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Effect of different nutrient management practices on yield and nutrient uptake by maize in an acid Alfisol of North-West Himalayas

Sanjay K Sharma[1] • Chandan Thakur[1] • Dhanbir Singh[1] • Pawan Pathania[2] • SakshiVishvamitera*[1]

[1]Department of Soil Science, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur-176062

[2]Department of Agronomy, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur-176062

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ABSTRACT

The present investigation was carried out to standardise the best nutrient management practice for maize *cv.*BajauraMakka in an acid hill soil. The experiment consisted of three replications in a randomized block design having eleven treatments comprising recommended NPK levels, and, their integration with FYM, and lime, organic farming package, three Natural Farming System (NFS) practices involving formulations based on excreta of indigenous (*Desi*) cows, crossbred cows and buffalo, and their supplementation with 25 per cent of recommended NPK. The results showed that the highest grain (42.25 q ha^{-1}),stover (71.82 q ha^{-1}) and total biological yield was recorded under RDF + FYM @ 10 t ha^{-1}. Among organic treatments, higher grain (29.13 q ha^{-1}) and total biological yield (65.01 q ha^{-1}) was recorded under organic farming practices followed by NFS-*Desi* cow (20.64 and 50.98 q ha^{-1}, respectively). The highest total N (147.53 kg ha^{-1}), P (34.19 kg ha^{-1}) and K (97.36 kg ha^{-1}) uptake by maize crop was recorded under RDF + FYM @ 10 t ha^{-1} which produced non-significant differences with RDF + lime. Among integrated organic treatments, organic farming practices + 25 per cent NPK recorded higher total NPK uptake followed by NFS-*D*esi cow+ 25 per cent NPK. The lowest grain (17.75 q ha^{-1}), stover (25.56.q ha^{-1}), total biological yield (43.30 q ha^{-1}) and total nutrient uptake (56.91 N, 13.66 P and 33.60 K kg ha^{-1}) by maize was recorded under NFS-buffalo treatment. Our results could provide a better understanding of the significance of integration of inorganic fertilizers with organic manure in maintaining soil fertility and thus, enhancing nutrient uptake, crop quality and production.

1. Introduction

Maize (*Zea mays* L.) is one of the most important grain crops, feeding more than 900 million people in underdeveloped nations, including India. It serves as a raw material for production of alcoholic drinks, food sweeteners, protein, oil, starch as well as a source of fuel. As per reports of FAOSTAT (2020), approximately 193.7 M ha area had been under maize cultivation globally in 2019–2020, producing nearly 1147.7 MT with an average productivity of 5.75 t ha^{-1}. The United States contributed 34% of world's maize production (FAOSTAT 2020) and is the topmost producer of crop. In India, maize covered an area of 9.3 M ha with production of 29 MT and the average productivity was 3.1 t ha^{-1} that accounted only 2% to the world's total production in 2019–2020 (USDA 2020). Out of the total cultivated area of the country, maize covers approximately 4 per cent and accounts for 9% of total food grain production. Because of its photo-thermo-insensitive nature, it can be produced throughout the year in a variety of agro-climatic zones (Yadav*et al.*, 2015). In India, maize is consumed mostly for food purpose, accounting approximately 28% of total maize production in the country. Being "Queen of Cereals", maize is an extremely nutrient exhaustive crop owing to its high genetic potential and fast growth habits. It requires more nitrogen (N), phosphorus (P) and potassium (K) for the proper development of all growth stages. In order to achieve high yield and maintain soil fertility, essential nutrient elements are required to be provided in an appropriate amount (Gezahegn 2021).

*Corresponding author: sakshivishvamitera@gmail.com

Between 1960 and 2015, global agricultural productivity raised more than triple (FAO 2017) aided by Green Revolution technologies (*viz.*, chemical fertilizers, pesticides, high yielding varieties etc.), which increased yields and revenues in comparison to traditional ways (Griggs 2001; Panneerselvam 2011). As a consequence, intensive, high-input agriculture reliant on chemical fertilizers, insecticides, irrigation and other chemicals emerged which has resulted in deteriorating soil health, low productivity, environmental damage, low quality produce and adverse health effects (Connor and Minguez 2012; Bhattacharyya *et al.*, 2015). In order to combat these adverse situations, more environmental-friendly and focused solutions such as sustainable intensification and agroecology has been promoted as alternative approaches to agriculture production which comply more closely with the UN Sustainable Development Goals (Rockstrom*et al.*, 2017; Wezel*et al.*, 2020). Consequently, a number of management practices have been developed that are supposed to be more sustainable substitutes to high-input traditional farming systems.

The appropriate and conjunctive application of suitable plant nutrients through combination of organic manures with inorganic fertilizers can provide the solutions to many problems *viz.,* increased price of inorganic fertilizers, deterioration effect on soil fertility and low productivity. Integrated nutrient management (INM) refers to the application of soil fertility management practices that maximize fertilizer and organic resource use efficiency to enhance crop production. Many researchers have also emphasized on the positive effect of INM practices on growth, yield attributes and NPK uptake by maize as compared to sole application of chemical fertilizers or organic manures (Panwar 2008; Samsul*et al.*, 2012; Kernal and Abera 2015; Almaz*et al.,* 2017; Negi*et al.*, 2021).

Organic farming has also gained popularity in India in recent years due to its high-quality produce, profitability per unit of produce and environmental safety (Thangasamy*et al.*, 2018). India had the most organic producers worldwide by 2015 (Willer and Lernoud 2017). In addition, when compared to traditional practices, organic farming has the potential to alleviate environmental concerns by eliminating the usage of chemical fertilizers and pesticides. However, switching from conventional to organic agriculture can result in poorer yields (Ponisio*et al.,* 2015) and less production consistency over time (Knapp and Van Der Heijden 2018). This will obviously have ramifications for food security, and whether organic farming can feed the globe without encroaching on natural ecosystems still remains questionable.

Another management system which has the potential to address both environment and socio-economic concern is 'Natural Farming System' (NFS). It refers to the use of homemade amendments from easily and readily available ingredients such as cow dung, cow urine, pulse flour, jaggery etc. which are intended to promote beneficial soil microbes, water retention, close nutrient cycling loops and ultimately, good soil health (Bharucha*et al.,* 2020; Smith *et al.*, 2020). However, SubhashPalekar Natural Farming (SPNF) system emphasizes the use of excreta from '*Desi*' cows only. Therefore, its applicability would be quite limited, as in our country, most of the farmers are rearing either crossbred cows or buffaloes. Most importantly, very less or no research work has been done on the effect of use of NFS formulations prepared using products of these cattle (crossbred cows or buffalo) on crop. Hence, there is a great need to evaluate the efficacy of NFS formulations prepared using the excreta and other products from these cattle, and also their integrated use with little quantity of chemical fertilizers.

In the coming decades, maize might be the most important future cereal crop as being a C_4plant, it has the potential to perform better under conditions of climate change. The lower yield levels of maize in India offers plenty of opportunities to enhance its productivity through the adoption and subsequent promotion of improved and better nutrient management practices.

However, the lack of systematic research on this aspect limits the realization of higher yield of maize. This study was, therefore, conducted to select the best combination of different nutrient sources in terms of crop yield for maize. The major goals of the investigation were (1) To investigate the impact of different nutrient sources on maize yield and (2) To find out the dynamics of nutrient uptake by maize under the influence of different manures and fertilizers.

2. Material and methods

Study site

The present study was conducted at Experimental Farm of Department of Agronomy, ChaudharySarwan Kumar Himachal Pradesh KrishiVishvavidyalaya, Palampur in 2020. The research area is situated at an altitude of approximately 1290 metres above mean sea level at $32^0 6'$N latitude and $76^0 3'$ E longitude. The study site lies in the North-Western Himalayas of district Kangra and falls under mid hills sub humid agro-climatic zone of Himachal Pradesh which receives average annual rainfall of about 2750 mm (nearly 80% is received between June to September months). These soils are believed to be developed from fluvo-glacial parent material and belong to the order Alfisol and subgroup TypicHapludalf and owe their origin to different kind of rocks such as slates, phyllites, quartzites, schists and gneisses. (Verma 1979). The weekly maximum and minimum temperature ranged between 26.0 to 30.5 and 13.0 to 20.1 °C, respectively during crop growth period.

The maize crop received total rainfall of about 1449.0 mm and the weekly relative humidity varied from 57.95 to 92.05 per cent.

Treatments and Experimental Details

Experiment was laid out in a randomized block design (RBD) with three replications comprising eleven treatments (Table 1). Recommended dose of fertilizers for maize is N 120, P_2O_5 60 and K_2O 40 kg ha^{-1}. Urea, Single Super Phosphate (SSP), and Muriate of Potash (MOP) were used as source of nitrogen, phosphorus and potassium. Half dose of N and full doses of P and K were applied at the time of sowing in treatments comprising inorganic fertilizers. The remaining half dose of nitrogen was top dressed in two equal splits at knee high and pre-tasseling stage of maize. Whole quantity of FYM (0.98% N, 0.47% P and 0.85 % K) was given before sowing as per the treatments of the experiment. Lime was applied as marketable lime ($CaCO_3$) passed through 100 mesh sieve and thoroughly incorporated @ 3.2 t ha^{-1} in the specified plots about four weeks prior to sowing of the maize. In organic farming plots, 50 per cent of N i.e., 60 kg N ha^{-1} was supplied through FYM and another 50 per cent was supplemented through vermicompost (average nutrient content of 1.83%, 0.97% and 0.73% of N, P and K, respectively on dry weight basis).

In NFS plots, the seeds were treated with beejamritfor 30 minutes before sowing. Ghanjeevamrit was applied @ 250 kg ha^{-1} along with sieved FYM @ 250 kg ha^{-1} followed by application of jeevamrit @ 500 l ha^{-1} at sowing and sprays of 10 % jeevamrit were given five times at 21days interval during crop growth. Soybean was intercropped in between the rows of maize plants in the ratio of 2:1. Mulching with locally available organic residues was also done. In addition, fermented butter milk @ 12.5 l ha^{-1} was sprayed at 60 days after sowing (DAS) and at grain filling stage of maize. The method of preparation of beejamrit, jeevamrit and ghan-jeevamrit are given in Table 2, and their NPK composition are given in Table 3.

Sample Analysis

Ten plants were randomly selected and tagged in each treatment to study the yield characteristics and nutrient uptake. The grain and stover samples collected from each plot at harvest were cleaned, dried in an oven at 60˚C, and then grinded. Nitrogen and phosphorus content in grain and stover samples was estimated using the micro kjeldahl and vanadomolybdophosphoric acid method, respectively, given by Jackson (1973). Potassium content was estimated using flame photometry given by Black (1965). The nutrient uptake by grain and stover was calculated using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

Data Analysis

The intent of carrying out this study was to compare different treatments (conventional, INM, organic treatments, integrated-organic treatment and Natural Farming System) as a function of yield and nutrient uptake. The data generated from field and laboratory studies were subjected to statistical analysis. The technique of analysis of variance (ANOVA) was used for the interpretation of results. Statistical analysis was done as per standard procedure described by Gomez and Gomez (1984).

3. Results and Discussions

Grain, Stover and Total Biological Yield

Analysis of maize yield data (Table 1) revealed that the significantly highest grain, stover and total biological yield (42.25 q ha^{-1}, 71.82 q ha^{-1} and 114.07 q ha^{-1}, respectively) was recorded under T_2 (100% NPK + FYM @ 10 t ha^{-1}) treatment. The treatment T_3 i.e., 100% NPK + lime was observed to be the second best treatment with respect to grain, stover and total biological yield (40.51 q ha^{-1}, 67.65 q ha^{-1} and 108.16 q ha^{-1} respectively) of maize. On comparing organic treatments, T_4 (Organic farming practices) showed higher grain and total biological yield (29.13 q ha^{-1} and 65.01 q ha^{-1} respectively) which was followed by T_5 i.e., NFS-*Desi* cow treatment (50.98 q ha^{-1}), however, in case of stover yield, organic farming (T_4) recorded higher yield (35.88 q ha^{-1}) which produced non-significant differences with T_5 treatment (30.34 q ha^{-1}). Among integrated organic treatments, organic farming + 25 per cent NPK i.e., T_8 recorded higher grain, stover and total biological yield (31.64 q ha^{-1}, 47.84 q ha^{-1} and 79.48 q ha^{-1} respectively) which was followed by T_9 i.e., NFS-*Desi* cow + 25 per cent NPK treatment (24.88 q ha^{-1}, 38.82 q ha^{-1} and 63.70 q ha^{-1}, respectively). T_7 (NFS-Buffalo) recorded lowest grain (17.75 q ha^{-1}), stover (25.56 q ha^{-1}) and total biological yield (43.30 q ha^{-1}) of maize.

FYM amended treatment recorded the significantly highest yield. It might be due to addition of nutrients through inorganic fertilizers and FYM and release of nutrients from the native sources in soil due to high biological activity which resulted in high dry matter production (Shilpashree*et al.,* 2012). Highest yield under T_2 might be due to the increased net assimilation rate which led to production of more amounts of metabolites and phytohormones followed by their mobilization from source to sink which ultimately resulted in higher yield (Negi*et al.,* 2021). Sharma *et al.* (1987) and Gupta *et al.* (1996) also reported similar results, indicating that using organic manures in conjunction with NPK fertilizers improves soil fertility by increasing the population of beneficial microflora in the soil as well as improving the physical properties of the soil, thus, increasing crop yield. Further, the improvement in yield with integrated use of FYM and inorganic fertilizers might be due to slow and controlled release of nutrients in the soil through mineralization of organic manures and availability of nutrients as per crop demand which might have facilitated better crop growth (Mitra *et al.,* 2010).

NFS-*Desi* cow treatments (T_5) recorded higher grain, stover and total biological yield of maize than NFS-Crossbred (T_6) and NFS-Buffalo treatments (T_7). Overall, the per cent increase registered by NFS-*Desi* cow treatments over NFS-Crossbred and NFS-Buffalo treatments was 10.31% and 16.28 % respectively, and it might be attributed to higher microbial count in NFS products prepared from dung and urine of *desi* cow thereby leading to increase in the soil microbial activity, consequently enhancing soil organic carbon and nutrients uptake throughout the crop cycle.

Nutrient Uptake (N, P and K)

The different fertilizers and manures treatments influenced NPK uptake by maize crop and the highest total N uptake (147.53 kg ha^{-1}) by maize crop was recorded under 100 per cent NPK + FYM @ 10 t ha^{-1} i.e., T_2 which was statistically at par (140.37 kg ha^{-1}) with T_3 i.e., 100 per cent NPK + lime treatment (Fig. 1). Among organic treatments, organic farming treatment i.e., T_4 recorded higher total N uptake (87.47 kg ha^{-1}) followed by T_5 i.e., NFS-*Desi* cow treatment (69.51 kg ha^{-1}). Among integrated organic treatments, T_8 i.e., organic farming + 25 per cent NPK treatment recorded higher total N uptake (105.45 kg ha^{-1}) followed by T_9 treatment i.e., NFS-*Desi* cow + 25 per cent NPK (84.73 kg ha^{-1}). The lowest total N uptake (56.91 kg ha^{-1}) by maize crop was recorded under the treatment NFS-Buffalo i.e., T_7.

The highest N uptake under FYM amended treatment might be due to the increased availability of nutrients in the soil by the addition of different sources of nutrients and also favoured the release of nutrients from organic sources through mineralization by microorganisms and their subsequent uptake by maize crop (Bharath *et al.,* 2017). The increase in N uptake could also be ascribed to slow and continued supply of the nutrients, coupled with reduced N losses via denitrification or leaching, which might have improved the synchrony between plant nitrogen demand and supply from the soil (Mitra *et al.*, 2010; Puli *et al.*, 2017; Negi *et al.*, 2021). Organic farming treatment (T_4) recorded higher total nitrogen uptake among organic treatments which might be attributed to greater root development, resulting in higher nutrient absorption (Meena *et al.,* 2011). NFS-*Desi* cow treatment i.e., T_5 also recorded higher total N uptake (69.51 kg ha^{-1}) than other NFS treatments which might be due to high activity of microbes, thereby, promoting the mineralization and hence N uptake by the crop.

Significantly highest total P uptake (34.19 kg ha^{-1}) by maize (Fig. 2) was recorded under treatment comprising 100 per cent NPK + FYM @ 10 t ha^{-1} (T_2) which was followed (30.69 kg ha^{-1}) by T_3 i.e., 100 per cent NPK + lime treatment. Among organic treatments, organic farming i.e., T_4 recorded higher total P uptake (23.23 kg ha^{-1}) followed by T_5 i.e., NFS-*Desi* cow treatment (16.40 kg ha^{-1}). Among integrated organic treatments, organic farming + 25 per cent NPK (T_8) recorded higher total P uptake (23.32 kg ha^{-1}) followed by T_9 i.e., NFS-*Desi* cow treatment + 25 per cent NPK (18.3 kg ha^{-1}). The lowest total P uptake (13.66 kg ha^{-1}) by maize crop was recorded under the T_7 i.e., NFS-Buffalo treatment.

The significantly highest total P uptake under T_2 might be due to production of organic acids by FYM which had solubilizing effect on soil P and organic anions which retards phosphorus fixation in the soil thereby increasing its uptake (Singh *et al.,* 2009). The integration of inorganic fertilizer in combination with FYM has proved to be better in maintaining higher level of available phosphorus whereby leading to increase in phosphorus uptake, which is in conformation with the findings of Sandhu and Meelu (1974), Nehra *et al.* (2001) in wheat, Tolanur and Badanur (2003), Panwar (2008) in maize and mustard, and Sharma *et al.* (2016). The total K uptake by maize crop (Fig. 3) was observed to be highest (97.36 kg ha^{-1}) under T_2 i.e., 100 per cent NPK + FYM @ 10 t ha^{-1} treatment which produced non-significant differences (93.16 kg ha^{-1}) with T_3 i.e., 100 per cent NPK + lime. Among organic treatments, T_4 i.e. organic farming recorded higher total K uptake (47.70 kg ha^{-1}) which was statistically at par (44.34 kg ha^{-1}) with T_5 *viz.* NFS-*Desi* cow treatment. Among integrated organic treatments, organic farming + 25 per cent NPK (T_8) recorded higher total K uptake (23.32 kg ha^{-1}) which was followed by T_9 i.e. NFS-*Desi* cow + 25 per cent NPK (18.30 kg ha^{-1}). The lowest total K uptake by maize crop was recorded under T_7 (NFS-Buffalo).

Total K uptake by grains and stover of maize was recorded highest under the treatment comprising integration of FYM with full recommended dose of NPK which might be due to additional amount of nutrients supplied by FYM along with potassic fertilizer and also beneficial effects of organic matter addition derived in connection with improvement in physico-chemical properties of soil which led to increase in uptake of nutrients (Das *et al.,* 2009). Pathak *et al.* (2005); Thakur *et al.* (2011) and Das *et al.* (2012) also reported similar findings i.e. integrated use of fertilizers and manures enhances potassium uptake. It could also be attributed to the fact that the K bound in the interlayer spaces of minerals becomes mobile over time as a result of the decomposition of

FYM applied along with NPK, and during this phase, plants take up considerable amount of K from soil (Mohapatra *et al.,* 2008).

Overall, conjunctive use of organic manures with inorganic fertilizers might have led to the enrichment of biological activity and release of organic acids which might have degraded and mobilized the occluded soil nutrients to available form (Reddy and Reddy 1998). Thus, favourable effect of farmyard manure in the root zone resulted in increased availability and uptake of nutrients by the plants, which was reflected through increase in maize grain and stover yield in INM. Similar findings were also reported by Kalhapure *et al.* (2014) and Chaudhary *et al.* (2017).

Cow dung and cow urine (ingredients of jeevamrit) are high in beneficial bacteria and amino acids, which could lead to an increasing percentage of N in plants. Jaggery in jeevamrit contains around 30% of the recommended daily intake of K, which is a quality nutrient for plants growth, as well as a carbon source. However, the findings of our study indicated that the sole application of products of NFS (beejamrit, jeevamrit and ghanjeevamrit) did not result in higher yield and uptake of nutrients when compared to all other treatments and it could be due to rapid mineralization of nutrients in FYM and chemical fertilizers (Kulkarni and Gargelwar 2019). In addition to this, quality of beejamrit, jeevamrit and ghanjeevamrit depends upon sources from which they are being prepared. The dung, urine and jaggery used for preparation of these products might be of low grade which would have resulted in low mineralization rate of nutrients in soil. The results of NFS may be improved in further studies by obtaining ingredients from reliable sources.

4. Conclusion

From the study, it may be concluded that the integration of organic manure with chemical fertilizers can provide balanced nutrition to the maize crop which plays extremely important role in realizing maximum yield of the crop. Our results could provide a better understanding of the significance of adding on organic manure to inorganic fertilizers in order to enhance the nutrient uptake and boost up maize yield.

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Table 1. Effect of different treatments on maize yield

Treatments	**Grain yield ($q\ ha^{-1}$)**	**Stover yield ($q\ ha^{-1}$)**	**Total biological yield ($q\ ha^{-1}$)**
T_1 - 100%NPK	36.46	60.15	96.61
T_2 - 100%NPK+FYM	42.25	71.82	114.07
T_3 -100%NPK+Lime	40.51	67.65	108.16
T_4 - Organic farming	29.13	35.88	65.01
T_5 –NFS-*Desi* Cow	20.64	30.34	50.98
T_6 -NFS-Crossbred Cow	18.71	27.13	45.84
T_7 -NFS-Buffalo	17.75	25.56	43.30
T_8 -T_4+25%NPK	31.64	47.84	79.48
T_9 -T_5+25%NPK	24.88	38.82	63.70
T_{10} -T_6+25%NPK	24.11	37.13	61.25
T_{11} -T_7+25%NPK	22.57	34.30	56.87
LSD (P=0.05)	4.17	6.34	10.50

Table 2. Preparation of different natural farming inputs

Input	**Ingredients**	**Method of preparation**
Beejamrit	Cow dung – 5 kg Cow urine – 5 l Lime – 50 g Water – 20 l	• Soaked cow dung for 12 hours • Squeezed in the water tub • Added lime, soil, water & cow urine

	Handful of soil	• Stirred well and used
Jeevamrit	Cow urine – 10 l Cow dung – 10 kg Gram flour – 2 kg Jaggery – 2 kg Water – 200 l Handful of soil	• In 200 l water, added 10 l cow urine,10 kg cow dung, 2 kg jaggery, 2 kg gram flour • Mixed all above materials with stirrer • Stirred 2 times daily in the clockwise direction • Kept it for 48 hours under the shade and then used.
Ghan-jeevamrit	Cow urine – 10 l Cow dung – 100 kg Besan – 1 kg Jaggery – 1 kg Handful of soil	• Take 100 kg cow dung, 10 l cow urine, 1 kg jaggery, 1 kg gram flour. • Mixed all the contents, made balls with hand and dried under shade

Table 3.NPK content (%) of *Beejamrit*, *Jeevamrit* and *Ghan-jeevamrit* prepared using dung of different cattle

Dung Used	*Beejamrit*			*Jeevamrit*			*Ghan-Jeevamrit*		
	N	P	K	N	P	K	N	P	K
Desi Cow	0.457	0.115	0.273	0.203	0.048	0.078	1.19	0.464	0.865
Cross-bred Cow	0.485	0.119	0.297	0.220	0.049	0.085	1.37	0.468	0.993
Buffalo	0.476	0.118	0.270	0.216	0.046	0.069	1.32	0.430	0.753

Figures' legends

Figure 1. Grain, Stover and Total N uptake (kg ha^{-1}) by maize under different treatments

Figure 2. Grain, Stover and Total P uptake (kg ha^{-1}) by maize under different treatments

Figure3. Grain, Stover and Total K uptake (kg ha^{-1}) by maize under different treatments

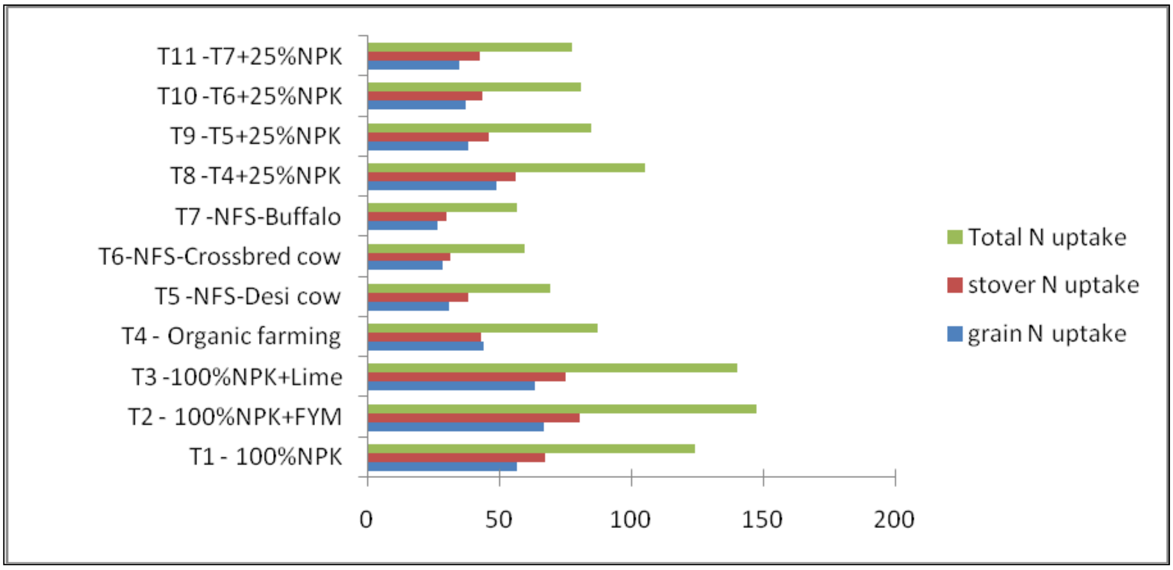

Figure 1

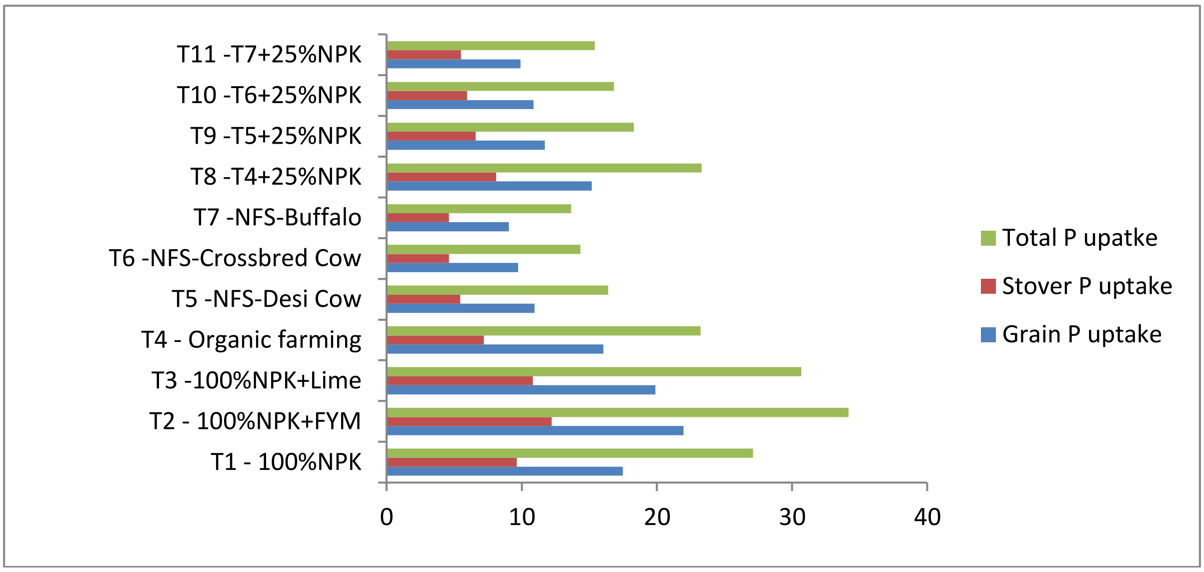

Figure 2.

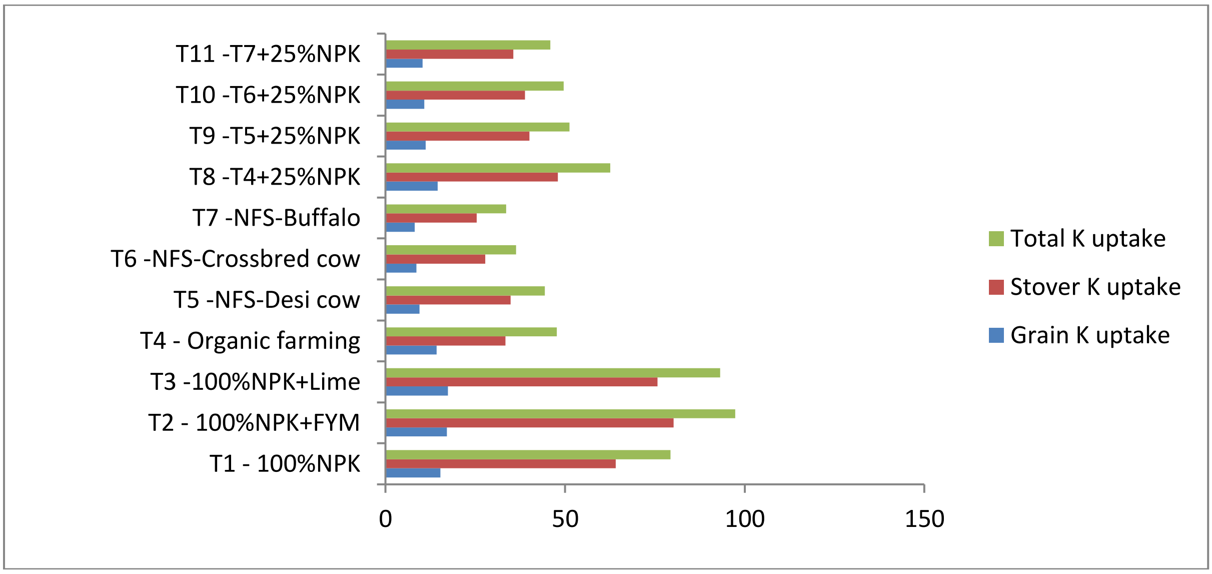

Figure 3.