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Effect of three decade long application of chemical fertilizer and amendments on crop yield under maize - wheat cropping system in an acid alfisol

R. P. Sharma, Vandana Kaushal, Gayatri Verma* and S. P. Sharma

*Regional Research Station, Punjab Agriculture University, Gurdaspur (Punjab), INDIA
Department of Soil Science, CSK HPKV, Palampur (Himachal Pradesh), INDIA
*Corresponding author. E-mail:drgayatriverma@gmail.com

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Abstract: The results on the effect of three decade long term application of chemical fertilizers and amendments on the yield of continuous maize-wheat crop rotation in an acid alfisol at Palampur revealed that continuous omission of essential nutrients in a maize-wheat sequence resulted in an appreciable decline in the grain yield of maize and wheat crops. A remarkable reduction in crop yield was noticed in plots where nitrogen was applied alone. Use of recommended level of N alone through urea had deleterious effect on crop productivity. The continuous exhaustion of native pools of K in 100% NP treated plots appreciably reduced percent grain yield. Application of farmyard manure (FYM) and lime along with NPK fertilizers increased the crop yield. The integrated use of optimal dose of NPK and FYM give better and more sustainable yields.

Keywords: Farmyard manure, Long-term fertilization, Maize, Wheat and Yield

INTRODUCTION

To secure India's food and nutritional demands sustained agricultural production is of utmost importance. Overdependence on high analysis fertilizers has encouraged the process of land degradation and is badly influencing production potential and soil health. As a result most of the productive soils are becoming unproductive. Imbalanced fertilization is one of the important factor limiting crop yields. Problem is more severe in acid soils which are under continuous cropping (Prasad *et al.*, 2010). Single or short-term fertilizer experiments, however, only give a partial picture of yield sustainability and crop responses to the use of various inputs. Therefore, the adoption of integrated nutrient management and continuous cropping system has become the need of hour for enhancing soil quality and crop productivity from food security point of view in Indian agriculture. The long-term field experiments (LTFE) on the other hand, provide means to evaluate sustainability and environmental impact of subsistence soil quality (Lal, 1994). Hence, in the present investigation, the study on the effect of chemical fertilizers and amendments on crop yields under maize -wheat cropping system was undertaken.

MATERIALS AND METHODS

The study was undertaken at the experimental farm of College of Agriculture since 1972 on a Typic Hapludalf soil of Palampur (32^0 N,76^0 E,1280 m above mean sea level). The climate of the study area was wet temperate with June to September being the wettest months and the area received a mean annual rainfall of 2213±557 mm. The mean monthly temperature varied from 30^0C (May-June) to 5^0C (December-January). The experiment consisted of various fertility treatments on a fixed rotation of maize -wheat. At the initiation of the experiment, soil of the experimental field was silty clay loam having pH 5.8, organic carbon 7.9 g kg^{-1}, available N 736, available P 12 and available K 194 kg ha^{-1}, respectively. The eleven treatments with four replications in a randomized block design were as follows:

T_1 - Control	T_7 - 100 % NPK + Zn
T_2 - 100 % N	T_8 - 100 % NPK + HW
T_3 - 100 % NP	T_9 - 50 % NPK
T_4 - 100 % NPK	T_{10} - 150 % NPK
T_5 - 100 % NPK + FYM	T_{11} - 100 % NPK (-S)
T_6 - 100 % NPK + lime	

The 11th treatment was introduced in kharif 1981. The 100 percent NPK dose corresponds to the state level recommendations for the corresponding nutrients is 120, 26 and 26 and 120, 26 and 18 kg ha^{-1} N, P and K for maize and wheat, respectively. The fertilizers used were urea, single super phosphate, diammonium phosphate (for T_{11} only), muriate of potash, zinc sulphate (for T_7 only) and lime (for T_6 only). The lime was applied at the rate of 900 kg ha^{-1} as marketable lime ($CaCO_3$) passed through 100 mesh sieve only to maize crop every year till the soil pH rose to about 6.5. Zinc was applied as $ZnSO_4$ at the rate of 25 kg ha^{-1} every year to both the crops. farmyard manure (FYM) that contained 60 % moisture, 1.01, 0.26 and 0.40 % N, P and K, respectively on dry weight basis, application was made at the rate of 10 t ha^{-1} on fresh weight basis to the maize crop only, which corresponded to the practice being followed by the farmers

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of the region. The varieties of the crops grown were PCL 3438 for maize and HPW 42 for wheat. The crops were raised following recommended package of practices. The chemical weed control measures were followed in both the crops except in T_8 treatment, where weeds were removed manually.

After the harvest of the crops at maturity, grain and straw yields were recorded separately. Grain yield of maize was standardized at twelve per cent moisture content and stover yield on oven dry basis, whereas in wheat, yields of both grain and straw were recorded on air-dry basis. The effect of chemical fertilizers and amendments was studied on the grain yield of maize and wheat crop grown in a sequence for last 36 years.

Average change in absolute grain yield values (Δ_Y) of maize and wheat crops was worked out by summing up the increase or decrease in grain yield values over the preceding year for thirty six cropping cycles. The net result was divided by thirty six (the no. of cropping

$$\text{Per cent}(\Delta y) = \frac{(\Delta y)\text{for 36 years}}{\text{Absolute yield obtained in the first cycle}} \times 100$$

cycle). The percent in each treatment was then worked out as under:

RESULTS AND DISCUSSION

Long-term changes in crop yield: The yield of crops viz. maize and wheat obtained over thirty six years (1972-73 to 2008-09) are presented in tables 1 and 2. The maize (2005) of thirty third cropping cycle (33^{rd}) and wheat (2000-2001) grown during twenty nineth (29^{th}) cropping cycle failed due to unprecedented drought conditions. Therefore, maize crop grown during 2008 was considered to be the thirty fifth whereas, wheat grown during 2008-09 was considered to be the thirty sixth in a cycle for describing long term changes in the yield of crops. The absolute grain yield values of both the crops in each treatment fluctuated over the years due to large variations in the weather conditions over the years.

Effect of zero fertilization on crop yield: The grain yield of maize and wheat crops in the plots receiving no fertilizer, fluctuated over the years, but showed a general declining trend. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops between thirty-six cropping cycles was 3.4 and -33.8 kg ha^{-1}, respectively. The low yield levels of both the crops over the years are understandable and could be explained due to poor inherent capacity of the soils under study to meet the requirements of crop in respect of the essential nutrients.

Effect of application of commercial fertilizers on crop yield: The application of N alone (without FYM) had the most deleterious effect on crop yield. The grain yield of both the crops declined to zero level since the twenty-second and twenty-third cropping cycles, respectively. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops between thirty-six cropping cycles due to N fertilization only was -88.2 and -67.7 kg ha^{-1}, respectively. The drastic reduction in the yield levels of both the crops clearly brought out the deleterious effects of imbalanced use of chemical fertilizers on the productivity. These findings are in agreement with those of Swarup (2000) and Sharma *et al*. (2002) who also demonstrated complete degradation of soils in plots treated with nitrogen through nitrogenous fertilizers alone and thereby resulting in zero yield levels after about twenty to thirty years of experimentation. Application of N alone was significantly inferior to the unfertilized control was also reported by Singh *et al.* (2009).

The 36^{th} maize crop showed severe deficiency of K, which resulted in drastic reduction in the grain yield of the maize crop due to its continuous omission in the plant nutrition. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops was between thirty-six cropping cycles was -96.3 and -84.6 kg ha^{-1}, respectively. Since, the soils under study are inherently acidic in nature and have poor P supplying power; therefore the significant increase in yield levels

Table 1. Long term effect of chemical fertilizers and amendments on grain yield of maize (kg ha^{-1}).

Treatment	Grain yield (kg ha^{1})								Δ_Y (per annum)
	Year of cropping								
	1972	1977	1982	1987	1992	1997	2000	2008	
Control	352	159	364	88	430	0	782	456	3.4
100 % N	2981	1235	205	30	30	0	0	0	88.2
100 % NP	4328	2638	2740	340	1280	1070	2370	1025	-96.3
100 % NPK	4158	3048	4634	3228	3490	2000	4660	266.	-42.3
100 % NPK + FYM	5569	3938	6754	4515	4820	3500	6370	4346	-341
100 % NPK + lime	4921	3770	4829	4423	4030	3140	6650	4102	-21.6
100 % NPK + Zn	4523	3275	5009	2968	4390	1760	3820	2460	-60.2
100 % NPK + HW	4179	2925	5781	3070	3510	2190	4887	2862	-43.4
50 % NPK	1981	2370	3800	2517	2240	890	3117	1606	-9.5
150 % NPK	6317	3573	5828	3888	4290	1310	3275	2470	-113.0
100 % NPK (-S)	-	-	4276	2488	2190	1250	2635	970	30.7

Table 2. Long term effect of chemical fertilizers and amendments on grain yield of wheat (kg ha^{-1}).

Treatment	Grain yield (kg ha^{-1})								
	Year of cropping								
	1972-73	1977-78	1982-83	1987-88	1992-93	1997-98	2000-01	2008-09	Δ_Y (per annum)
Control	1010	250	450	150	220	360	541.5	408	-33.8
100 % N	2270	310	490	100	130	0	0	0	-67.7
100 % NP	3810	1380	2700	1540	1380	630	783	1080	-84.6
100 % NPK	3930	1420	3290	2750	2180	1000	1733	1850	-89.2
100 % NPK + FYM	4300	1870	4060	3530	3040	1650	2479	3050	-72.4
100 % NPK + lime	4190	1770	3550	3220	2470	2300	2231	2843	7.4
100 % NPK + Zn	4100	1510	2900	2420	2230	950	1504	1803	-91.9
100 % NPK + HW	5120	1360	2940	2650	2140	1980	1783	2090	-116.8
50 % NPK	2660	980	1400	2360	1100	1040	1033	1423	-53.0
150 % NPK	4700	1650	4010	3660	2430	830	1666	1633	-123.0
100 % NPK (-S)	-	-	2690	1990	1750	730	849.7	1255	-51.4

of both the crops due to application of P in combination with N is explainable and is in agreement with the findings of Bhatnagar *et al.* (1994). Addition of P with N increased maize grain yield was probably due to the higher response of P in these soils. Moreover, application of P decreases soil acidity and Al toxicity and also increases exchangeable cations, thus influencing crop yields (Verma and Singh, 1996). A considerable decline in the productivity of both the crops in the absence of K application could possibly be explained on the ground that the soil under study have rich native reserves in the form of exchangeable and non-exchangeable forms of K and therefore no response to its application in the initial years is indicative of their high K supplying capacity. However, its continuous mining resulted in the depletion of native reserves affecting the growth of both the crops in the subsequent years of crop production (Subehia *et al.*, 2005).

Unlike maize, the grain yield of wheat, showed a declining trend. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops was -42.3 and -89.2 kg ha^{-1} between thirty-six cropping cycles. This could be explained from the fact that the wheat grains remove 50 percent higher K than maize grains (Mengel and Kirkby, 1987) indicating thereby, high K needs of wheat than maize crop. The decline in yield of wheat specifically after twentieth cycle could, therefore, be attributed to depleting K reserves in the later years of crop production. Also, the consistently higher removals of K than its additions by both the crops have led to mining of K in the later years of crop production (Sharma *et al*., 2002).

Effect of graded dose of chemical fertilizers on crop yield: The effect of 50 percent NPK (sub optimal dose), 100 percent NPK (optimum) and 150 percent NPK (super optimum) was studied on maize and wheat productivity for thirty-six years. It was revealed that reducing the application of chemical fertilizers to 50 percent of recommended level considerably reduced the grain yield of maize as well as wheat crop. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops was between thirty-six cropping cycles under 50 percent NPK was 9.5 and -53.0 kg ha^{-1}, respectively. A comparatively low yield with the application of 50 percent NPK than 100 percent NPK have had less exhaustive effects on native reserves of soil NPK and thus, has sustained yield at low levels. Increasing application rate of NPK to 150 percent of the recommended level considerably increased the grain yield of maize as well as wheat crops during the initial years. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops between thirty-six cropping cycles was -113.0 and -123.0 kg ha^{-1}, respectively in the plots receiving 150 percent NPK. The decline in the yield of these crops after twenty four years of crop production even under high inputs is due to the mining of secondary nutrients particularly Mg (Sharma *et al*., 2002).

Effect of combining FYM, lime or Zn with inorganic fertilizers on crop yield: Compared to the use of inorganic fertilizers alone (100 % NPK) the productivity of maize and wheat crops was considerably raised in the plots receiving FYM in addition to the application of 100 per cent NPK. Thakur *et al.* (2011) also reported that integrated use of optimal dose of fertilizer and organic manure treatments is superior to super optimal dose. The production levels of maize and wheat crops with the combining of FYM with NPK were 5569 and 4300 and 4346 and 3050 kg ha^{-1} in the first and thirty-six cropping cycle, respectively. The sustenance of crop yield levels, following integrated nutrient management programmes has been documented by a number of workers elsewhere in India (Sharma *et al.*, 2002 and Pathak *et al.*, 2005).

Applying lime in combination with recommended level of chemical fertilizers (100 % NPK + lime) increased the yield of maize and wheat crops as compared to the plots receiving only 100 % NPK. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops under 100 per cent NPK +

lime between thirty-six cropping cycles was -21.6 and 7.4 kg ha^{-1}, respectively. The results could be explained in view of the findings of Mahajan *et al.* (1997) and Hati *et al.* (2008) who demonstrated the role of lime in ameliorating soil acidity and thereby increasing the productivity of such problematic soils.

Combining Zn with 100 percent NPK showed considerable decline in the grain yield of maize and wheat crops since the year 1997. The average change in the absolute grain yield values (Δ_Y) of maize and wheat crops was between thirty-six cropping cycles in the plots receiving Zn in combination with 100 percent NPK was -60.2 and -91.9 kg ha^{-1}, respectively. The decline in yield may probably be because of the increased level of Zn as well as P in the soils. Besides this, the antagonistic effect of Zn and P might have also played a role in reducing the yield of both the crops during the later years of crop production (Sinha *et al.*, 1997).

Effect of high analysis fertilizers on crop yield: The effect of diammonium phosphate (DAP), one of the high analysis sulphur free phosphatic fertilizer studied on productivity of maize and wheat crops indicated that the average change in the absolute grain yield values (Δ_Y) of maize and wheat crops was between thirty-six cropping cycles in the treatment involving the use of high analysis sulphur free P fertilizer (DAP) was -30.7 and -51.4 kg ha^{-1}, respectively. The DAP in comparison to SSP contained 46 percent phosphorus but no sulphur and Ca. Its continuous use has therefore, led to sulphur mining of the soils resulting in drastic reduction in the crop yields. Therefore, the ‘S’ needs of the crops have to be replenished through alternate source of sulphur for sustaining productivity of cropping systems. Subehia *et al.* (2005) have also reported that continuous use of DAP as P source results in S deficiency causing reduction in crop yields.

Conclusion

From the present study, it is concluded that under continuous cropping with maize and wheat in sequence over last three decades, balanced fertilization not only sustained the higher yields, but also improved the soil fertility. Use of recommended levels of nitrogen alone through urea had deleterious effect on crop productivity. Use of chemical fertilizers at 50% of their recommended levels is no solution to meet out the ever increasing food grain demand of the country as revealed by consistently low grain yields of maize and wheat crops for the last three decades. Super optimal dose of NPK though gave higher yield over 100% NPK for quite a number of years, but does not seem to be sustainable at present level of crop production. Therefore, integrated use of optimal dose of NPK and FYM give better and more sustainable yields and also correct the micronutrient and secondary nutrient deficiencies and soil acidity problems.

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