Use of potassium to increase irrigated rice production

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Dedication

This thesis is dedicated to my late father

Mohammed A. Bhiah

To my mother, wife and my children

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To whom I miss

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Abstract

Rice (*Oryza sativa*.L) is the main staple food in Iraq, but productivity is low compared to other major rice-producing countries. The most popular rice cultivar (Amber33) has a lodging problem. Lodging of rice in Iraq reduces production by 25 – 30% and may be related to the agronomic practice since the 1960s of supplying high nitrogen (N) and phosphorus (P) nutrition in the absence of applied potassium (K). There are concerns that soil K depletion is leading to K deficiency. In addition, the inherently high salinity in many Iraqi rice-growing regions, is a further problem which can affect both yields and quality.

This study investigated the effect of K application on rice growth and yield parameters and lodging incidence under high N status and flooded conditions in a Black Vertosol and clay loam soil during the years 2009 – 2011. Experiments were undertaken in glasshouses at the University of New England, and at farms in Iraq which have experienced problems with rice lodging, to investigate the effect of K fertilisation on rice growth using six rice cultivars. These cultivars (namely IR52713, IR45427, Amber13, Amber33, Koshihikari and Basmati370) are known to have different susceptibilities to lodging.The selected cultivars, Amber13 and Amber33 (standard and long culm) were most susceptible to lodging.

Pot experiments were undertaken on a Black Vertosol (pH= 6.8; $EC_{(1:5)}$= 0.7 – 0.8 dS/m; K= 0.22 $cmol_c$/kg) to examine the effects of K on lodging, tillering, plant height, shoot and root dry matter production, stem diameter, stem strength, tissue K content and K uptake. Pots were laid in a complete randomized design (CRD) with four replicates. The treatments consist of control (no K addition) and 200 mg K/kg, with a combination of N, P and sulphur (S), 300 mg N/kg, 50 mg P/kg and 20 mg S/kg respectively. Plant

measurements were taken at either panicle initiation or just prior to grain filling before being harvested.

The results showed that lodging can be reduced following K application in standard rice varieties (i.e. Amber13) similar to those grown in Iraq. Also, application of K significantly ($P < 0.05$) increased tiller number (40 – 140%), plant height (< 30%), shoot (120 – 140%) and root (80 – 300%) dry matter production and stem diameter (30 – 80%) in all cultivars, although differences between cultivars were observed. Furthermore, applied K significantly ($P < 0.05$) increased stem strength, tissue K content and K uptake. Lodging occurred primarily from the base, due to poor root growth in the absence of K. Potassium application successfully overcame lodging incidence in some selected cultivars like Amber13.

Field experiments were conducted at different locations in Iraq (Najaf, Al Diwaniyah and Ash Shamiyah) to examine the effects of K on plant growth and yield parameters. Experiments were carried out on clay loam soils (pH= 7.6 – 8.12; $EC_{(1:5)}$ = 4.3 – 11.5 dS/m; K= 0.3 $cmol_c$/kg), and were set up using randomised complete block design (RCBD) with three replicates. The treatments consist of control (no K addition) and 200 kg K/ha, with a combination of N, P and S, 200 kg N/ha, 50 kg P/ha and 20 kg S/ha respectively. Plant measurements were taken at harvest.

Results from the experiments at Najaf and Al Diwaniyah in Iraq showed that the application of K significantly ($P < 0.05$) increased K concentration in soil, plant tissues (leaf and stem) and K uptake by grain and stem. At Najaf, K significantly increased the number of panicle per m^2, 1000 grain-weight, grain yield (26%) and straw yield (28 – 36%) in Amber33 and IR52713 cultivars, while there was no effect of K on plant height, number of filled grain, panicle length and harvest index (HI). At Al Diwaniyah, K

application significantly increased grain and straw yields by 281 – 76% and 14 – 65%, respectively as well as HI. At Ash Shamiyah (single replicate), K increased grain and straw yields by 92 % and 34%, respectively and further evidence was provided that K application could overcome rice lodging in the field. The addition of K increased rice yield as a consequence of the physiological role of K, particularly with respect to plant water relations.

A glasshouse experiment was conducted to examine the interaction of K application with contrasting salinity (0.8 and ~7 dS/m) on mineral nutrient status of rice and on plant mortality. There were four K fertiliser treatments, applied with a basal combination of N, P and S: 0 mg K/kg, 200 mg K/kg upfront, 200 mg K/kg as a split dose (50, 75 and 75 mg K/kg at transplanting, 40 and 65 days after transplanting (DAT), respectively) and 400 mg K/kg upfront. A basal dose of N, P and S was applied and pots were set up in CRD with three replicates. Soil and plant measurements were taken during the vegetative stage.

Rice growth decreased and mortality increased by 37 – 60% with increasing salinity. However, K application improved plant growth, increased soil solution K activity ratio (AR^K) and potentially overcame an antagonistic effect between Na^+ and K^+ uptake resulting in decreased plant tissue Na^+/K^+ ratio.

Another glasshouse experiment was conducted as a pot trial to examine the effect of K on rice growth parameters such as plant height, tillering and shoot and root dry matter production, under saline conditions (3 – 4 dS/m). There were two levels of K, applied with a basal combination of N, P and S: 0 and 200 mg K/kg. The 200 kg K/ha was applied as two equal 100 mg/kg applications upfront and 30 DAT. Pots were set up in CRD with three replicates. Plant measurements were taken during the vegetative stage. The result showed that increasing K rate (200 mg K/kg) significantly ($P < 0.05$) increased plant

height (10 – 23%, tillering (20 – 69%), shoot (12 – 70%) and root (3 – 109%) dry matter production. These experiments demonstrated that K application had a vital role in mitigation of the adverse effects of salt stress on the growth rate of rice.

To investigate the response of rice roots to K application, an experiment was conducted under glasshouse conditions and laid out according to CRD with eight replicates. Potassium was applied at the rates of 0, 100 and 200 mg/kg soil with half at planting and half as a surface application 30 days after transplanting (DAT), with a basal supply of N, P and S. Root measurements were taken at harvest. All root parameters were positively affected by K application. Potassium significantly ($P < 0.05$) increased root dry weight (39 – 84%), total root length (60 – 256%), root surface area (56 – 156%), root volume (68 – 251%), root diameter (< 34%) and root distribution (80 – 298%) in the top 5 cm of soil of the studied cultivars. Therefore the application of K improved all aspects of root system development resulting in increased uptake of water and nutrients as well as providing the plant with improved anchorage.

To conclude, the research reported in this thesis provides evidence that K application will increase rice production under specific flooded and saline conditions, overcome the incidence of lodging in pot and field grown rice, and suggests that split application of K may be a strategy worth investigating in the field should appropriate technology be available.

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