improving the level of soil organic matter (SOM) is a prerequisite to ensure soil quality, future productivity and sustainability as it influences soil physical, chemical and biological properties (Singh, 2008). In addition, being a direct source of plant nutrients, SOM also indirectly influences the availability of plant nutrients in soil from native pools.

The balanced fertilization through integrated use of manures and fertilizers has been found useful in various cropping sequences. In order to investigate the long term influence of fertilization on soil properties as well as on crop productivity the present study was undertaken in sorghum-wheat cropping sequence on a Vertisol.

MATERIAL AND METHODS

The long term fertilizer experiment was initiated during *kharif* 1988 on the Research Farm of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in Maharashtra ($22^0$42' N and $77^0$02' E, 307.42 m above mean sea level). The soil is a vertisol with alkaline pH (8.1), high cation exchange capacity (48 c mol (p^+) kg^{-1}), medium soil organic carbon (4.6 g kg^{-1}), total nitrogen (0.044 %), low available phosphorus (8.4 kg ha^{-1}) and high available potassium (358 kg ha^{-1}). The present investigation was undertaken during 2007-08 after 19th cropping cycle of this long term experiment.

The experiment consisted of twelve treatments *viz.*, T_1- 50 % NPK, T_2- 100 % NPK, T_3- 150 % NPK , T_4- 100 % NPK(S free), T_5- 100 % NPK + 2.5 kg Zn ha^{-1}, T_6-100 NP, T_7- 100 % N, T_8- 100 % NPK+ FYM @10 t ha^{-1}, T_9-100 % NPK (S free) + 37.5 kg S ha^{-1}, T_{10}- FYM @ 10 t ha^{-1}, T_{11}- 75 % NPK and T_{12}-Control. The experiment was laid out in randomized block design and replicated four times. The experiment is being conducted on same site and same randomization. The nutrients were applied through the fertilizers like urea, single super phosphate, muariate of potash and diammonium phosphate (T_4 and T_9). Sulphur was applied through gypsum (T_9 only) for sorghum crop and zinc was applied through zinc sulphate once in two years for wheat crop only (T_5 only).

Farmyard manure was applied every year one month before sowing of sorghum crop. The recommended fertilizer doses were applied as 100:50:40 and 120:60:60 kg N, P_2O_5 and K_2O ha^{-1} to sorghum and wheat crops, respectively. During the year of study, sorghum (CSH-9) was sown during first week of July and harvested in second week of november and wheat (AKW-1071) was sown during second fortnight of november and harvested in first week of April. The grain and straw yields of each crop were recorded and plot wise soil samples were (0-20 cm). A collected after harvest of wheat which were analyzed for pH, electrical conductivity, organic carbon, total N and K (Jackson, 1967). Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and available P by Olsen's method (Olsen *et al*., 1954). The available S was estimated by turbidimetric method (Chesnin and Yien, 1950). The fresh soil samples immediately after harvest were used for estimating biological properties. Soil microbial biomass carbon was estimated by Chloroform fumigation and extraction method (Singh *et al*. 2005) and soil microbial biomass nitrogen by modified direct extraction method (Jenkinson and Ladd, 1981) and dehydrogenage assay was done by incubation with triphenyle tetrazolium chloride (TTC) and calcium carbonate method (Singh *et al*.,2005).

RESULTS AND DISCUSSION

Soil chemical properties:

Soil organic carbon and total nitrogen:

Long term manuring and fertilization recorded highest organic carbon (6.77 g kg^{-1}) and total N (0.059%) with application of FYM @10 t ha^{-1} +100% NPK (T_8) which was found significantly superior over all other treatments (Table 1). The increase in organic carbon over a period of 19 years under integrated nutrient management can be attributed to addition of farm yard manure which stimulated the growth and activity of microorganism and better root biomass. The soil organic carbon and total N were enhanced due to long term application of FYM @ 10 t ha^{-1} + 100% NPK by 14.1 and15.1 per cent as compared to super optimal dose of fertilizers (150% NPK). The 31.31 and 22.98 % increase in organic carbon and total nitrogen by the application of INM was observed over only NPK through chemical fertilizers.

Application of sulphur @ 37.5 kg ha^{-1} along with 100% NPK also recorded increase in organic carbon (5.21 g kg^{-1}) as compared to only 100% NPK (S free) (5.10 g kg^{-1}) which may be due to higher biomass produced with balanced supply of NPK and S. The treatment of 100 % NPK application also showed significant increase in organic carbon (5.11 g kg^{-1}) over initial content (4.6 g kg^{-1}). Similar trend was also noticed in total nitrogen content. This could be attributed to the increase in plant as well as root biomass in the soil due to balanced fertilization ensuring easy availability of nutrients to the crop (Bhardwaj *et al.,* 1994). This study has clearly indicated that integrated nutrient management followed over a long term was beneficial in maintenance of organic carbon levels in vertisols of semi-arid regions of central India. This has also increased the total nitrogen status of soils which is useful for nitrogen management under intensified cropping in the subsequent years to supply better amounts of nitrogen to the crops after its mineralization.

pH and electrical conductivity:

The soil pH was not significantly influenced due to long term fertilization and manuring (Table 1) which ranged from 7.75 to 7.98 in different treatments. The continuous application of fertilizers and manures had significant effect on electrical conductivity of soil. Application of inorganic fertilizers slightly increased the EC of soil. The highest value of EC (0.341 dS m^{-1}) was recorded by application of 150 per cent NPK followed by 100 per cent NPK + FYM @10 t ha^{-1} (0.336 dS m^{-1}) while the lowest EC (0.270 dS m^{-1}) was recorded in control.

Available nutrients:

Long term manuring and fertilization registered significant increase in soil available N, P and K at 100% NPK + FYM @10 t ha^{-1} and found significantly superior over all other treatments except the treatment of super optimal dose (150 % NPK). Long term application of FYM @ 10 t ha^{-1} + 100 % NPK increased the availability of N, P, K and S by 2.6, 12.4, 6.7 and 9.1 per cent as compared to super optimal dose of fertilizers (150 % NPK) without any organic addition. Application of FYM @10 t ha^{-1} during every year in *kharif* season to sorghum only did not maintain NPK status of soils.

Availability of phosphorus increased to the extent of 91 per cent in the treatment of optimal

Table 1. Long term effect of various treatments on chemical properties of soil under sorghum-wheat cropping sequence

Treatments	OC (g kg^{-1})	Total N (%)	pH	EC (dS m^{-1})
T_1 - 50%NPK	4.32	0.0428	7.937	0.281
T_2 - 100%NPK	5.11	0.0483	7.847	0.314
T_3 - 150%NPK	5.93	0.0516	7.782	0.341
T_4 - 100%NPK (S free)	5.10	0.0479	7.853	0.293
T_5 - 100%NPK + 2.5 kg Zn ha^{-1}	5.15	0.0492	7.832	0.324
T_6 - 100%NP	4.90	0.0461	7.869	0.311
T_7 - 100%N	4.29	0.0432	7.883	0.307
T_8 - 100%NPK + FYM @ 10 t ha^{-1}	6.77	0.0594	7.749	0.336
T_9 - 100%NPK + 37.5 kg S ha^{-1}	5.21	0.0504	7.820	0.331
T_{10} - FYM only 10 t ha^{-1}	6.01	0.0512	7.817	0.284
T_{11} - 75% NPK	4.64	0.0433	7.862	0.289
T_{12} - Control	2.81	0.0331	7.982	0.270
SE(m)±	0.13	0.0017	0.067	0.014
CD (p=0.05)	0.38	0.0046	-	0.042

Table 2. Long term effect of various treatments on availability of macro nutrients in soil under sorghum wheat cropping sequence

Treatments	Available nutrient (kg ha^{-1})			
	N	P	K	S (ppm)
T_1 - 50%NPK	186	16.21	309	36.06
T_2 - 100%NPK	280	30.96	388	44.13
T_3 - 150%NPK	305	32.98	431	58.08
T_4 - 100%NPK (S free)	267	29.11	371	33.38
T_5 - 100%NPK + 2.5 kg Zn ha^{-1}	282	29.07	386	48.61
T_6 - 100%NP	260	29.83	339	40.54
T_7 - 100%N	248	24.70	299	34.05
T_8 - 100%NPK + FYM @ 10 t ha^{-1}	313	37.08	460	63.39
T_9 - 100%NPK + 37.5 kg S ha^{-1}	283	31.16	391	65.18
T_{10} - FYM only 10 t ha^{-1}	253	28.81	338	31.58
T_{11} - 75% NPK	214	19.92	348	43.01
T_{12} - Control	175	12.17	230	28.67
SE(m)±	4.24	0.263	3.25	0.42
CD (p=0.05)	12.21	0.755	9.36	1.16

dose of NPK (T_2) over 50 per cent dose of NPK (T_1) and it was found higher by 6.5 per cent in the treatment of super optimal dose of NPK (T_3) over optimal dose of NPK (T_2). The treatment of integrated nutrient management also recorded significant build up of soil P. This may be attributed to build up of phosphorus in soil by addition of phosphorus every year. These finding corroborates with the results reported by Bhandari *et al.* (1992). The availability of potassium was decreased in treatment 100% N, where no potassium fertilizer was applied since the beginning of experiment. This may be ascribed to imbalanced application of inorganic fertilizer. These findings commensurate with the results reported by Lal *et al.* (1990).

The increase in available N, P and K observed in the treatment of integrated nutrient management may be through direct addition of organic matter from farmyard manure in combination with 100% NPK which might have helped in multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form and

Table 3. Long term effect of various treatments on soil biological properties under sorghum-wheat cropping sequence

Treatments	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	Dehydrogenase activity (µg g^{-1} 24 h^{-1})
T_1 - 50%NPK	187	12.36	37.32
T_2 - 100%NPK	214	14.95	41.95
T_3 - 150%NPK	227	16.03	45.69
T_4 - 100%NPK (S free)	208	13.86	41.06
T_5 - 100%NPK + 2.5 kg Zn ha^{-1}	217	14.30	43.14
T_6 - 100%NP	196	12.74	40.11
T_7 - 100%N	179	11.98	36.97
T_8 - 100%NPK + FYM @ 10 t ha^{-1}	247	17.53	49.78
T_9 - 100%NPK + 37.5 kg S ha^{-1}	220	14.80	44.19
T_{10} - FYM only 10 t ha^{-1}	222	15.18	45.08
T_{11} - 75% NPK	192	13.34	38.81
T_{12} - Control	139	8.86	32.51
SE(m)±	10.37	0.70	0.61
CD at 5%	29.49	1.95	2.23

Table 4. Yields of sorghum and wheat under long term fertilization in sorghum-wheat cropping sequence

Treatments	Sorghum grain (q ha^{-1})	Wheat grain (q ha^{-1})	Total productivity (q ha^{-1})
T_1 - 50%NPK	26.25	14.40	40.65
T_2 - 100%NPK	38.71	27.32	66.03
T_3 - 150%NPK	46.12	32.16	78.28
T_4 - 100%NPK (S free)	34.67	24.01	58.68
T_5 - 100%NPK + 2.5 kg Zn ha^{-1}	39.98	28.07	68.05
T_6 - 100%NP	27.63	14.35	41.98
T_7 - 100%N	21.69	10.26	31.95
T_8 - 100%NPK + FYM @ 10 t ha^{-1}	50.84	34.41	85.25
T_9 - 100%NPK + 37.5 kg S ha^{-1}	39.36	25.73	65.09
T_{10} - FYM only 10 t ha^{-1}	15.84	3.01	18.85
T_{11} - 75% NPK	30.98	18.91	41.89
T_{12} - Control	1.98	0.56	2.54
SE(m)±	0.76	0.71	
CD at 5%	2.18	2.03	

solubilization of native P in the soil through release of organic acids (Tolanur and Badanur, 2003). This has been further reflected in the sustained crop productivity over a long term cropping period of 19 years justified by adequate and balanced supply of plant nutrients to the intensive cropping sequence.

Soil biological properties

The application of recommended dose of fertilizers in combination with FYM @ 10 t ha^{-1} recorded significant increase in biological parameters namely soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and dehydrogenase activity (DHA) to the extent of 8.8, 9.3, and 9.0 per cent over higher dose of only chemical fertilizers without organics (Table 3). This can be ascribed to direct addition of organic matter through farmyard manure and increase in root biomass which helped in growth and development of soil microorganisms causing beneficial effect on SMBC, SMBN and DHA. Application of FYM @ 10 t ha^{-1} (only to sorghum) significantly increased SMBC, SMBN and DHA over control which might be due to presence of easily water soluble carbon, which acts as source of energy for soil organisms (Manna and Ganguly, 1997). The lowest value of SMBC was observed in the control treatment obviously due to unfavourable environment arising out of depletion of nutrients due to continuous cropping without any fertilization or manuring. However, the highest SMBC in the INM treatments was due to its congenial environment for microbial growth for enrichment through plant residue incorporation due to higher yield as well as FYM application (Grego *et al.,* 1998).

The soil microbial biomass nitrogen was decreased at 100% NP and 100% N to the tune of 17.6 per cent and 24.8 per cent as compared to 100% NPK (T_2) indicating necessity of balanced fertilizer application for enhancing soil microbial activity. It was further observed that combined use of FYM with 100% NPK increased microbial biomass nitrogen by 17.3 per cent over optimal NPK levels indicating augmented effect of organics in microbial activities. Selvi *et al* (2004) reported that FYM is not only rich in carbon but also in nitrogen and other macro and micronutrients.

The DHA increased with graded levels of fertilizer doses from 50 to 150 per cent NPK. Application of FYM + 100% NPK recorded significantly highest DHA (49.78 µg g^{-1} 24 hr^{-1}) as compared to all other treatments. The increase in DHA was 18.6 per cent due to INM over 100% NPK through chemical fertilizers. The addition of FYM coupled with inorganic fertilization exerted a stimulating influence on the preponderance of bacteria (Selvi *et al,* 2004). The DHA was significantly higher at 100% NPK (41.95 µg g^{-1} 24 h^{-1}) and 100 % NP (40.11 µg g^{-1} 24 h^{-1}) as compared to 100% N (36.97 µg g^{-1} 24h^{-1}), suggesting balanced application of nutrients is necessary for DHA. Jain *et al.* (2003) also reported significant increase in DHA due to balanced supply of nutrients.

Crop productivity

The highest productivity of sorghum and wheat (50.84 and 34.41 q ha^{-1}) were recorded with the application of FYM @10 t ha^{-1} +100% NPK which was significantly higher than 150% NPK (46.12 and 32.16 q ha^{-1}). Non application of potassium (T_6) and phosphorus and potassium (T_7) through chemical fertilizer showed reduction in the total productivity over 100% NPK (T_2) to the tune of 36.4 and 51.6 per cent, respectively (Table 4). The productivity of sorghum and wheat were significantly increased with application of 37.5 kg S ha^{-1} coupled with 100 % NPK to the extent of 9.8 per cent as compared to 100% NPK (without sulphur). Increasing levels of NPK showed linear and significant increase in productivity of sorghum and wheat. The lowest productivity was recorded in the control treatment. This indicates that sustainability in productivity of sorghum and wheat could be maintained by integrated use of organic and inorganic fertilizers. This is substantiated by the results reported by Naphade *et al.* (1995) and Ravankar *et al.* (1998). However, use of only FYM during *kharif* was not found to increase crop yields to a sustainable level in long run.

Relationship of soil properties with crop productivity

A highly significant positive correlation of total productivity was observed with available K (r=0.92**), available S (r=0.82**), available N (r=0.76**) available P (r=0.74**) and whereas, moderately positive significant correlation was observed with organic carbon (r=0.68**), total nitrogen (r=0.71**), SMBC (r=0.69**), SMBN(r=0.72**) and DHA (r=0.71**). This indicated that total productivity of sorghum and wheat grown in Typic Haplusterts was enhanced and controlled by these soil parameters.

Thus, it could be concluded that long term application of FYM @ 10 t ha^{-1} in combination with 100% recommended NPK to sorghum and wheat significantly improved the soil chemical and biological properties as well as productivity of sorghum and wheat.

Neither organic sources nor chemical fertilizers alone can achieve sustainability in crop productivity under intensive cropping sequence, where nutrient turnover in soil plant system is much higher. Hence, judicious use of organics and chemical fertilizers not only increase the yield but also sustains the productivity.

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(Received on 12.07.2011 and revised on 18.07.2011)