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Short Communication

Effect of five decades of application of inorganic fertilizers, farm yard manure and lime on maize and wheat productivity in an acid *Alfisol*

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Abstract

The effect of continuous application of fertilizers and amendments on maize and wheat yield in an acid *Alfisol* during 2019-20 was evaluated in a field experiment at the research farm of the Department of Soil Science, CSKHPKV Palampur (HP). The field experiment was conducted on a pre-established long-term fertilizer experiment (1972-73) which comprised of ten treatments up to 1980-81. The eleventh treatment, consisting of 100 per cent NPK (-S) was introduced in *kharif*, 1981. Thereafter, another treatment, consisting of *Beejamrita, Jeevamrita and Ghanajeevamrita* (Natural Farming) was introduced in *kharif*, 2019. The soil of the experimental area was silty clay loam and classified taxonomically as "Typic Hapludalf". Continuous application of fertilizers and amendments for forty-seven years significantly influenced the yield of maize and wheat. The highest productivity of maize as well as wheat was recorded in the treatment comprising 100 per cent NPK + FYM and was statistically comparable with 100 per cent NPK + lime. Continuous application of N alone over the decades resulted in no yield. However, potassium and sulphur omission from the fertilization schedule for more than four decades resulted in drastic reduction in the yield. The grain and stover/straw yield recorded in natural farming plots was significantly lower as compared to other treatments except control

Key words: maize, wheat, yield, fertilizers, manures, *Alfisol*

There is a fast decline in per capita arable land due to increasing population pressure. Hence further requirement of food-grains has to be met through more intensification of agriculture. Fertilizers are essential for crop production and productivity but their continuous and imbalanced use has a negative impact on production potential and soil health. The problem is exacerbated in acid soils that are heavily cropped. One of the possible alternatives for maintaining soil health in relation to crop productivity is integrated nutrient management (INM) (Majhi *et al*. 2021). Further, such INM strategy could help to stabilize the yield and increase farmer's income (Nanda *et al*. 2016a). Organic manures can be applied to improve soil fertility and sustain productivity as it not only supplies macro and micro-nutrients but also improves physical, chemical, and biological properties of soil (Nanda *et al*. 2016b). Among organic manures, farmyard manure (FYM) is the easily accessible and low-cost, proven nutrient source that has been used by Indian farmers since time immemorial (Nanda *et al*. 2016a). It can improve yield on sustained basis and soil health (Nanda *et al*. 2016b) and check the mining of micro-nutrients (Singh *et al*. 2019a) if used continuously. On the other hand, imbalanced fertilizer application may disturb nutrient availability resulting in decreased soil productivity. Issues of deteriorating crop productivity and soil health can be efficiently addressed by the combined application of chemical fertilizers and organic manures (Singh *et al*. 2019a).

Maize-wheat is the major farming system of Himachal Pradesh. The area under maize and wheat in the state is 0.205 and 0.330 million hectares with production of 0.762 and 0.672 million tonnes, respectively. These two crops account for the majority of the state's staple food output, accounting for around 85.6 per cent of the total food-grain production (Anonymous 2021). Long-term experiments conducted at a particular situation are very useful to assess the impact of manurial practices on changes in soil properties and identify the best practice for achieving the highest productivity. Long-term fertilizer experiments (LTFEs) (Majhi et al. 2019) indicated a positive impact of farmyard manure (FYM), S and Zn on yield. Keeping these facts in mind, the current investigation was carried out in a forty seven-year-old Long Term Fertilizer Experiment at CSKHPKV, Palampur, India with the objectives to determine the continuous effect of NPK, FYM and lime on the maize and wheat productivity in an acid *Alfisol*.

The present investigation was carried out in an ongoing long-term fertilizer experiment (LTFE) started during 1972-73 (*rabi*) at the research farm of the Department of Soil Science, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site is situated at $32^0 6'$N latitude and $76^0 3'$ E longitude at an altitude of about 1290 m above mean sea level, in the Palam valley of Kangra district and is characterized as zone-II under mid hills sub-humid zone of Himachal Pradesh. Soil of the study area was silty clay loam in texture and was classified as "Typic Hapludalf". The experiment consisted of twelve treatments which 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 + Zinc (Zn); T_6 -100% NP; T_7 -100% N; T_8 -100% NPK + FYM; T_9 -100% NPK (-S); T_{10} -100% NPK + lime; T_{11} - Natural Farming; T_{12}-control. The treatment T_{11} (Natural Farming) was introduced during *kharif* 2019. The experiment was conducted in randomized block design (RBD) with three replications and the plot size was 15 m^2 (5m × 3m). Due to the marked build-up of available P, the original treatment structure was slightly modified from kharif 2011, optimal and super optimal doses of P were reduced by 50 per cent and in case of 50 per cent NPK, the addition of farmyard manure (FYM) @ 5 t ha^{-1} on dry weight basis to maize crop only was also included. In treatment T_{11}, practices of natural farming were followed for raising the crop. *Ghanajeevamrita* @ 250 kg/ha was applied and incorporated in the plots prior to sowing. Seeds were treated with *Beejamrita* @ 100 ml/kg seed before sowing. The seeds were mixed with *Beejamrita* with clean hands and all the seeds were coated uniformly. The coated seeds were spread on a plastic sheet in the shade and were allowed to dry for 2 to 3 hours. Application of *Jeevamrita* @ 500 litre/ha was done at the time of sowing followed by spray of *Jeevamrita* at an interval of 21 days after dilution (1:10) with water. Beejamrita contained 0.63, 0.18 and 0.26 per cent N, P and K respectively. N, P and K contents in *Jeevamrita* were 0.28, 0.08 and 0.10 percent, respectively. *Ghanajeevamrita* contained 1.33, 0.84 and 0.73 per cent N, P and K, respectively. Lantana @ 25 t/ha was used for mulching.

The maize crop (Kanchan Gold) was sown on 21^{st}June, 2019 and harvested on 19^{th} October, 2019. In case of maize crop, one pre-sowing irrigation was given. Thereafter the crop met its water requirement through rainfall, which was very high during the entire crop growth period. The wheat crop (HPW-368) was sown on 21^{st} November, 2019 and harvested on 15^{th} May, 2020. The wheat crop was irrigated with tube well water at the crown root initiation, tillering, late jointing, flowering and dough stages. Chemical weed control measures were followed using atrazine @ 1.125 kg/ha (as pre-emergence) in the maize crops and Vesta (ClodinafopPropargyl 15% + Metsulfuron Methyl 1% WP @ 169 g/acre (as post-emergence) in the wheat crop (except in T_4 and T_{11}), where weeds were removed manually. The results obtained are presented below:

Productivity of maize

The data with respect to productivity of maize (*kharif* 2019) have been presented in table 1. It is evident from the data that yield of maize was significantly affected by continuous application of fertilizers and amendments for forty-seven years. A perusal of data in table 1 revealed that not even a single grain or blade of maize could be harvested where recommended N alone through urea has been applied continuously for the last 47 years. The data in table 1 further indicated that in rest of the treatments, the grain yield varied from 7.59 q ha^{-1}(control) to 54.77 q ha^{-1} (100 per cent NPK + FYM). The yield recorded under 100 per cent NPK + lime (T_{10}) was at par with 100 per cent NPK + FYM (T_8) with the value of 51.91 q ha^{-1}. These two treatments (T_8 and T_{10}) were significantly higher than rest of all the treatments, while control (T_{12}) was significantly lower than all the treatments as far as the grain yield of maize was concerned.

Hand weeding (T_4) treatment increased maize yield by about 14 per cent over chemical weed control (T_2). It is noteworthy that the application of super optimal dose of NPK i.e. 150 per cent of recommended NPK did not show any beneficial effect on maize productivity, rather it declined the productivity by about 13 per cent as compared to recommended dose of NPK (T_2). Application of zinc did not show any beneficial effect on productivity of maize. Further, omission of potassium (T_6) and sulphur (T_9) from fertilization schedule resulted in significant reduction in grain yield as compared to 100 per cent NPK. The grain yield in 100 per cent NP (T_6) was 15.74q ha^{-1}. The treatment T_6 declined the productivity by about 60 per cent as compared to recommended dose of NPK (T_2). The grain yield in 100 per cent NPK (-S) (T_9) was 14.89 q ha^{-1}. The treatment 100 per cent NPK (-S) (T_9) declined the productivity by about 63 per cent as compared to recommended dose of NPK (T_2). It is noteworthy that reduction in yield was more with the omission of sulphur as compared to potassium. This highlights the significance of sulphur nutrition in maize cultivation. The statistics clearly revealed that using manure or lime as amendments in combination with the recommended dose of NPK resulted in higher maize yield than the sole application of NPK. The grain yield recorded in natural farming plots was significantly lower as compared to other treatments except control.

The trend in case of stover yield under various treatments was similar to grain yield. Barring T_7, stover yield ranged from 13.78 q ha^{-1} (control) to 95.11 q ha^{-1} (100 per cent NPK + FYM). The stover yield (89.55 q ha^{-1}) with the application of lime (T_{10}) was statistically at par with 100 per cent NPK + FYM (T_8) (95.11 q ha^{-1}). These two treatments recorded significantly higher stover yield than rest of the treatments. Similar to grain yield, there was significant reduction in stover yield with the omission of either potassium or sulphur from the fertilization schedule as compared to 100 per cent NPK. However, it was significantly higher in both the plots compared to control (T_{12}). Like grain yield, stover yield in natural farming plots was also significantly lower as compared to other treatments except control.

Productivity of wheat

The data pertaining to wheat grain and straw yield have been presented in table 1. It was observed that with the continuous application of 100 per cent N alone through urea for the forty-seven years the yield

Table 1. Effect of long-term use of fertilizers and amendments on productivity of maize and wheat

Treatment	Productivity (q ha^{-1})					
	Maize 2019			Wheat 2019-20		
	Grain	Stover	Biological	Grain	Stover	Biological
T1: 50% NPK	40.30	66.44	106.75	16.78	27.33	44.11
T2: 100% NPK*	39.67	65.11	104.78	17.06	27.78	44.83
T3: 150% NPK*	35.22	58.67	93.89	16.00	24.89	40.89
T4: 100% NPK + Hand Weeding (HW)	45.17	75.56	120.73	19.67	32.45	52.11
T5: 100% NPK + Zn ($ZnSO_4$@ 25 kg ha^{-1})	39.39	67.33	106.72	16.67	26.89	43.55
T6: 100% NP	15.74	26.44	42.18	8.22	13.33	21.56
T7: 100% N	0.00	0.00	0.00	0.00	0.00	0.00
T8: 100% NPK + FYM@10 t ha^{-1} (to maize crop only)	54.77	95.11	149.89	28.11	44.67	72.78
T9: 100% NPK (-S)), P through DAP	14.89	25.33	40.23	7.55	12.22	19.77
T10: 100% NPK + lime @ 900 kg ha^{-1}	51.91	89.55	141.46	26.55	43.78	70.33
T11: Natural Farming**	11.27	19.23	30.50	5.45	10.23	15.68
T12: Control	7.59	13.78	21.37	4.11	6.89	11.00
CD (P = 0.05)	4.96	8.66	13.59	1.99	3.92	5.82

** Natural Farming (Application of *Beejamrita* + *Ghanajeevamrita* + mulch + spray of *Jeevamritaat* 21 days interval)

*100 per cent NPK application rate corresponds to the state level recommendation for respective nutrients (i.e. 120 kg N and 60 kg P_2O_5 ha^{-1} to both maize and wheat and 40 and 30 kg K_2O ha^{-1} to maize and wheat, respectively).

in 100 per cent N had declined to zero. Among rest of the treatments, the grain yield varied from 4.11 q ha^{-1} (control) to 28.11 q ha^{-1} (100 per cent NPK + FYM). It is clear from the data that application of fertilizers either alone or in combination with amendments (FYM and lime) increased grain yield of wheat significantly. Yield recorded under 100 per cent NPK + FYM (28.11 q ha^{-1}) was at par with 100 per cent NPK + lime (26.55 q ha^{-1}). The plots where Zn was applied along with 100 per cent NPK (T_5), grain yields were found to be at par with 100 per cent NPK alone, the value being 16.67 q ha^{-1}. The addition of P in combination with N showed marked increase in wheat productivity over N alone and control treatment. Like maize, the continued absence of potassium and sulphur in crop nutrition led to drastic decline in the wheat yield. The treatment 100 per cent NP (T_6) recorded 52 per cent lower yield as compared to recommended dose of NPK (T_2). The omission of sulphur declined the productivity by about 56 per cent as compared to recommended dose of NPK (T_2). Like maize, reduction in wheat yield was more when sulphur was omitted as compared to potassium. The grain yield recorded in natural farming plots was significantly lower as compared to other treatments except control.

Barring T_7, straw yield ranged from 6.89 q ha^{-1} (control) to 44.67 q ha^{-1} (100 per cent NPK + FYM). The straw yield in 100 per cent NPK + lime was 43.78 q ha^{-1}. This was statistically at par to 100 per cent NPK + FYM and both of these treatments were significantly superior to rest of the treatments. The plots where Zn (T_5) or 150 per cent NPK (T_3) were applied, straw yield of wheat was found to be at par with 100 per cent NPK (T_2). The straw yields in the absence of potassium (T_6) and sulphur (T_9) were significantly higher than zero-fertilized plots (T_{12}) but significantly lower than the balanced fertilized plots (T_2). Like grain yield, straw yield in natural farming plots was also significantly lower as compared to other treatments except control.

The highest maize and wheat yield obtained in 100 per cent NPK + FYM (T_8), might be due to the addition of organic manure along with inorganic fertilizers, which might have improved the soil organic matter content and supplied not only the additional quantities of NPK directly, but also secondary and micro nutrients (Singh *et al*. 2019a). It might also be attributable to improved physical, chemical and biological properties of the soil as a result of continuous FYM application, which created a favourable environment for plant growth and nutrient uptake (Mishra *et al*. 2008; Patial *et al*. 2022). The response of added FYM in combination with chemical fertilizers is generally ascribed to the beneficial effects on soil productivity. The organic manures supply complexing agents to the soil which maintain balanced supply of nutrients to the plants. The insoluble nutrients present in soil are solubilized due to fulvic acid and humic acid liberated from the organic materials and become available to plants for their growth (Kumari et al. 2013). These results are in line with the findings of Chauhan et al. (2020) and Anjali (2022).

Application of lime improved maize and wheat productivity which might be due to increase in soil pH, decrease in the active forms of Al and soil acidity, reduction in P fixation and increase in Ca and Mg content in soil, thereby providing favourable conditions for crop growth (Kaushal 2006). These findings corroborate the findings of Kumar *et al*. (2020), Bharti *et al*. (2021) and Patial *et al*. (2022). Application of N alone (T_7) declined the soil pH which might be due to the release of hydrogen ions during nitrification of ammonical ions produced after the hydrolysis of urea. The decline in pH might have increased the concentration of Al and Fe ions to toxic levels, thus resulted in zero yield of maize and wheat. Singh *et al*. (2019b) have also reported complete degradation of soil in plots treated with nitrogen alone over a period of time and thereby resulting in zero yields. Deleterious effects of use of nitrogen alone on crop production have also been reported by a number of workers in the country (Chauhan *et al*. 2018 and Anjali 2022).

The low yield levels of both the crops over the years in control plots might be due to the mining of nutrients, absence of external supply of nutrients and poor inherent capacity of the soils under study to meet the requirement of crops in respect of the essential nutrients and may also be due to decrease in soil organic carbon content (Shambhavi *et al*. 2017; Chauhan *et al*. 2020). Decline in maize and wheat yield was recorded in the treatment where recommended dose of P was applied through DAP (S-free fertilizer) in place of SSP. The DAP in comparison to SSP contains 46 per cent P but no sulphur and calcium. Its continuous use has therefore, led to depletion of S reserves in the soil resulting in drastic reduction in the crop yields (Kundu *et al*. 2016). These are in line with the findings of Singh *et al*. (2019a) and Chauhan *et al*. (2020).

The application of super-optimal level of NPK (150 %) decreased the yield of maize and wheat probably due to emerging deficiencies of secondary and micro nutrients particularly Mg (Das et al. 2012). While, comparatively lower yields in sub-optimal level of NPK (50 %) might be due to inadequate supply of nutrients as compared to optimal treatment and thus, sustained yield at low levels. The increase in yield of both the crops under 100 per cent NPK + HW treatment over 100 per cent NPK might be due to the increase in soil organic matter content under this treatment as a result of recycling of weed biomass, leading to improvement in the physico-chemical properties and microbial processes in the soil (Babita 2010).

Application of phosphorus along with nitrogen considerably increased yield of maize and wheat compared to the application of nitrogen alone. A better supply of phosphorus has been associated with proliferous root growth resulting in enhanced water and nutrient absorption. The yield of maize declined in later years due to continuous mining of potassium resulting in depletion of its native reserves. The absence of potassium from fertilization schedule resulted in potassium deficiency in soil. Since potassium is required for activation of enzymes, starch synthesis, nitrogen uptake and protein synthesis, its deficiency in soil might have led to decreased maize and wheat yield (Chaudhary *et al*. 2018). It does not enter into the structural composition of any part of the plant, yet plays an important role in maintaining the vigour of plant. The low yield in natural farming plots might be due to insufficient supply of nutrients to the crop throughout the growth period as both maize and wheat are exhaustive crops having high nutrient requirement.

Conclusions

Long-term integrated use of inorganic fertilizers and organic manure (FYM) found superior in comparison to alone application of inorganic fertilizers to sustain the crop productivity in a maize-wheat cropping system grown on an acid *Alfisol* in northern India. Continuous omission of potassium and sulphur for the last forty seven years reduced the productivity of both the crops significantly in comparison to balanced fertilization. Results of more than four decades of experimentation suggested that the recommended dose of fertilizers along with organic manure is a viable option for restoring soil organic carbon and nutrient turnover, thereby improving the productivity of both the crops for the long run under irrigated moisture regimes. Application of lime in combination with 100 per cent NPK also recorded higher productivity of both the crops. The grain and stover/straw yield recorded in natural farming plots was significantly lower as compared to other treatments except control. Therefore, it is inferred from the study that it is necessary to apply nutrients in a balanced manner to check the degradation of soil health.

Conflict of interest: The authors declare that there is no conflict of interest in this research paper.

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