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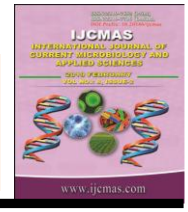

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Study the Organic and Inorganic Fraction of Nitrogen in Soil under Long Term Maize-Wheat Cropping Sequence

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A B S T R A C T

The present study was conducted to know the organic and inorganic fraction of nitrogen in soil under long term maize-wheat cropping sequence. It was observed that the effect of fertilizers and manures on ammonical nitrogen were reduces with depth irrespective of various treatment applied and with nitrate nitrogen, decreasing trend of this fraction with depth was observed. The pooled analysis of both year results reveals that the highest hydrolysable ammonia nitrogen (HAN) was found in treatment *i.e.* T_9-100% NPK + FYM 10 t ha^{-1}. Hydrolysable NH_4^+ –N + hexose amine-N form of nitrogen also decreases with depth irrespective of different treatments applied. Hexose amine nitrogen content reduces with depth irrespective of various treatment applied. Unidentified hydrolysable nitrogen content reduces with depth irrespective of various treatment applied. Application of fertilizer alone or in integration with FYM results in significant decrease in AAN and Total hydrolysable nitrogen irrespective of depth. The highest total nitrogen was observed under T_9- 100% NPK + FYM 10 t ha^{-1} application at three depth 889.08, 818.44 and 705.54 mg kg^{-1} ha respectively.

Introduction

The maize - wheat cropping sequence is very important cropping sequence for meeting local food needs and ensuring food security. Maize [*Zea mays* L.] - wheat [*Triticum aestivum* (L.)] is the most prominent and popular double cropping sequence under irrigated conditions in north-western parts of India. The contribution of this cropping sequence to total cereal production is considerably large, being 31% of wheat (72.06 mt) and 6% of maize (14.1 mt) (FAI, 2006). Traditionally being a monsoon season crop, maize-wheat is still the predominant maize based system (1.8 m ha) and is 3rd major crop-rotation in India and contributes ~3.0% in national food basket (Jat *et al.*, 2013). Indian soils have become deficient not only in major plant nutrients like nitrogen, phosphorus and in some cases, potash but also in micronutrients such as zinc, boron and to a limited extent iron, manganese, copper and molybdenum have also been reported to be deficient. Transformation of added nitrogen through fertilizers or manures into different forms of nitrogen in soil and their availability to crops depends on soil properties and nature of nitrogen sources added to soils. Nitrogen dynamics related to its availability to plants is always a subject of practical interest. In most soils, N is mainly organic in nature, hence normally only a small portion of total nitrogen is present in an inorganic form which, except in soils containing much fixed ammonium, is easily available to plants (Stevenson, 1982) With regard to its utilization 40-50 per cent of applied nitrogen is utilized by crop, about 15-25per cent is lost by different mechanisms and 20-30per cent remains in the soil as the fractions that are relatively inert and do not contribute more than 3-5 per cent to the succeeding crop.

The knowledge of distribution of various forms of nitrogen in soil attains greater importance in understanding the potential of a soil in supplying them to the crops and also to understand the nitrogen use efficiency by crops. Hence, it becomes an essential part of nitrogen management during the process of crop production (Shilpa shree *et al.*, 2012).

Materials and Methods

The present study was conducted at the Instructional farm, Rajasthan College of Agriculture, Udaipur during 2015-16 and 2016-17.

Experimental soil

The long term fertilizer experiment was initiated in 1996 - 97; the composite soil sample was drawn from 0-15 cm depth prior to treatment application in order to ascertain initial fertility status and physico-chemical properties of the experimental soil. Experimental field was sandy clay loam in texture, non-saline and slightly alkaline in reaction. The macro and micronutrient analysis revealed that soil was medium in N, P, K, S and have sufficient level of DTPA extractable Fe, Mn, Zn and Cu.

Results and Discussion

Nutrients, both natives as well as applied either through chemical fertilizers or by way of organic amendments, undergo a series of transformations due to continuous manuring and cropping which, in turn, may have substantial impact on their availability to crops.

The results with respect to different fractions of nitrogen in relation to long-term additions of chemical fertilizers alone or in combination with FYM under different treatments have been presented below.

Inorganic fraction of nitrogen

Ammonical nitrogen

Data pertaining to the effect of fertilizers and manures on ammonical nitrogen were presented in (Table 1). Application of fertilizers alone or in combination with FYM treatment resulted in a significant build up of ammonical nitrogen over control.

Data presented shows that ammonical nitrogen (NH_4^+- N) content of the soil after harvest of maize- wheat crop varied from 13.09 to 19.87 mg kg^{-1} and 13.50 to 20.28 mg kg^{-1} at 0-15 cm, 12.96 to 19.74 and 12.74 to 19.52 mg kg^{-1} at 15-30 cm and 12.15 to 18.93 and 11.75 to 18.55 mg kg^{-1} at 30-45 cm depth during 2015-16 and 2016-17, respectively. Application of 100% NPK + FYM 10 t ha^{-1} (T_9) resulted higher content of NH_4^+- N at three depths, during 2015-16 and 2016-17. Pooled data also reveals that the highest 20.08, 19.63 and 18.74 mg kg^{-1} NH_4^+- N with 100% NPK + FYM 10 t ha^{-1} application at 0-15 cm, 15-30 cm and 30-45 cm as compared to 13.29, 12.85 and 11.95 mg kg^{-1} under control was obtained. Ammonical nitrogen content reduces with depth irrespective of various treatment applied.

Nitrate nitrogen

Nitrate nitrogen (NO_3^-- N) differed significantly during both of years (Table 2). Nitrate nitrogen content of the soil at 0-15 cm, 15-30 cm and 30-45 cm depth after harvest of wheat crop varied from 4.55 to 7.05 mg kg^{-1}, 4.52 to 7.02 mg kg^{-1} and 4.47 to 6.97 mg kg^{-1} in treatments, respectively during 2015-16 and 2016-17. The higher value was recorded in T_{11}-150% NPK at 0-15 cm (7.05 and 7.10 mg kg^{-1}), at 15-30 cm (7.02 and 7.00 mg kg^{-1}) and at 30-45 cm (6.97 and 6.95 mg kg^{-1}) during 2015-16 and 2016-17, respectively, followed by T_6 (100% NPK+ S) with 6.96 and 7.01 mg kg^{-1} NO_3^-- N at 0-15 cm depth which was at par with T_{11}. The decreasing trend of this fraction with depth was observed. Pooled analysis also reveals the same pattern of the nitrate nitrogen.

Organic fraction of nitrogen

Hydrolysable ammonia nitrogen

The pooled analysis of both year results reveals that the highest hydrolysable ammonia nitrogen(HAN) was found in treatment *i.e.* T_9-100% NPK + FYM 10 t ha^{-1}.The highest values of HAN 149.65 and 158.20 mg kg^{-1}, 127.85 and 123.21 mg kg^{-1} and 120.50 and 117.14 mg kg^{-1} at 0-15 cm, 15-30 cm and 30-45 cm depth was recorded during 2015-16 and 2016-17, respectively followed by 150% NPK (T_{11}) with pooled values 130.78, 120.88 and 118.03 mg kg^{-1} at 0-15 cm, 15-30 cm and 30-45 cm depth, respectively. This form of nitrogen also decreases with depth irrespective of different treatments applied (Table 3).

Hydrolysable NH_4^+ –N + hexoseamine-N

The higher pooled value was recorded under application of 100% NPK + FYM 10 t ha^{-1} (T_9) followed by T_{11} -150% NPK. The highest values of NH_4^+ –N + hexoseamine-N171.50 and 182.35 mg kg^{-1}, 148.26 and 142.46 mg kg^{-1} and 137.86 and 134.03 mg kg^{-1} at 0-15 cm, 15-30 cm and 30-45 cm depth was recorded during 2015-16 and 2016-17 followed by 150% NPK (T_{11}) with pooled values 152.48, 137.68 and 132.73 mg kg^{-1} at 0-15 cm, 15-30 cm and 30-45 cm depth. This form of nitrogen also decreases with depth irrespective of different treatments applied (Table 4).

Hexoseamine nitrogen

Data presented in (Table 5) shows that hexoseamine nitrogen (HSN) content of the soil after harvest of maize- wheat crop varied from 13.20 to 21.85 mg kg^{-1} and 13.30 to 24.15 mg kg^{-1} at 0-15 cm, 10.10 to 20.41 and 9.40 to 19.25 mg kg^{-1} at 15-30 cm and 8.30 to 17.36 and 7.50 to 16.89 mg kg^{-1} at 30-45 cm depth during 2015-16 and 2016-17, respectively. Application of 100% NPK + FYM 10 t ha^{-1} (T_9) resulted higher content of HSN at three depths, during 2015-16 and 2016-17. Pooled data also reveals that the highest 23.00, 19.83 and 17.13 mg kg^{-1} HSN with 100% NPK + FYM 10 t ha^{-1} application at 0-15 cm, 15-30 cm and 30-45 cm as compared to 13.25, 9.75 and 7.90 mg kg^{-1} under control was obtained. Hexose amine nitrogen content reduces with depth irrespective of various treatment applied.

Amino acid nitrogen

Amino acid nitrogen (AAN) varies from 99 to 161 mg kg^{-1}, 87.15 to 154.15 mg $kg^{-1}$and 82.35 to 152.76 mg $kg^{-1}$and 79.95 to 150.36 mg $kg^{-1}$and 78.25 to 148.66mg kg^{-1}during 2015-16 and 2016-17 at 0-15, 15-30 and 30-45 cm depth, respectively (Table 6). The significantly higher value of AAN163.95, 153.46 and 149.51mg kg^{-1} in T_9 treatment at 0-15 15-30 and 30-45 cm depth and it is closely followed by T_{11}- 150% NPK and T_8-(100% NPK + *Azotobacter*) treatments.

Table.1 Effect of fertilizers and manures on ammonical nitrogen (mg kg^{-1}) in soil under maize–wheat cropping sequence at different depth

Treatments	Ammonical nitrogen (NH_4^+- N)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	13.09	13.50	13.29	12.96	12.74	12.85	12.15	11.75	11.95
T2 = 100% N	13.80	14.21	14.01	13.67	13.45	13.56	12.86	12.48	12.67
T3 = 100% NP	17.51	17.92	17.71	17.38	17.16	17.27	16.57	16.19	16.38
T4 = 100% NPK	18.89	19.30	19.10	18.76	18.54	18.65	17.95	17.57	17.76
T5 = 100% NPK + Zn	16.84	17.25	17.04	16.71	16.49	16.60	15.90	15.52	15.71
T6 = 100% NPK+ S	14.79	15.20	14.99	14.66	14.44	14.55	13.85	13.47	13.66
T7 = 100% NPK+ Zn + S	16.12	16.53	16.33	15.99	15.77	15.88	15.18	14.80	14.99
T8 = 100% NPK + *Azotobacter*	17.64	18.05	17.85	17.51	17.29	17.40	16.70	16.30	16.50
T9 = 100% NPK + FYM 10 t ha^{-1}	19.87	20.28	20.08	19.74	19.52	19.63	18.93	18.55	18.74
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	13.36	13.77	13.56	13.23	13.01	13.12	12.42	12.04	12.23
T11 = 150% NPK	19.25	19.66	19.45	19.12	18.90	19.01	18.31	17.93	18.12
T12 = FYM 20 t ha^{-1}	14.87	15.28	15.08	14.74	14.52	14.63	13.93	13.54	13.74
S.Em.±	0.37	0.38	0.26	0.36	0.36	0.25	0.34	0.33	0.24
C.D. (P = 0.05)	1.06	1.09	0.74	1.05	1.04	0.72	1.00	0.97	0.68

Table.2 Effect of fertilizers and manures on nitrate nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Nitrate Nitrogen (NO_3^-N)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	4.554	4.604	4.579	4.524	4.504	4.514	4.474	4.453	4.463
T2 = 100% N	5.759	5.809	5.784	5.729	5.709	5.719	5.679	5.658	5.668
T3 = 100% NP	6.295	6.345	6.320	6.265	6.245	6.255	6.215	6.194	6.204
T4 = 100% NPK	6.563	6.613	6.588	6.533	6.513	6.523	6.483	6.462	6.472
T5 = 100% NPK + Zn	6.741	6.791	6.766	6.711	6.691	6.701	6.661	6.640	6.650
T6 = 100% NPK+ S	6.964	7.014	6.989	6.934	6.914	6.924	6.884	6.863	6.874
T7 = 100% NPK+ Zn + S	6.920	6.970	6.945	6.890	6.870	6.880	6.840	6.759	6.799
T8 = 100% NPK + *Azotobacter*	6.518	6.568	6.543	6.488	6.468	6.478	6.438	6.417	6.427
T9 = 100% NPK + FYM 10 t ha^{-1}	6.920	6.970	6.945	6.890	6.870	6.880	6.840	6.809	6.824
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	5.893	5.943	5.918	5.863	5.843	5.853	5.813	5.782	5.797
T11 = 150% NPK	7.054	7.104	7.079	7.024	7.004	7.014	6.974	6.953	6.963
T12 = FYM 20 t ha^{-1}	6.384	6.434	6.409	6.354	6.334	6.344	6.304	6.283	6.293
S.Em.±	0.142	0.143	0.101	0.141	0.141	0.099	0.140	0.139	0.099
C.D. (P = 0.05)	0.409	0.412	0.285	0.407	0.405	0.282	0.403	0.402	0.279

Table.3 Effect of fertilizers and manures on hydrolysable ammonia nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Hydrolysable Ammonia Nitrogen (HAN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	105.00	105.55	105.28	92.20	87.56	89.88	78.26	75.43	76.85
T2 = 100% N	119.75	121.30	120.53	108.95	105.31	107.13	99.05	97.29	98.17
T3 = 100% NP	122.90	125.45	124.18	112.10	111.46	111.78	101.45	98.46	99.96
T4 = 100% NPK	123.55	128.10	125.83	118.75	117.11	117.93	110.50	108.09	109.30
T5 = 100% NPK + Zn	123.95	124.50	124.22	116.15	112.51	114.33	108.34	102.50	105.42
T6 = 100% NPK+ S	123.35	123.90	123.63	115.55	112.91	114.23	110.02	104.80	107.41
T7 = 100% NPK+ Zn + S	124.00	125.60	124.80	119.20	115.56	117.38	107.60	105.54	106.57
T8 = 100% NPK + *Azotobacter*	124.25	125.80	125.03	112.45	110.81	111.63	106.04	101.75	103.90
T9 = 100% NPK + FYM 10 t ha^{-1}	149.65	158.20	153.93	127.85	123.21	125.53	120.50	117.14	118.82
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	110.50	113.05	111.78	108.70	106.06	107.38	102.39	99.04	100.72
T11 = 150% NPK	130.00	131.55	130.78	121.20	120.56	120.88	118.53	117.52	118.03
T12 = FYM 20 t ha^{-1}	121.50	126.05	123.78	119.70	116.06	117.88	115.02	113.05	114.04
S.Em.±	2.82	2.86	2.01	2.62	2.55	1.82	2.41	2.34	1.68
C.D. (P = 0.05)	8.11	8.25	5.68	7.54	7.33	5.16	6.95	6.74	4.75

Table.4 Effect of fertilizers and manures on hydrolysable NH4+ –N + hexoseamine-N (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Hydrolysable NH_4 –N + Hexoseamine-N								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	118.20	118.85	118.53	102.30	96.96	99.63	86.56	82.93	84.75
T2 = 100% N	135.85	142.50	139.18	120.95	116.89	118.92	109.25	107.29	108.27
T3 = 100% NP	139.50	146.15	142.83	125.62	124.54	125.08	113.79	109.91	111.85
T4 = 100% NPK	141.40	152.05	146.73	128.86	127.13	128.00	119.71	117.15	118.43
T5 = 100% NPK + Zn	141.25	141.90	141.57	126.92	122.78	124.85	117.42	111.28	114.35
T6 = 100% NPK+ S	141.35	142.00	141.68	127.45	124.29	125.87	120.30	114.45	117.38
T7 = 100% NPK+ Zn + S	143.50	144.25	143.88	129.58	125.88	127.73	117.49	114.75	116.12
T8 = 100% NPK + *Azotobacter*	143.50	150.15	146.83	130.44	127.91	129.18	122.61	117.18	119.90
T9 = 100% NPK + FYM 10 t ha^{-1}	171.50	182.35	176.93	148.26	142.46	145.36	137.86	134.03	135.95
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	128.50	136.15	132.33	121.35	118.18	119.77	113.68	109.40	111.54
T11 = 150% NPK	150.50	154.45	152.48	138.50	136.86	137.68	133.73	131.72	132.73
T12 = FYM 20 t ha^{-1}	137.50	141.15	139.33	134.60	130.52	132.56	129.08	126.49	127.79
S.Em.±	3.23	3.35	2.32	2.93	2.84	2.04	2.69	2.60	1.87
C.D. (P = 0.05)	9.30	9.65	6.57	8.45	8.19	5.77	7.74	7.48	5.28

Table.5 Effect of fertilizers and manures on hexoseamine nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	**Hexoseamine Nitrogen (HSN)**								
	0-15 cm			**15-30 cm**			**30-45 cm**		
	2015-16	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**	**2015-16**	**2016-17**	**Pooled**
T_1 = Control	13.20	13.30	13.25	10.10	9.40	9.75	8.30	7.50	7.90
T2 = 100% N	16.10	21.20	18.65	12.00	11.58	11.79	10.20	10.00	10.10
T3 = 100% NP	16.60	20.70	18.65	13.52	13.08	13.30	12.34	11.45	11.90
T4 = 100% NPK	17.85	23.95	20.90	10.11	10.02	10.07	9.21	9.06	9.14
T5 = 100% NPK + Zn	17.30	17.40	17.35	10.77	10.27	10.52	9.08	8.78	8.93
T6 = 100% NPK+ S	18.00	18.10	18.05	11.90	11.38	11.64	10.28	9.65	9.97
T7 = 100% NPK+ Zn + S	19.50	18.65	19.08	10.38	10.32	10.35	9.89	9.21	9.55
T8 = 100% NPK + *Azotobacter*	19.25	24.35	21.80	17.99	17.10	17.55	16.57	15.43	16.00
T9 = 100% NPK + FYM 10 t ha^{-1}	21.85	24.15	23.00	20.41	19.25	19.83	17.36	16.89	17.13
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	18.00	23.10	20.55	12.65	12.12	12.39	11.29	10.36	10.83
T11 = 150% NPK	20.50	22.90	21.70	17.30	16.30	16.80	15.20	14.20	14.70
T12 = FYM 20 t ha^{-1}	16.00	15.10	15.55	14.90	14.46	14.68	14.06	13.44	13.75
S.Em.±	0.41	0.52	0.33	0.31	0.30	0.21	0.27	0.25	0.19
C.D. (P = 0.05)	1.19	1.50	0.94	0.91	0.86	0.61	0.80	0.74	0.53

Table.6 Effect of fertilizers and manures on amino acid nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Amino Acid Nitrogen (AAN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	99.00	99.25	99.13	87.15	82.35	84.75	79.95	78.25	79.10
T2 = 100% N	122.50	126.15	124.33	118.65	116.58	117.62	114.18	112.48	113.33
T3 = 100% NP	128.00	128.37	128.19	122.15	121.39	121.77	118.99	117.29	118.14
T4 = 100% NPK	132.00	138.58	135.29	128.10	128.00	128.05	125.60	123.90	124.75
T5 = 100% NPK + Zn	132.50	133.15	132.82	126.64	124.30	125.47	121.90	120.20	121.05
T6 = 100% NPK+ S	132.50	134.59	133.55	128.65	125.50	127.08	123.10	121.40	122.25
T7 = 100% NPK+ Zn + S	133.50	133.78	133.64	127.40	122.89	125.15	120.49	118.79	119.64
T8 = 100% NPK + *Azotobacter*	134.00	135.50	134.75	130.25	129.00	129.63	126.60	124.90	125.75
T9 = 100% NPK + FYM 10 t ha^{-1}	161.00	166.89	163.95	154.15	152.76	153.46	150.36	148.66	149.51
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	133.00	136.50	134.75	129.34	128.34	128.84	125.94	124.24	125.09
T11 = 150% NPK	146.50	152.75	149.63	140.55	137.27	138.91	134.87	133.17	134.02
T12 = FYM 20 t ha^{-1}	128.50	133.85	131.18	123.65	123.55	123.60	121.15	119.45	120.30
S.Em.±	3.06	3.12	2.18	2.91	2.85	2.04	2.80	2.76	1.96
C.D. (P = 0.05)	8.80	8.99	6.17	8.38	8.22	5.76	8.06	7.94	5.55

Table.7 Effect of fertilizers and manures on unidentified hydrolysable nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Unidentified Hydrolysable Nitrogen (UHN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	196.30	196.80	196.55	180.77	176.50	178.64	170.22	168.43	169.33
T2 = 100% N	224.45	224.80	224.63	211.92	207.90	209.91	202.50	200.64	201.57
T3 = 100% NP	243.00	243.58	243.29	230.47	226.45	228.46	218.65	215.31	216.98
T4 = 100% NPK	261.60	266.96	264.28	249.05	244.03	246.54	240.48	238.68	239.58
T5 = 100% NPK + Zn	264.24	264.77	264.51	251.61	245.60	248.61	240.89	236.56	238.72
T6 = 100% NPK+ S	266.15	266.11	266.13	253.60	248.43	251.02	242.35	239.50	240.93
T7 = 100% NPK+ Zn + S	264.50	264.91	264.71	251.57	247.95	249.76	244.08	240.20	242.14
T8 = 100% NPK + *Azotobacter*	263.50	264.18	263.84	250.38	247.01	248.70	245.04	241.24	243.14
T9 = 100% NPK + FYM 10 t ha^{-1}	277.50	282.83	280.17	264.50	260.65	262.58	258.59	254.58	256.59
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	284.00	284.60	284.30	271.45	267.45	269.45	259.80	250.42	255.11
T11 = 150% NPK	273.80	274.30	274.05	261.26	257.25	259.26	251.20	248.00	249.60
T12 = FYM 20 t ha^{-1}	249.00	252.65	250.83	236.45	232.43	234.44	229.00	227.89	228.45
S.Em.±	6.13	6.15	4.34	5.81	5.71	4.07	5.56	5.44	3.89
C.D. (P = 0.05)	17.66	17.71	12.27	16.73	16.44	11.51	16.01	15.65	10.98

Table.8 Effect of fertilizers and manures on total hydrolysable nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Total Hydrolysable Nitrogen (THN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	413.50	414.90	414.20	370.22	350.81	360.52	335.98	240.93	288.46
T2 = 100% N	482.80	493.45	488.13	451.52	441.37	446.45	427.33	315.10	371.22
T3 = 100% NP	510.50	518.10	514.30	478.24	472.38	475.31	452.00	334.52	393.26
T4 = 100% NPK	535.00	557.59	546.30	506.01	499.16	502.59	487.27	363.76	425.52
T5 = 100% NPK + Zn	537.99	539.82	538.90	505.17	492.67	498.92	481.77	356.92	419.35
T6 = 100% NPK+ S	540.00	542.70	541.35	509.70	498.22	503.96	486.15	359.17	422.66
T7 = 100% NPK+ Zn + S	541.50	542.94	542.22	508.55	496.72	502.64	480.35	355.14	417.75
T8 = 100% NPK + *Azotobacter*	541.00	549.83	545.42	511.07	503.92	507.50	494.14	363.02	428.58
T9 = 100% NPK + FYM 10 t ha^{-1}	610.00	632.07	621.04	566.91	555.87	561.39	546.70	403.23	474.97
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	545.50	557.25	551.38	522.14	513.97	518.06	501.50	377.66	439.58
T11 = 150% NPK	570.80	581.50	576.15	540.31	531.38	535.85	520.18	378.75	449.47
T12 = FYM 20 t ha^{-1}	515.00	527.65	521.33	494.70	486.50	490.60	481.09	350.47	415.78
S.Em.±	12.41	12.62	8.85	11.65	11.38	8.14	11.07	8.19	6.88
C.D. (P = 0.05)	35.71	36.31	24.99	33.53	32.75	22.99	31.85	23.56	19.44

Table.9 Effect of fertilizers and manures on non-hydrolysable nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Non-Hydrolysable Nitrogen (NHN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	121.00	121.43	121.22	109.30	108.17	108.74	99.08	97.45	98.27
T2 = 100% N	150.68	151.11	150.90	142.98	137.85	140.42	135.75	133.64	134.70
T3 = 100% NP	159.14	159.57	159.36	151.44	146.31	148.88	142.50	139.48	140.99
T4 = 100% NPK	187.50	187.93	187.72	179.80	174.67	177.24	172.59	160.50	166.55
T5 = 100% NPK + Zn	148.16	148.59	148.37	140.46	135.33	137.89	133.00	128.21	130.60
T6 = 100% NPK+ S	209.10	209.53	209.32	201.40	196.27	198.84	186.26	175.26	180.76
T7 = 100% NPK+ Zn + S	173.48	173.91	173.70	165.78	160.65	163.22	157.42	119.00	138.21
T8 = 100% NPK + *Azotobacter*	150.96	151.39	151.18	143.26	138.13	140.70	135.08	131.08	133.08
T9 = 100% NPK + FYM 10 t ha^{-1}	240.8	241.23	241.02	233.10	227.97	230.54	222.14	187.87	205.01
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	144.23	144.66	144.45	136.53	131.4	133.97	129.23	127.49	128.36
T11 = 150% NPK	210.98	211.41	211.20	203.28	198.15	200.72	191.25	154.62	172.94
T12 = FYM 20 t ha^{-1}	219.37	219.80	219.59	211.67	206.54	209.11	205.07	172.45	188.76
S.Em.±	3.76	3.77	2.66	3.55	3.45	2.47	3.34	3.13	2.29
C.D. (P = 0.05)	10.81	10.84	7.51	10.22	9.93	6.99	9.60	9.01	6.46

Table.10 Effect of fertilizers and manures on total nitrogen (mg kg^{-1}) in soil under maize –wheat cropping sequence at different depth

Treatments	Total Nitrogen (TN)								
	0-15 cm			15-30 cm			30-45 cm		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 = Control	552.15	554.44	553.29	497.01	476.23	486.62	451.69	354.58	403.13
T2 = 100% N	653.05	664.14	658.59	613.46	597.94	605.70	581.18	466.44	523.81
T3 = 100% NP	693.45	701.94	697.69	653.33	642.10	647.71	617.29	496.39	556.84
T4 = 100% NPK	747.96	771.44	759.70	711.11	698.89	705.00	684.30	548.30	616.30
T5 = 100% NPK + Zn	709.74	712.46	711.09	669.06	651.19	660.12	637.34	507.30	572.31
T6 = 100% NPK+ S	770.85	774.44	772.65	732.69	715.84	724.27	693.14	554.76	623.95
T7 = 100% NPK+ Zn + S	738.03	740.36	739.19	697.22	680.02	688.62	659.80	495.71	577.75
T8 = 100% NPK + *Azotobacter*	716.13	722.01	719.07	674.50	661.98	668.24	648.53	513.00	580.77
T9 = 100% NPK + FYM 10 t ha^{-1}	877.60	900.56	889.08	826.65	810.24	818.44	794.62	616.47	705.54
T10 = FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	708.98	725.91	717.45	682.05	668.51	675.28	653.25	527.23	590.24
T11 = 150% NPK	808.09	819.68	813.89	769.74	755.44	762.59	736.72	558.26	647.49
T12 = FYM 20 t ha^{-1}	755.63	769.17	762.40	727.47	713.90	720.69	706.40	542.74	624.57
S.Em.±	16.64	16.90	11.86	15.70	15.32	10.96	14.88	11.80	9.49
C.D. (P = 0.05)	47.89	48.64	33.49	45.17	44.08	30.97	42.82	33.96	26.82

These treatments were found statistically at par and superior than rest of treatments. Application of fertilizer alone or in integration with FYM results in significant decrease in AAN irrespective of depth.

Unidentified hydrolysable nitrogen

Results indicates that unidentified hydrolysable nitrogen (UHN) content significantly influenced application of fertilizer alone or in integration with FYM treatments during both years at 0-15 15-30 and 30-45 cm depth (Table 7). The highest UHN 284.30, 269.45 and 255.11 mg kg^{-1} was observed at 0-15, 15-30 and 30-45 cm depth by applying T_{10} - FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM) followed by 280.17, 262.58 and 256.59 mg kg^{-1} respectively with T_9 treatment application. These both treatments were at par and significantly superior to other treatments. Unidentified hydrolysable nitrogen content reduces with depth irrespective of various treatment applied.

Total hydrolysable nitrogen

Total hydrolysable nitrogen (THN) fraction varies from 414.20 to 621.04 mg kg^{-1}, 360.52 to 561.39 mg kg^{-1} and 288.46 to 474.97 mg kg^{-1} at 0-15 15-30 and 30-45 cm depth under pooled analysis (Table 8). The highest 610 and 632.07 mg kg^{-1}566.91 and 555.87 mg kg^{-1} and546.70 and 403.23 mg kg^{-1} THN was observed at 0-15, 15-30 and 30-45 cm depth, during 2015-16 and 2016-17 respectively, at T_9 *i.e.* 100% NPK + FYM 10 t ha^{-1} application.

This treatment is closely followed by (150% NPK) T_{11} treatment application. These treatments were found statistically at par and superior than rest of treatments. Application of fertilizer alone or in integration with FYM results in significant decrease in Total hydrolysable nitrogen irrespective of depth.

Non-hydrolysable nitrogen

Pooled over the year result was significant in non-hydrolysable nitrogen (Table 9). The significant higher pooled value 241.02,230.54 and 205.01 mg kg^{-1} was recorded by application of 100% NPK + FYM 10 t ha^{-1} (T_9) to maize – wheat crops followed by 219.59,209.11 and 188.76 mg kg^{-1} in T_{12} and 211.20,200.72 and 172.94 mg kg^{-1} under T_{11} treatment at 0-15cm, 15-30 cm and 30-45 cm depth, respectively. Similar trend was observed in both years. Higher values of NHN was 240.80 and 241.23 mg kg^{-1} in surface soil (0-15 cm) 222.14 and 187.87 mg kg^{-1} in sub surface soil (15-30 cm and 30-45 cm) during 2015-16 and 2016-17 respectively with application of 100% NPK + FYM 10 t ha^{-1} treatment.

Total nitrogen

Total nitrogen content ranged from 553.29 to 889.08 mg kg^{-1}, 486.62 to 818.44 mg kg^{-1} and 403.13 to 705.54 mg kg^{-1} at 0-15, 15-30 and 30- 45 cm depths (Table 10). The highest total nitrogen was observed under T_9- 100% NPK + FYM 10 t ha^{-1} application at three depth 889.08, 818.44 and 705.54 mg kg^{-1}, respectively followed by T_{11} - 150% NPK and FYM 20 t ha^{-1}(T_{12}) treatment. Similar trend was observed in both years. The significant difference under these treatment plots result of continuous application of fertilizers from last 20 year in this cropping system experiment. It is also evident from the data that total nitrogen fraction is more at surface soil (0-15 cm) than the subsurface soil (15-30 cm and 30-45 cm depth) irrespective application of fertilizer alone or with combination of FYM. As well as total nitrogen contain ammonical-N (3.10%), nitrate-N (0.87%), hydrolysable ammonia-N (16.99%), hydrolysable NH_4^+ –N + hexoseamine-N (19.58%), hexoseamine-N (2.60%), amino acid-N (18.21%), unidentified hydrolysable-N (34.15%), total hydrolysable-

N (71.94%) and non-hydrolysable-N (24.08%) in the soil under maize-wheat cropping sequence.

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