International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 2338-2343
© 2020 IJCS
Received: 25-01-2020
Accepted: 27-02-2020

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Long term effect of chemical fertilizers and amendments on chemical pools of nitrogen in maize-wheat cropping system in an acid Alfisol

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2ai.9098

Abstract
The present investigation was carried out in the ongoing long term fertilizer experiment at Department of soil science, CSKHPKV Palampur. The influence of thirty six years of cropping with different chemical fertilizers and amendments on the contents and total N, inorganic N and organic N fractions at 0-0.15 m and 0.15-0.30 m depths was investigated in an Acid Alfisol. Continuous combined use of chemical fertilizers and FYM and manual weeding in 100% NPK treated plots resulted in significant increase in the soil organic carbon content compared to rest of the treatments. However, higher organic carbon content was recorded under surface soils. Continuous application of chemical fertilizers either alone or in combination with FYM or lime influenced different organic and inorganic nitrogen fractions significantly except non hydrolysable-N at both the depths. Hydrolysable ammonical-N was found to be the most dominant organic nitrogen fraction. Different organic and inorganic –N fractions at surface and subsurface soils were significantly and positively correlated with available N.

Keywords: Soil organic carbon, organic and inorganic nitrogen fraction

Introduction
Addition of organics not only supplies the additional nutrients to the growing plants, but also affects the availability of native nutrient as well as nutrients added through chemical fertilizers. Their incorporation may influence forms and availability of nutrients due to the release of organic acids and other microbial products during decomposition (Stevenson 1967) [1]. Hence, understanding of nutrient transformation under long-term cropping, fertilization and amendments is essential in developing an efficient fertilizer management programme. Long-term fertilizer experiments are needed to know the impact of continuous application of fertilizers and amendments with varying combination of nutrients on nutrient dynamics. The ongoing long-term fertilizer experiment at Palampur (HP) provided an ideal base to study the transformation of nitrogen into various pools as well as its exact nature and relationship within the soil-plant system as influenced by continuous use of chemical fertilizers and amendments in an acid Alfisol. Most of the N transformation studies have largely been confined to the top soil, although plants also utilise N from the deeper horizons. However, other studies have shown that a significant proportion of N mineralisation occurs in subsoil’s (Hades *et al.* 1986; Patra *et al.* 1999) [2, 3].

Materials and Methods
The present study was carried out in an ongoing long-term fertilizer experiment started during 1972-73 (rabi) at the research farm of College of Agriculture, Palampur 1290 meters above mean sea level (amsl). The area falls in the wet temperate zone with annual rainfall of 2500-3000mm with the maximum (75%) received during the wet season (June-September). The mean maximum temperature remains about 31 ^{0}C during the hottest months of May to June. December to February are the coldest months with minimum temperature of about 5 0C. Soil of the study area was silty loam in texture and classified as Typic Hapludalf. The soil had pH 5.8; organic carbon 7.9 g kg-1; and 12.1 [cmol (p+) kg-^{1}] soil. It contained 736, 12 and 194.2 kg ha-1 soil of available N ($KMnO_4$-N), P (Olsen’s-P) and K (Neutral 1N NH_4OAc-K), respectively.

The experiment was started with 11 treatment combinations replicated three times in randomized block design with 15 m^2 plot for each treatment. The experiment initially comprised of 10 treatments each replicated four times in randomized block design (RBD). The 11th treatment consisting of 100 per cent NPK (-S) was introduced in *kharif,* 1981. Treatments were,T1-control; T2-100% N; T3-100% NP; T4- 100% NPK; T5- 100% NPK + FYM @10 t ha-1 (to maize crop only); T6-100% NPK + lime (lime was applied @ 900 kg ha-1 till the pH attained at neutrality); T7-100% NPK + Zn; T8-100% NPK + Hand Weeding (HW); T9-100% NPK (-S), P through DAP; T10-150% NPK (super optimal) and T11- 50% NPK (sub optimal).

The processed soil samples were analyzed for organic carbon, Total N, available N ($KMnO_4$-N) and different organic forms of N viz., total hydrolysable, amino acid-N, hydrolysable NH_4-N, amino sugar-N (Bremner1965) [4]. Unidentified-N was calculated by subtracting sum of amino acid-N, hydrolysable NH_4-N and amino sugar-N from total hydrolysable-N. Non hydrolysable-N was calculated by subtracting sum of total hydrolysable-N and total inorganic-N from total N. Inorganic forms of N namely NH_4-N and NO_3-N were determined by steam distillation method (Black, 1965) [5]. The inorganic forms of N were determined immediately after the collection of soil samples.

Results and Discussions

Effect of chemical fertilizers and amendments on chemical pools of nitrogen

In this study, nitrogen was fractionated into total hydrolysable-N, non hydrolysable-N and inorganic N (NH_4-N and NO_3-N). Total hydrolysable N was further fractionated into hydrolysable ammonical-N, amino acid-N, amino sugar-N and unidentified –N. Total N was also determined in the present study.

Hydrolysable ammonical- N

The hydrolysable ammonical-N in the surface layer ranged from a lowest value of 131 mg kg^{-1} under control to a highest value of 270 mg kg^{-1} under 100% NPK+FYM treatment. There was a significant increase in hydrolysable ammonical-N content with the use of chemical fertilizers either alone or in combination with amendments as compared to control. The increase in 100% N (T_2) and 100% NP (T_3) treated plots was about 33 and 42 per cent compared to control, respectively. A consistent increase was recorded with the increase in NPK levels from 50% to 150% NPK. Compared to 100% NPK, application of FYM and lime along with 100% NPK increased hydrolysable ammonical-N content significantly, Whereas, the treatments 100% NPK and 100% NPK (-S) with values of 252 mg kg^{-1} and 248 mg kg^{-1}, respectively, were at par with 100% NPK + Zn (238 mg kg^{-1}).A depletion to the extent of 26 per cent was recorded in this fraction due to continuous cropping without fertilization as the content in control plot was 131 mg kg^{-1} against 177 mg kg^{-1} in adjacent fallow plots.

In subsurface layer, the hydrolysable ammonical-N varied from 100 mg kg^{-1} under control to 225 mg kg^{-1} under 100% NPK+FYM. The content of hydrolysable ammonical-N under subsurface followed almost similar trend in all the treatments as was observed under surface layer. However, subsurface soil layer recorded lesser content as compared to surface soil layer in all the treatments and depletion in this fraction in this layer was 17.4 per cent. Depletion in subsurface layer clearly demonstrated that subsurface layer do contribute to N nutrition of growing plants. Application of 150% NPK and 100% NPK+FYM recorded 13.7 and 28.3 per cent increase over 100% NPK, respectively.

Table 1: Effect of long-term use of chemical fertilizers and amendments on hydrolysable ammonical-N (mg kg^{-1})

Treatment	Soil depth (m)	
	0-0.15	0.15-0.30
T_1: Control	131	100
T_2: 100% N	196	148
T_3: 100% NP	226	161
T_4: 100% NPK	252	183
T_5: 100% NPK+ FYM	297	255
T_6: 100% NPK+ lime	273	216
T_7: 100% NPK+ Zn	238	176
T_8: 100% NPK+ HW	269	198
T_9: 100% NPK (-S)	248	179
T_{10}: 150% NPK	278	212
T_{11}: 50% NPK	185	143
Fallow	*177*	*121*
CD (P= 0.05)	16.1	26.1

The availability of nitrogen due to continuous addition of NPK fertilizers particularly at optimal and super optimal rates and FYM might have contributed directly to the immobilization of N in this organic fraction. Moreover, lot of roots and stubbles have been returned to the soil in these treatments. Decomposition of these organic materials also releases N. Similar increase in the hydrolysable ammonical-N due to long-term application of NPK and FYM have also been reported earlier by Gupta *et al*. (1988) [6], Kher and Minhas (1992) [7], Bhardwaj *et al*. (1994) [8], Santhy *et al.* (1998) [9], Sarawad *et al.* (2001) [10] and Sihag *et al.* (2005) [11].

Amino acid-N

It is confirmed from the data about 22 and 29 per cent of total N and total hydrolysable-N, respectively. The variation in amino acid-N content in surface layer was from 92 mg kg^{-1} under control to 283 mg kg^{-1} under 100% NPK + FYM. The results indicated that like hydrolysable ammonical-N, application of chemical fertilizers either alone or in combination with FYM/lime increased amino acid-N significantly over control. Similarly, application of 100% NPK+FYM, 100% NPK +lime and 150% NPK increased amino acid-N significantly over 100% NPK alone. The effect of Zn application and method of weed control was not significant. The treatments *viz.*, 100% N (T_2) and 100% NP

(T_3) with values of 145 and 169 mg kg^{-1} were, however, at par.

In subsurface layer, the amino acid-N content varied from 85 mg kg^{-1} in control plots to 228 mg kg^{-1} under 100% NPK + FYM treatment. The treatment wise trend in subsurface layer was almost similar as was observed under surface layer. The continuous addition of N through chemical fertilizers, FYM and root biomass over the years might have contributed to the build up in the fraction of organic nitrogen. These results corroborate the findings of Subba Rao and Ghosh, (1981) [12]. The long-term application of fertilizers and organic manures maintains or enhances the amino acid-N content in soil which otherwise suffers loss due to intensive cultivation (Sarawad *et al.* 2001) [10]. Also, the effectiveness of 100% NPK+ lime in maintaining higher amino acid-N content compared to 100% NPK treatment could be attributed to the improvement in physical, physico-chemical and biological properties of soil (Kher and Minhas 1992) [7]. Continuous cropping without fertilization led to a depletion of 22 and 13 per cent in this fraction in surface and subsurface layers, respectively. Similar depletion in this pool of organic N has also been reported by Sammy Reddy *et al.* (2003) [13] in the soils of Barrackpore (WB) under rice-wheat-jute cropping system.

Table 2: Effect of long-term use of chemical fertilizers and amendments on amino acid-N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	**0.15-0.30**
T_1: Control	92	85
T_2: 100% N	145	105
T_3: 100% NP	169	129
T_4: 100% NPK	182	149
T_5: 100% NPK+ FYM	283	228
T_6: 100% NPK+ lime	231	196
T_7: 100% NPK+ Zn	189	158
T_8: 100% NPK+ HW	199	165
T_9: 100% NPK (-S)	162	129
T_{10}: 150% NPK	218	180
T_{11}: 50% NPK	136	125
Fallow	*118*	*98*
CD (P= 0.05)	28.7	22.6

Amino sugar-N

A close look at the data revealed that the amino sugar-N content varied from 26 mg kg^{-1} under control to 78 mg kg^{-1} under 100% NPK+FYM in surface soil. The results indicated that the amino sugar N constituted 6.4 and 8.2 per cent of total N and total hydrolysable N, respectively. The data further revealed that all the treatments increased amino sugar-N significantly over control.

Table 3: Effect of long-term use of chemical fertilizers and amendments on amino sugar-N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	**0.15-0.30**
T_1: Control	26	22
T_2: 100% N	45	30
T_3: 100% NP	51	41
T_4: 100% NPK	52	40
T_5: 100% NPK+ FYM	78	70
T_6: 100% NPK+ lime	61	50
T_7: 100% NPK+ Zn	57	42
T_8: 100% NPK+ HW	53	38
T_9: 100% NPK (-S)	45	41
T_{10}: 150% NPK	65	54
T_{11}: 50% NPK	41	32
Fallow	*32*	*25*
CD (P= 0.05)	7.7	7.1

Increasing levels of NPK *i.e* 50, 100 and 150% resulted in consistent increase in amino sugar-N content. However, 100% NPK + Zn, 100% NPK + HW and 100% NPK (-S) were statistically at par with 100% NPK. A depletion to the extent of 18.8 per cent was recorded with the continuous cropping when fallow plots were compared with untreated plots.

In case of subsurface soil layer, amino sugar-N content varied from 22 in control to 70 mg kg^{-1} in 100% NPK + FYM treatment. There was a decline in the content of amino sugar-N with the increase in soil depth. The pattern of treatment effect was almost same as that in surface layer. In subsurface layer, the depletion due to cropping was less as compared to surface layer, the extent being 12 per cent.

The continuous addition of N through organic and inorganic sources over thirty six years might have contributed directly to the enrichment of this pool of organic N. Moreover, addition of FYM might have created favourable environment for the growth and development of heterotrophic micro organisms. As bacteria synthesize a number of polysaccharides containing amino sugar units, an increase in amino sugar-N is expected (Bremner 1951; Mahapatra and Khan 1967) [14, 15]. The growth of the fungal mycelium which contains polysaccharides like chitin (Bremner 1951; Mahapatra and Khan 1967) may be the source of amino sugar-N resulting in the build up of this fraction in low pH soils. Similar build up in this fraction under same set of agro-climatic conditions has also been reported by Sharma and Verma (2001) [16] under rice-wheat sequence.

Unidentified-N

This fraction of N was calculated by subtracting the sum of hydrolysable ammonical-N, amino sugar-N and amino acid-N from total hydrolysable-N. In general, this fraction of N constituted about 20 and 26 per cent of total N and total hydrolysable-N, respectively. A perusal of the data revealed that the content of unidentified-N in surface layer varied from 107 mg kg^{-1} under control to 201 mg kg^{-1} under 100% NPK + FYM treatment. There was a general increase in the content of unidentified-N with the application of chemical fertilizers and amendments. Application of P along with N (T_3) and K along with N and P (T_4) did not influence this fraction significantly in comparison to 100% N alone (T_2). Organically amended plots (T_5) increased the content of unidentified-N significantly over optimal fertilization (100% NPK) by 17 per cent. The other treatments were statistically at par with 100% NPK except zero fertilization (T_1). Unlike other fractions, graded doses of NPK (50, 100 and 150 per cent) did not differ significantly among themselves.

Table 4: Effect of long-term use of chemical fertilizers and amendments on unidentified–N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	**0.15-0.30**
T_1: Control	107	101
T_2: 100% N	150	131
T_3: 100% NP	153	136
T_4: 100% NPK	169	142
T_5: 100% NPK+ FYM	201	165
T_6: 100% NPK+ lime	179	158
T_7: 100% NPK+ Zn	166	147
T_8: 100% NPK+ HW	163	140
T_9: 100% NPK (-S)	176	151
T_{10}: 150% NPK	171	144
T_{11}: 50% NPK	158	136
Fallow	*121*	*109*
CD (P= 0.05)	22.6	17.9

The variation in unidentified-N content in the subsurface layer was from 101 mg kg^{-1} in control to 165 mg kg^{-1} under 100% NPK + FYM. The treatment-wise pattern in subsurface soil layer was similar to surface soil. Irrespective of the treatments, the content of unidentified-N was lower in subsurface soil than surface soil. The content in 100% NPK + FYM treated plots was about 17 per cent higher than 100% NPK treated plots. The treatments comprising application of 100% NPK + FYM and 150% NPK were statistically at par. Continuous cropping without fertilization (T_1) depleted the unidentified-N to the order of 11.6 per cent and 7.3 per cent in surface and subsurface layer, respectively, in comparison to adjacent fallow.

A build up in unidentified-N with continuous use of chemical fertilizers and FYM for thirty six years might be due to the immobilization of applied N in this form as observed earlier by Santhy *et al.* (1998) [9], Sarawad *et al.* (2001) [10] and Sammy Reddy *et al.*, (2003) [13] in the soils of Tamil Nadu, New Delhi and Barrackpore (WB), respectively.

Total hydrolysable-N

The total hydrolysable-N content in surface layer ranged from 356 mg kg^{-1} under control to 859 mg kg^{-1} under 100% NPK + FYM treatment. Total hydrolysable N constituted about 78 per cent of total N. The results clearly demonstrated that there was a general increase in hydrolysable-N with the use of chemical fertilizers alone or chemical fertilizers along with other amendments over no fertilization. Graded levels of NPK *viz.* 50, 100 and 150% NPK increased total hydrolysable-N by 31.5, 45.6 and 52.2 per cent over control, respectively. Application of amendments *viz.* lime and FYM along with 100% NPK increased total hydrolysable-N significantly over 100% NPK alone. The content of total hydrolysable N in the subsurface layer ranged from 308 mg kg^{-1} under control to 718 mg kg^{-1} under 100% NPK + FYM treatment. There was a decrease in the content of total hydrolysable-N with the increase in soil depth.

Table 5: Effect of long-term use of chemical fertilizers and amendments on total hydrolysable-N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	0.15-0.30
T_1: Control	356	308
T_2: 100% N	536	414
T_3: 100% NP	599	467
T_4: 100% NPK	655	514
T_5: 100% NPK+ FYM	859	718
T_6: 100% NPK+ lime	744	620
T_7: 100% NPK+ Zn	650	523
T_8: 100% NPK+ HW	684	541
T_9: 100% NPK (-S)	631	500
T_{10}: 150% NPK	732	590
T_{11}: 50% NPK	520	436
Fallow	*448*	*353*
CD (P= 0.05)	32.8	36.1

All the treatments in the subsurface soil layer followed the same trend as was observed under surface layer. Since there was a build up in all the constituent fractions of hydrolysable N i.e. hydrolysable ammonical-N, amino acid-N, amino sugar-N and unidentified-N, hence the increase in total hydrolysable N with the continuous use of either chemical fertilizers alone or in combination with amendments is understandable.

Table 6: Effect of long-term use of chemical fertilizers and amendments on non hydrolysable-N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	0.15-0.30
T_1: Control	111	94
T_2: 100% N	118	102
T_3: 100% NP	124	110
T_4: 100% NPK	128	112
T_5: 100% NPK+ FYM	146	132
T_6: 100% NPK+ lime	139	119
T_7: 100% NPK+ Zn	127	117
T_8: 100% NPK+ HW	130	114
T_9: 100% NPK (-S)	132	110
T_{10}: 150% NPK	136	122
T_{11}: 50% NPK	121	108
Fallow	*118*	*96*
CD (P= 0.05)	NS	NS

These results are in line with those of Kher and Minhas (1992) [7], Sammi Reddy *et al.* (2003) [13] and Tabassum *et al.* (2010) [17]. The integrated treatment showed a significant increase in total hydrolysable-N over chemical fertilizer treatments. This might be due to carry-over effect of continuous use of organic sources and accumulation of organic residues, which in turn, contributed higher build up in soil and thus recorded increase in total hydrolysable N over control (Basumatry and Taludkar 1998) [18]. The application on 100% NPK + lime resulted in improving the total hydrolysable N fraction content in soil which could be due to the improvement in physical, physico-chemical and biological properties of soil (Kher and Minhas 1992) [7]. Lower content of total hydrolysable-N in subsurface soil may be because of less accumulation of carbon in this layer.

Non hydrolysable-N

Non hydrolysable-N was calculated by subtracting the sum of total hydrolysable-N and inorganic-N (NH_4-N and NO_3-N) from total N. This fraction constituted 15.8 per cent of total N. The results indicated that non hydrolysable-N varied from 111 mg kg^{-1} in control to 146 mg kg^{-1} in 100% NPK + FYM treatment. Like hydrolysable N fractions, highest content was recorded under 100% NPK + FYM and lowest under zero fertilization. Unlike hydrolysable N fractions, non hydrolysable-N was not influenced significantly either with the use of chemical fertilizers alone or in combination with amendments. In subsurface layer, the content of non hydrolysable-N were ranged from minimum value of 94 mg kg^{-1} in control to 132 mg kg^{-1} in 100% NPK + FYM treatment. Here again, the effect of chemical fertilizers or

conjuctive use of organic manure and chemical fertilization was found non-significant.
These findings are in accordance with those of Sarawad *et al.* (2001) [10] who reported non-significant effect of chemical fertilizers and manure from the long-term fertilizer study being conducted at New Delhi. Continuous cropping without fertilization led to depletion to the extent of 6 and 2 per cent in surface and subsurface layer, respectively. The extent of depletion of non hydrolysable N with the continuous cropping was less as compared to that of hydrolysable N which further supports the view that hydrolysable fraction is more susceptible to mineralization than non hydrolysable N (Ferguson and Gorby 1971) [19].

Ammonical -N
The NH_4-N content in surface soil layer varied from a minimum value of 17.0 mg kg^{-1} under control to 38.3 mg kg^{-1} under 100% NPK + FYM treatment (Table 4.13). This fraction constituted 3.6 per cent of total N. In general, all the treatments increased NH_4-N significantly over control. The contents of NH_4-N in 100% N, 100% NP and 100% NPK treated plots were 21.3, 25.0 and 31.0 mg kg^{-1} respectively. A consistent increase in NH_4-N content was registered with the increase in NPK levels *i.e.* from 50% to 150%. There was an increase of 8.7 per cent in manually weeded plot (T_8) when compared with 100% NPK treated plot (T_4) where chemical weed control was followed.

Table 7: Effect of long-term use of chemical fertilizers and amendments on NH_4-N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	**0.15-0.30**
T_1: Control	17.0	18.3
T_2: 100% N	21.3	23.0
T_3: 100% NP	25.0	25.7
T_4: 100% NPK	31.0	33.7
T_5: 100% NPK+ FYM	38.3	41.3
T_6: 100% NPK+ lime	37.0	37.3
T_7: 100% NPK+ Zn	30.7	30.7
T_8: 100% NPK+ HW	33.7	36.0
T_9: 100% NPK (-S)	29.0	30.0
T_{10}: 150% NPK	34.0	35.0
T_{11}: 50% NPK	26.3	28.0
Fallow	*19.2*	*19.9*
CD (P= 0.05)	2.4	5.1

As regards the subsurface soils, the NH_4-N content varied from 18.3 in control to 41.3 mg kg^{-1} in 100% NPK + FYM treated plots. Unlike organic N fractions, NH_4-N contents were slightly higher in subsurface soils than surface soils. However, the treatment wise pattern was almost same as that was observed in case of surface soil. Long-term application of 100% NPK + FYM, 100% NPK + HW, 100% NPK + lime and 150% NPK increased NH_4-N content by 125.3, 98.2, 117.6 and 100 per cent over control.
The increase in NH_4-N with the application of chemical fertilizers is understandable as hydrolysis of urea results in the release of ammonium ions in the soil. Regarding the organically amended soil, mineralization/ammonification of organic nitrogen in these plots might have contributed NH_4-N ions in the soil. These results are in close conformity to the findings of Sammy Reddy *et al.* (2003) [13]. The higher content of NH_4-N in subsurface soil may be because of the leaching of ammonical ions to lower layer. Similar depth wise distribution of NH_4-N has also been reported by Gupta *et al.* (2005) [20].

Nitrate-N
The NO_3-N content varied from 10 mg kg^{-1} under control to 28 mg kg^{-1} under 100% NPK + FYM treatment in surface soil layer. This fraction constituted 2.6 per cent of total N. Graded doses of NPK (50, 100 and 150%) increased NO_3-N content by 73.0, 117.0 and 150.0 per cent over control. The superoptimal dose of NPK (T_{10}) and continuous integrated use of FYM and chemical fertilizers (T_5) increased NO_3-N content by 150.0 and 180.0 per cent, respectively over untreated plots (T_1). The treatments consisting of 100% NPK + lime, 100% NPK +Zn, 100% NPK+ HW and 100% NPK (-S) did not differ significantly from 100% NPK (T_4).
The NO_3-N content in the subsurface soil layer varied from a minimum of 12.0 mg kg^{-1} under control to a maximum of 29.3 mg kg^{-1} under 100% NPK + FYM treatment. Like NH_4-N, the contents of NO_3-N were higher in subsurface soil layer than surface soil layer. The effect of different treatments on NO_3-N followed the same trend as in surface layer. Continuous application of 100% NPK + FYM and 150% NPK increased NO_3-N content by 144.2 and 141.6 per cent, respectively over control. Continuous application of NPK either alone or in combination with and FYM ensured higher NO_3-N content which may be ascribed to nitrification of NH_4-N to NO_3-N by soil micro-organisms (Santhy *et al.* 1998) [9]. Like NH_4-N, higher NO_3-N content in sub surface layer may be attributed to leaching of NO_3 ions from upper to lower layer. Similar findings have been reported by Gupta *et al.* (2005).

Table 8: Effect of long-term use of chemical fertilizers and amendments on NO_3- N (mg kg^{-1})

Treatment	Soil depth(m)	
	0-0.15	**0.15-0.30**
T_1: Control	10.0	12.0
T_2: 100% N	19.7	21.7
T_3: 100% NP	22.7	24.3
T_4: 100% NPK	21.7	25.0
T_5: 100% NPK+ FYM	28.0	29.3
T_6: 100% NPK+ lime	24.3	26.7
T_7: 100% NPK+ Zn	23.0	26.3
T_8: 100% NPK+ HW	23.7	24.0
T_9: 100% NPK (-S)	20.7	23.3
T_{10}: 150% NPK	25.0	29.0
T_{11}: 50% NPK	17.3	18.0
Fallow	*11.5*	*13.4*
CD (P= 0.05)	3.3	6.1

Total N
Total N varied from 494 mg kg^{-1} in control to 1071 mg kg^{-1} in 100% NPK + FYM treatment in the surface soil layer. Long-term sole use of chemical fertilizers or combined use of fertilizers and FYM/lime influenced the total N content significantly. Organically amended plots (T_5) registered significantly higher total N content (1071 mg kg^{-1}) than rest of the treatments. The treatments like 100% NPK, 100% NPK + Zn and 100% NPK (-S) with total N values of 836, 831 and 813 mg kg^{-1}, respectively, were statistically alike. Continuous cropping without fertilization for thirty six years depleted total N in control by about 17 per cent in comparison to adjacent fallow.

Table 9: Effect of long-term use of chemical fertilizers and amendments on total- N (mg kg^{-1})

Treatment	Soil depth (m)	
	0-0.15	**0.15-0.30**
T_1: Control	494	432
T_2: 100% N	695	561
T_3: 100% NP	770	627
T_4: 100% NPK	836	685
T_5: 100% NPK+ FYM	1071	921
T_6: 100% NPK+ lime	944	803
T_7: 100% NPK+ Zn	831	697
T_8: 100% NPK+ HW	871	715
T_9: 100% NPK (-S)	813	663
T_{10}: 150% NPK	927	776
T_{11}: 50% NPK	685	590
Fallow	*597*	*482*
CD (P= 0.05)	49.4	51.3

In subsurface soil, total N content ranged from 432 mg kg^{-1} to 921 mg kg^{-1}. The effect of different treatments on total N content was almost similar to that of subsurface soil. A build up was recorded under all the treatments as compared to control. Depletion to the extent of about 10 per cent was registered in total N content in this layer. Invariably, the content under each treatment was lower in subsurface soil than surface soil.

The increase in total N content with the continuous use of chemical fertilizers either alone or in combination with amendments for thirtysix years may be ascribed to the increase in different organic and inorganic N fractions in the present study. Similar increase in total N content due to the application of N through inorganic or organic sources has also been recorded elsewhere in the country by Sarawad *et al.* (2001) [10] and Sihag *et al.* (2005) [11]. Similar to soil organic carbon content, total N contents were higher in surface soil than subsurface soil.

Conclusions

- The continuous use of chemical fertilizers and amendments for thirty six years in an acid Alfisol brought out marked increase in the organic and inorganic fractions of N, total N and organic carbon content compared to the untreated plots.
- Different fractions of nitrogen were higher in the plots which received organics and inorganics (100% NPK + FYM) compared to the plots receiving only chemical fertilizers (100% NPK) for thirty six years. Among all the fractions, hydrolysable ammonical-N was found to play major role in the supply of nitrogen.

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