Effect of potassium on rice lodging under high nitrogen nutrition

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Abstract
Lodging of rice in Iraq reduces production by 30-35% and may be related to the agronomic practice of supplying high nitrogen (N) and phosphorus (P) nutrition in the absence of applied potassium (K). An experiment was undertaken in glasshouses at the University of New England to investigate the effect of K fertilisation on rice growth using a standard rice variety similar to that grown in Iraq (Amber13). Two semi-dwarf varieties known to have different susceptibility to lodging were used for comparison. Amber13 was most susceptible to lodging. Application of K significantly 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 varieties, although differences between varieties were observed. Lodging occurred primarily from the base, due to poor root growth in the absence of K. Potassium application successfully overcame lodging incidence in all three varieties. Trials of both K application, and seedling planting depth, should be instigated in lodging susceptible areas of the Iraqi rice production region.

Key Words
Lodging, rice, potassium, nitrogen.

Introduction
Rice (*Oryza sativa*.L) is one of the major cereal crops in Iraq and critical for food security. The productivity of the most common Iraqi rice variety, Umber33, (3.2 t/ha) may be improved through basic improvements in soil fertility and agronomy. According to Iraqi farmers, lodging in Umber33 can cause up to 30-35% yield loss. Agronomic factors affecting lodging are nitrogen (N) supply (and timing) and potassium (K) and silicon nutrition. Increased and timely N supply, promoting vigorous vegetative growth and increased panicle size and weight, may result in lodging. Similarly, insufficient tissue K is known to increase lodging incidence. Consequently, N nutrition and K availability are key factors in isolating the cause of lodging in Iraqi rice production systems. The objective of this study was to evaluate K application on lodging and growth of a range of rice varieties under high N input conditions.

Methods
The 10-20cm layer of a non-sodic, non-saline Black Vertosol (EC: 0.64 dS/m; pH(1:5): 6.8; exchangeable K: 0.20 $cmol_c$/kg and total N: 0.042%) was collected from Delungra in northern NSW, Australia. Nitrogen was applied as a split application totalling 300 mg N/kg as urea to all pots. Potassium was applied as 200 mg K/kg as potassium sulphate to half the pots. Basal applications of phosphorus (50 mg P/kg) as calcium tetra hydrogen di-orthophosphate, and sulphur as gypsum (82 mg S/kg to match S additions in the K treatments) were applied prior to planting. Three rice varieties (Amber13, IR 52713 and IR 45427), differing in lodging susceptibility were chosen and 2 seedlings/pot were planted. Plants were grown aerobically and maintained near field capacity until the last N application at pre-tillering, before they were flooded. The 8 treatment pots (4 with K and 4 without) were completely surrounded by 16 K treated buffer pots, within variety to ensure height differences were not confounded, and to ensure that treatments were growing inside a canopy and effects of glasshouse air movement and light interception on plant stems were uniform.

Culm strength and culm diameter measurements were made at 72 and 84 days after transplanting (DAT). The diameter of the culm (mm) was measured using an electronic digital vernier calliper in the glasshouse on selected tillers in the middle of the 1st above ground internode (Mu *et al.* 2004). The stem strength (g/stem) of the rice straw was assessed using a Briquette breaking machine, commonly used to assess modulus of rupture as described by Moldenhauer and Moldenhauer (1994). The stem cross-section, cut 20 cm above the ground, was divided into two parts. The test was performed with increasingly heavy weights until the sample failed. Plant height (cm) measurements were made on the main tillers from the base of the culm to the tip of tallest leaf. Measurements were repeated 25 times for each treatment. Plant shoots and roots were collected 85 DAT following gentle rinsing to remove soil, they were dried at 80 ˚C for 48 h and weighed. The data was analysed using R.

Results

Lodging

Lodging was observed in all three varieties to different extents. Lodging occurred primarily from the base of the plants (Figure 1).

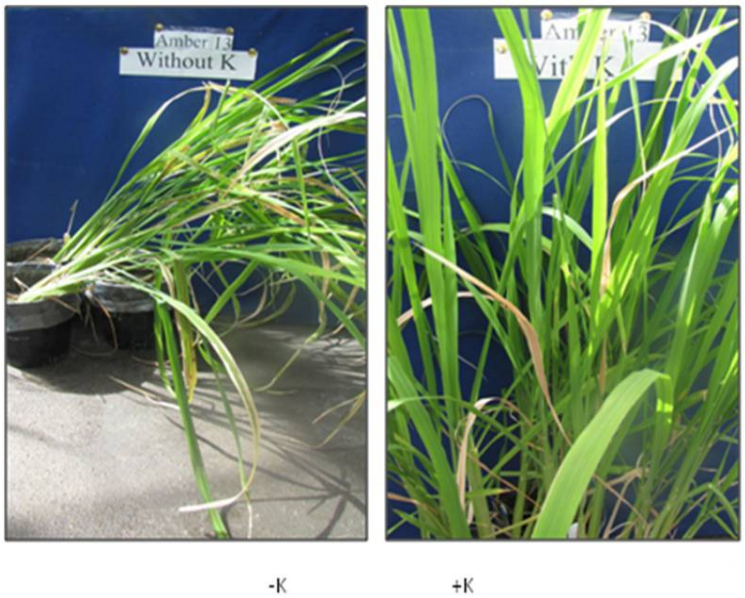

Figure 1. Effect of potassium application (No potassium vs 200 mg K/kg) on lodging of Amber13 grown for 84 days in a glasshouse on a K responsive Black Vertosol.

Growth measurements

Shoot growth increased by 120% in Amber13 and IR45427 and 140% in IR52713 following K application and there was no interaction between K and variety. Potassium application also significantly increased the number of tillers in all varieties; however the increase in tiller number was greater in IR52713 compared with other varieties (Figure 2). As expected, the standard variety Amber 13 was taller (94cm) than semi-dwarf rice varieties (74 and 82 cm). Potassium application increased plant height by <30% in all varieties but there was no interaction between K and variety ($p>0.05$).

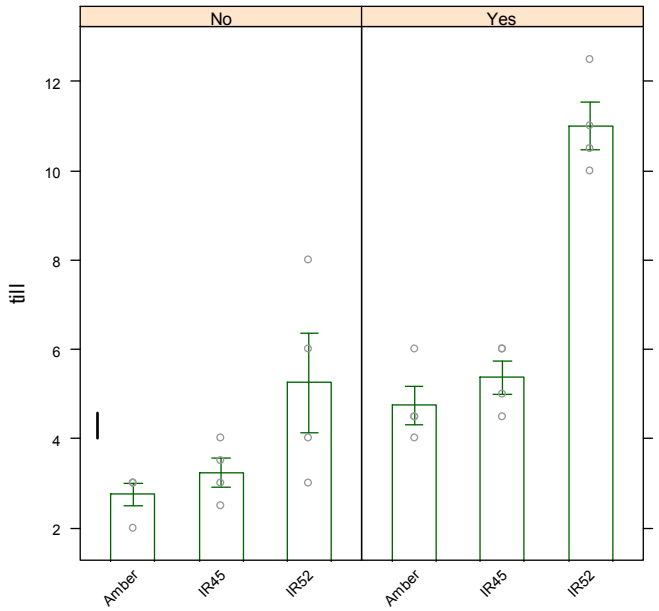

Figure 2. Effect of potassium application (No potassium vs 200 mg K/kg) on tiller number of three rice varieties grown for 84 days in a glasshouse on a K responsive Black Vertosol. Values are the mean of 4 replicates with standard error indicated by bars. LSD=1.22.

Application of K increased both thick and thin shoot diameter in all the varieties. The standard height Amber13 variety recorded the greatest relative increase in stem diameter with increases of 32% in thick stem diameter and 84% in thin diameter. Application of K increased the basal stem strength of all varieties. But the improvement was not statistically significant. The culm of variety IR52713 started to bend when 440 g of weight was exerted, whereas the varieties Amber 13 and IR45427 bent at the application of lower weight (150 g and 310 g respectively). Potassium significantly ($p<0.05$) increased the upper stem strength by 30% in all varieties. Potassium application significantly ($p<0.001$) increased root dry matter production by 80-300%; although IR45427 did not respond to the same extent as the two other varieties (Figure 3).

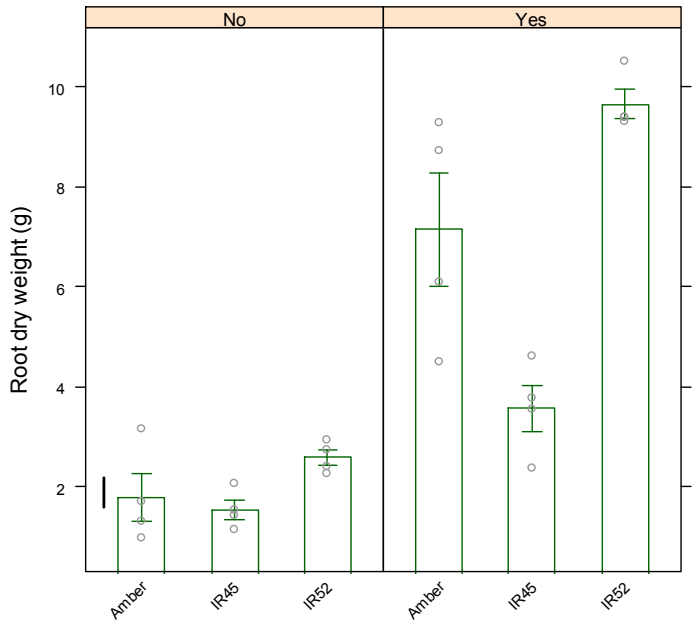

Figure 3. Effect of potassium application (No potassium vs 200 mg K/kg) on root dry weight (g/pot) of three rice varieties grown for 84 days in a glasshouse on a K responsive Black Vertosol. Values are the mean of 4 replicates with standard error indicated by bars. LSD=1.2.

Discussion

Under conditions of high N status and low K status, the standard rice variety Amber13, which is very similar in growth habit and provenance to the Iraqi rice variety Amber33, was more susceptible to lodging than semi-dwarf varieties. Application of N promotes vegetative growth and plant height, and regular applications of N without supplemental K are not conducive to strong plant stands. The lack of K application in Iraq is a historical anomaly based off recommendations from the British Soil Survey group in the mid 1950's who correctly identified K application was not required for rice growth due to high soil K reserves. However, 60 years of continuous rice production without K application may have reduced soil K supply considerably; hence the yield loss currently observed across swathes of Iraqi rice production areas. This experiment demonstrated that application of K can reduce the incidence of lodging in the presence of high N supply and should be trialled in Iraqi rice paddocks in the next growing season.

The symptoms of K deficiency observed in this trial, in all varieties, namely reduced stem strength and diameter, decreased tiller number and plant height and growth, are consistent with other studies investigating rice response to applied K (Bohra and Doerffling 1993; Surendran 2005; Kant and Kafkafi 2002; Crook and Ennos 1995) and increased lodging (Mahbub *et al.* 2006; Williama and Smith 2001).

Lodging can occur at three places in rice plants, from the base, in mid-tiller and as a result of heavy panicles. In this experiment panicle initiation was the stage at which plants were harvested, hence it was not investigated. However, although mid-tiller stem strength was increased in response to K application, the key site at which lodging occurred in this study was at the base/culm of the plant. This is most likely related to poor root growth (Figure 3) providing insufficient anchorage for plant growth. Application of K significantly improved root growth and hence anchorage, reducing the incidence of lodging. Another potential alternative to improve lodging resistance therefore may be deeper planting depths, which will be investigated in K deficient soils in subsequent experiments.

Conclusion

Lodging can be reduced following K application in standard rice varieties similar to those grown in Iraq. Strip trials of K application and seedling planting depth should be undertaken in susceptible regions in the Iraqi rice production areas.

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