International Journal of Chemical Studies 2018; 6(4): 3234-3239

International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 3234-3239

Received: 08-05-2018
Accepted: 13-06-2018

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Effect of integrated nutrient management on nitrogen dynamics under groundnut-wheat system of typic haplustepts in long term fertilizer experiment

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Abstract
Our study on soil N dynamics was conducted in the year 2015 after wheat. It focused on the effects of soil managements with sole and combined applications of mineral and organic fertilizers in the long-term experiment conducted since 1999 at instructional farm, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat. The long-term fertilizer experiment included twelve fertilization treatments and each treatment had four replicates were arranged in a randomized block design. With respect to forms of nitrogen it can be deduced that there was a declined in soil nitrogen levels. After 16 year application of sole and combined applications of mineral and organic fertilizers in the long-term fertilizer experiment the available-N status marginally increased in treatments which received FYM (T_8 and T_9). At initial stage of experiment (1st year) average available nitrogen status of LTFE soils falls under medium range (250-500 kg N ha^{-1}), but after 16th year all treatments exhibited low range of available nitrogen status in soil, except treatments which received FYM (T_8 and T_9) which showed medium range in available-N status of long term fertilizer experiment soils. The overall, organic carbon and total-N status increased significantly after 16 year of experiment, whereas ammonical-N and nitrate–N status of LTFE soils in general decreased after long run, but ammonical-N increased in the treatment T_{10} due to fixation of atmospheric nitrogen by *Rhizobium* bacteria. It was established here that for maintaining N fertility of soil at long run, addition of FYM is essential with inorganic fertilizers. In long term fertilizer experiment soils, the per cent depletion of different forms of nitrogen was interesting under all treatments. The total-N and organic carbon showed negative depletion after a span of 16 year, whereas mixed trend was observed in available-N fraction, where maximum positive per cent depletion was recorded in T_7 and T_{12} treatment and maximum negative per cent depletion was noted in T_9 treatment which received FYM.

Keywords: Integrated nutrient management, nitrogen fraction, long term fertilizer experiment, calcareous soils

Introduction
Nitrogen is an important element for plant life. In the importance it comes only next to carbon, hydrogen and oxygen as it figures in the composition of proteins, nucleic acid, growth hormones, vitamins *etc*. It is also one of the main structural components of a living organism. Soil nitrogen is primarily in the organic fraction of the soil. The atmosphere above the soil contains 79 % nitrogen, but this nitrogen can only be used directly by leguminous plants, which have symbiotic nitrogen-fixing microorganisms, such as *Rhizobium*, in nodules on their roots. In the lithosphere, igneous rocks are the main source of soil nitrogen (Stevenson, 1986) [19]. Most of the nitrogen in the plough layer of arable soils is present in a continuum of complex organic form (Kelley and Stevenson, 1995) [9], hence only a small proportion of total N is present in the available forms (NH_4^+ and NO_3^-) in the soil. Nitrate is first reduced to ammonium level in a series of steps in order to be absorbed by the plants. The average Indian soil contains about 0.05 per cent nitrogen. To supplement N, along with organic sources, extensive and continuous application of mineral fertilizers stimulate mineralization and immobilization, thereby influencing the biological transformation of the nitrogen in soil (Duhan *et al*., 2005) [5].

Nitrogen occurs in soil as inorganic and organic compounds. Nitrates and nitrites of calcium, potassium *etc*. are the main inorganic forms of nitrogen, while organic form chiefly the proteins. The mineral N of the soil exists as NH_4^+, NO_3^- and sometimes NO_2^- either in soil solution, on exchange sites of soil particles or as NH_4^+ held by clay minerals. Some gaseous nitrogen may also be found in the soils atmosphere and dissolved in soil solution. In most soils, about 95-98 % of total N is bound in organic compounds, and the rest is in inorganic forms which, except in soils containing much fixed ammonium, are easily available to plants (Stevenson, 1982). In the tropics, available N is rarely adequate for plant growth unless it is replenished by organic N mineralization. Continuous addition of fertilizer N along with organic manures is known to stimulate mineralization and immobilization (Asami, 1971) [1], thereby affecting the levels of different organic and inorganic soil N fractions. Considering this fact, there is a urgent need to study the dynamics of different fractionsof nitrogen under intensive cropping system and hence, the present investigation was planned.

Materials and Methods

Study Site Description

The AICRP LTFE was started in the year 1999 at Instructional Farm, College of Agriculture, Junagadh Agricultural University at Junagadh to study the effect of continuous application of fertilizers (N, P, and K) and manure in a groundnut-wheat crop rotation. In present work of LTFE soils, which was started 16 years back on Typic Haplustepts calcareous clay soil, there was addition of different amounts of major nutrients fertilizers, which changes in soil status in terms of major nutrients as well as soil organic carbon fraction content in soil. The LTFE experiment site is situated between 20.39º to 21.8ºN latitude and 69.0º to 72.3ºE longitude with altitude of 60 meters above the mean sea level. The climate is subtropical in Junagadh. The average annual temperature is 25.7 °C in Junagadh. Average annual rainfall is about 903 mm with 45 rainy days. About 91% of the annual rainfall is received during southwest monsoon season (June-September).

Soil Description

The experiment soils are calcareous in nature derived from trap basalt, lime stone and sand stone under semi arid climate. Taxonomically, the soil is classified as *Haplustepts*. The soil is dominated by smectite group of clay minerals, which give rise to mild cracking in dry season, due to which it is further classified as Typic Haplustepts at sub group level. The experimental soils was calcareous ($CaCO_3$- 42.2 %) in nature, alkaline in reaction (pH 8.2), free from salinity ($EC_{2.5}$-0.19 dS m^{-1}), had CEC 27.3 cmol (p+) kg and clayey in texture. From fertility point of views, it was medium in available nitrogen (271.23 kg ha^{-1}), low in available phosphorus (P_2O_5-25.51 kg ha^{-1}) but high in available potassium (K_2O-363.57 kg ha^{-1}).

Treatments

The long-term fertilizer experiment included twelve fertilization treatments and each treatment had four replicates were arranged in a randomized block design. All plots were continuously under groundnut - wheat rotation from the beginning of the experiment. The twelve treatments were T_1- 50 % NPK of recommended doses in Groundnut-wheat sequence, T_2- 100 % N P K of recommended doses in Groundnut -wheat sequence, T_3 -150 %N P K of recommended doses in Groundnut -wheat sequence,T_4 - 100 % N P K of recommended doses in Groundnut –wheat sequence + $ZnSO_4$ @ 50 kg ha^{-1} once in three year to Groundnut only (*i.e.* 99, 02, 05 *etc*.), T_5 - N P K as per soil test,T_6 - 100 % N P of recommended doses in Groundnut –wheat sequence, T_7 - 100 % N of recommended doses in Groundnut -wheat sequence, T_8 - 50 % N P K of recommended doses+ FYM @ 10 t ha^{-1} to Groundnut and 100 % N P K to wheat, T_9 - Only FYM @ 25 t $ha^{-1}$to Groundnut only, T_{10} - 50 % N P K of recommended doses + *Rhizobium* + PSM to Groundnut and100 % N P K to wheat, T_{11} - 100 % N P K of recommended doses in Groundnut -wheat sequence (P as SSP) and T_{12} –Control.

Soil sampling and analysis

In the experiment, groundnut crop was grown during *kharif* 1999-2000 and wheat crop was grown during *rabi*1999-2000. The soil samples were collected during three periods (1^{st} and 16^{th}years), initial year (1999- before Groundnut) and 16^{th}year (2015- after Wheat). For the present study, soil samples were collected after crop harvest with the help of tube auger from the each plot of the above mentioned treatments representing the plough layer (20 cm). These soil samples were cleaned and air-dried. The soil samples, after air-drying, were ground with wooden mortar and pestle to pass through a 2 mm plastic sieve. The bulk soil samples were stored in polyethylene bags for chemical analysis.

The soil samples were analyzed for determining the forms of nitrogen on the basis of method mentioned below.

Total Nitrogen: Total nitrogen was determined by the modified kjeldahal method (Jackson, 1973).

Available nitrogen: Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956).

Ammonical nitrogen: Ammonical nitrogen was determined by Richardson's method (Richardson, 1938) N.B. - It's modification of Olsen method.

Nitrate nitrogen: Nitrate nitrogen was determined after Olsens extraction for ammonia (Olsen, 1929) [10].

Organic carbon: Organic carbon was determined by wet oxidation method (Walkley and Black, 1935) [22].

***Depletion percent:** These nutrients depleted from soil by different cycles were calculated by the formula:

$$\text{Depletion of nutrient (\%)} = \frac{\text{Nutrient status - Nutrient status of index year of final year}}{\text{Nutrient status of index year}} \times 100$$

Statistical Analysis

All the analytical data recorded during the course of investigation were subjected to statistical analysis by using Randomized Block Design. Statistical analysis was completed using the SPSS 16.0 software package for Windows. Statistically significant differences were identified using analysis of variance ANOVA. As per the method outlined by Panse and Sukhatme (1985) [11], the value of test at 5 and 1 per cent level of significant was determine and the values of SEm, CV per cent also calculate. The pooled analysis of two cycles of data was carried out as per procedure suggested by Cochran and Cox (1967) [4].

Result and Discussion

Available Nitrogen

The available nitrogen status of LTFE soils showed non-significant difference among the treatments in 1^{st} year, 16^{th}

year and pooled result. Year x treatment interaction was also found significant (Table-1). In 1st year the non-significantly higher value of available-N was observed under the application of 100 % N to groundnut-wheat sequence. But after 16year the non-significant highest value of available N was observed under application of FYM @ 25 t/ha to groundnut only (T_9) followed by 50 % NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence & 100% NPK to wheat (T_8). This results was in confirmation with the finding of Varalakshmi *et al.*,(2005) who reported that available N significantly improved with the use of 100 % recommended fertilizer + 7.5 t FYM ha^{-1}. There was overall decreased in available N status of soil after a period of 16 year than initial year but it was marginally increased in treatments which received FYM and NPK as per soil test. This might be due to increase in organic matter content of soil due to application of FYM and fulfill crops requirement through soil test bases. The increasing N status in FYM received plot, it could be resulted due to better biological activities in the presence of FYM. Similarly, Shilpashree *et al.*, (2012) [16] reported that significantly lower available nitrogen status was recorded in the treatments which received nitrogen only through fertilizers and without any organic matter application including absolute control compared to all other treatments and Eresha *et al.*, (2016) [6] was also reported that the higher available nitrogen was recorded in treatment receiving FYM along with inorganic fertilizers in long term fertilizer experiment (LTFE).

Table 1: Status of available nitrogen in soils of LTFE in 1st year and after 16th year.

Treatment	Available N (kg ha^{-1})		
	1st year	16th year	Pooled
T_1	252.84	262.07	257.46
T_2	296.35	272.19	284.27
T_3	249.31	248.30	248.81
T_4	262.64	269.36	266.00
T_5	235.98	246.11	241.05
T_6	261.46	244.09	252.78
T_7	299.88	241.45	270.67
T_8	264.21	278.60	271.41
T_9	261.46	283.23	272.35
T_{10}	292.04	264.43	278.24
T_{11}	292.04	267.22	279.63
T_{12}	286.55	243.28	264.91
MEAN	271.23	260.03	265.63
S.Em.±	23.53	16.38	14.34
C.D. at 5 %	NS	NS	NS
C.V. %	17.35	12.60	15.27

Organic carbon (O.C.)

The organic carbon showed significant difference in 16th year and pooled result and it was recorded higher under application of FYM @ 25 t ha^{-1} to groundnut only (T_9) followed by 50 % NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence and 100 % NPK to wheat (T_8). In long term, there seems to be an increase in soil organic carbon after 16th year of experimentation (Table-2). This increase in organic carbon content could be due to enhanced root development of crop resulting in higher residues as a result of intensive farming with continuous fertilizer applications. This increase was attributed to the addition of FYM, because addition of organic manure helps to stimulate the growth and activity of microorganism, thus resulting in the improvement of root and shoot growth, leading to production of higher biomass which increased soil organic carbon (Kaur *et al.,* 2008). Reddy *et al.,* (2017) was also found that among the various treatment continuous use of farm yard manure with 100 % NPK treatment resulted in highest organic carbon content in soil compared to other treatments. There was overall increased in organic carbon status of LTFE soils after16th year as compared to initial status of soil (1st year). In 1st year the non-significantly higher value of organic carbon was observed under 50 % NPK of RDF in Groundnut-Wheat sequence (T_1) treatment followed by T_6 (150 % NPK of RDF in Groundnut-Wheat sequence). The FYM application improved soil physical condition, ultimately root growth increases and more biomass added to the soil, seems to increases organic carbon status of the particular soil.

Table 2: Status of organic carbon and total nitrogen in soils of LTFE in 1st year and after 16th year.

Treatment	Organic carbon (%)			Total N (%)		
	1st year	16th year	Pooled	1st year	16th year	Pooled
T_1	0.615	0.621	0.618	0.053	0.053	0.053
T_2	0.548	0.677	0.612	0.047	0.058	0.053
T_3	0.510	0.668	0.589	0.044	0.058	0.051
T_4	0.555	0.684	0.619	0.048	0.059	0.053
T_5	0.525	0.670	0.597	0.045	0.058	0.051
T_6	0.600	0.621	0.610	0.052	0.054	0.053
T_7	0.510	0.631	0.571	0.044	0.054	0.049
T_8	0.563	0.758	0.660	0.048	0.066	0.057
T_9	0.525	0.790	0.657	0.045	0.068	0.057
T_{10}	0.563	0.649	0.606	0.048	0.056	0.052
T_{11}	0.563	0.667	0.615	0.048	0.058	0.053
T_{12}	0.540	0.631	0.586	0.047	0.054	0.050

MEAN	0.551	0.672	0.612	0.048	0.058	0.053
S.Em.±	0.048	0.015	0.025	0.004	0.001	0.002
C.D. at 5 %	NS	0.044	NS	NS	0.004	NS
C.V. %	17.240	4.550	11.540	17.220	4.760	11.580

Total Nitrogen

The total nitrogen showed significant difference among treatment in 16th year and pooled over years and only non-significant result were observed in 1st year (Table-2). In16th year and pooled, the highest value of total nitrogen was observed under application of FYM @ 25 t ha^{-1} to groundnut only (T_9) and it was at par with 50 % NPK of RDF + FYM @ 10 t ha^{-1} to groundnut-wheat sequence & 100 % NPK to wheat (T_8)which could be resulted due to better biological activities in the presence of FYM. Redda and Kebede (2017) revealed that total N contents of the soil increased with the use of FYM in conjunction with inorganic fertilizers. In 1st year the non-significantly higher value of total nitrogen was observed under application of 50 % NPK of RDF in groundnut-wheat sequence (T_1) treatment followed by application of 150 % NPK of RDF in groundnut-wheat sequence (T_6). Similar resul ts were also reported by Reddy *et al.,* (2003).

Table 3: Status of ammonical nitrogen and nitrate nitrogen in soils of LTFE in 1st year and after 16th year.

Treatment	Ammonium-N (mg kg^{-1})			Nitrate-N (mg kg^{-1})		
	1st year	16th year	Pooled	1st year	16th year	Pooled
T_1	29.000	34.000	31.500	12.250	19.250	15.750
T_2	40.250	41.000	40.625	21.000	13.000	17.000
T_3	71.750	42.500	57.125	27.000	15.250	21.125
T_4	28.000	46.250	37.125	21.000	17.750	19.375
T_5	29.750	38.250	34.000	28.000	13.250	20.625
T_6	71.000	33.000	52.000	22.750	11.750	17.250
T_7	31.500	32.500	32.000	35.000	23.000	29.000
T_8	35.000	48.250	41.625	31.000	20.500	25.750
T_9	54.250	52.750	53.500	35.000	23.500	29.250
T_{10}	35.000	58.000	46.500	29.750	25.750	27.750
T_{11}	56.000	35.500	45.750	42.000	20.750	31.375
T_{12}	38.500	24.000	31.250	35.750	19.000	27.375
MEAN	43.333	40.500	41.917	28.375	18.563	23.469
S.Em.±	2.509	2.420	1.743	1.596	1.429	1.071
C.D. at 5 %	7.218	6.962	NS	4.591	4.113	3.024
C.V. %	11.580	11.950	11.760	11.250	15.400	12.910

Ammonical Nitrogen

The ammonical nitrogen showed significant difference due to different INM treatments in 1stand 16th year (Table-3). In first year, the highest value was recorded in plot of T_3 treatment *i.e.* 100 % NPK RDF followed by T_6 treatment *i.e* 100 % NP RDF in groundnut-wheat sequence, while in 16th year the highest value was recorded in plot of T_{10} treatment *i.e*50 % NPK + *Rhizobium* + PSM to groundnut and 100 % NPK to wheat followed by FYM @ 25 t ha^{-1} to groundnut only (T_9). It might be due to fixation of atmospheric nitrogen to the soil by microbes and better biological activities in the present of FYM. This finding is corroborated with Rajani *et al.,* (2010) who observed that there was an increased in ammonical-N and nitrate –N status of LTFE soils in the treatment with *Rhizobium* culture due to fixation of atmospheric nitrogen by *Rhizobium* bacteria. Whereas when pooled over years, the highest value of ammonical-N was found in T_3 treatment followed by T_9 and T_6 treatment. In long run, there was a slight decreased in overall ammonical nitrogen status of the LTFE soil. The results are supported by earlier works of Sihag *et al.,* (2005) [17], Balagopalan *et al.,* (1986) [2], who observed that surface soil samples decrease in NH_4-N.There was overall decrease in ammonical-N status of LTFE soils after a span of 16 years, but here it was interesting that in T_1, T_4 and T_{10} treatment ammonical-N status of that soil improved, that might be due to low crop yield and atmospheric-N fixation by *Rhizobium* bacteria in soil of T_{10} treatment.

Nitrate Nitrogen

The significant differences found in status of nitrate-N in LTFE soils at 1st year and 16th year, due to various INM treatments (Table-3). The pooled result over years was also showed significant difference among treatments. Initially (1st year), the highest value for nitrate-N (42.0 mg kg^{-1}) were recorded in plot of T_{11} treatment *i.e* 100 % NPK of recommended dose of Groundnut-Wheat sequence. After 16th year, the highest value of nitrate-N (25.75 mg kg^{-1}) was recorded in plot which received T_{10} treatment and it was at par with T_9*i.e* FYM @ 25 t ha^{-1} to groundnut only and T_7. It might be due to fixation of atmospheric nitrogen by *Rhizobium* bacteria. These overall results were also in agreement with the work of earlier worker (Sihag *et al.,* 2005) [17]. Adding green manure favored the soil conditions and might have helped in the mineralization of soil N leading to build up of increased N status in soil. Whereas, when pooled over years, the highest value of nitrate-N was found with T_{11} treatment followed by T_9 and T_7 treatment. There was overall decrease in status of nitrate-N after 16th year as compared to initial year. Balagopalan *et al.,* (1986) [2] was also reported similar results *i.e.* overall decrease of nitrate nitrogen in surface soil samples.

Depletion per cent of different forms of nitrogen

In LTFE soils after a span of sixteen year the total nitrogen showed negative depletion that means it increased (Table-4) and that were ranged from -0.755 in T_1 (50 % NPK of recommended dose of Groundnut-Wheat sequence) to -50.99 per cent in T_9 (FYM @ 25 t ha^{-1}). Similar results were also found in case of O. C. per cent depletion, ranged from -0.976 in T_1 to -50.476 in T_9. These results were also in agreement with the finding of Sihag *et al.,* (2005) [17] that, the application of chemical fertilizer alone or their combined with organic manures significantly increased all the form of nitrogen over control or their initial status. Among various N fractions, amino acid nitrogen was dominant N fraction. Whereas ammonical nitrogen showed negative trend in per cent depletion, except in T_3, T_6, T_9, T_{11} and T_{12} were positive depletion was noted, the highest per cent depletion of ammonical N was noted in T_6 (100 % NP of recommended dose of Groundnut-Wheat sequence). In case of nitrate nitrogen, all treatments exhibited positive

Table 4: Depletion per cent of different forms of nitrogen after 16 year groundnut-wheat sequence in LTFE soils.

Treat.	Total-N	O.C.	Amm.-N	Nitr.-N	Av.-N
T_1	-0.755	-0.976	-17.241	-57.143	-3.652
T_2	-23.729	-23.540	-1.863	38.095	8.152
T_3	-30.682	-30.980	40.767	43.519	0.406
T_4	-23.013	-23.243	-65.179	15.476	-2.559
T_5	-27.152	-27.619	-28.571	52.679	-4.291
T_6	-3.675	-3.500	53.521	48.352	6.645
T_7	-24.146	-23.725	-3.175	34.286	19.484
T_8	-35.258	-34.636	-37.857	33.871	-5.448
T_9	-50.993	-50.476	2.765	32.857	-8.325
T_{10}	-15.464	-15.275	-65.714	13.445	9.453
T_{11}	-18.969	-18.472	36.607	50.595	8.501
T_{12}	-17.204	-16.852	37.662	46.853	15.102

depletion, except T_1, this might have been attributed to leaching losses and crop uptake mostly this form of nitrogen. Same picture was also found in case of available nitrogen, where the highest positive depletion was noted in treatment which received 100 % N (T_7) and higher negative depletion was noted in both the treatments which received FYM *i. e.* T_8 (50 % NPK + FYM @ 10 t ha^{-1} to Groundnut and 100 % NPK to wheat) & T_9 (FYM @ 25 t ha^{-1}). These finding corroborate the result of Rajani *et al.,* (2010) who observed that in LTFE soils the per cent depletion of different forms of nitrogen was interesting under all treatments. In LTFE soils the total-N and O.C showed negative depletion after a span of 16 year and available-N exhibited positive depletion in all treatments.

Conclusion

The continuous use of chemical fertilizers and amendments for sixteen years in a medium black calcareous Typic Haplustepts brought out marked increase in the different fractions of nitrogen viz. total nitrogen, available nitrogen, ammonical nitrogen, and nitrate nitrogen and organic carbon content compared to the untreated plots. The different fractions of nitrogen were higher in the plots which received organic and inorganic fertilizers (T_8 & T_9) compared to the plots receiving only chemical fertilizers for sixteen years. Application of chemical fertilizer N (NPK, NP, and NK) was also a feasible way to increase different fraction of nitrogen in soils, compared with control treatment. Continuous cropping without fertilization proved deleterious to soil health as it resulted in a marked depletion of various N fractions throughout the soil profile. Thus, these results suggest that there is a need for supplying fertilizer as per crop requirement along with other nutrients and organic manures to sustain N reserves and enhance the N availability in Typic Haplustepts under intensive cropping. The integrated use of optimal fertilizer dose with FYM could be the better proportion in view of the above findings as well as the additional advantage of creating a favorable environment with the use of the latter in terms of improved physical and biological properties of soil.

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