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Anil Kumar
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Rajeev Kumar
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Lavakush
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Sanjeev Kumar
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Sugriv Kumar Maurya
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Ashok Kumar
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Corresponding Author:
Rajeev Kumar
Janta Mahavidyalaya Ajitmal Auraiya, Uttar Pradesh, India

Effect of inorganic and organic sources of nutrient on NPK content, NPK uptake, apparent nitrogen recovery, nitrogen use efficiency and Protein content in rice under rice wheat cropping system

Anil Kumar, Rajeev Kumar, Lavakush, Sanjeev Kumar, Sugriv Kumar Maurya and Ashok Kumar

Abstract
Food security is a major global issue because of the very fast growth of population with decreasing natural resources. Rice (*Oryza sativa* L.) is the most important staple cereal crop in the world. Application of nitrogen (N) fertilizer has improved crop yield in the world during the past five decades but with considerable negative impacts on the environment. New solutions are therefore urgently needed to simultaneously increase yields while maintaining decreasing applied N to improve the nitrogen use efficiency (NUE) of crops. Plant NUE is inherently complex with each step (including N uptake, translocation, assimilation, and remobilization) governed by multiple interacting genetic and environmental factors. Based on the current knowledge, researcher developed some possible approaches for enhancing NUE, by molecular manipulation of genes and integrated nutrients management practices for improving NUE. Development of integrated research approaches, mainly based on whole-plant physiology, quantitative genetics, forward and reverse genetics, agronomical approaches to improve NUE, is a major objective in the future.

Keywords: rice, nitrogen use efficiency, ANR, nitrogen uptake, protein

Introduction
Plant are dependence on inorganic and organic nutrients and, 85-90 million tonnes of nitrogenous fertilizers are added to the soil worldwide annually (Good *et al.*, 2004). Lowering fertilizers input of plants with better nitrogen use efficiency is one of the main goals of research on plant nutrition (Hirel *et al.*, 2007). The use of nitrogen through plants involves several steps, including uptake, assimilation, translocation and, when the plant is ageing, recycling and remobilization. The plants have an ability to capture nitrogen from the atmosphere through biological process as well as from soil. In soil its availability depends on soil type, environment and plant species. It has been estimated that about 50-70 percent of nitrogen provided to the soil is lost through leeching and volatilization process (Hodge *et al.*, 2000). Nitrogen use efficiency in plants is complex process and its depends on availability nitrogen in the soil which is used by plant in his life span.
Nitrate uptake occurs at the root level and two nitrate transport systems have been shown to coexist in plants and to act co-ordinately to take up nitrate from the soil solution and distribute it within the whole plant (Maathuis, 2009). The Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) model was used for determining the region specific balanced NPK uptake requirements and recommendations for a target yield of taro (Jinimol, 2019). The constants for minimum and maximum accumulation (kg^{-1} nutrient) of N (33 and 177), P (212 and 606) and K (25 and 127) were derived as standard model parameters (Jinimol, 2019). Excessive application of nitrogen fertilizer may not result in yield improvements but will lead to serious environmental problems. From 1960 to 2012, the global N fertilizer consumption increased by 800% (Shuangjie *et al.*, 2017). Although the rate of cereal grain yield increased by 65% between 1980 and 2010, the consumption of chemical fertilizers increased by 512% (Shuangjie *et al.*, 2017). nitrogen use efficiency can be expressed as NUpEXNUtE=yield/N available. High N fertilizer input leads to low nitrogen use efficiency (NUE) due to the rapid N losses from ammonia volatilization, denitrification, surface runoff, and leaching in the soil-flood water system. As plant NUE is the grain yield per unit of supplied N, also an integration of NUpE and NUtE on sequence, significant environmental problems, (i.e., soil acidification,

air pollution, water eutrophication) occurred. The complete information on inorganic and organic nutrients in rice with regard to rice productivity, grain quality, soil health/quality and their residuals effect on wheat profitability in Indian soils, is very limited. Hence, the present experiment was conducted to evaluate effect of inorganic and organic sources of nutrient on NPK content, NPK uptake, apparent nitrogen recovery, nitrogen use efficiency and protein content in rice under rice wheat cropping system.

Methods and Materials

A Field experiment was conducted at Experimental Research Farm Janta Mahavidiyalaya Ajitmal, Auraiya during 2014-15 and 2015-16 to investigate the effect of inorganic and organic source of nutrient on NPK content, NPK uptake, apparent nitrogen recovery, nitrogen use efficiency and protein content in rice under rice wheat cropping system. The soil of the experimental field was sandy loam having pH 7.1, organic carbon 0.52%, available nitrogen 162.7 kg N ha^{-1}, available phosphorus 18.5 kg P_2O_5 ha^{-1}, available potassium 200.3 kg K ha^{-1}.The experiment consisted of seven treatments *viz.,*

T_1- Control,
T_2 -25% N (FYM) + 75% N (fertilizers) ,
T_3 - 50% N (FYM) + 50% N (fertilizers),
T_4 –75% N (FYM) + 25% (fertilizers N),
T_5 -100% N (FYM) ,
T_6 -25% (green Manures) + 75% (fertilizer N),
T_7-50% (green Manure) + 50% (fertilizer N),
T_8 – 75% (green Manure) + 25% (fertilizer N),
T_9 - 100% N (green Manure),
T_{10} –25% N (Poultry manure) + 75% (fertilizer N),
T_{11}-50% N (Poultry manure) + 50% (fertilizer N),
T_{12}-75% N (Poultry manure) + 25% (fertilizer N)
T_{13}-100% (Poultry manure)
T_{14-} 25% N (Wool based) + 75% (fertilizer N)
T_{15-} 50% N (Wool based) + 50% (fertilizer N)
T_{16-} 75% N (Wool based) + 25% (fertilizer N)
T_{17-} 100% N (Wool based)
T_{18-} 100% (fertilizer N)

Were laid out in randomized block design with three replications .The inorganic fertilizers were supplied through urea, diammonium phosphate, muriate of potash and gypsum. The rice variety Pant-10 was transplanted in rows 20x10 cm and wheat variety PBW 343 is sowing. The organic manures were applied in 15 days before transplanting as per treatment. Full dose of phosphorus, potassium, half of nitrogen (as per treatment) applied at the time of transplanting. Remaining $^1/_4$ of nitrogen was applied after 30 DAT and ¼ of Nitrogen at 65 DAT. The crop was harvested in the month of December. Recording of data of different character *viz.* NPK content (%) in grain, NPK content (%) in straw, NPK uptake (kg ha^{-1}) in grain, NPK uptake (kg ha^{-1}) in straw, apparent nitrogen recovery (%), nitrogen use efficiency and protein content in grain as per schedule. Available nitrogen was determined by alkaline permagnate method(Subbiah and Asija, 1956) [7], available phosphorous determined (olsen,1954), available K by ammonium acetate using flame photometer (Jackson,1973) [2] method Statistical analysis was based on the method analysis of variance as suggested by Panse and Sukhatme (1967) [6] and the standard error difference was computed by at 5% and 1% level of significance.

Result and Discussion

A significant enhancement was recorded of different treatments of inorganic and organic nutrients on NPK content during both the years of experimentation Table 1. The highest NPK content in grain (1.663 N, 0.460 P, 0.590 K and 1.660 N, 0.452 P, 0.580 K) were observed in T_{18} (100% fertilizer) during experimentation. Decrease in fertilizers and increase in organic nutrients NPK content showed decreasing trends. Organic sources of nutrients wool waste (1.600, 0.401, 0.502 and 1.465, 0.406, 0.510) absorbed maximum NPK followed by poultry manure, green manure and FYM. While lowest NPK content was recorded in control (T_1). In straw highest content was recorded in (T_{18}), while wool based caused higher NPK absorption. However, control showed poor results. Different organic and inorganic nutrients sources significantly influenced NPK uptake in rice grain and straw. The maximum NPK uptake by treatment combination T_{18} comparison to other treatment combination. Decrease in inorganic fertilizers dose with increasing organic nutrients sources NPK uptake decline. The average value of NPK uptake was higher in wool based organic nutrients followed by poultry manure, green manure and FYM. The lowest NPK uptake was noted in control in both rice grain and straw. The perusal of data indicated that a significant result was showed in apparent nitrogen recovery percentage (ANR%) during both the year. The highest ANR% (66.35 and 65.50 was noted in treatment T_{18} (100% NPK) and lowest ANR% (29.78%) was recorded in organic combination in FYM. Among the organic source wool based showed better performance among all the treatment combination. A different inorganic and organic source of nutrients on nitrogen use efficiency was significantly affected by different treatment combination. The highest NUE (20.90 and 19.81) was recorded in treatment combination T18. However, the lowest NUE (13.18 and 13.76) value was noted in treatment combination FYM (T_2-T_5). Protein% in grain significantly affected by different treatment combination. The maximum protein was observed in T_{18} (100% inorganic nutrients NPK). The decreased in inorganic nutrients and increased organic nutrients decreasing trend was noted in protein content in grain. Organic sources the wool based content maximum protein in grain than other organic nutrients sources. The lowest protein content was noted under control. It may be due to organic sources of nutrients releases many macro, micro nutrient as well as growth promoting substances which enhances the cell division and cell enlargement and also increases water/nutrients absorption, translocation of solute resulting more accumulation of photosynthete which was translocate from source to sink. Similar results were also reported by earlier Kumar *et al.,(*2018) [3], Kumar *et al.*, (2019*)* [4].

The residual effect of inorganic and organic sources of nutrient on NPK content, NPK uptake, apparent nitrogen recovery, nitrogen use efficiency and protein content in wheat under rice wheat cropping system was noticed and results indicated in Table 2. A significant enhancement was noticed in residual effect of different treatments on the NPK content in grain. The maximum NPK content in grain was recorded in T_{18}, while lowest NPK was noted in T_1. Wool waste showed significantly higher NPK content in grain in comparison to other organic based of nutrients. The maximum NPK content in straw was recorded in T_{18}, while lowest NPK was noted in T_1. With the increase in organic nutrients decrease in inorganic nutrients sources NPK content increase in straw. Wool based accumulates maximum NPK in straw followed by poultry, green manure and FYM during both the years of experimentation. Uptake of NPK significantly affected by different sources of inorganic and inorganic nutrients. The maximum NPK uptake in grain and straw noticed under T_{18} (100% N) and lowest in T_1. In organic based the wool waste showed better performance in comparison to other organic sources. A significant enhancement was noticed in residual effect of different treatments on the apparent nitrogen recovery. The wool waste significantly recorded higher ANR per cent (50.43% and 49.95 ANR%) and FYM (27.51% and 27.30 ANR%) showed lowest ANR per cent in wheat. A significant effect of different inorganic and organic nutrient sources on nitrogen use efficiency. The inorganic sources of nutrients showed poor performance in comparison to other organic nutrients sources. Wool based recorded higher nitrogen use efficiency followed by green manure, poultry manure and FYM. The perusal of data presented in table 2, the protein content in wheat is significantly influenced by different treatment combination. Application of wool based produced highest protein (14.53%and 15.50%) in wheat grain followed by poultry manure, green manure and FYM. The lowest protein per cent (10.53 and 10.53%) was recorded under control. The organic manures showed higher residual effect in comparison to inorganic fertilizers. . It might be due to organic sources of nutrients releases slowly-slowly many macro, micro nutrient as well as growth promoting substances which enhances the cell division and cell enlargement and also increases water/nutrients absorption, translocation of solute resulting more accumulation of photosynthete which was translocate from source to sink. This finding also corroborated with the results of Abdul *et al.*, (2008) [1], Kumar *et al.*, (2019) [4]. While inorganic fertilizers are highly solubilising nature resulting fast release of nutrients in soil solution some of them are utilised by crop plant some of lost due to saline/ water logged/high temperature condition nitrogenous fertilizers are denitrified or leeched out, phosphatic fertilizers are converted in chelating compound and fixed on soil collides resulting unavailability of nutrients to crop plant.

Table 1: Effect of different treatments on NPK Content, NPK Uptake, Apparent nitrogen recovery (ANR), Nitrogen Use Efficiency (NUE) and Protein content of rice in rice wheat cropping sequence

Treatments	NPK content (%) in grain						NPK content (%) in straw						NPK uptake (kg ha^{-1}) in grain						NPK uptake (kg ha^{-1}) in straw					
	2015			2016			2015			2016			2015			2016			2015			2016		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T_1	1.832	0.325	0.710	1.830	0.312	0.698	0.720	0.102	0.90	0.700	0.101	0.91	40.34	7.156	15.63	40.26	6.86	15.35	25.28	3.58	31.60	31.60	3.51	31.64
T_2	1.910	0.398	0.740	1.911	0.397	0.739	0.810	0.128	1.12	0.808	0.125	1.10	53.48	11.14	20.72	53.28	11.07	20.61	33.38	5.27	46.16	46.16	5.14	45.29
T_3	2.020	0.400	0.746	2.000	0.399	0.743	0.812	0.129	1.14	0.809	0.127	1.13	60.09	11.90	22.19	56.94	11.65	21.69	354.11	5.41	47.05	47.05	5.33	47.46
T_4	2.225	0.402	0.752	2.220	0.401	0.750	0.814	0.131	1.16	0.812	0.130	1.15	69.46	12.55	23.47	69.26	12.51	23.40	34.96	5.62	48.97	48.97	5.54	49.04
T_5	2.267	0.416	0.758	2.265	0.415	0.759	0.843	0.135	1.17	0.843	0.136	1.16	72.88	13.37	24.36	72.84	13.34	24.40	36.85	5.90	51.15	51.15	5.85	40.90
T_6	1.912	0.410	0.752	1.910	0.408	0.750	0.839	0.133	1.25	0.837	0.132	1.23	55.83	11.97	21.95	55.39	11.83	22.04	35.84	5.68	53.40	53.40	5.55	51.80
T_7	2.252	0.413	0.753	2.250	0.411	0.751	0.841	0.137	1.30	0.839	0.137	1.29	67.92	12.45	22.71	67.77	12.37	22.62	36.12	5.88	55.83	55.83	5.88	55.45
T_8	2.290	0.415	0.759	2.228	0.416	0.758	0.843	0.140	1.31	0.841	0.139	1.30	73.69	13.35	24.72	73.63	13.38	24.38	36.30	6.02	56.42	56.42	5.97	55.87
T_9	2.380	0.432	0.763	2.380	0.433	0.761	0.850	0.142	1.33	0.859	0.142	1.32	79.73	14.47	25.56	79.49	14.89	25.41	38.24	6.38	59.83	59.83	6.37	59.29
T_{10}	2.222	0.419	0.763	2.220	0.427	0.760	0.863	0.141	1.29	0.860	0.141	1.27	67.10	12.65	23.04	66.60	12.31	22.80	37.67	6.15	56.32	56.32	6.06	54.63
T_{11}	2.301	0.472	0.765	2.229	0.471	0.762	0.871	0.146	1.33	0.868	0.143	1.32	71.67	14.70	23.82	71.56	14.66	23.72	38.30	6.42	58.49	58.49	6.21	57.35
T_{12}	2.390	0.492	0.780	2.389	0.491	0.779	0.890	0.147	1.34	0.888	0.145	1.33	78.87	16.23	25.74	78.78	16.19	25.69	39.17	6.47	58.98	58.98	6.38	58.52
T_{13}	2.405	0.498	0.782	2.404	0.499	0.781	0.892	0.149	1.35	0.890	0.148	1.35	83.26	17.24	27.07	83.20	17.27	27.03	40.91	6.83	62.38	62.38	6.78	61.89
T_{14}	2.501	0.501	0.781	2.500	0.502	0.780	0.898	0.148	1.37	0.895	0.145	1.34	80.78	16.18	25.22	80.27	16.11	25.04	39.64	6.53	60.48	39.38	6.38	58.96
T_{15}	2.502	0.507	0.785	2.580	0.504	0.783	0.900	0.152	1.40	0.899	0.150	1.39	84.96	17.21	26.65	83.08	16.74	26.01	40.39	6.82	62.83	40.09	6.69	61.99
T_{16}	2.525	0.520	0.786	2.523	0.521	0.785	0.901	0.153	1.41	0.900	0.152	1.41	86.15	17.42	26.81	85.78	17.71	26.69	41.55	7.05	65.02	41.47	7.00	64.97
T_{17}	2.527	0.522	0.788	2.525	0.523	0.787	0.9020	0.155	1.43	0.901	0.153	1.46	88.87	18.35	27.71	88.42	18.31	27.56	42.25	7.26	66.99	42.18	7.16	68.35
T_{18}	2.420	0.498	0.779	2.395	0.495	0.778	0.795	0.128	1.22	0.792	0.127	1.20	74.34	15.29	23.93	71.89	14.85	23.35	34.28	5.51	52.60	34.13	5.46	51.66
SE (DIFF)	0.047	0.016	0.0055	0.029	0.0090	0.010	0.0178	0.0045	0.043	0.018	0.005	0.038	1.35	0.488	0.967	1.27	0.621	0.920	1.007	0.170	1.97	0.950	0.148	1.28
CD (0.05%)	0.086	0.033	0.011	0.059	0.183	0.021	0.036	0.0093	0.088	0.037	0.01	0.078	2.75	0.992	1.967	2.58	1.262	1.86	2.046	0.346	2.42	1.930	0.301	2.61

Treatments	Apparent nitrogen recovery (%)		Nitrogen use efficiency		Protein content (%) in grain	
	2015	2016	2015	2016	2015	2016
T_1	-	-	--	-	10.53	10.53
T_2	17.70	17.45	4.98	4.90	10.98	10.97
T_3	23.80	21.93	6.44	6.00	11.61	11.50
T_4	32.32	32.74	7.66	7.66	12.93	12.76
T_5	36.75	37.09	8.44	8.46	10.03	13.02
T_6	21.78	21.70	5.83	5.83	10.99	10.99
T_7	32.01	32.69	6.78	6.76	10.49	12.93
T_8	36.97	37.64	8.46	8.47	13.16	12.81
T_9	43.62	44.56	9.56	9.50	13.68	13.68
T_{10}	32.62	32.50	6.81	6.66	12.77	12.76
T_{11}	37.14	37.23	7.60	7.60	13.23	13.16
T_{12}	43.65	44.38	9.14	9.13	13.74	13.73
T_{13}	48.78	49.50	10.50	10.50	13.82	13.82
T_{14}	45.66	45.88	8.56	8.47	14.38	14.37
T_{15}	49.77	48.76	9.95	8.88	14.38	13.38
T_{16}	51.72	50.16	10.08	10.00	14.57	14.50
T_{17}	54.58	55.00	10.95	10.85	14.53	14.51
T_{18}	35.83	32.43	7.25	6.68	13.91	13.77
SE (DIFF)	1.153	0.848	0.198	0.246	0.020	0.16
CD (0.05%)	2.34	1.723	0.43	0.499	0.047	0.34

Table 2: Effect of different treatments on NPK Content, NPK Uptake, Apparent nitrogen recovery (ANR), Nitrogen Use Efficiency (NUE) and Protein content of Rice in rice wheat cropping sequence

Treatments	NPK content (%) in grain						NPK content (%) in straw						NPK uptake (kg ha^{-1}) in grain						NPK uptake (kg ha^{-1}) in straw					
	2015			2016			2015			2016			2015			2016			2015			2016		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T_1	1.311	0.242	0.318	1.311	0.242	0.316	0.501	0.075	1.100	0.500	0.705	1.104	27.49	5.05	6.65	26.51	4.88	6.40	16.57	2.49	36.79	16.31	2.44	36.06
T_2	1.381	0.340	0.422	1.311	0.339	0.418	0.541	0.161	1.643	0.539	0.1593	1.641	54.54	13.42	18.67	53.86	13.24	16.34	31.48	9.41	95.74	30.62	9.06	93.38
T_3	1.360	0.332	0.400	1.379	0.236	0.395	0.540	0160	1.630	0.538	0.1597	1.628	51.95	12.67	15.27	51.62	12.42	15.03	30.94	9.22	94.14	29.65	8.88	91.25
T_4	1.358	0.319	0.382	1.357	0.318	0.380	0.539	0.159	1.623	0.536	0.1580	1.609	51.26	12.05	14.44	51.12	12.00	14.33	30.84	9.10	92.83	28.78	8.47	86.16
T_5	1.332	0.269	0.342	1.356	0.268	0.340	0.536	0.132	1.402	0.532	0.1313	1.401	42.77	8.63	10.97	72.97	8.58	10.89	28.40	7.00	73.51	28.13	6.93	74.05
T_6	1.372	0.352	0.562	1.369	0.351	0.383	0.542	0.168	1.695	0.541	0.1650	1.692	55.59	14.25	22.96	54.10	13.88	22.13	32.34	10.02	101.15	31.33	9.55	98.01
T_7	1.360	0.334	0.550	1.359	0.335	0.554	0.541	0.165	1.680	0.539	0.1633	1.678	54.06	13.53	21.85	53.13	13.07	21.37	31.51	9.61	97.94	30.73	9.31	95.75
T_8	1.351	0.320	0.525	1.349	0.319	0.546	0.540	0.163	1.665	0.538	0.1620	1.663	52.59	12.46	20.44	52.27	12.25	20.27	30.88	9.32	95.23	30.63	9.25	94.74
T_9	1.341	0.281	0.490	1.340	0.280	0.523	0.539	0.140	1.561	0.536	0.1397	1.558	47.22	9.89	17.24	47.10	9.93	17.17	29.23	7.59	84.59	28.86	7.51	83.89
T_{10}	1.490	0.422	0.572	1.488	0.419	0.489	0.549	0.173	1.785	0.548	0.1710	1.782	63.38	18.63	24.44	62.37	17.58	23.96	40.60	12.66	130.66	39.22	12.22	127.50
T_{11}	1.471	0.418	0.564	1.471	0.416	0.572	0.547	0.171	1.778	0.545	0.1690	1.776	60.82	17.30	23.31	60.39	17.10	23.03	38.91	12.16	126.38	38.59	11.96	125.77
T_{12}	1.422	0.401	0.555	1.420	0.407	0.561	0.546	0.170	1.755	0.542	0.1680	1.753	57.72	16.28	22.52	57.23	16.14	22.29	38.19	11.25	123.00	37.92	11.76	122.29
T_{13}	1.395	0.389	0.512	1.389	0.389	0.553	0.542	0.165	1.755	0.539	0.1640	1.678	54.54	15.20	20.01	54.16	15.16	19.98	31.59	9.61	97.82	31.33	9.51	97.43
T_{14}	1.662	0.459	0.598	1.657	0.455	0.512	0.588	0.175	1.678	0.586	0.1713	1.827	76.36	21.07	27.47	72.76	19.99	26.14	45.86	13.65	142.89	44.60	13.09	139.12
T_{15}	1.660	0.459	0.578	1.660	0.441	0.595	0.586	0.172	1.832	0.582	0.1687	1.811	75.03	19.85	26.11	69.82	18.55	24.19	44.96	13.20	139.32	43.91	12.91	136.44
T_{16}	1.631	0.441	0.567	1.632	0.435	0.575	0.572	0.169	1.815	0.569	0.1643	1.802	70.30	18.79	24.37	68.21	18.21	23.57	42.33	12.46	133.29	41.64	12.36	131.75
T_{17}	1.600	0.437	0.542	1.465	0.406	0.565	0.570	0.162	1.788	0.568	0.1640	1.788	60.97	16.52	23.02	67.15	16.48	22.28	4049	11.66	127.08	40.26	11.64	126.76
T_{18}	1.663	0.460	0.590	1.660	0.452	0.580	0.590	0.176	1.833	0.586	0.1730	1.831	76.49	21.15	27.02	64.47	19.90	25.59	47.20	14.08	146.79	45.08	13.29	140.70
SE (DIFF)	0.010	0.137	0.129	1.05	0.123	0.136	0.0027	0.0055	0.00709	0.0028	0.00359	0.0914	1.786	0.850	1.121	1.922	0.729	0.957	1.393	0.716	4.5731	1.432	0.658	4.098
CD (0.05%)	0.021	0.028	0.026	1.01	0.0251	0.027	0.0046	0.122	0.0144	0.0053	0.0072	0.0185	3.63	1.727	2.27	3.90	1.482	1.945	2.832	1.456	9.29	2.90	1.337	8.32

Treatments	Apparent nitrogen recovery (%)		Nitrogen use efficiency		Protein content (%) in grain	
	2015	2016	2015	2016	2015	2016
T_1	-	-	--	-	7.53	7.53
T_2	39.47	33.71	15.49	15.69	7.94	7.53
T_3	32.25	32.03	14.40	15.00	7.82	7.43
T_4	32.69	30.89	13.53	14.56	7.80	7.80
T_5	22.58	22.51	9.30	9.80	7.65	7.29
T_6	36.63	35.50	16.32	16.06	7.88	7.87
T_7	34.59	34.29	15.70	15.75	7.82	7.80
T_8	32.83	33.39	15.03	15.44	7.76	7.56
T_9	26.99	27.60	11.95	12.44	7.71	7.70
T_{10}	50.17	48.97	18.20	18.06	8.56	8.55
T_{11}	46.36	46.79	17.03	17.35	8.45	8.95
T_{12}	45.05	43.60	16.40	16.73	8.17	8.16
T_{13}	43.20	35.55	15.15	15.65	8.02	7.98
T_{14}	65.12	62.11	20.83	19.73	9.55	9.52
T_{15}	63.26	59.09	19.99	18.19	9.54	9.54
T_{16}	57.85	55.85	18.40	17.98	9.37	9.30
T_{17}	47.85	43.81	16.95	16.80	9.20	8.42
T_{18}	66.35	65.60	20.90	19.81	9.61	9.58
SE (DIFF)	1.20	1.11	0.855	0.767	0.50	0.28
CD (0.05%)	2.28	2.26	1.739	1.558	0.12	0.05

5. Conclusions

NPK content, NPK uptake, apparent nitrogen recovery per cent, nitrogen use efficiency and protein content in rice and their residual effect on wheat crops showed better performance. The conjoint nutrients application showed better result in comparison to sole application of nutrients. The wool waste gave better results in this regards. There is a complex regulation of N uptake, assimilation, and remobilization. Enhanced NUE can be achieved by genetically modifying plants and integrated agricultural management practices. Developing an integrated research program combining approaches, mainly based on whole-plant physiology, quantitative genetics forward and reverse genetics, and agronomy approaches to improve NUE, is a major objective in the future.

6. References

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