Research Findings

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Impact of Potassium on Nitrogen Utilization by Rice under Saline Conditions

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Nitrogen (N) utilization by plants is evaluated by measuring the uptake of N from the soil together with N fertilizer taking into account the subsequent assimilation of acquired N in the production of crop yield. On the basis of a large number of experiments conducted on farmers' fields, Cassman *et al.* (2002) observed that generally more than 50 percent of applied N is not assimilated by crop plants. In particular, N fertilizer is used rather inefficiently by cereals for grain production.

Improving nitrogen utilization is of paramount importance from agronomic, economic as well as environmental viewpoints. Several strategies to improve nitrogen utilization include balanced N and potassium (K) nutrition. Balanced nutrition is especially important if crops are to benefit from the synergistic relationship between N and K for uptake and assimilation (Milford and Johnston, 2007). This approach is particularly of value in considering imbalanced fertilizer use when, for example, inadequate application of K is combined with excess application of N, which is often a serious problem in modern intensive agricultural production systems.

Imbalanced use of fertilizers is detrimental to soil fertility and crop yield which, in the long run, results in mining of soil nutrients and loss of plant nutrients supplied in excess. For successful

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agricultural production, imbalanced fertilization should be avoided. In this respect, several investigations have been conducted at different locations in Egypt on various crops supplied with different N, P and K fertilizer combinations (Abdel-Hadi *et al.*, 1990; Hegazy *et al.*, 1990; Mohamed *et al.*, 1992; Genaidy and Hegazy, 1994 and Khadr *et al.*, 1994).

The field study reported in this paper was carried out to investigate the impact of K fertilization on N utilization by rice plants grown under saline conditions. The study was part of a collaborative project between the IPI (WANA region) and the Soils Water and Environment Research Institute (SWERI) in Egypt.

Materials and methods

A field trial was initiated in the 2006 summer season and continued until 2011 (with the exception of the 2007 summer season) at El-Serw Research Station (Damietta Governorate, North Egypt) to test the interactive effect of N, P and K on rice yield and the influence of K fertilization on nitrogen utilization by rice plants. The experiment included five treatments set as omission plots, i.e. control (without fertilization and with NPK), NP (-K), NK (-P) and PK (-N). The five treatments were arranged in a Latin Square Design with five replicates, using a surface irrigation system. N, P and K, as urea, single super phosphate (SSP) and muriate of potash (MOP) fertilizers were applied at the recommended kg ha^{-1} rates for rice (142.8 N, 35.7 P_2O_5, and 57.12 K_2O respectively). The P and K fertilizers were added during land preparation before transplanting the rice seedlings; two-thirds of the N fertilizer application was also added during land preparation before planting while the rest was applied 30-40 days after transplanting.

Soil analysis

Soil samples were collected and analysed from the experimental site. Soil texture was determined as described by Piper (1950). Available nitrogen was extracted by K-sulphate solution (1%), then analysed using the direct MgO-Devarda Alloy procedure and the steam distillation system, as described by Black (1982). Available P was determined according to Olsen (1954); available K was determined by flame photometer after ammonium acetate extraction according to Jackson (1973). The pH was determined in soil suspension (1:2.5) and total soluble salts estimated as EC (dS m^{-1}) in soil extract (1:5) then multiplied by 0.32 to obtain total soluble salts (%) according to Jackson (1973). Soil analytical data from the El-Serw site are shown in Table 1.

Plant analysis

At harvest the grain and straw yields per hectare were recorded. At the end of the 2011 season, grain samples were taken from each treatment then ground, wet digested and analyzed for total N, P and K (according to Chapman and Pratt, 1961).

Results and discussion

Grain and straw yields

The results of grain and straw yields for five summer seasons from 2006 to 2011 (except 2007) and the average relative increases are detailed in Table 2. The results of the five seasons on rice yields confirmed that N is by far the most important nutrient for cereal yield formation: in all years, the omission of N (i.e. the PK treatment) gave yields significantly lower than NPK, demonstrating that adding only P and K does not provide a significant yield increase over the control. In all years, K application (i.e. NPK treatment) resulted in a significant yield increase (over NP), while that of P (i.e. NPK treatment over NK) was found significant in only two years out of the five. Among the three nutrients, the addition of N combined with P and/or K gave the highest grain and

Table 1. Soil analysis of El-Serw.

Soil texture	pH	Total soluble salts (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)
Clay	8.7	0.46	35	7.8	450

Note: This data indicates that the El-Serw high pH clay saline soil is extremely low in available P and moderately well supplied with available K.

Table 2. Effect of balance fertilization on grain (2006-2011) and straw yield (mean of five years, 2006-2011).

Treatments	Grain yield					Average yield (2006-2011)			
	2006	2008	2009	2010	2011	Grain	Straw	Relative increase in grain yield	Relative increase in straw yield
	mt ha^{-1}							%	
Control	7.59 c†	7.37 c	8.75 d	7.38 c	7.89 d	7.85	6.73	-	-
NP	10.14 b	8.68 b	9.89 b	8.48 b	8.89 b	8.99	7.89	14.5	17.2
NK	10.16 b	8.92 b	10.48 a	9.56 a	9.37 a	9.58	8.17	22.0	21.4
PK	7.88 c	7.52 c	8.94 c	7.8 c	8.22 c	8.12	7.04	3.4	4.6
NPK	11.83 a	9.78 a	10.86 a	9.21 a	9.55 a	9.85	8.72	25.5	29.5

Note: Application rates: N: 142 kg N ha^{-1}; P: 35.7 kg P_2O_5 ha^{-1}; K: 57.12 kg K_2O ha^{-1}. †Means followed by the same letter are not statistically different from each other at 0.05 probability level. **Significance at the 0.01 probability level.

straw yields compared with the control or PK combination. The balanced NPK combination surpassed the other combinations during the five seasons, with the addition of K fertilizer, along with P and N fertilizers, increasing both grain and straw yields. The data presented indicates that, over the five seasons, rice grain yield increased from 7.85 mt ha^{-1} for the control to 8.99, 9.58, 8.12 and 9.85 mt ha^{-1} for NP, NK, PK and NPK respectively with corresponding relative increases of 14.5, 22.0, 3.4 and 25.5 percent relative to the control. Straw yield showed the same trend and the balanced combination also recorded the highest increase during the five seasons.

However, the yield increase due to each fertilizer nutrient, i.e. the effect of N, P or K, decreased over the experimental period (2006 through 2011) as shown in Table 3 and Fig. 1. Similarly, agronomic efficiencies were also reduced but, interestingly, that of K was always higher than N, representing a high benefit from K application. The reduction in rice yield response with time could be attributed to improvements in soil fertility (which may have been very low at the onset of the experiment) as a result of balanced fertilization, so the rice yield showed a smaller response at the end of the experimental duration, although showing relatively high agronomic efficiencies (5-11.6 kg kg^{-1}). Another factor that may have contributed to improving soil fertility is that a mole drain, which was established in the experimental site one or two years before setting up the experiment, resulted in a fall in ground water level from 50 to 150 cm below the soil surface. This fall may have helped in reducing soil salinity thus increasing nutrient availability to improve soil fertility.

N, P, K content in rice grain

The effect of balanced fertilization on nutrient concentrations in the grains, and nutrient uptake by the grains estimated during summer season 2011 are presented in Table 4. It was observed that no significant differences were obtained among the various fertilizer treatments concerning the effects on N, P or K concentrations in rice grains. However, there was a slight decrease in N, P and K concentrations in the grain of plants fertilized with NPK fertilizers and N and K uptake was higher in plants which received NK or NPK fertilizers compared with other fertilizer treatments.

N utilization efficiency

Nitrogen use efficiency can be defined as the maximum economic yield produced per unit of nutrient applied, absorbed or utilized by the plant to produce grain and straw (Fageria and Baligar, 2001). However, in the literature, nutrient use efficiency has been defined in several ways including: Apparent recovery efficiency, and internal utilization efficiency which were calculated using the following formula:

Internal utilization efficiency (IE) = grain yield/N uptake (kg grain/kg N) (Dobermann (2007), and

Apparent recovery efficiency (ARE %) = (N_f - N_u/N_a) x 100 (Fageria *et al.*, 1997) where:

- N_f = total N uptake by grain yield in fertilized plots (kg ha^{-1}).
- N_u = total N uptake by grain yield in unfertilized control plots (kg ha^{-1}).
- N_a = total fertilizer N applied (kg N ha^{-1}).

The calculation of IE and ARE shown in Table 4 revealed that K fertilization improved the utilization of the added N fertilizers (where IE reached 67.11 and 67.57 by the combination between NK and the NPK combination respectively; the corresponding values for ARE were 9.4 and 10.6% respectively). In this respect,

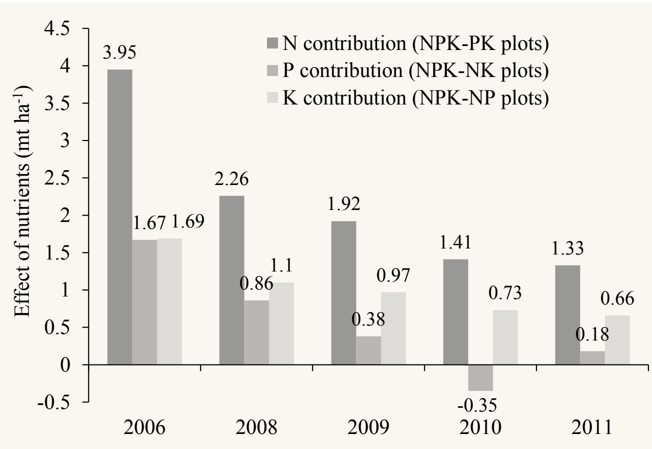

Fig. 1. Effect of N, P and K contribution in rice grain yield.

Table 3. Contribution of N, P and K in omission plots to grain yield (mt ha^{-1}) and the agronomic efficiency (kg kg^{-1}) obtained for N, P and K fertilization.

Nutrient	2006		2008		2009		2010		2011		Average 2006-2011	
	mt ha⁻¹	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*	*mt ha⁻¹*	*kg kg⁻¹*
N (NPK-PK plots)	3.95	27.8	2.26	15.9	1.92	13.5	1.41	9.9	1.33	9.4	2.2	15.3
P (NPK-NK plots)	1.67	46.8	0.86	24.1	0.38	10.6	-0.35	-9.8	0.18	5.0	0.5	15.4
K (NPK-NP plots)	1.69	29.6	1.10	19.3	0.97	17.0	0.73	12.8	0.66	11.6	1.0	18.0

Note: Application rates were 142.8 kg N, 35.7 kg P_2O_5 and 57.12 kg K_2O ha^{-1}.

Table 4. Effect of balanced fertilization on N, P and K concentration in rice grain and N utilization efficiency as well as N recovery efficiency during season 2011.

Treatments	N	P	K	N uptake	P uptake	K uptake	Grain yield	IE	ARE
	----------%----------			----------*kg ha*$^{-1}$----------			*mt ha*$^{-1}$	*kg grain kg*$^{-1}$ *N*	*%*
Control	1.60	0.52	0.16	126.24	41	12	7.89	62.50	-
NP	1.56	0.51	0.15	138	45	13	8.89	64.10	8.76
NK	1.49	0.46	0.15	139	43	14	9.37	67.11	9.42
PK	1.59	0.52	0.15	130	42	12	8.22	62.89	-
NPK	1.48	0.47	0.14	141.34	44	13	9.55	67.57	10.63

Note: IE=Internal utilization efficiency, final grain yield per unit of N uptake; ARE=$(N_f-N_u)/N_a$ x 100.

Srinivasarao (2010) reported that nitrogen utilization depends on several agronomic factors including balanced and proper nutrient use; where balancing the N fertilizer application of different crops with K fertilizer is an urgent need to achieve higher grain yield per unit of N uptake.

Conclusions

Under the saline heavy clay soils at El-Serw (Damietta governorate, North Egypt), rice was grown to test the effect of possible combinations of N, P and K fertilizers on rice yield and N utilization efficiency. The results confirmed that N is by far the most important nutrient for cereal yield formation, but K achieved the highest agronomic efficiencies. The addition of nitrogen combined with P and/or K gave the highest grain and straw yield compared with PK combination. However, it was observed that yield increases due to NPK fertilization decreased year by year during the experimental duration possibly due to soil fertility improvement as a result of balanced fertilization. Potassium fertilization also improved the utilization of the added N fertilizer. Moreover, N recovery efficiency was the highest with the NPK combination.

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The paper “Impact of Potassium on Nitrogen Utilization by Rice under Saline Conditions” also appears on the IPI website at:

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