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Effect of long-term application of organic and inorganic fertilizers on maize-wheat cropping system at different forms of nitrogen and soil properties

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Abstract
Effect of long-term use of organic and inorganic fertilizers on nitrogen forms were studied under maize-wheat (41 years) cropping systems by conducting both field and laboratory studies. Soil pH decreased with the continuous application of inorganic fertilizers and organic manure under maize-wheat cropping system. Soil pH decreased however, SOC, available N, available P and available K improved with continuous application of organic and inorganic fertilizers under maize-wheat and systems. Continuous application of inorganic fertilizers, alone or in combination with organic manure led to marked increase in the total soil N, total hydrolysable- N (THN) (amino acid-N, ammonia-N, amino sugar-N, hydrolysable unknown-N) and non-hydrolysable-N. The effect of FYM with 100% NPK in maize-wheat was more pronounced in increasing the total soil N and THN. Maximum grain, straw yield and N, P and K uptake in the maize-wheat cropping systems were observed with an application of 100% NPK+FYM.

Keywords: inorganic, fertilizer, N fractions, organic, soil properties

Introduction

The nitrogen found in soil can generally be classified into inorganic and organic forms. The larger amount (95 to 99%) occurs in the organic forms as a part of the soil organic matter complex and micro flora which is not immediately available to growing plants, which was acid hydrolysable, constituting 62 to 87 per cent of the total soil nitrogen and the major organic –N hydrolysable fractions were the amino-acids (30-45% of total N), amino sugars (5-10% of soil total N) and hydrolysable (10-20% of TN) and the balance were referred to as unidentified N (Stevenson and Cole, 1999) [34].

It is only the inorganic form *viz*. NH_4^+-N and NO_3-N which is commonly taken up by plants. The organic forms of soil nitrogen occur as consolidated amino acids or proteins, free amino acids, amino sugars and other complexes, generally unidentified compounds. Prasad and Sinha (1995) [25] reported that the priming effect and mineralization of root stubbles of rice, wheat and green gram improved all the organic N fractions, besides addition of N through green manure biomass during last three years.

Sulce *et al* (1996) [36] observed relatively high proportions of non-hydrolysable N, to a maximum of 47% of total N. Cultivation, manuring and other agricultural practices can alter the proportions of hydrolysable and non-hydrolysable N. In some studies, the proportion of non-hydrolysable-N was found to be relatively higher in unfertilized or intensively managed soils, whereas the application of farmyard manure led to an increased hydrolyzability of the organic N compounds present In contrast, Sharpley and Smith (1995) [32] reported higher proportions of non-hydrolysable N in manured compared to non-manured soils.

Sharma and Verma (2001) [31] reported that *Lantana* incorporation resulted in highest (9 to 37%) increase in total amino acid N (serine+threonine N and amino acid N), followed by hexosamine N (4-16%) and minimum in hydrolysable NH_4^+-N. Application of FYM alone recorded higher NH_4^+-N and NO_3-N content in soil throughout the incubation period (Duhan *et al* 2005) [10].

Nitrogen fractions can provide an assessment of soil organic nitrogen changes induced by management such as cropping system and inorganic and organic fertilization (Zimmer *et al* 2005, Wander *et al* 2007) [42, 39].

Additional N provided by organic fertilization was primarily concentrated into amino acid-N, hydrolysable unknown N and non-hydrolysable nitrogen (Huang *et al* 2009) [14].

Guldekar and Ingle (2009) [12] reported improved status of N fractions with the application of N in combination with FYM, Zn and S. The relative abundance of N fractions in soil followed the order insoluble humin-N > hydrolysable NH_4^+-N + amino sugar-N > amino acid-N > acid soluble humin-N > fixed NH_4^+-N >NO_3-N > exchangeable NH_4^+-N.

The long-term application of 100% NPK + FYM resulted in the highest amount of total N in soil which was closely followed by 150% NPK in maize-wheat cropping system. While application of 150% NPK resulted in the highest amount of hydrolysable NH_3^+-N and of NO_3^--N, amino acid N content was highest in soils under 100% NPK + S treatment. Amino acid-N and hydrolysable NH_3^+-N were the dominant fractions of N in soil irrespective of treatment. Long term use of optimum dose of NPK either alone or in conjunction with FYM/S resulted in a significant increase in the amount of hydrolysable N fraction in soil. A significant increase in the total hydrolysable N, mainly through hydrolysable unknown N was observed during the cropping sequence (Zhang *et al* 2009) [41].

Tabassum *et al* (2010) [37] repeated applications of fertilizer N alone, N with FYM or poultry manure or urban compost, FYM alone led to a significant increase in organic C, total N, hydrolysable N (i.e., amino acid N, hydrolyzable NH_4-N, hexose amine N) and non-hydrolysable N in both surface and subsurface soils as compared to initial status in a vertisol soybean-wheat cropping system. The status of various organic N fractions was higher in surface than the subsurface soils. On the other hand, continuous cropping without fertilization and manuring resulted in depletion of total hydrolysable N in control over the initial status by 8.5% in surface soils and 6.4% in the subsurface soils a better correlation between amino acid N in surface and hydrolyzable NH_4^+-N in the subsurface soils with yield of and N uptake by soybean and wheat crops.

Sekhon *et al* (2011) [30] reported that continuous application of mineral fertilizers alone or in combination with organic manures for 7 years, led to marked increase in total nitrogen, hydrolysable N (amino acid-N, amino sugar-N, ammonia-N, hydrolysable unknown-N) and non-hydrolysable N compared with their original status in soil. The effect of press mud (PM) treatment was more pronounced in increasing total and hydrolysable N compared with FYM or green manure (GM) treatment. Incorporation of PM, FYM and GM along with mineral fertilizers increased the total N content by 32.8, 18.3 and 5.1% and that of hydrolysable N by 25.7, 19.6 and 9.5%, respectively, over mineral fertilizer treatment.

Materials and methods

Experimental Details

The treatment comprised of 6 fertilizer combinations. Each treatment was replicated three times in a plot size of 12x15 m^2 The treatments consisted of control, 100%N, 100%NP, 100%NPK 150% NPK and 100%NPK+FYM at 10 t per ha were selected for maize-wheat. The urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) were used to supply N, P and K, respectively. The farmyard manure @ 5 Mg ha^{-1} was applied annually before rice transplanting. On an average, 10 Mg of FYM contained 350 g C kg^{-1}, 5 g N kg^{-1}, 2.5 g P kg^{-1}, 15 g K kg^{-1} and its annual application supplied 5250 kg C ha^{-1}, 75 kg N ha^{-1}, 37.5 kg P ha^{-1} and 225 kg K ha^{-1} to rice-wheat system.

The maize and wheat crops were cultivated as per agronomic practices recommended under irrigated conditions by Punjab Agricultural University, Ludhiana. The full dose of P and K was applied at the time of transplanting and sowing of rice and wheat respectively. In maize, N was applied in three split doses (1/3rd dose at transplanting, 1/3rd dose after 3 weeks of transplanting and another 1/3rd dose after 6 weeks of transplanting). In wheat ½ of the N was applied at the time of sowing and remaining ½ of N was broadcast at the time of first irrigation.

Soil sampling and analyses

Soil samples were collected by boring at 4 random places in each plot with the help of post hole auger four soil depths (0–15, 15cm) after the harvesting of wheat in 2012. The samples from sites were mixed to get a composite sample for each plot.

Soil chemical properties

Collected soil sample were analyzed by following method**:**

Soil pH

The pH of (surface and other depths) soil samples was measured (1:2 soil: water suspension) using pH meter fitted with calomel glass electrode.

Electrical conductivity (EC)

Electrical conductivity was determined in the supernatant liquid of 1:2 soil water suspension using solu-bridge conductivity meter.

Organic Carbon (OC)

Organic carbon was estimated using Walkley and Black's (1934) rapid titration method.

Available P

The available phosphorus of soil was extracted with 0.5 M $NaHCO_3$ (pH 8.5) (Olsen's *et al* 1954) [22]. The content of phosphorus in the extract was determined by ascorbic acid reductant method using spectrophotometer at 760 nm.

Available Potassium

Neutral 1N ammonium acetate method described by (Merwin and Peech, 1950) [21]. was used determining available potassium content of the soil.

Total Nitrogen

Total nitrogen in soil was determined by kjeldhal's method described by Page *et al* (1982) [23] in digestion block of reactor digestion system with controlled temperature.

Available Nitrogen

It was estimated by alkaline potassium permanganate method described by Subbiah and Asija (1965) [35].

Organic form of nitrogen

Different fractions of the soil nitrogen were analyzed using the procedure proposed by Stevenson (1996). To prepare soil hydrolysates, 20 g of soil was heated (110–120-Cº) under reflux for 12 h in 125 ml Erlenmeyer flasks fitted with a 24/40 ground-glass joint for attachment to a 40-cm Liebig condenser, after treatment with 20 ml of 6 M HCl and two drops of octyl alcohol. The mixture was filtered through Whatman No. 50 filter paper in a 5.5-cm-diameter polypropylene Buchner funnel under vacuum, during which rinsing was done two to three times with 10 ml of deionized water from a wash bottle to complete transfer of the hydrolysate from the flask to the funnel, and the same rinsing process was repeated to ensure removal of the hydrolysate from the soil. The filtrate was collected in a 125-ml polyethylene bottle fitted with a screw-cap lid and was stored in a refrigerator at -5°C. Prior to use, the hydrolysate was transferred to a 250 ml beaker, and 1 M NaOH was added while monitoring pH with continuous stirring, so as to obtain a pH of approximately 4.0. Neutralization was continued in the same manner using 1 M NaOH, until a pH of 6.5 to 6.8 had been achieved. The neutralized hydrolysate was diluted to 100 ml with deionized water, and then was returned to the bottle originally used for storage and kept under refrigeration. After preparing neutralized soil, hydrolysates were analyzed for total hydrolysable-N (THN), ammonia-N (AMMN) and organic N fractions, viz. amino acid-N (AAN), amino sugar-N (ASN), hydrolysable unknown-N (HUN) and non-hydrolysable-N as per the procedures given below:

Plant analysis

At the time of maturity both grain and straw samples were collected for all the crops and analyzed of total N, P and K content. Plant samples were dried at about 60˚ C and their dry weight was recorded. Grain and straw yield were also recorded.

1. Total N

Plant material (0.5g) was digested in concentrated H_2SO_4 with digestion mixture consisting K_2SO_4, $CuSo_4$, Se and HgO. After digestion, the extract obtained was analyzed for N using a micro-kjeldhal assembly according to procedure outlined by Jackson (1973) [15]. Total N uptake was calculated by multiplying N content with dry matter yield.

2. Total P

Plant material (0.5g) was digested in diacid mixture of HNO_3 and $HClO_4$ (3:1) and total P content in the extract was determined by vanadomolybdate phosphoric acid yellow colour method using spectrophotometer at wavelength of 470 nm (Jackson, 1973) [15].

3. Total K

Plant material (0.5g) was digested in di acid mixture of HNO_3 and $HClO_3$ (3:1) and total K content was analyzed with the help of flame photometer (Pratt 1982) [26].

Statistical analysis

The data were subjected to randomized complete block design analysis of variance and the treatment means were compared using least significant difference at the 5% level. Data related to crop yield, and all the soil properties were analyzed by calculating ANOVA by using computer program (SAS 1994) [29] Simple correlations were calculated between various soil attributes and crop yield and nutrient uptake.

Table 1: Procedure followed to determine different forms of N.

S. No.	N Form	Procedure
1	Total hydrolysable-N (THN)	5 ml hydrolysate + 0.5 g K_2SO_4–catalyst mixture +2 ml conc. H_2SO_4 will be heated on the hot palet the mixture cleared and then steam distillation ammonia-N liberated with boric acid and titrated with the standard acid solution
2	Non-hydrolysable- N (NHN)	It is the difference between total soil-N and total hydrolysable-N
3	Amino acid-N (AAN)	5 ml hydrolysate +1 ml 0.5 M NaOH will be heated on a boiling water bath for 20 min. After cooling, 500 mg citric acid and 100 mg ninhydrin will be added and again heated on a boiling water bath for 10 min. Steam distillation will be done immediately after adding 1.25g of phosphate–borate buffer mixture, 10 ml deionized water and 2 ml of 5 M NaOH to the cooled mixture the ammonia-N liberated with boric acid and titrated with the standard acid solution
4	Ammonia-N (AMMN)	Steam distillation of 10 ml hydrolysate with MgO
5	Amino sugar-N (ASN)	It is the difference between ammonia + amino sugar-N and ammonia-N
6	Hydrolysable unknown-N (HUN)	It will be calculated from the difference of total hydrolysable N - the N accounted for as (ammonia-N + amino acid + amino sugar)-N

Note: In each method, the NH_3 liberated by steam distillation was collected in 4% boric acid indicator solution and the amount of N was determined by titration with 0.005 M H_2SO_4

Result and discussion

Table 2: Effect of long term of organic and inorganic fertilize on soil pH, EC and organic carbon.

Treatments	Depth (cm)					
	pH		EC		OC	
	0-15	15-30	0-15	15-30	0-15	15-30
Control	7.74	7.55	0.16	0.16	2.8	2.1
100%N	7.21	7.38	0.17	0.16	3.5	2.5
100%NP	7.17	7.40	0.18	0.17	3.7	2.7
100%NPK	7.39	7.32	0.19	0.17	4.0	2.7
150%NPK	7.02	7.14	0.21	0.19	4.0	2.9
100% NPK+FYM	7.19	7.19	0.19	0.19	5.3	3.7
CD (5 %)	0.23	0.18	0.02	NS	0.4	0.3

The continuous application of fertilizer and organic manure for 41 years decreased soil pH from its initial value of 8.2 to 7.02-7.74. Soil pH value decreased from 7.74 in control to 7.21, 7.17, 7.39, 7.02 and 7.19 in 100%N, 100%NP, 100%NPK, 150%NPK and 100%NPK along with FYM respectively in 0-15 cm soil depth of maize-wheat cropping system (Table 2). The decrease in soil pH was significant in all treatments compared to control plots. The maximum decrease in soil pH was observed in 100% NPK+FYM treatment.

Soil EC value ranged from 0.16 dsm^{-1} in control to 0.21 dsm^{-1} with an application of 150% NPK in 0-15 cm soil depth under maize-wheat cropping system after 41 years of cropping cycles. The increase in EC might be due to the increase in base saturation of the soil where optimum rate of fertilizer and manure was applied compared to the control plots. Similar results were also reported from the long-term fertilizers experiment on soybean–wheat–maize (fodder) cropping system by Hati *et al* (2007) [13].

Soil organic carbon (SOC) is the key soil property which indicates the fertility status of the soil**.** The soil organic carbon was 2.8 g kg^{-1}in control (unfertilized plot), it increased to 3.5, 3.7, 4.0, 4.0 and 5.3 g kg^{-1} under 100%N, 100%NP, 100%NPK, 150%NPK and 100% NPK+FYM respectively (Table 4.1.3).There was significantly increase in SOC with application of 100%N, 100%NP, 100%NPK, 150%NPK and 100%NPK+FYM compared to control in 0-15 cm, 15-30 cm depth. The increase in SOC of all the fertilizer treatments might be due to the continuous addition of root biomass, root exudates and plant biomass in soil with time. These results show that the application of inorganic fertilizers over the last four decades on regular basis leads to increase in soil organic carbon. Similar results were also reported by Katkar *et al* (2011) [16].

Table 3: Effect of long term organic and inorganic fertilizer application on soil available N, P and K.

Treatments	Depth cm					
	N		P		K	
	0-15	15-30	0-15	15-30	0-15	15-30
Control	93.3	88.1	13.7	12.4	67.2	59.9
100%N	109.2	96.5	16.9	14.1	66.5	78.0
100%NP	113.7	98.6	77.7	48.9	89.2	75.8
100%NPK	125.4	119.3	82.7	53.2	105.7	86.2
150%NPK	133.8	130.2	81.9	69.8	119.5	87.9
100%NPK+FYM	141.1	133.0	90.9	83.5	123.2	126.7
CD (5%)	4.5	6.9	5.1	24.3	28.4	5.8

Effect of long term organic and inorganic fertilizer application on soil available N, P and K

Soil available N in surface soil (0-15cm) increased significantly with an application of N fertilizer (Table 3). It increased from 93.3 in control to 109.2 kg ha^{-1} with the of soil available nitrogen increase significantly with each treatment over control and in between treatments in surface soil. However, 100% NP along with potassium increased soil available nitrogen content (15-30 cm) significantly. In 15-30 cm soil layer, available N ranged between 88.1 to 133.0 kg ha^{-1}. Available N content increased significantly with an application of N fertilizer. Soil N content increased from 88.1 in control to 96.5, 98.6, 119.3 and 133.0 kg ha^{-1} with an application of 100% N, 100%NP, 100%NPK and 100%NPK+FYM, respectively. With an application of FYM along with NPK the increase in soil available N over 100%NPK was significant. These observations also find support from other research workers (Singh *et al* 2007, Katkar *et al* 2011) [33, 16].

The available P content of soil as affected by various fertilizer treatments has been shown in the Table 3. The availability of P in the surface soil (0-15 cm) increased significantly with the application of P fertilizers. It was increased from 16.9 in 100%N plot to 77.7 kg ha^{-1} with the application P i.e. 100%NP treated plots. The available P increased with the application of K along with NP fertilizers, but the increase was narrowly fouled the levels of significance. The maximum P content was observed in the 100% NPK+FYM treatment. In 15-30 cm soil layer, the available P ranged between 12.4 kg ha^{-1} in control plot to 83.5 kg ha^{-1} in 100%NPK+FYM treatment. Soil available P content increased significantly from 12.4 and 14.1 kg ha^{-1} in control and only N treated plots to 48.9, 53.2, 69.8 and 83.5 kg ha^{-1} in 100%NP, 100%NPK, 150%NPK and 100%NPK+FYM treated plots, respectively. With the application of FYM along with 100%NPK, there was significant increase in soil available P over 100%NPK. Similar result was reported from the long-term experiment on maize-wheat-cowpea cropping system by Brar *et al* (2004) [7].

Available K content increased from 67.2 kg ha^{-1} in control (unfertilized plots) to 105.7, 119.5 and 123.2 kg ha^{-1} under 100%NPK, 150%NPK and 100%NPK+FYM, respectively (Table 3). Application of K fertilizers over the decades on regular basis leads to increase in soil available K content. The available K status of the surface soil decreased from initial 88 kg ha^{-1} when K fertilizer was not applied. Similar results were reported from the long-term experiments conducted by Brar *et al* (2000) [6], Baley *et al* (2002) [3].

Table 4: Long term effect organic and inorganic fertilizer application on soil organic forms of nitrogen.

Organic N F (mg kg^{-1})							
Treatment	T S N	Total H N	Ammonia N	Amino Sugar N	Amino acid	HUN	NHN
Control	397.7	307.7	88.6	33.0	88.7	97.4	90.0
100%N	499.1	386.0	103.5	36.0	110.7	135.8	113.1
100%NP	522.6	408.3	116.7	39.0	114.8	137.8	114.3
100%NPK	595.0	477.0	133.3	53.3	143.7	146.6	118.0
150%NPK	641.7	497.7	137.7	58.3	153.3	148.3	144.0
100%NPK+FYM	714.2	539.3	147.0	61.8	163.3	167.2	174.9
CD (5 %)	32.4	8.1	12.1	6.3	6.6	3.7	2.9

Long term effect organic and inorganic fertilizer application on soil organic forms of nitrogen

All organic forms of N content at 0-15 cm soil depth increased significantly with the application of combined inorganic fertilizers and organic manure. The total soil N ranged from 397.7 in control to 714.2 mg kg^{-1} in NPK with FYM. The THN values ranged from 307.7 in control to 539.3 mg kg^{-1} in NPK with FYM, ammonia-N was observed to be 88.6 in control and increased to 147mg kg^{-1} in NPK with FYM, amino sugar-N was from 33.0 to 61.8 mg kg^{-1} in NPK with FYM, amino acid-N was from 88.7-163.8 mg kg^{-1} in NPK with FYM. The HUN was found to be observed from 97.4 to 167.2 mg kg^{-1} in NPK with FYM and NHN content was from 90 to 174.9 mg kg^{-1} in NPK with FYM, respectively (Table 4).

The total hydrolysable nitrogen and its constituent fractions revealed that the amount of total hydrolysable N (THN) was significantly greater due to application of fertilizers as compared to control. and was highest due to 100%NPK+FYM treated among all the six fertilizer treatments (Table 4). The highest dose of NPK significantly increased the contents over the 100 per cent NPK dose.

The amounts of hydrolysable ammonia-N, amino acid N and amino sugar N in soil showed significant increased due to application of fertilizers alone or along with FYM whereas changed in hydrolysable unknown N content were also significant increased (Table 4). With the combined application of inorganic fertilizers and organic manure dose resulted the highest amount of hydrolysable ammonia-N, amino acid N content under 100 per cent NPK with FYM treatment. The amount of amino sugar N was also found to be the highest, which was due to 100 per cent NPK with FYM application. Similar results were reported by Sarawad and Dhyansingh (2005) [31] with the long-term application of inorganic fertilizer and organic manure on maize-wheat-cowpea cropping system.

All the hydrolysable N fractions and non-hydrolysable N found out a significant increased, which was due to the inorganic fertilizers or organic-amended treatments over their respective control. These results indicated that the application of mineral fertilizers along with organic manures could be more beneficial proposition than the application of inorganic fertilizer alone to improve the status of organic N in the soil.

The amounts of all four hydrolysable N fractions [amino acid-N (AAN), amino sugar-N (ASN), ammonia-N (AMMN), hydrolysable unknown N (HUN)] and non-hydrolysable N (NHN) was significantly lower in unfertilized treatment after 41 years on maize-wheat cropping system in (Table 4). The greater depletion of hydrolysable N forms under continuous multiple cropping cultivation without manuring compared with adjacent fallow has also been reported by Liang *et al* (2000) [18]; Sarawad and Dhyansingh (2005) [28]; Xiao *et al* (2006) [40]; Wander *et al* (2007) [39] and Sekhon *et al.* (2011) [30].

Table 5: Effect of long-term use of organic and inorganic fertilizers and on grain and straw yield, and uptake of N, P and K by maize.

Treatments	yield (q ha^{-1})		Total uptake (Kg ha^{-1})		
	Grain yield	Straw yield	N	P	K
Control	19.1	31.9	37.2	5.7	23.2
100%N	26.5	64.6	69.8	9.3	48.3
100%NP	35.2	66.9	89.3	14.2	53.8
100%NPK	44.5	74.5	111.3	18.5	70.8
150%NPK	44.9	75.4	116.4	19.3	73.6
100% NPK+FYM	54.8	83.1	144.9	27.3	88.4
CD (5 %)	6.7	10.5	13.7	4.4	9.0

Grain and straw yield of maize and NPK uptake

The straw yield of maize crop varied from 31.9 q ha^{-1} in control to 83.1q ha^{-1} in the plots with the application of FYM along with 100%NPK. Straw yield of maize increased significantly from 31.9 q ha^{-1} in control to 64.6 q ha^{-1} with the application of 100%N. Increase in the straw yield was not significant with application of P, K and FYM. Similar results were also reported by Dhillon *et al* (2006) [9].

Maize crop responded significantly to different fertilizer treatments and organic manure because the experimental soil was low in organic matter and had a low N supplying capacity. Therefore, a response to applied fertilizers on such soil was evident. Increased N supply in the rhizosphere as a result of application of highest amount of readily available N per unit of mass of the soil which have caused an increase in dry matter production of maize with increasing N levels in maize based cropping systems (Cai and Qin, 2006) [8].

Nitrogen uptake by maize crop ranged from 37.2 to 144.9 kg ha^{-1} under different fertilizer treatments. Application of N, P and K significantly increased total N uptake by maize from 37.2 kg ha^{-1} in control to 69.8, 89.3 and 111.3 kg ha^{-1} with an application of 100% N, 100% NP and 100%NPK, respectively. The increase in total N uptake by maize crop was not significant with the application of 150%NPK compared to 100% NPK treatments. However, application of FYM along with NPK showed maximum value (144.9 kg ha^{-1}) of N uptake by maize crop which was found to be significant over 100%NPK and 150% NPK. Similar findings were reported by Aulakh and Bahl (2001) [1] and Freeman *et al* (2007) [11].

Total P uptake by maize crop ranged from 5.7 kg ha^{-1} in control to 27.3 kg ha^{-1} with an application of 100%NPK+FYM treated plots. Total P uptake increased significantly in not with N maize crop with an application of P fertilizers. It increased from 5.7 kg ha^{-1} in control to 9.3, 14.2, 18.5, 19.3 and 27.3 with an application of 100%N, 100%NP, 100%NPK, 150%NPK and 100%NPK+FYM respectively. The results further revealed that the maximum P uptake by maize crop was observed in the integrated use of inorganic fertilizers and organic manure. The increase in plant P content with fertilizer P application may be attributed to more available P in P treated plots which resulted higher uptake of nutrients by the plants growing in these plots. Beri *et al* (2003) [4] also reported that the plant P content increased with the application of P fertilizers.

Potassium uptake by maize ranged from 23.2 to 88.4 kg ha^{-1} (Table 5) under different fertilizer treatments. Application of N significantly increased the K uptake by maize crop from 23.2 to 48.3 kg ha^{-1}. However, the increase in K uptake was not significant with P application. It increased significantly with K application from 53.8 to 73.6. Integrated use of FYM along with NPK showed maximum K uptake by maize crop which was significantly higher than NPK treatment.

The increase in K uptake by maize crop with K application may be attributed to the higher amount of available K in K treated plots. The total K uptake in maize was affected with the application of FYM along with NPK. These result clearly showed that the total K uptake by maize was found to be the highest in fertilized plots over control. The increased in total K uptake with the application of N and K fertilizer may be due to the increase in plant K content, biomass production and finally the yield of the crop. The increase in total K uptake with fertilizer K application has also seen reported earlier by Aulakh *et al* (2007) [2].

Table 6: Effect of long-term use of inorganic fertilizers and organic manure on grain and straw yield, and uptake of N, P and K by wheat.

Treatments	**yield (q ha^{-1})**		**Total uptake (Kg ha^{-1})**		
	Grain yield	**Straw yield**	**N**	**P**	**K**
Control	13.5	25.3	20.9	3.5	18.4
100%N	38.3	59.1	76.9	11.3	51.4
100%NP	44.9	64.0	84.9	14.6	59.5
100%NPK	45.7	76.0	99.1	16.3	73.7
150%NPK	45.0	73.5	100.9	19.4	77.9
100%NPK+FYM	48.6	87.0	120.1	21.8	95.1
CD (5 %)	6.3	9.2	21.7	2.3	9.6

Grain and straw yield of wheat and NPK uptake

Grain yield of wheat varied from 13.5 q ha^{-1} in control to 48.6 q ha^{-1} with the combined application of 100%NPK and FYM (Table 4) the wheat grain yield increased significantly with the applications of N. The wheat grain yield increased from 13.5 to 38.3, 44.9, 45.7, 45.0 and 48.6 q ha^{-1} with the application of 100%N, 100%NP, 100%NPK, 150% NPK and 100%NPK+FYM respectively. The response of N and P to wheat was 24.8 and 6.6 q ha^{-1}. Wheat grain yield increased significantly with integrated use of NPK with FYM over N and control plots. However, increase in wheat grain yield with the application of FYM along with NPK compared 100%NPK was not significant.

The straw yield of wheat plant varied from 25.3 q ha^{-1} in control to 87.0 q ha^{-1} with the application of NPK along with FYM. The straw yield of wheat increased significantly with the application of 100%N over control. The straw yield of wheat increased significantly with the application of K along with NP fertilizer over 100%NP. Wheat straw yield with application of integrated use of FYM along with NPK was significantly higher over all other fertilizer treatments.

It was evident that the wheat crop responds significantly to N application. The experimental soil was low in organic matter and had a low N supplying capacity. Therefore, a response to addition of fertilizer in such soil was obvious. Perhaps increased N supply in the rhizosphere with the addition of higher amounts of readily available N per unit of mass of soil have caused an increase in dry matter production of wheat (Beri *et al* (2003) [4]. Similar results were reported by Aulakh and Bahl (2001) [1].

The N uptake by wheat crop varied between 20.9 and 120.1 kg ha^{-1} depending upon fertilizer treatments (Table 6). The nitrogen uptake increased significantly with an application of N fertilizer alone. The N uptake by wheat crop increased from 20.9 kg ha^{-1} in control to 76.9, 84.9, 99.1, 100.9 and 120.1 kg ha^{-1} with the applications of 100%N, 100%NP, 100%NPK, 150%NPK and 100%NPK+ FYM, respectively. The maximum nitrogen uptake was observed by wheat with the application FYM along with 100%NPK treatment. Increase in N uptake was found to be insignificant with P application. Balanced use of inorganic fertilizer resulted increase in N uptake by wheat crop compared to imbalanced fertilization. Similar results were reported by Mann *et al* (2006) [20], Rehana *et al* (2007) [27] and Kumar and Shivay (2010) [17] found that highest N uptake by wheat crop were observed with the application of combination of inorganic fertilizer and organic manure.

The P uptake of wheat crop ranged from 3.5 kg ha^{-1} in control to 21.8 kg ha^{-1} with the application of FYM along with 100%NPK. Application of N fertilizer alone showed significant effect on P uptake by wheat crop. However, P uptake by wheat crop increased significantly with the application of P along with N. The P uptake in wheat crop further increased but not significantly with the application of K along with NP because balanced use of fertilizers help to establish better root system of the crop thus nutrient uptake increased in wheat crop. It increased from 3.5 kg ha^{-1} in control and 11.3 kg ha^{-1} in N amended plots to 14.6, 16.3, 19.4 and 21.8 kg ha^{-1} in 100%NP, 100%NPK, 150%NPK and 100%NPK+FYM, respectively. The P uptake with the integrated use of FYM along with NPK was significantly higher overall inorganic fertilizers treatments. These results indicated that the total P uptake by wheat increased with the application of P fertilizers. (Bholanthanathsaha *et al* (2013) [5].

The K uptake by wheat crop ranged from 18.4 kg ha^{-1} in control to 95.1 kg ha^{-1} under different fertilizer application treatments. The application of N significantly increased the K uptake in the wheat from 18.4 kg ha^{-1} to 51.4 kg ha^{-1}. The K uptake by wheat increased from 18.4 kg ha^{-1} in control to 51.4, 59.5, 73.7, 77.9 and 95.1 kg ha^{-1} with the application of 100%N, 100%NP, 100%NPK, 150%NPK and 100%NPK with FYM, respectively.

Increase in the K uptake in wheat with the application of 100% N was found to be significant over control. Application of P along with N showed insignificant increased in K uptake in wheat over 100% N plots alone. However, it increased significantly with application of FYM along with 100% NPK over 100% NPK with addition of K also increased K uptake over NP significantly. The increase of K uptake with the applications NPK fertilizers may be due to the increase in plant K content, biomass production and finally the yield of the crop. This may be due to the role of K in improving growth which ultimately resulted to higher yield. These results are in conformity with the finding of Patil *et al* (1995) [24]; Dhillon *et al* (2006) [20] and Maitra *et al* (2008) [19].

Conclusion

Long-term application of fertilizers and organic manures improved mineral and organic fractions of soil N under the maize-wheat cropping system. Organic N constituted about 714.2 mg^{-1} of total soil N as compared with the 397.7 mg kg^{-1} share of mineral N. Grain yields and N uptake of maize and wheat were maximum with application of 100% NPK+FYM treatment. Continuous application of balanced fertilizers and organic manures had a prominent effect on AAN among the known hydrolyzable fractions of organic nitrogen. Application of N or NP mineral fertilizers resulted in accumulation of N into hydrolyzable unknown N fraction. The 97.4 mg kg^{-1} of variation in maize and 167.2 mg kg^{-1} of variation in wheat productivity was explained by amino acid nitrogen and amino sugar nitrogen fractions. Integrated use organic manures and inorganic fertilizers improved the N fractions in soil thus helps to increase maize and wheat production.

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