EFFICIENCY OF ORGANIC, INORGANIC NITROGEN FERTILIZERS AND THEIR COMBINATIONS ON RICE IN SALINE-SODIC SOILS

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KEYWORDS	ABSTRACT
Nitrogen, Saline-Sodic Soil, Organic and Inorganic Fertilizer	A pot experimental work was conducted during 2014 by using RCBD design at Faculty of Agriculture Gomal University Dera Ismail Khan (KP) Pakistan. The results of pot experiments in open air indicated, that the nitrogen transformation in soil and nitrogen uptake of the rice plants were strongly influenced through the applied factors. Different combinations of nitrogen fertilizers have been tested with successful results in the rice productions. In case of rice straw and in combination with the Mineral-N fertilizer caused the decreased grain yield production, consequently bad N-uptake takes place in the crop particularly at tillering stage. Green manure has in all combinations an increased N-uptake due to the excessive N-application and the 3 times increased grain yield as compare to application of Mineral-N without organic fertilizers. The increase in yield was especially very clear with the application of urea as compare to ammonium sulfate. The application of green manure in combination with urea increased N-use efficiency and grain yield of the applied nitrogen considerably as compare to the ammonium sulfate.

INTRODUCTION

Rice (Oryza Sativa L.) occupies an important position among the cereals for the area and production. In Pakistan, it is annually cultivated on area of 2,899 thousand hectares with a total grain production of 7,442 thousand tones (Anonymous, 2018). Abiotic stresses like salinity and drought are the main obstacles of crop productivity worldwide and will remain to be a great challenge in future for enhancing crop productivity especially of salt sensitive crops like rice. According to an estimate in Pakistan, crop yield loses due to the salinity are 20% (Rehman, Harris & Ashraf, 2005; Ashraf, Athar, Haris & Kwn, 2008). Irrigated rice is a major cereal crop in Pakistan after wheat (Anonymous, 2016). Main export item of Pakistanis rice and provide 30% supply of the rice to world (Anonymous, 2017a). In Saline-sodic soils efficient fertilizer management is needed, which in Pakistan covers an area of approximately 11.5 × 106 ha^{-1} (Anonymous, 2005).

The rice cultivation is mostly practiced under flooding condition, which results in high cumulative removal of exchangeable sodium caused by mobilization of native insoluble calcium carbonate as the result of increased hydrolysis, and carbon dioxide, liberated by plant roots (Ghafoor, Green & Cresser, 2008). To improve the productivity of the saline-sodic soils physical, chemical and the biological methods are being practiced all over the world. Organic manuring can replace the costly chemical applications as it is proved to be beneficial in enhancing crop yields and improve soil health (Ibrahim, Rashid, Nadeem & Mahmood, 2000). Amongst the major nutrients required by the crops Nitrogen plays an important role in overall yield production (Santos, Korndorfer & Pereimoa, 2015) as it is linked with the photosynthesis vegetative growth that significantly increase dry biomass (Rashidi, Ebadi, Parmoon, Jahanbakhsh & Haghighat, 2015).

The reduction in nitrogen (N) availability coupled with carbohydrate accumulation due to decreased surface area may cause decline in the biomass production under saline soil conditions (Moradi & Ismail, 2007; Thitisaksakul & Maysaya, 2008). Thus, realizing the importance of the crops in moderately salt-affected soils, investigations to determine the suitable application rate of N under the such soil conditions are critical (Murtaza, 2011). Some researchers have indicated that the requirements of N and other mineral nutrients for crops in salt-affected soils are different than those on normal soils probably due to the different physical and chemical properties of the soils (Lodhi, Arshad, Azam, Sajjad & Ashraf, 2009).

LITERATURE REVIEW

The Pakistani rice has specific quality value in the world due to its aroma and length. So rice production has great importance in Pakistan and share 6% in agriculture and 0.6% in GDP (Anonymous, 2017b). For sustainable crop production, integrated use of organic and inorganic fertilizers has proved to be highly beneficial. In this connection, Soomro, Tunio, Chand and Rajper (2013) demonstrated that the use of organic manures together with inorganic manures compared to the addition of organic or inorganic manures alone had a significant and positive effect on soil health and crops. Mangla (2006) describe the side effects of excessive use of synthetic fertilizer which affect rice growth, productivity and soil health. Baksh, Hussain and Sabir (2017) stressed upon integrated nutrition of the rice through the organic and inorganic means to boost up the yield of rice.

The combined application of inorganic and organic amendments, like farm manure and humic acid, improves their effectiveness for increasing the soil properties (Ullah & Bhatti 2007). The decaying organic matter increases soil CO_2 concentrations and releases H^+ when it dissolves in the water. The released H^+ enhances $CaCO_3$ dissolution and liberates more calcium (Ca) for sodium (Na) exchange (Ghafoor et al., 2008). Moreover, organic materials improve soil physico-chemical properties that accelerate exchange of cations on soil solids and leaching of the salts from the root zone (Clark, Dodgshun, Sale & Tang, 2007), hence preventing root from salt injuries and roots can grow more smoothly. Use of farm manure in combination with gypsum significantly improves soil physicochemical properties of sodic soils as compared to solo application (Ullah & Bhatti, 2007).

When Urea fertilizers are applied, the hydrolysis process starts very slow consequently, the urea hydrolysis rate may also be affected due to the ionic composition of the soil solution. That ultimately reduces urease activity. Therefore, keeping in view the above shortcomings following objectives have been focused for proper solution of the oriented problems:

- ✓ To know the type of differences in N-transformation, N-effect on crop production and N-uptake through the rice plant occurred between the organic fertilizers of different N-content and different mineralization processes are.
- ✓ To see the effect, the type of the Mineral-N urea and the ammonium sulfate in the salin-sodic soil.
- ✓ To fine the differences produced on the N-uptake, production through the diverse type of organic and inorganic fertilizers.

MATERIALS AND METHODS

Research Site

The soil samples were collected from soil of Agronomic Research Area, Faculty of Agriculture Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan from a depth of 15-30cm.

Chemical Nature of Soil

To observe how soil affects ground water, pot experiments were conducted during three consecutive crop seasons (2012 to 2014). The soil had a carbon content of 2.21% a total N content of 7.51 mg/100 g, clay 30.4%, pH value 7.70 and exchangeable sodium 35.48% 7 ppm P_2O_5, 0.65% organic matter, 90 ppm K_2O.

Research Techniques

The pot size was 180 cm^3. Each plastic pot was filled with 3.5 kg absolute dried soil, thoroughly mixed and ground to pass through 2 mm mesh. As manure 2 g dried material pro kg soil finely ground rice straw (C/N ratio 97.14) or green manure from Soya (C/N ratio 11.09) were thoroughly mixed with the soil according to the plan of experiment. All pots received a basal application of 91 ppm (parts per million) P and 208 ppm K (calculated at the basis of air dried soils) in the form of KH_2PO_4 and K_2SO_4 solution at the time of the plantation. The pots were irrigated immediately after the filling and also maintained under continuous flooding (2 cm) for 3 weeks. After this pots were treated with 166 ppm mineral N fertilizer (urea or ammonium sulfate calculated on the basis of the air dried soils). One week after the application of Mineral-N eight rice seedlings were planted in each pot.

DATA ANALYSIS

The whole experiment was repeated three times by using RCBD design. Averages per treatment calculated and resented by line graph. Soil samples were collected from each treatment and analyzed for H_2O, soil pH and mineral nitrogen (NO_3-N and NH_4-N). Later, the crop was harvested and dried for straw and grain to record the yield. Then analyzed for total N content according to Maibaum (1983) with the modified Semi micro Jeldhal method given by Bremner (1965). To find the significant differences amongst the means as well as LSD, obtained results were subjected to statistical analysis of variance (ANOVA)

Table 1 Plan of the Tested Factors

Plan of the tested factors organic fertilizers, urea and ammonium sulfate	
S. No.	**Factor**
1	Urea
2	Ammonium Sulfate
3	Straw incorporation
4	Green manure “Soya” application
5	Straw + Urea
6	Straw + Ammonium Sulfate
7	Green manure “Soya” + Urea
8	Green manure “Soya” + Ammonium Sulfate

RESULTS AND DISCUSSION

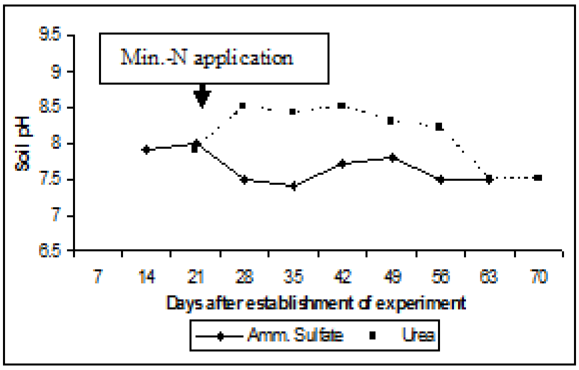
The rice plants showed poor growth during the early growth phase with the application of urea fertilizer as compare to ammonium sulfate. The urea application increased the soil alkalinity, which resulted higher deficiency of many micronutrients due to high pH (Rehman, Aziz, Farooq, Wakeel & Rengel, 2012). Similarly, Rengel (2015) also reported an increased solubility of micronutrients, especially Mn, Cu, Fe, and Zn, and the uptake through the plants due to the low pH values in soils. The experimental results have been described and discussed in the following paragraphs under various headings:

pH Dynamics in Soil

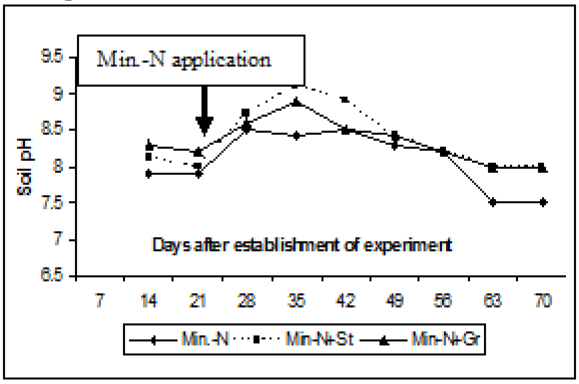
The results of the pH measurements in the pots are given in Figure 1. According to the expectations there was an increase in pH values after the hydrolysis of urea in all treatments of urea application. Later on decrease of pH values may be explained due to the release of organic acids and CO_2 in the soil. The increase in pH with the application of ammonium sulfate in combination with green manure may be due to excessive NH_4-N concentration in soil.

Figure 1 Changes in Soil pH Values During the Period of Study

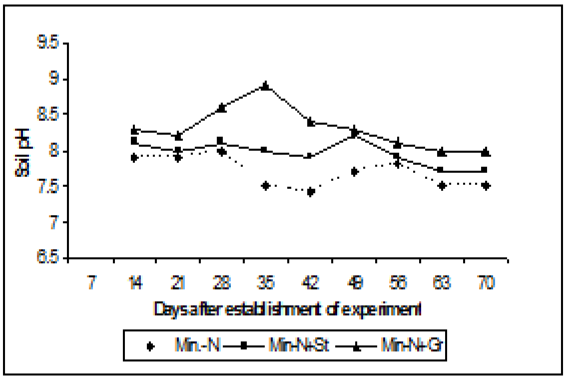
A. Without Organic Fertilizers (Control)



B. Urea in Combination with Organic Fertilizers



C. Ammonium Sulfate in Combination with Organic Fertilizers



Mineral Nitrogen in Soil

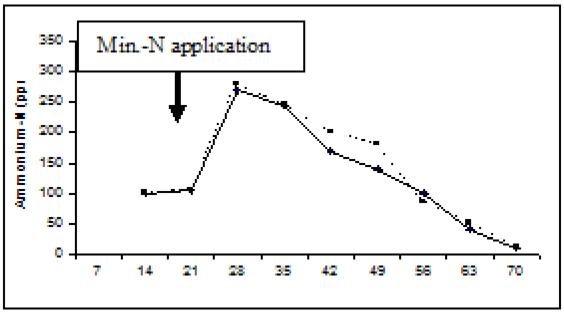
According to expectations no nitrate was produced after the anaerobic transformation of applied organic and mineral N fertilizers in the experimental soils. The dynamics of ammonium N concentration is given in Figure 2. The soil contained a high concentration of mineral nitrogen and also a light transferable organic matter. This may be a reason of high NH_4-N concentration in the soil before the application of Mineral-N fertilizer.

The concentration of the ammonium in all treatments reduced with the passage of time depending upon the type of the applied organic fertilizers more or less quickly. In view of NH_4-N dynamics this is observed, that about 28 days after the mineral N application the phase of intensive N-uptake was started through the plants. In first four weeks after the application of mineral N fertilizer the reduction in total N may be the reason of N losses through NH_3-volatilization or denitrification, meanwhile in the early growth period of the rice plants the N-uptake through the plants was very low. A part of ammonium may also be fixed on the clay particles while the soil used in the experimental showed a high part of clay (30.4%).

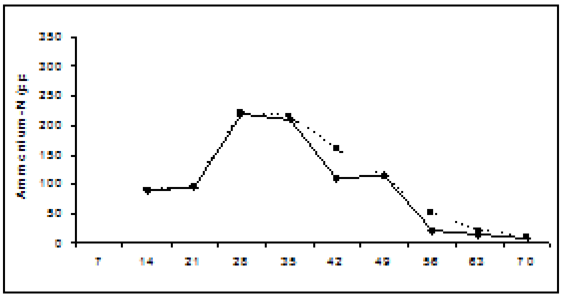
With the application of ammonium sulfate there were temporarily lowest Ammonium-N concentrations as compare to urea application. This may be due to the higher N uptake through the vigorous rice plants as a result of favorable soil conditions (low pH-values in soil and as a result of this a better availability of micronutrients).

Figure 2 Changes in Mineral- N in Soils During the Period of Study

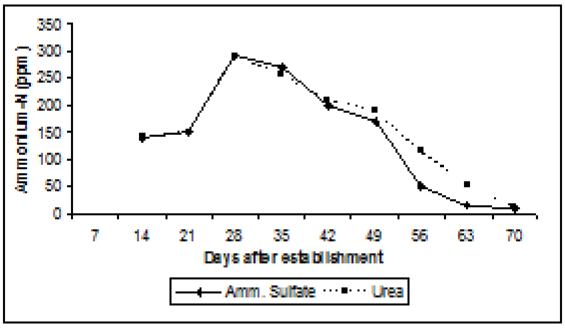
A. Without Organic Fertilizers (Control)



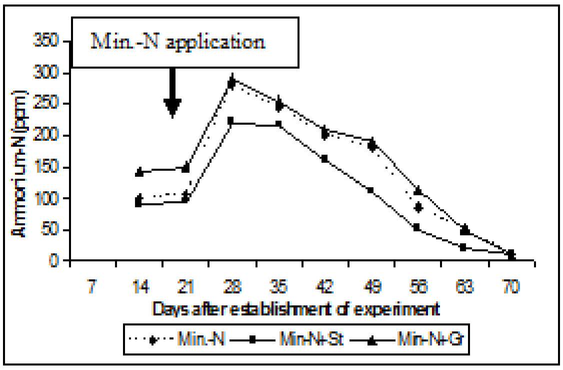
B. Incorporation of Rice Straw



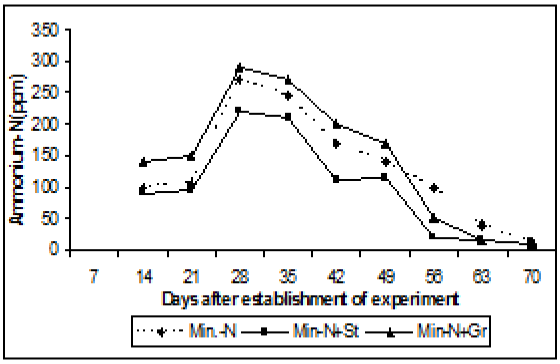
C. Incorporation of Green Manure



D: Urea in Combination with Organic Fertilizers



E: Ammonium Sulfate in Combination with Organic Fertilizers



Effect of Straw

According to the expectations the rice straw incorporation caused the decrease in NH_4-N concentration in soil during whole period of analysis as compare to mineral N fertilizer alone. Reduction in Ammonium-N concentration was larger in application of ammonium sulfate as compare to urea fertilizer. For reduction with ammonium sulfate application it is assumed, that this was caused through higher N-uptake of rice plants due to favorable soil conditions.

Effect of Green Manure

The application of green manure (Soya) caused the higher NH_4-N concentrations in the soil as compare to the Mineral-N fertilizer due to the net mineralization of organic N-substances. In the period of 4 To 7 weeks after application of Mineral-N fertilizer there were lower NH_4-N concentration in soil with ammonium sulfate application as compare to urea in combination with a green manure. As already explained, in this time period it may be due to the higher N-uptake of rice plants with the application of ammonium sulfate in combination with favorable growth conditions.

Grain Yield Production

The obtained grain yields in all treatments are presented in table 1. The incorporation of rice straw without mineral N resulted in decreased grain yield as compare to control treatment (without organic manure). The application of green manure (Soya) redoubled grain yield as compare to without organic fertilizer. Ammonium sulfate alone increased the grain yield due to favorable soil conditions as compare to urea application.

Table 2 Grain Yield (g/pot) Under Influence of Diverse Organic & Inorganic N Fertilizers

Treatment	Control	Straw	Soya	Min-N	Straw + Min-N	Soya+ Min-N	$GD_{5\%}$
Urea Application	11.70	7.60	21.80	24.52	17.84	39.47	2.23
Ammonium Sulphate App	11.70	7.60	21.80	26.14	20.62	33.17	2.23

Effect of Straw

According to the expectations the incorporation of rice straw reduced the grain yields without Mineral-N and with the combination of Min-N fertilizers. About 6% reduced grain yield found in application of urea as compare to ammonium sulfate. Ammonium sulfate fertilizer produced significant higher grain yield due to favorable soil conditions as compare to urea fertilizer.

Effect of Green Manure

The incorporation of green manure caused a noticeable increased grain yield as compare to all other combinations. The strongest increase in grain yield i.e. 60% (as compare to Min-N alone) showed the application of urea plus green manure. By the application of ammonium sulfate in combination with green manure there was more than 26% increase in the grain yield as compare to ammonium sulfate alone (Fig. C). The reason for the lowest increase with the ammonium sulfate application (as compare to urea) may be due to reason, that transformation of applied ammonium sulfate in highly reduced conditions (after the decomposition of light remineraliseable material of green manure) caused the production of H_2S, which has affected the rice plants in early growth period (Yadav, 2013).

Nitrogen Recovery and Rice Production(g) applied N

With the difference method calculated rates of N-recovery efficiency (%) are given in Table 2 and the rice production/g applied nitrogen (g rice/g N) is presented in table 3. The rates of N-recovery (%) make it visible, that the source of mineral N applied alone has no influence on it. However, the grain production/g N was higher with application of ammonium sulfate (14.44) as compare to urea application (12.82) due to the favorable soil conditions.

Table 3 Nitrogen RE (%) Under Influence of Diverse Organic & Inorganic N Fertilizers

Treatment	Min. N	Min. N+ Straw	Min.N+Soya
Urea Application	40.5	42.8	55.9
Ammonium Sulphate Application	40.0	44.7	45.9

Effect of Straw

The estimated rates of N-recovery showed, that additional incorporation of rice straw with the application of urea has resulted only minor differences. However, the rice straw in combination with ammonium sulfate increased visibly the grain yield/g N as compare to urea application. It is assumed, that from ammonium sulfate released nitrogen has encouraged the grain yield determining factors due to the favorable soil conditions after the transformation and for the plant uptake. Probably the poor decomposition of rice straw by ure in early days not shoed good results due to unavailability of nutrients to rice crop.

Table 4 Production UAN (g rice/g N) Under the Influence of Different Organic and INF

Treatment	Min. N	Min. N+ Straw	Min.N+Soya
Urea Application	12.82	5.86	17.61
Ammonium Sulphate Application	14.44	8.51	13.46

Effect of Green Manure

The incorporation of N rich material soya in combination with Mineral-N resulted in higher N-recovery as compare to Mineral-N alone. In accordance with N-recovery rates obtained the visible higher grain yield/g N with the urea application after the green manure as compare to ammonium sulfate.

CONCLUSIONS

From this study on saline-sodic soils it may be concluded that urea application increased the soil alkalinity, which reduced the solubility of micronutrients, especially Mn, Cu, Fe, and Zn, as well as uptake through the plants due to the high pH values in soils. Besides, flooded rice soils established experiments showed that the N-uptake of the rice plants especially in initial growth phase was strongly influenced through the soil biochemical conditions (e.g. for the rice plants harmful nitrite accumulation, from the decomposition of organic substances released phototoxic compounds as H_2S formation). The time of application, quantity and combination of organic and/or mineral fertilizers, time of the flooding and time of plantation must be used to minimize the negative effects of these factors. The organic fertilizers have influenced uptake and effectiveness of the nitrogen through the decomposition and transformation of N-content.

The net immobilization of nitrogen supporting N-arm material (e.g. rice straw) can reduce in fact the N-losses, especially when the mineral-fertilizer nitrogen should be applied in time of decomposition. The positive influencing results for the rice production may be only then achieved, when during the period of maximum N-requirement of the rice plants again sufficient supply of the organic tied N through remineralization was secured. The time of the remineralisation of the microbial captured mineral N was not detected in this study, while the balance of the N-fractions (Nt or in organic form tied nitrogen) in definite time periods obtained soil samples were not carried out. Herewith it is also difficult to estimate N losses. Light mineralized N-rich organic fertilizer material (soya) in combination with mineral N fertilizers favored N-losses. There is opportunity to conduct more research studies on application time of green manure, time of flooding, time of plantation and time of Mineral-N fertilization, to achieve extra beneficial effects of the applied Mineral-N in combination with green manure.

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