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LONG-TERM EFFECT OF PRESCRIPTION BASED NUTRIENT APPLICATION ON FORMS OF NITROGEN IN RELATION TO SOIL CHEMICAL PROPERTIES, YIELD AND NUTRIENTS UPTAKE IN AN ACID ALFISOL OF NORTHWESTERN HIMALAYAS

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ABSTRACT

On an average, hydrolysable-ammonical-N, amino acid-N, serine+threonine-N, hexosamine - N, unidentified - N, non-hydrolysable - N, ammonical-N and nitrate-N contributed 24.3, 24.4, 5.4, 7, 23, 6.4, 5.5 and 3.6 percent, respectively towards the total-N in acid Alfisol of Northwestern Himalayas. Chemical fertilizers alone or in combination with FYM as per prescription based approach for yield targets of 30 and 40 q ha^{-1} resulted in higher contents of nitrogen fractions. Application of fertilizers along with FYM for a yield target of 40 q ha^{-1} enhanced the contents of hydrolysable-ammonical-N, amino acid-N, serine+threonine-N,hexoseamine-N, unidentified - N and non-hydrolysable-N fractions by about 42.7, 41.4, 80.0, 47.4, 50.6 and 35.1, percent, respectively. However, no fertilization depleted these fractions by 24, 17, 23, 3.6, 12 and 8 per cent, respectively. The CEC and OC showed positive relationship with all nitrogen fractions except non-hydrolysable-N. Hydrolysable-ammonical-N had highest correlation with available N (r=0.882) and grain yield (r=0.898) whereas, amino acid-N showed the highest correlation with stover yield (r=0.902). Among nitrogen fractions maximum correlation of nitrate-N was found with total-N (r=0.917) followed by hydrolysable-N (0.910).

KEY WORDS
Acid Alfisol
Chemical fertilizers
Maize yield, Nitrogen forms, Prescription, STCR

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INTRODUCTION

India's food grain production increased from 74.2 million tonnes (1967-68) to 252.23 million tonnes (2015-16), while the consumption of fertilizers increased from 1.1 million tonnes to 26 million tonnes during the same period. These figures depict that fertilizers consumption during this period increased 25.2 times, but the increase in food grain production is only 3.3 times. On the other side, one billion plus population in India is increasing at a rate of 2.2 percent per annum and is expected to stabilize only around 2050. By 2025 total food grain demand of the country will reach 291 million tonnes comprising 73 million tonnes of maize (Kumar and Shivay 2010). Until the population stabilizes, India has to keep producing more food matching the population growth rate. Further, horizontal expansion in area is not possible, rather per capita land availability is likely to reduce from 0.12 ha in 2015 to 0.10 ha in the year 2025. Declining soil fertility and mismanagement of plant nutrients have made the task of providing food for the increasing population beyond more difficult (Regar and Singh, 2014). Therefore, we have to look for the approaches for vertical growth in agricultural productivity on sustainable basis, to feed this ever increasing population. This would require better planning and resource management besides intensification of cropping. Fertilizers have played a predominant role in increasing the productivity of crops, and would continue to do so, provided these are used judiciously as per crop requirement and soil status. However, imbalanced fertilizer use not only results in lower yields but also deteriorates the soil health (Subba Rao and Srivastava, 1998).This imbalanced nutrient use has resulted in wide gap between crop removal and fertilizer application. Thus, balanced NPK fertilization has received considerable attention in India (Ghosh et al., 2004). To ensure balanced fertilizer application soil testing is the key. However to judiciously use nutrients from organic as well as inorganics, target yield approach (Ramamoorthy et al., 1967) employing soil testing and crop correlation has evolved as one of the most efficient nutrient management approaches. This approach takes into account the absolute content of available nutrients present in soil for realizing the desired yield. Among plant essential nutrients, nitrogen is considered important for various functions. 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 which is not immediately available to crop plants. 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. Plant-available N in soils originates from fertilizer N additions and mineralization of organic N, including soil organic matter, crop residues, and organic wastes.Incorporation of different organic materials along with fertilizer N has been found to affectthe amount and distribution of organic N fractions considerably in soil (Shilpashree *et al.,* 2012). The significant contribution of amino acid N and hydrolysable NH_4^+-N towards available N in soil is a positive indicator for substitution of N by organic residue. The continuous addition of organic manures along with chemical fertilizers may stimulate mineralization and immobilization of plant nutrients, thereby affecting their distribution in different organic and inorganic forms in soil. Therefore, the present study was undertaken to study the effect of continuous application of chemical fertilizers and organics based on different nutrient management approacheswith special reference to the prescription based nutrient management on different forms of nitrogen, their relationship with soil chemical properties, maize yield and nutrient uptake after 6^{th} maize-wheat cycle.

MATERIALS AND METHODS

The soil samples were collected after harvest of maize during 2013 at depth of 0-0.15m from an ongoing long-term experiment initiated during *Kharif*, 2007 with maize-wheat cropping system at the research farm of Himachal Pradesh Krishi Vishvavidyalya, Palampur. Likewise, the soil samples were also collected from the adjoining plot that was kept fallow since initiation of the experiment in 2007 (termed "*Buffer Plot*") for assessing depletion/buildup in various forms of N in treated plots. The present investigation was conducted during 6^{th} cropping sequence of maize-wheat. The experimental farm is situated at 32°6' N and latitude, 76°3' E longitude and an altitude of 1290 m. The climate of the experimental site is characterized as wet temperate. The average rainfall of the area is 2500 mm. Soil of the experimental area was classified as *Typic Hapludalf* as per the taxonomic system of soil classification (Soil Survey Staff 1975) and was silty clay loam in texture. Other important chemical characteristics of the surface soil (0-0.15m) at the initiation of the experiment in *Kharif*, 2007 were as follows; acidic in reaction (soil pH 5.2); organic carbon 7.2g kg^{-1}; available N, P and K 236, 41 and 272 kg ha^{-1}, respectively and cation exchange capacity (CEC) 12.1 c mol (p^{+}) kg^{-1}. The field experiment was carried out in randomized block design with 3 replications and unit plot size was 5 x 3m.

The investigation comprised 8 treatments over the years: T_1- Control, T_2- Farmers' Practice (FP) *i.e.* 25 % of general recommended dose of N (30 kg N ha^{-1}) + 5 t ha^{-1} FYM on dry weight basis, T_3- General recommended dose (GRD) *i.e.* 120, 60, 40 kg ha^{-1} N, P_2O_5 and K_2O, respectively, T_4- Soil test based fertilizer application (STB), T_5- Target yield 30 q ha^{-1} (T_{30}) *i.e.* chemical fertilizers as per STCR approach for yield target of 30 q ha^{-1}, T_6- Target yield 30 q ha^{-1} with FYM @ 5 t ha^{-1} (T_{30} IPNS) *i.e.* 5 t ha^{-1} FYM + chemical fertilizers as per STCR approach for yield target of 30 q ha^{-1}, T_7-Target yield 40 q ha^{-1} (T_{40}) *i.e.* chemical fertilizers as per STCR approach for yield target of 40 q ha^{-1} and T_8- Target yield 40 q ha^{-1} with FYM @ 5 t ha^{-1} (T_{40} IPNS) *i.e.* 5 t ha^{-1} FYM + Chemical Fertilizers as per STCR approach for yield target of 40 q ha^{-1}.FYM in the specified treatments was applied @ 5 t ha^{-1} on dry weight basis.

Fertilizer doses in case of target yield treatments were worked out using equations given below (Anonymous, 2007).

$$FN = 5.88\,T - 0.23\,SN - 0.93\,ON$$

$$FP_2O_5 = 4.87\,T - 1.22\,SP - 0.81\,OP$$

$$K_2O = 3.66\,T - 0.49\,SK - 0.51\,OK$$

In above equations, FN, FP_2O_5, FK_2O are doses of N, P_2O_5 and K_2O, respectively in kg ha^{-1}. T is the yield target (q ha^{-1}), SN, SP and SK are soil available N, P and K contents before sowing of the crop, respectively in kg ha^{-1}. Whereas ON, OP and OK are N, P and K supplied by FYM, respectively in kg ha^{-1}.

One third dose of N and full dose of P and K were applied at the time of sowing. The remaining one third N was top dressed at knee high and the other one third applied at pre-tasseling stage in maize. The sources of N, P and K were urea, SSP and MOP, respectively. FYM application was made @ 5 t ha^{-1} on dry weight basis to maize, which corresponded to 12.5 t ha^{-1} on fresh weight basis, with 60 percent moisture. Average nutrient content in FYM on dry weight basis was 0.51, 0.22 and 0.44 percent of N, P and K, respectively. Thus, 5 t ha^{-1} FYM on fresh weight basis contained 25.5 kg N, 11.5 kg P and 22 kg K ha^{-1}.

The maize crop (*var. Kanchan*) was sown in June, 2013 and harvested in October, 2013. One pre-sowing irrigation was given to maize crop. Thereafter the crop met its water requirement through rainfall, which was very high during the entire crop growth period. Chemical as well as manual weed control measures were followed during the crop period.

Soilsamples collected from a depth of 0-0.15 m before sowing and after the harvest of maize (*kharif*, 2013) were air dried and ground in a wooden pestle and mortar to pass through 2 mm sieve and subsequently stored in polyethylene bags for determination of various chemical parameters. The other lot was passed through 100 mesh screen and was stored in polythene bags for determining different fractions of N. Three composite soil samples from 0-0.15 m depth were also drawn from adjacent buffer plots. The methods employed for analysis of samples for various parameters are given below in table 1.

For determination of inorganic fractions 3 g of soil was shaken with 30 ml of 2N KCl for 1 hour and filtered. The extract was then stored in refrigerator for further estimation of NH_4^+-N and NO_3^--N as per the procedure given by Black (1965), while organic N fractions *viz*., different hydrolysable N and total N were analysed following methods suggested by Bremner (1965). Non-hydrolysable N was worked out by subtracting the total hydrolysable N and inorganic N from total N.

RESULTS

Inorganic Fractions of N

The results presented indicate that ammonical nitrogen (NH_4^+-N) was the dominant fraction among inorganic forms of N (Table 2), and found significantly higher (46.7 mg kg^{-1}) in treatmentT_8 (Target yield 40 q ha^{-1} with FYM @ 5 t ha^{-1} i.e. 5 t ha^{-1} FYM + chemical fertilizers as per STCR approach for yield target of 40 q ha^{-1}) than other conventional treatments.

Ammonical-N constituted about 5.5 and 61.4 % of total N and total inorganic N, respectively. IPNS approach based treatments recorded higher amounts of NH_4^+–N compared to that of the treatments which received only fertilizers. This could be attributed due to the increased rate of mineralization of organic matter in the soil which was enhanced by the addition of FYM and hence caused a buildup of NH_4^+-N in soil. Similarly, Sheoran *et al.* (2016) reported that increasing rates of NPK application had a favourable influence on exchangeable NH_4^+-N in soil.

Nitrate-N (NO_3^--N) content in soil is dependent upon the rate of formation, crop removal, leaching, volatilization, denitrification, addition of NO_3^-Nthrough fertilizers and organic manures and rate of mineralization. In this study NO_3^--N (36 mg kg^{-1}) in treatment (T_8) differed significantly than other treatments. Application of fertilizers in combination with FYM for targeted yield of 40 q ha^{-1} further increased the NO_3^--N contents significantly over GRD (T_3) and STB (T_4) treatments by 54 and 52 percent, respectively. Target yield treatments along with FYM (T_8) proved superior to treatment which received only fertilizers without any organics. This could be attributed to the increased microbial activity; increase in soil pH might have enhanced nitrification process with a reduction in leaching losses (Udaysoorian *et al.,* 1989; Benbe *et al.,* 1991). In case of only fertilizer treated plots without organics, the conversion of NH_4^+-N to NO_3^-N was rapid as reported by Udaysooriyan *et al.* (1989) and Benbe *et al.* (1991) and this might have resulted in more leaching loss of NO_3^-N.

In generaltotal inorganic N (NH_4^+ -N + NO_3^- -N) in soil constituted about 9.03% of total N. Incorporation of FYM and fertilizers increased both NH_4^+-N and NO_3^--N in soil which may be due to their release during the process of decomposition of added organic materials. Brady and Weil (2007) also reported that on decomposition of organic matter, mineralization takes place that releases NH_4^+-N during ammonification and NO_3^--N during the process of nitrification.The integrated use of organics and inorganics (T_6 and T_8), recorded higher values of NH_4^+-N and NO_3^--N in comparison to chemical fertilizer treated plots (T_3, T_4, T_5 and T_7) which might be due to the additive effect of farm yard manures and fertilizers.The increase in the FYM applied soil is understandable as the cultivation enhances the decomposition of organic material and mineralization/ammonification of organic-N might have contributed NH_4^+-N in soil. In chemical fertilizers treated plots, increase in content is due to hydrolysis of nitrogenous fertilizers that resulted in the release of ammonium ions in soil. These results are in close conformity with the findings of Bhardwaj *et al.* (1994), Guldekar and Ingle (2009).

Table 1: Methods used for soil analysis

Soil property	Method employed
Soil pH (1: 2.5, soil: water)	Potentiometric (Jackson 1973)
Organic carbon	Rapid titration (Walkley and Black 1934)
Cation exchange capacity	Neutral 1N ammonium acetate extraction (Piper 1966)
Available nitrogen	Alkaline permanganate (Subbiah and Asija 1956)
Organic fractions-N	Acid hydrolysis method (Bremner 1965)
Inorganic fractions-N	Steam distillation method (Black 1965)

Table 2: Effects of long-term application of prescription based chemical fertilizers and FYM on nitrogen fractions in 0-0.15 m soil depth (mg kg^{-1})

Treatment	Inorganic Fractions		Organic fractions of Nitrogen							
	NH_4^+-N	NO_3^-N	HNH_4^+-N	AA-N	ST-N	HA-N	UN	TH-N	NH-N	Total N
T1	21.0	9.3	102.7	116.0	21.5	36.6	110.1	386	34.0	451
T_2	28.0	17.7	142.0	146.0	30.2	40.0	138.0	496	39.0	581
T_3	35.7	23.3	159.0	149.4	32.0	43.9	160.7	544	42.6	646
T_4	38.3	23.7	170.0	159.0	34.0	46.3	161.5	571	42.7	676
T_5	39.7	25.3	174.5	175.5	38.2	49.5	163.4	601	44.9	711
T_6	42.0	27.7	188.5	185.0	46.3	52.3	168.5	640	46.2	756
T_7	44.3	30.3	177.3	194.1	43.4	50.4	184.8	650	49.3	774
T_8	46.7	36.0	194.1	198.0	50.4	56.0	188.3	687	50.0	819
CD(P=0.05)	6.12	5.35	13.02	13.34	6.17	8.90	24.54	14.6	NS	6.7
Buffer plot	22.0	16.0	136.0	140.0	28.0	38.0	125.0	465	37.0	540

HNH_4^+-N = Hydrolysable ammonical-N, AA-N = Amino acid-N, ST-N = Serine + Threonine-N, HA-N = Hexoseamine-N, TH-N = Total hydrolysable-N; NH4+-N = Ammonical-N, NO_3-N = Nitrate –N, NH-N = Non hydrolysable-N

Table 3: Correlation coefficient (r) relating N fractions and soil chemical properties

Soil chemical properties	NH_4^+-N	AA-N	ST-N	HAN	UN	THN	NH_4^+-N	NO_3^-N	NH-N
Soil pH	0.344	0.236	0.384	0.386	-0.080	0.267	0.157	0.428*	0.165
OC	0.816**	0.853**	0.908**	0.688**	0.563**	0.896**	0.803**	0.845**	0.224
CEC	0.874**	0.822**	0.819**	0.671**	0.613**	0.906**	0.781**	0.834**	0.398

NH4+-N = Ammonical N; NO_3-N = Nitrate N; HNH4+-N = Hydrolysable-N;HA-N = Hexoseamine N; AA-N = Amino acid N; ST-N = Serine + threonine-N; UN = Unidentified-N; NH-N = Non hydrolysable-N ; *Significant at 5% level, ** Significant at 1% level

Table 4: Relationship of different nitrogen fractions with available N, maize yield and total N uptake

N fractions	Yield Grain	Stover	N-uptake	aavaila Available-N
NH_4^+-N	0.718**	0.824 **	00.818**	0.764**
NO_3^-N	0.836**	0.829**	0.856**	0.845**
HNH_4^+-N	0.898**	0.878 **	0.906**	0.882**
HA-N	0.692**	0.665*	0.691**	0.604**
AA-N	0.843**	0.902 **	0.891**	0.865**
ST-N	0.895**	0.836**	0.882**	0.761**
UN	0.736**	0.660**	0.714**	0.730**
NH-N	0.303	0.338	0.348	0.475*

*Significant at 5% level, ** Significant at 1% level; NH_4+-N = Ammonical N; NO_3-N = Nitrate N; HNH_4+-N = Hydrolysable-N;HA-N = Hexoseamine N; AA-N = Amino acid N; ST-N = Serine + threonine-N; UN = Unidentified-N; NH-N = Non hydrolysable-N.

Table 5: Correlation of different N fractions

N-Fractions	NH_4^+-N	NO_3-N	HNH_4^+-N	HA-N	AA-N	ST-N	TH-N	UN	TN
NO_3-N	0.834**								
HNH4+-N	0.889**	0.879**							
HAN	0.740**	0.695**	0.694**						
AA-N	0.799**	0.790**	0.803**	0.693**					
ST-N	0.821**	0.894**	0.835**	0.776**	0.898**				
TH-N	0.910**	0.910**	0.947**	0.705**	0.890**	0.901**			
UN	0.633**	0.643**	0.637**	0.444*	0.437*	0.491*	0.744**		
TN	0.877**	0.917**	0.939**	0.673**	0.898**	0.898**	0.944**	0.720**	
NH-N	0.099	0.322	0.226	-0.046	0.212	0.236	0.304	0.439*	0.365

*Significant at 5% level, ** Significant at 1% level.

Organic fractions of N

Amongdifferent forms of organic N, hydrolysable and non-hydrolysable forms were estimated, which collectively constituted about 96% of total Nin soil. The total hydrolysable-N constituted about 92% of total organic N and 84% of total N; whereas, non-hydrolysable N constituted about 8 and 6.4% of total organic and total N, respectively (Table 2). Among the hydrolysable organic forms of nitrogen, amino acid-N and hydrolysable-NH_4^+-Nwerethe most dominant fractions (23-26% of total N), followed by the hexosamine-N (6.5-8%). This indicates that total hydrolysable-N contributed more to the total-N, compared to other fractions, thus indicating the existence of major portion of N in the organic form (Shilpashree *et al.,* 2012). Inorganically treated plots (T_3, T_4, T_5 andT_7) recorded comparatively lower content of all the organic forms of nitrogen, than treatments based on STCR approach along with FYM application. In the present study, STCR approach based fertilizer application along with FYM were incorporated continuously over a period of 6 years, the replenishment of amino acid N might have been much higher in comparison to its mineralization and thus showed an increase in this form of N while decomposition of organic compounds might have resulted in the buildup of hydrolysable NH_4^+-N. These results are in accordance with the findings of Singhal *et al.* (2012). Increasing levels of either chemical fertilizers or integrated use of chemical fertilizers and manures increased all the hydrolysable N fractions significantly except unidentified N, which showed a decreasing trend. Similar results have been reported by Sihag *et al.* (2005).

Total N

The total N in T_8 (819 mg kg^{-1}) was the highest indicating higher build up of total N due to conjunctive application of fertilizers along with FYM under treatments based on STCR approach, where fertilizers were applied along with FYM. Addition of organic materials has been reported to increase total N also, by Guldekar and Ingle (2009) and Kumar (2003).

Relationship of different nitrogen fractions with soil chemical properties

The data with respect to the correlation among various chemical pools of N and soil properties have been given in Table 3. Organic carbon and CEC were found to bear significant and positive relation with different chemical pools of N, except non hydrolysable-N (r = 0.224 for OC, r = 0.398). However, the effect of soil pH did not reach to the level of significance, except nitrate-N which is significant in nature and unidentified nitrogen is negatively correlated with r value -0.0795. Whereas nitrate-N showed a positive and significant relationship with soil pH which is acidic in nature.

A significant N mineralization detected in soil with pH value between 4-5, indicating that the microorganisms can adapt to acid conditions (Dhamak *et al.*, 2014).

Relationshipof different nitrogen fractions with available N, maize yield and N uptake

Available N was positively and significantly correlated with all the N fractions at 1 per cent level of significance except NH-N (Table 4). Maximum correlation of available nitrogen was found with hydrolysable ammonical-N (r = 0.882) followed by amino acid-N (r = 0.865). Grain yield of maize was positively and significantly correlated with all the N fractions except non hydrolysable-N which showed positive but non-significant correlation with maize grain yield. Grain yield's maximum correlation (r = 0.898) was found with hydrolysable ammonical-N followed by serine + threonine-N (r = 0.895) and amino acid-N (r = 0.843). Singhal *et al.* (2012) also found a significant and positive relationship of grain yield with hydrolysable ammonical N, amino acid N, and ammonical-N. Whereas for maize stover maximum correlation (r=0.902) was found with amino acid-N, followed by hydrolysable ammonical-N (r=0.878) and serine+ threonine - N (r=0.836). These results clearly showed that organic N fractions such as hydolysable NH_4^+-N, amino acid-N, serine+threonine-N controlled the availability of N in soil and were major source of nitrogen to crop uptake. Kumar (2003), Subehia and Dhanika (2013) reported similar relationship between crop yield and different fractions of nitrogen.

Nitrogen uptake by maize had a positive and significant relationship with ammonical-N, nitrate-N, amino acid-N, unidentified-N, serine+threonine-N and hexosamine-N, whereas non hydrolysable-N showed positive but non-significant relationship with grain uptake of nitrogen (r=0.348).Maximum correlation (r=0.906) of nitrogen uptake was found with hydrolysable ammonical-N followed by amino acid-N (r=0.891), serine+threonine-N (r=0.882) and nitrate-N (r=0.856). Similar significant and positive relationship between these forms and maize productivity and N uptake had been observed by Sarawad et al. (2001), Duraisami et al.(2001) and Subehia and Dhanika(2013).

Relationship among different fractions of nitrogen

All the fractions of nitrogen were positively and significantly correlated among themselves except non hydrolysable-N which was found positively but non-significantly correlated with other fractions of nitrogen. Hexoseamine-N showed a negative relation with other N fractions(Table 5). Maximum correlation (r=0.910) of ammonical-N was found with total hydrolysable-N followed by hydrolysable ammonical-N (r=0.889) and total-N (r=0.877). Similarly, maximum correlation of nitrate-N was found with total-N (r=0.917) followed by total hydrolysable-N (r=0.910), whereas hydrolysable ammonical-N waspositivelyandsignificantly correlated with all fractions except non hydrolysable-N. Maximum correlation (r=0.947) of hydrolysable ammonical-N was found with total hydrolysable-N followed by total nitrogen (r=0.939) and serine+threonine-N. Likewise hexosamine-N was found highly correlated with serine+threonine-N (r=0.776), followed by TH-N (r=0.705) and amino acid-N (r=0.693). Highest significant correlation (r=0.898) of amino acid-N was found with serine+threonine-N followed by total hydrolysable nitrogen.

Significant correlation among the nitrogen fractions could be due to the fact that these fractions are dependent on each other for their synthesis during mineralization process (Pathak and Sarkar 1995). Singh et al. (1999) also found positive and significant correlation among different fractions of nitrogen except non-hydrolysable-N which was probably due to production of these two fractions from sources other than through mineralization of organic nitrogen.

Organic N fractions progressively increased in soil with the prescription based nutrient application, especially treatments comprising conjunctive use of fertilizers along with FYM. Amino acid-N, hydrolysable NH_4^+-N, hexosamine-N were found to be better indices of soil-N mineralization and its availability.

These results clearly suggest that application of nitrogen N along with other nutrient sources based on prescription based approach is required to sustain N reserves and enhance the N availability in soil. The prescription based nutrient management (IPNS as well as non-IPNS) could be the better option for creating a favourable environment in terms of improved soil properties and nutrients' availability.

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