Journal of Soil and Water Conservation **20**(1): 100-106, January-March 2021
ISSN: 022-457X (Print); 2455-7145 (Online); DOI: 10.5958/2455-7145.2021.00013.8

Productivity and NPK uptake by maize as influenced by conjunctive use of FYM, lime and fertilizers in an acid Alfisol

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Received: 29 October 2020; Accepted: 07 January 2021

ABSTRACT

A field experiment was conducted on maize crop during *kharif* 2019 at experimental farm of the department of Soil Science, CSKHPKV, Palampur to study the effect of conjoint use of FYM and lime along with recommended dose of fertilizers on yield and NPK uptake by maize in acid soils of Palampur (Himachal Pradesh). The experiment was laid out in a randomized block design with eleven treatments replicated thrice. Results revealed that integrated use of FYM and lime along with recommended dose of fertilizers recorded significantly higher grain and stover yield as compared to separate use of FYM or lime with recommended dose of fertilizers. Application of 100% NPK + 10 t FYM/ha + lime incorporation @ 100% Lime Requirement (LR) showed a yield response of 22.4 q/ha, 12.9 q/ha and 13.9 q/ha over 100% NPK alone (T_2), 100% NPK + 10 t FYM/ha and 100% NPK + lime incorporation @ 100% LR, respectively. The grain yield of maize (34.90 q/ha) recorded under 100% NPK + 10 t FYM/ha + lime incorporation @ 1/10th LR in furrow was at par with 100% NPK + 10t/ha FYM/ha + lime incorporation @ 100% LR (36.48 q/ha). Integrated use of FYM, lime and 100% NPK increased the NPK uptake significantly over 100% NPK. The highest N, P and K uptake was recorded in 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR. Hence, it can be inferred from the study that conjunctive use of FYM and lime along with optimal doses of fertilizers is essential to enhance the productivity of maize in acid soils. The dose of lime can be reduced by applying lime in furrow instead of broadcasting.

Key words: FYM, Lime, Maize, Uptake, Grain and Stover Yield

INTRODUCTION

Maize, one of the most important cereal crops of the world, is the third leading cereal crop of the world after rice and wheat (Ramzani *et al*., 2017). It is major source of food, feed, fodder and industrial raw material and provides enormous opportunity for crop diversification, value addition and employment generation. It is one of the most versatile crops with wider adaptability in diverse ecologies and can be grown under varied agroclimatic conditions. It is characterized by a genetic diversity of a very high order that imparts it a very favourable position towards meeting the emerging challenges. In India, it occupies an area of 9.18 million ha with the total production and productivity of 27.23 million tonnes and 26.65 q/ha, respectively (Anonymous, 2018a). In Himachal Pradesh, the total production of maize is 0.74 million tonnes with the productivity of 26.72 q/ha on an area of 293 thousand hectares (Anonymous, 2018b).

Maize, being an exhaustive crop, has very high nutrient demand. Achieving high maize yield requires adequate and balanced supply of plant nutrients as declining soil fertility is a prominent constraint for maize production (Sharma and Arora, 2008, 2010). Among other crop production constraints, soil acidity has been recognized as one of the important production problems across the globe. Soil acidity is a serious problem in more than 30 per cent of the world's land and affecting nearly 50 per cent of the world's potentially arable land (von Uexkull and Mutert, 1995). Approximately one-third of the cultivated land in India is affected by soil acidity (Mandal, 1997). A considerable area (25-30%) in six districts of the state i.e., Chamba, Kangra, Kullu, Shimla, Mandi and Sirmour is occupied by acid soils (Sharma *et al*., 2006). Crop productivity on such soils is mostly constrained by aluminium and iron toxicity, phosphorus deficiency, poor supply of calcium and magnesium, low base saturation, impaired biological activity

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and other acidity-induced soil health and plant nutritional problems (Kumar *et al*., 2012). Soil acidity management *vis-a-vis* crop productivity improvement on such soils needs immediate attention of researchers and policy planners for enhancing food security globally and regionally. Amelioration of soil acidity is the need of hour to double the income of farmers by the year 2022 as productivity is comparatively low in acid soils.

Liming is an effective practice in enhancing crop yield particularly in regions affected by acid soils. Lime incorporation along with judicious use of different sources of nutrients is recommended to increase the availability of essential nutrients to plants and ameliorate other acidity-induced soil health constraints on such soils and plant nutritional problems (Kumar *et al*., 2012). The use of lime is a potential option for sustainable management of soils for restoring soil health of acid soils. The combined use of organic manure and balanced fertilizers has been reported to help in improving crop growth, uptake of nutrients, and yield of maize (Sharma *et al*., 2014; Li *et al*., 2017). In the earlier studies pertaining to lime application in the state, its effect was not evaluated in association with FYM. So, there was an urgent need to generate information on the performance of integrated use of inorganic as well as organic amendments in maize. Keeping in view, the scanty information available on the combined effect of FYM and lime along with fertilizers on productivity and NPK uptake by maize, the present study was undertaken in an acid Alfisol. Moreover, the information on the performance of natural farming treatment in comparison to State recommended dose of fertilizers pertaining to productivity and NPK uptake was also lacking.

MATERIALS AND METHODS

The experiment was carried out at the Research farm of the department of Soil Science, CSKHPKV, Palampur, situated at $32^0 7'$ N latitude and $76^0 31'$ E longitude in Kangra district of Himachal Pradesh during *kharif* 2019. The soil of the experimental site was silt loam in texture and classified as *Typic Hapludalf*. The soil was acidic in reaction with pH 5.49. The contents of organic carbon, available N, available P and available K were 8.34 g/kg, 291 kg/ha, 11.1 kg/ha and 228 kg/ha, respectively. There were eleven treatments which were replicated three times in a randomized block design. The treatments were as follows: T_1: control; T_2: 100% NPK; T_3: 100% NPK + 5 t FYM/ha; T_4: 100% NPK + 10 t FYM/ha; T_5: 100% NPK + lime incorporation @ 100% LR; T_6: 100% NPK + lime incorporation @ $1/10^{th}$ LR, T_7: 100% NPK + 5 t FYM/ha + lime incorporation @ 100% LR; T_8: 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR; T_9: 100% NPK + 5 t FYM/ha + lime incorporation @$1/10^{th}$ LR in furrow, T_{10}: 100% NPK + 10 t FYM/ha + lime incorporation @ $1/10^{th}$ LR in furrow and T_{11}: *Beejamrita* + *Jeevamrita* + *Ghanajeevamrita* (Natural Farming). The treatment T_{11} was included to compare natural farming treatment with the already existing nutrient management practices recommended by the CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur. The study was conducted on maize (variety Bajaura Makka). The recommended dose for maize crop is 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. The sources of N, P and K were urea, single super phosphate and muriate of potash, respectively for all treatments except T_1 (control) and T_{11} (natural farming). Half dose of N and full doses of P_2O_5 and K_2O were applied as basal dose. The remaining half N was top dressed in two equal splits at knee high and pre-tasseling stage. In treatment T_{11}, practices of natural farming were followed. *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. Application of *Jeevamrita* @ 500 l/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. The lime requirement (LR) was determined by SMP buffer method (Shoemaker *et al*. 1961) and agricultural lime ($CaCO_3$) was used as source of lime. It was applied @ 100% LR through broadcasting in the soil and @ $1/10^{th}$ LR in furrows. After the harvest of crop, grain and stover samples were collected and NPK contents were determined using standard methods to calculate the uptake.

RESULTS AND DISCUSSION

Grain and stover yield of maize

The significant difference in grain and stover yield of maize with integrated use of FYM and lime along with optimal dose of fertilizers was recorded. The grain and stover yield of maize varied from 4.58 q/ha and 8.61 q/ha in control to 36.48 q/ha and 58.06 q/ha in 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR, respectively (Table 1). All the treatments increased grain and stover yield of maize significantly over control except T_{11} but the increase was more distinct under integrated use of FYM and lime along with inorganic fertilizers (T_7 to T_{10}).

Table 1. Effect of conjoint use of FYM, lime and fertilizers on maize yield

Treatment	Yield (q/ha)	
	Grain	Stover
T_1: Control	4.58	8.61
T_2: 100% NPK	14.12	24.11
T_3: 100% NPK + 5 t FYM/ha	18.44	30.56
T_4: 100% NPK + 10 t FYM/ha	23.56	38.05
T_5: 100% NPK + lime incorporation @ 100% LR	22.50	35.83
T_6: 100% NPK + lime incorporation @ 1/10th LR in furrow	18.93	31.11
T_7: 100% NPK + 5 t FYM/ha + lime incorporation @ 100% LR	32.29	51.39
T_8: 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR	36.48	58.06
T_9: 100% NPK + 5 t FYM/ha + lime incorporation @ 1/10th LR in furrow	28.76	45.83
T_{10}: 100% NPK + 10 t FYM/ha + lime incorporation @ 1/10th LR in furrow	34.90	54.72
T_{11}: *Beejamrita + Jeevamrita + Ghanajeevamrita*	5.65	13.83
CD (P=0.05)	3.69	6.17

Application of FYM or lime along with optimal dose of fertilizers increased the grain and stover yield of maize significantly over 100% NPK alone. It was observed that application of FYM @ 5 t /ha (T_3) and 10 t /ha (T_4) along with 100% NPK resulted in 30.6 and 66.9% higher grain yield over 100% NPK alone, respectively. Similarly, lime incorporation @ 1/10th LR in furrow (T_6) and 100% LR (T_5) recorded an increase of 34.1 and 59.3 per cent in grain yield over 100% NPK, respectively. Similar trend was observed in stover yield.

Compared to 100% NPK + 10 t FYM/ha (T_4) and 100% NPK + lime incorporation @ 100% LR (T_5), integrated use of optimal dose of fertilizers along with 10 t FYM/ha and lime incorporation @ 100% LR (T_8) recorded an increase of 54.8 and 62.1 per cent in grain yield, respectively. It is clear from the data that the conjoint use of FYM and lime with recommended dose of NPK resulted in significantly higher yield of maize as compared to separate use of FYM or lime along with recommended dose of NPK.

It is noteworthy that the grain (36.48 q/ha) and stover (58.06 q/ha) yield recorded in 100% NPK + 10 t FYM/ha + lime @ 100% LR (T_8) was statistically at par with the grain (34.90 q/ha) and stover (54.72 q/ha) yield recorded in 100% NPK + 10 t FYM/ha + lime incorporation @ 1/10th LR in furrow (T_{10}). Similarly, grain and stover yield in T_7 and T_9 was found to be statistically at par. From this, it can be inferred that the dose of lime can be reduced to 1/10th of lime requirement through furrow application instead of broadcasting without significant reduction in yield.

Increase in yield with application of FYM could be attributed to balanced amount of nutrients supplied through FYM and improvement in soil physical and biological properties which might have promoted root growth resulting in greater nutrient and water absorption leading to better crop yield. These results are in conformity with the findings of Ram *et al*. (2016), Holik *et al*. (2018), Macholdt *et al*. (2019), Singh *et al*. (2019) and Thakur *et al*. (2021). The positive effect of FYM may also be ascribed to removal of aluminium and other toxic substances from soil solution. Use of lime boosted the maize yield which might be ascribed to the amelioration of soil acidity which might have lowered the toxicity due to aluminium and hydrogen, increase in availability of Ca, Mg, and improvement in cation exchange capacity and pH leading to improved physical and biological properties of soil (Shambhavi *et al*., 2018; Dhiman *et al*., 2019; Thakur *et al*. 2019; Chauhan *et al*., 2020; Thakur *et al*., 2021). The increase in yield due to combined effect of FYM, lime and inorganic fertilizers has been reported by Kumar (2015a) and Fekadu *et al*. (2018). The low yield in plots under natural farming can be attributed to inadequate supply of nutrients to the crop during growth period. The yield recorded in control was lowest due to non-addition of fertilizers causing mining of nutrients, decline of chemical, physical and biological properties of soil thus resulting in poor soil productivity.

Nitrogen uptake

The conjunctive use of FYM, lime and chemical fertilizers influenced nitrogen uptake by maize significantly compared to sole use of fertilizers. Nitrogen uptake by maize grain and stover was observed to range from 5.73 and 5.18 kg/ha in

control (T_1) to 61.14 and 43.63 kg/ha in 100% NPK + 10 t FYM/ha + lime @ 100% LR (T_8), respectively (Table 2). It was noted that integrated use of 100% NPK and FYM or lime (T_3 to T_6) recorded significantly higher N uptake by grain and stover over 100% NPK alone (T_2). Further, the combined application of FYM and lime along with optimal dose of fertilizers (T_7 to T_{10}) recorded significantly higher N uptake by grain and stover over rest of the treatments (T_1 to T_6 and T_{11}).

The separate as well as combined application of FYM and lime with recommended dose of NPK increased the total N uptake significantly over 100% NPK alone. Application of 10 t FYM/ha (T_4) and lime @ 100% LR (T_5) resulted in increase in total N uptake to the extent of 81.3 and 60.8 per cent over 100% NPK, respectively. The plots receiving 100% NPK + lime (full dose through broadcasting) (T_5) recorded N uptake statistically at par with furrow application of $1/10^{th}$ dose of lime + 100% NPK (T_6). The treatments comprising 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8) and 100% NPK + 10 t FYM/ha + lime incorporation @ $1/10^{th}$ LR in furrow (T_{10}) were statistically at par with respect to total N uptake. Compared to 100% NPK (T_2), the treatments T_8 and T_{10} recorded an increase of 69.4 and 61.1 kg/ha in total N uptake.

Nutrient uptake is a function of yield and nutrient concentration in plant. Therefore, the trend of nutrient uptake resembled well with yield of different treatments. Conjoint use of organic manures along with mineral fertilizers increased the N uptake over sole use of fertilizers which may be attributed partly to addition of nitrogen from decomposition of FYM and partly to improvement in overall soil environment. It might have resulted in root proliferation, ultimately leading to better absorption of water and nutrients from soil and applied fertilizers. Such beneficial effect of FYM on N uptake has also been reported earlier by different researchers (Sindhi *et al*., 2016; Kumari *et al*., 2017; Gourav *et al*., 2019). The increase in N uptake due to liming may be ascribed to increase in microbial activity which, in turn, might have enhanced the mineralization of organic N thereby releasing more N in the soil (Meena *et al*., 2017; Otieno *et al*., 2018; Gourav *et al*., 2019).

Phosphorus uptake

Application of FYM or lime along with 100% NPK significantly improved the P uptake over control and 100% NPK alone (Table 2). The treatments comprising integrated use of 100% NPK + FYM + lime (T_7 to T_{10}) increased P uptake significantly over other treatments. The highest P uptake by maize grain recorded in 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8) was statistically at par with 100% NPK + 10 t FYM/ha + lime incorporation @ $1/10^{th}$ LR in furrow (T_{10}). The increase in P uptake by maize grain due to

Table 2. Effect of conjoint use of FYM, lime and fertilizers on N, P and K uptake by maize

Treatment	Uptake (kg/ha)								
	N			P			K		
	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
T_1: Control	5.73	5.18	10.91	1.44	0.48	1.92	1.47	5.06	6.53
T_2: 100% NPK	19.86	15.52	35.38	4.68	1.70	6.38	5.26	16.00	21.26
T_3: 100% NPK + 5 t FYM/ha	27.72	20.61	48.33	6.25	2.15	8.40	7.24	22.00	29.24
T_4: 100% NPK + 10 t FYM/ha	37.28	26.85	64.13	8.19	3.08	11.27	9.57	28.65	38.22
T_5: 100% NPK + lime incorporation @ 100% LR	33.15	23.73	56.88	8.26	3.31	11.57	8.49	25.04	33.53
T_6: 100% NPK + lime incorporation @ $1/10^{th}$ LR in furrow	27.58	20.33	47.91	6.61	2.57	9.18	6.80	21.92	28.72
T_7: 100% NPK + 5 t FYM/ha + lime incorporation @ 100% LR	52.07	35.90	87.97	12.35	5.06	17.41	12.60	38.18	50.78
T_8: 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR	61.14	43.63	104.77	14.32	6.56	20.88	15.30	48.16	63.46
T_9: 100% NPK + 5 t FYM/ha + lime incorporation @ $1/10^{th}$ LR in furrow	46.12	31.60	77.72	10.46	4.12	14.58	11.23	34.22	45.45
T_{10}: 100% NPK + 10 t FYM/ha + lime incorporation @ $1/10^{th}$ LR in furrow	57.34	39.17	96.51	13.03	5.50	18.53	14.63	43.96	58.59
T_{11}: *Beejamrita + Jeevamrita + Ghanajeevamrita*	7.79	6.65	14.44	1.67	0.63	2.30	1.61	6.58	8.19
CD (P=0.05)	6.30	4.20	9.28	1.37	0.93	1.76	1.44	4.69	5.90

application of 10 t FYM/ha (T_4) and lime incorporation @ 100% LR (T_5) over 100% NPK was 75.0 and 76.5 per cent, respectively. It was observed that P uptake in 100% NPK + lime incorporation @ 100% LR (T_5) was significantly higher than 100% NPK + lime incorporation @ 1/10th LR in furrow (T_6), the increase being 25 per cent.

Compared to 100% NPK, T_7 and T_9 recorded 7.67 and 5.78 kg/ha higher P uptake respectively. The plots under natural farming (T_{11}) recorded significantly lower uptake of P by maize grain over 100% NPK, the decrease being 64.3 per cent. Similar trend was observed in case of P uptake by maize stover.

The total uptake by maize varied from 1.92 in control (T_1) to 20.88 kg/ha in 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8). Conjoint application of FYM, lime and 100% NPK (T_7 to T_{10}) increased the total P uptake by maize significantly as compared to rest of the treatments. The natural farming treatment did not increase the total P uptake over control significantly.

The increase in P uptake with addition of FYM might be due to release of P during mineralization of organic P and chelating action of organic acids released during decomposition of FYM on Al, Fe and Mn thereby increasing P availability. Similar results have been reported by Sharma *et al*. (2016), Meena *et al*. (2017) and Gourav *et al*. (2019). The higher P uptake due to application of lime might be ascribed to the reduction in P fixation by decreasing the activity of Al and Fe ions, which are potential P fixers, thereby increasing P availability to the crops (Rajneesh *et al*., 2017; Otieno *et al*., 2018; Verde *et al*., 2018; Gourav *et al*., 2019).

Conjoint application of FYM, lime and 100% NPK significantly improved the P uptake which might be due to the beneficial effect of FYM and lime. The results corroborate the findings of Fekadu *et al*. (2018). The low P uptake in plots under control and natural farming can be ascribed to the low P availability under these treatments which adversely affected the crop growth and P uptake drastically.

Potassium uptake

Integrated use of FYM, lime and 100% NPK (T_7 to T_{10}) increased the K uptake by maize grain significantly over individual application of FYM or lime with recommended dose of NPK fertilizers (Table 2). The increase in K uptake due to application of 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8) and 100% NPK + 10 t FYM/ha + lime incorporation @ 1/10th LR in furrow (T_{10}) was to the extent of 10.04 and 9.37 kg/ha over 100% NPK alone, respectively.

The K uptake by maize stover was higher than K uptake by maize grains in all the treatments. The K uptake by maize stover recorded in plots under 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8) and 100% NPK + 10 t FYM/ha + lime incorporation @ 1/10th LR in furrow (T_{10}) was significantly superior to rest of the treatments and led to increase of 32.16 and 27.96 kg/ha K uptake over 100% NPK, respectively.

The total K uptake by maize ranged from 6.53 kg/ha in control (T_1) to 63.46 kg/ha in 100% NPK + 10 t FYM/ha + lime incorporation @ 100% LR (T_8). Addition of FYM or lime in combination with 100% NPK improved the total K uptake significantly over 100% NPK. Application of FYM @ 10 t/ha (T_4) and lime @ 100% LR (T_5) along with optimal dose of fertilizers registered 79.8 and 57.7 per cent increase in total K uptake over 100% NPK, respectively. Control plots recorded lowest value of total K uptake followed by natural farming treatment.

Higher K uptake with incorporation of FYM might be ascribed to the favourable soil environment leading to improved crop growth, apart from the additional supply of K through FYM. The results corroborate the findings of Mishra and Mahapatra (2016), Sindhi *et al*. (2016), Meena *et al*. (2017) and Gourav *et al*. (2019). Positive effect of lime on K uptake could be attributed to the improvement in soil environment for crop growth and consequently higher crop yield. Another reason for increase in K uptake may be the release from non-exchangeable form and also due to reduction in K fixation by liming. Similar findings have been reported by Meena *et al*. (2017), Rajneesh *et al*. (2017) and Gourav *et al*. (2019) in acid soils of Palampur. Similarly, the positive effect of integrated use of FYM, lime and fertilizers on K uptake has been reported by Kumar (2015b). The low uptake of K in treatments under control (T_1) and natural farming (T_{11}) can be ascribed to the low availability of nutrients for crop growth and subsequently low crop yields.

CONCLUSION

Results from the present investigation indicated that conjunctive use of FYM and lime along with recommended dose of chemical fertilizers recorded significantly higher maize yield than individual use of FYM or lime with recommended dose of NPK. The yield recorded under 100% NPK + FYM @ 10t/

ha + lime incorporation @ 1/10th LR in furrow was at par with 100% NPK + FYM @ 10t/ha + lime incorporation @ 100% LR which clearly demonstrated that dose of lime can be reduced to 1/10th of lime requirement through furrow application treatment. Hence, with the furrow application of lime we can save the quantity of the lime to be applied. Further, it was found that the productivity under the natural farming treatment was far below the existing recommended dose of nutrients. Application of FYM, lime and recommended dose of fertilizers increased the uptake of nutrients in terms of N, P and K significantly over separate application of FYM or lime with recommended dose of fertilizers. It can be concluded from the study that conjoint use of inorganic and organic sources of nutrients along with lime is essential to realize reasonably higher productivity of maize in acid soils.

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