Balance Use of Fertilizers :

Impact on Crop Productivity and Soil Quality under Long Term Fertilizer Experiments

Editors : Ashok K Patra, RH Wanjari, Dhiraj Kumar, Rahul Mishra, Muneshwar Singh and Anil Nagwanshi

AICRP on Long Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability

Project Coordinating Cell

ICAR - Indian Institute of Soil Science

Nabibagh, Berasia Road, Bhopal – 462 038 (M.P.)

Sardar Patel Outstanding ICAR Institution
FAO King Bhumibol World Soil Day Awardee

Balance Use of Fertilizers : Impact on Crop Productivity and Soil Quality under Long Term Fertilizer Experiments

SOIL IS ONE OF THE KEY COMPONENTS OF ECOSYSTEM and soil quality is the outcome of integrated management of most of the properties of soil that determine crop productivity and sustainability. Continuous application of inadequate and imbalance use of fertilisers leads to decline in soil organic matter and thus loss of soil quality. For sustainable production system with minimum damage to the environment there is need of balanced and integrated nutrient management (INM) practices to maintain organic matter under intensive production system. Sustaining and improving the soil organic matter is quite necessary to ensure better soil quality productivity and sustainability as it influences all the physical, chemical and biological properties of soil. Based on the "Rothamsted Classical Experiments" model and also considering the importance of manuring and fertilisation on soil and crop quality and the environment, the Indian Council of Agricultural Research (ICAR) launched the All India Coordinated Research Project on Long Term Fertilizer Experiments (AICRP-LTFE) to Study Changes in Soil Quality, Crop Productivity and Sustainability in September 1970. This AICRP has a mission of 'Soil Fertility Management through Integrated Plant Nutrient Supply for Enhancing and Sustaining Crop Production and Maintaining Soil Quality' with a mandate 'To conduct coordinated long term fertilizer experiments in different soil types under diversified cropping systems'. They were identified in all irrigated and intensively cropped areas representing different agro-climatic regions. There are 10 or 12 treatments in each experiment. These are: T_1 50% NPK dose; T_2 100% NPK dose; T_3 150% NPK dose; T_4 100% NPK dose + hand weeding; T_5 100% NPK dose + zinc or lime; T_6 100% NP; T_7 100% N; T_8 100% NPK +FYM; T_9 100% NPK (Sulphur free/sulphur source); T_{10} Unmanured (Control). At present, there are 17 locations under AICRP LTFE encompassing 9 major crops (Rice, wheat, soybean, maize, finger millet, sorghum, groundnut, safflower and jute), 9 major cropping systems spread over 11 AER and 14 AESR in India. The project is under the Natural Resource Management Division of ICAR and has 15 centres in different SAUs, two centres in ICAR Institutes with Coordination Cell at ICAR-Indian Institute of Soil Science, Bhopal. Keeping this in view, the findings emanated from AICRP on LTFE are briefed hereunder:

It is well documented that the crop productivity and soil quality are governed by several factors such as soil organic carbon status, balanced nutrient supply, nutrient use efficiency, soil biological health etc of the agricultural ecosystem.

Soil Organic Carbon

Soil organic carbon (SOC) is the key indicator of soil quality and affects majority of the soil properties. Thus, maintaining and enhancing it through better management practices viz., balanced and INM is highly needed. Results of the LTFEs conducted in different soil types and major cropping systems in the country clearly demonstrated that SOC improved on application of balanced (100% NPK) and INM (100% NPK+FYM) practices over imbalance nutrient application.

Soil Type	Centres	Initial	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+ Zn	100% NPK+ Lime	100% NPK+ FYM
		(g kg^{-1} soil)								
Alfisols	Bangalore	4.6	4.2	3.7	4.3	4.8	5.1	-	4.6	5.6
	Palampur	7.9	8.0	8.1	9.7	10.1	9.7	9.2	11.1	13.3
	Ranchi	4.5	4.1	4.7	4.6	4.7	4.6	-	3.8	5.5
Inceptisols	Barrackpore	7.1	5.6	6.6	7.1	7.2	7.3	7.0	-	8.9
	Ludhiana	2.2	2.9	3.8	3.8	4.2	4.1	4.1	-	5.3
	New Delhi	4.4	3.0	4.4	4.3	4.4	5.2	4.7	-	5.3
Vertisols	Jabalpur	5.7	4.2	5.2	6.7	7.6	8.7	7.6	-	8.9
Mollisols	Pantnagar	14.8	6.1	9.0	9.9	9.8	8.8	10.0	-	15.6

Crop Productivity

Balanced use of fertilizer as well as INM improved crop productivity across the LTFE sites. The balanced fertilizer use i.e. 100% NPK with inclusion of lime and zinc resulted in yield enhancement compared to imbalanced nutrient application over the years. The application of 100% N alone in the form of urea found to reduce the yield drastically and led to deleterious effect on soil quality and overall soil health. The acid soils (Alfisols) of Ranchi, Palampur and Bangalore are experiencing too much fatigue in recent years. Thus, at Palampur yield of maize and wheat reached to almost zero due to 100% N that was even inferior than unfertilized control during recent years.

Treatment	Pantnagar		Ranchi		Akola		Raipur		Palampur	
	Rice	Wheat	Soybean	Wheat	Sorghum	Wheat	Rice	Wheat	Maize	Wheat
	(kg ha^{-1})									
Control	1274	1184	552	715	427	390	1993	1132	600	400
100% N	3296	3182	438	855	1702	721	3308	1713	0	0
100% NP	4103	3447	673	3419	2652	1951	4473	2846	1456	863
100% NPK	3674	3363	1426	3259	3229	2391	4617	2860	3175	1904
150% NPK	3520	3306	1653	3403	3937	3060	5173	3179	2732	1542
100% NPK+Zn/Lime	4432	4071	2081	4218	3420	2560	4517	2873	2903	1658
100% NPK+FYM	5131	4748	2053	4302	4260	3186	5050	3103	4559	2879

Effect of application of only nitrogenous fertilizers (100% N) vis-à-vis INM (100% NPK+ FYM) on crop growth and productivity in Alfisols of Palampur.

Maize (100% N)

Maize (100% NPK+FYM)

Wheat (100% N)

Wheat (100% NPK+FYM)

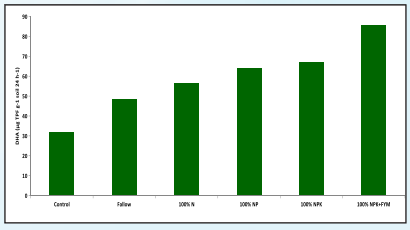
Yield Sustainability

The sustainable yield index (SYI) is a quantitative measure of sustainability and implies minimum guaranteed yield that is obtained relative to maximum yield. The SYI improved with balanced and INM over imbalanced and unfertilized control. The negative values of SYI were observed in Alfisols i.e. Finger millet and maize at Bangalore. Similarly, SYI values are approaching towards zero in maize and wheat grown in LTFE at Palampur and soybean and wheat at Ranchi. Thus, as a result of imbalanced nutrient application (control, 100% N, NP, 50% NPK) the SYI was negative indicating such nutrient options are not sustainable any more. This was a serious problem in acid soils (Alfisols). However, these treatments are important for developing the nutrient management strategies. On the contrary, the SYI values were found to be encouraging when crop was supplied either with balance nutrition or nutrients in integrated manner. The SYI derived for Kharif and rabi crops grown over the years in LTFEs in different agro-climatic regions are mentioned here.

Soil Type	LTFE Site	Crop	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+ FYM	100% NPK+ Lime
Alfisols	Bangalore	Finger millet	-0.26	-0.23	-0.19	0.45	0.61	0.56	0.43
		Maize	-0.20	-0.18	-0.11	0.49	0.60	0.63	0.52
	Palampur	Maize	0.01	0.07	0.15	0.35	0.36	0.53	0.47
		Wheat	0.04	0.05	0.15	0.28	0.28	0.42	0.40
	Ranchi	Soybean	0.10	0.03	0.21	0.49	0.47	0.62	0.60
		Wheat	0.02	0.03	0.40	0.47	0.51	0.61	0.56
Inceptisols	Barrackpore	Rice	0.15	0.29	0.34	0.35	0.41	0.40	-
		Wheat	0.11	0.30	0.36	0.38	0.47	0.41	-
	Coimbatore	Finger millet	0.08	0.12	0.36	0.37	0.41	0.46	-
		Maize	0.06	0.09	0.36	0.39	0.43	0.47	-
	Ludhiana	Maize	0.11	0.33	0.35	0.37	0.40	0.45	-
		Wheat	0.15	0.43	0.63	0.70	0.76	0.77	-
	New Delhi	Maize	0.25	0.34	0.38	0.44	0.50	0.51	-
		Wheat	0.38	0.58	0.67	0.74	0.81	0.82	-
Vertisols	Akola	Sorghum	-0.01	0.22	0.25	0.34	0.40	0.47	-
		Wheat	0.02	0.32	0.33	0.50	0.55	0.59	-
	Jabalpur	Soybean	0.13	0.15	0.26	0.31	0.33	0.35	-
		Wheat	0.14	0.15	0.5	0.54	0.57	0.59	-
Mollisols	Pantnagar	Rice	0.13	0.39	0.43	0.41	0.38	0.50	-
		Wheat	0.15	0.46	0.51	0.51	0.50	0.62	-

Soil Biological Health

Soil biological health reflects the microbial activity in soil. The dehydrogenase enzyme is one of the most critical indicator of soil respiratory activity as it affects the decomposition of organic matter in soil. The study indicated that dehydrogenase activities (DHA) are adversely influenced with imbalanced fertilizer use. Thus, balanced and INM is the option to revive the biological health of soil. It has been very well illustrated that 100% NPK and 100% NPK + FYM significantly improved the DHA in rice-wheat-jute intensive cropping in Inceptisols of Barrackpore.



Nutrient Use Efficiency

Nutrient use efficiencies of applied N, P and K in majority of crops indicated that the efficiency gradually improved with addition of each nutrient. The efficiency further improved with INM i.e. NPK+FYM in major crops and soils across LTFE sites. Nutrient use efficiency for maize and wheat crops in LTFE at Delhi showed such pattern.

Crop	100% N	100% NP	100% NPK	150% NPK	100% NPK+FYM
			Nitrogen use efficiency (%)		
Maize	39.4	50.5	62.2	77.7	61.4
Wheat	39.2	46.7	51.7	59.2	50.0
			Phosphorus use efficiency (%)		
Maize	-	13.7	17.9	30.8	27.5
Wheat	-	9.5	12.6	24.0	27.5
			Potassium use efficiency (%)		
Maize	-	-	62.1	91.2	110.1
Wheat	-	-	73.2	72.8	91.2

Nutrient Deficiency in LTFEs

As a result of imbalanced nutrient application there is an emergence of nutrient deficiency in some crops and soils over the years. Potassium is a yield limiting nutrient in Alfisols of Bangalore, Ranchi and Palampur. Similarly, N and S found to be deficient in maize at Bangalore. Zinc found controlling factor in rice grown in Molliols of Pantnagar (Uttarakhand) led to khaira disease. However, integrated nutrient management i.e. 100% NPK+FYM helped to meet out the deficiency of most of the macro and micronutrients across all the LTFEs.

N deficiency in finger millet (Bangalore)

K-deficiency in finger millet (Bangalore)

S-deficiency in maize (Bangalore)

K deficiency in soybean (Ranchi)

Balanced use of fertilizers and integrated nutrient management boost the crop growth and productivity of rice under LTFEs in Mollisols of Pantnagar (Uttarakhand)

Control

100% NPK-Zn

100% NPK + Zn

100% NPK+FYM

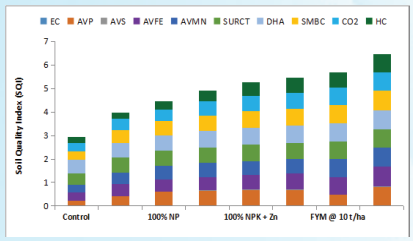
Revival of Crop Productivity and Soil Quality through Superimposition

Based on the studies from LTFEs, the effect of ameliorants and organic manures plays key role in sustaining crop productivity especially in Alfisols. An increase in yield is many folds higher with an application of lime and FYM in soybean and wheat at Ranchi. It has clearly shown that in treatments with imbalanced fertilizers use, application of lime or FYM along with 100% NPK is crucial in Alfisols of Ranchi.

Treatment	Soybean yield (kg ha^{-1})		Wheat (kg ha^{-1})	
	Mean (2002-2018)	Increase over original (%)	Mean (2002-2018)	Increase over original (%)
100% N (Original)	274	-	405	-
100% N +Lime	735	168.4	690	70.5
100% N +FYM	1534	459.9	1853	358.0
100% NP (Original)	623	-	3004	-
100% NP +lime	1096	75.8	3638	21.1
100% NP +FYM	1706	173.6	3905	30.0

Soil Quality

Soil quality index (SQI) is a tool to assess the soil quality of a given location so as to compare between management practices. Soil quality index is computed by selecting a set of soil quality parameters which are referred to as indicators. Results from LTFEs clearly depict the betterment of soil quality parameters on inclusion of FYM with 100% NPK (INM) and also in balanced treatment (100% NPK) compared to imbalanced nutrient application at LTFE locations.



Conclusion

Results emanated from long-term fertilizer experiments (LTFEs) clearly brought out that there is an increase in crop productivity on balanced nutrient application through fertilizers. It resulted in increase in carbon in soil and microbial population and thus ruled out the notion that chemical fertilizer deteriorate soil carbon and adversely affect the growth of the soil microorganisms. At Pantnagar, balanced fertilizer use with inclusion of Zn and S had additive effect on yield. In Alfisols, results indicated that application of urea alone (100% N) had deleterious effect on crop productivity. However, the FYM application found to be superior to lime amendment as far as soil productivity in Alfisols is concerned. Thus, the soils deteriorated with imbalanced fertilizer use could be revived with either organic manure addition or lime amendment as in case of Alfisols. The soil quality index (SQI) got improved with balanced and integrated nutrient management (100% NPK+FYM).

Prepared and Published by

Drs Ashok K Patra, RH Wanjari, Dhiraj Kumar, Rahul Mishra, Muneshwar Singh and Anil Nagwanshi

ICAR-Indian Institute of Soil Science

Nabibagh, Berasia Road, Bhopal 462 038 (Madhya Pradesh), India (June 2022)