The effect of P and K Nutrition on the tolerance of wheat and chickpea to subsoil salinity.

Dhananjay Singh[1], Yash Dang[2], Ram Dalal[3], Richard Routley[4] and Michael Mann[1]

[1]Department of Primary Industries and Fisheries, Roma, Qld 4455 www.dpi.qld.gov.au Email Dhananjay.Singh@dpi.qld.gov.au
[2]Department of Natural Resources Mines and Water, Toowoomba, Qld 4350. [3]Department of Natural Resources Mines and Water, Indooroopilly, Qld 4068. [1]Department of Primary Industries and Fisheries, Emerald, Qld 4720.

Abstract

Occurrence of sub-soil constraints, particularly high concentration of salt (NaCl) is common in dryland grain belt of northern Australia. This might be affecting the yield potential for common varieties of wheat and chickpea. Increased supplies of P, and to some extent K, have been reported to increase the tolerance of various plant species to salt concentrations. However, there has been no such study reporting on the tolerance of wheat and chickpea to salinity in response to increased supplies of P and K in northern Australia. A glasshouse study was undertaken to understand the effect of various concentrations of subsoil NaCl, P and K on common wheat and chickpea varieties growing in a brigalow soil (cracking grey-clay Vertisol). Increasing concentrations of subsoil NaCl (0, 3 and 6 g NaCl/ kg oven dried soil) had no effect on shoot dry matter (DM) at anthesis, whereas at maturity grain dry weight increased with increasing concentration of NaCl for Baxter and Sunco wheat varieties. On the other hand, both shoot DM and grain dry weight decreased more than 2-folds for Jimbour and Moti chickpea varieties. Higher salt concentration also decreased total water use, but increased the (biomass) water use efficiency (WUE) for both wheat and chickpea varieties. Increased supply of P (20 kg P/ha equivalent) increased the grain dry weight (across wheat and chickpea varieties) particularly at the higher concentration of NaCl. However, varieties responded differently to P and K nutrition. Increased P supply increased the WUE for Baxter and Moti, but had no effect on Sunco and Jimbour. Increased K supply (50 kg K/ha equivalent) increased the grain dry weight for Baxter, but decreased the grain dry weight for Sunco. Nevertheless, increased K supply, across varieties and other treatments, increased the harvest index. In general, enhanced tolerance of wheat plant to increasing concentrations of NaCl was due to increased main stem height and flag leaf length and width.

Key Words

Plant water use, water use efficiency, salt stress, sodium chloride, tolerance mechanism

Introduction

High Subsoil concentration of salt (NaCl) in southwest Queensland has been recently found to reduce water uptake and grain yields for wheat and chickpea (Dang et al. 2006; Dang et al. this conference). However, supplementary phosphorus (P) and potassium (K) nutrition has been widely reported to mitigate the adverse effects of high salinity on both fruit/grain yield and whole plant biomass for various crop plants (Ravikovitch and Yoles 1971; Awad et al. 1990; Martinez and Lauchile 1994; Marschner 1995; Kaya et al. 2003). In this lysimeter study, we experimented with a factorial combination of P, K and NaCl and their effects on wheat and chickpea varieties growing in a brigalow soil (cracking grey-clay Vertisol) for grain yield, shoot biomass, water use efficiency (WUE) and mechanisms of tolerance to salt stress.

Materials and Methods

The experiment was conducted at the Roma Research Station, southwest Queensland. The experimental unit was a reconstituted brigalow soil packed (to a 1.2 bulk density) in cylindrical PVC pots (60 cm long, and 10 cm in diameter), with the closed bottom end. Treatments consisted of 3 concentrations of NaCl (low, medium and high; representing 0, 3 and 6 g NaCl per kg oven dried soil, and equivalent to 0, 1800 and 3600 mg/kg of Cl ion), 2 concentrations of P (low and high; 0 and 20 kg P/ha equivalent), 2 concentrations of K (low and high; 0 and 50 kg K/ha equivalent), and 2 varieties of wheat (Baxter and Sunco) and chickpea (Jimbour and Moti). Treatments were arranged in a factorial combination for a randomised complete block design with 6 replications. Only the bottom 45-50 cm of the soil column was treated with the salt treatment to simulate subsoil salinity, whereas the whole soil column was treated with the P and K treatments plus basal N (100 kg N/ha equivalent) and supplementary micronutrients (Zn, Mn, Mg, Fe, B and Cu at appropriate concentrations). Mono Ammonium Phosphate, Potassium Phosphate (mono basic), and Urea were used to supply K, P and N. Each pot was thinned to one plant. The water regime in each pot was maintained between 50% and 80% field capacity by weighing and watering the pots once or twice a week. The surface of pots was covered with a thick (5cm) mulch to reduce the soil evaporation. Control pots with or without surface mulch, and replicated pots with free standing water were used to determine surface evaporation, plant water use and transpirational WUE. A destructive sampling was undertaken at anthesis for 3 reps for various morphometric and morphological measurements. Grain yield was determined at maturity from the remaining 3 reps.

Results and Discussion

Wheat grain yield increased but chickpea grain yield decreased with increasing concentrations of added NaCl to soil (Fig. 1). Grain yield for wheat increased by about 18%, whereas chickpea grain yield decreased by more than 90% when salt concentration increased from 0 to 6 g NaCl/kg dry soil. Dang et al. (2006) noted from field studies that increasing Cl levels (>1000 mg Cl/kg dry soil) in soil was more damaging with respect to water availability and grain yield for both wheat and chickpea compared with Na levels. In the current study, an addition of 3 or 6 g of NaCl/kg dry soil should have increased the levels of Cl to a very toxic concentration to about 1800 and 3600 mg/kg soil, respectively for the wheat plants. Furthermore, there was no significant change in total shoot dry matter for wheat in this study, but shoot dry matter decreased for chickpea with increasing salt concentrations (data not presented). Chickpea found to be more sensitive to salt compared with wheat, similar to other field studies in this region (Dang et al. 2006, and this conference).

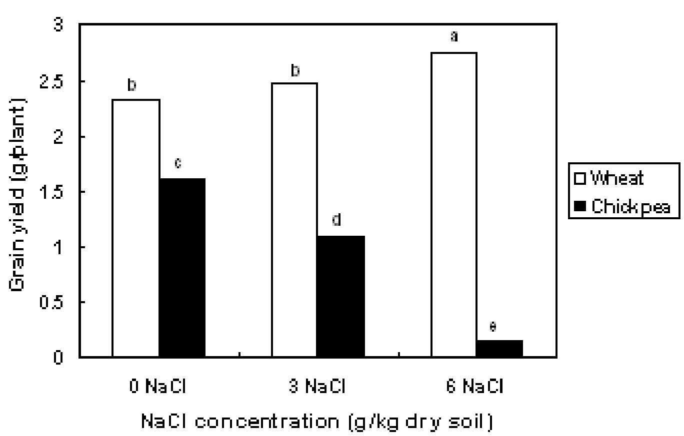

Fig.1. Effect of NaCl on grain yield for wheat and chickpea. Different letters on top of the bars indicate significant differences between treatments.

Total plant water use (kg water/plant) decreased by 16% and 64% for wheat and chickpea respectively when salt concentration increased from 0 to 6 g NaCl/kg dry soil (Fig. 2a). In contrast to plant water use, WUE (g shoot dry matter/kg of water) increased by 24% for wheat, from 0 and 6 g NaCl. Similarly, chickpea WUE also increased by 24% between 0 and 3 g NaCl, but it dropped to previous level when salt concentration increased from 3 to 6 g NaCl (Fig. 2b).

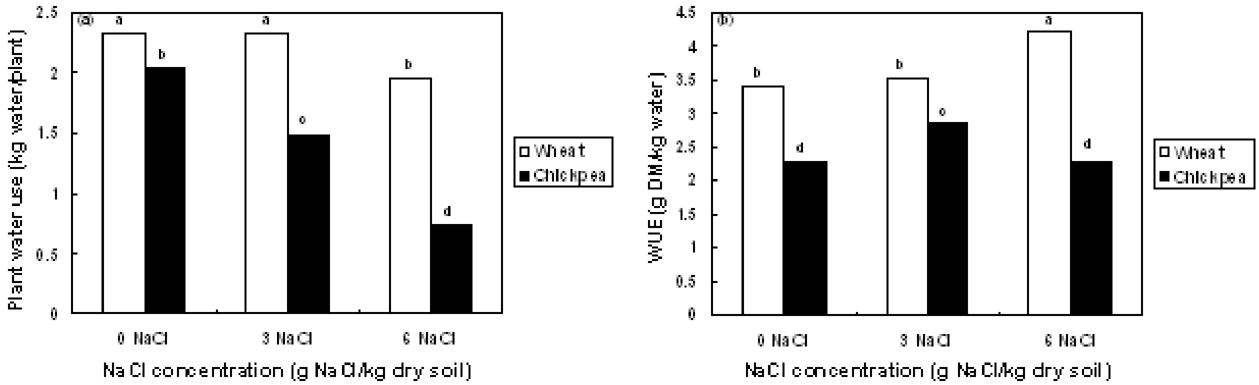

Fig.2. Effect of NaCl on (a) plant water use, and (b) WUE for wheat and chickpea. Different letters on top of the bars indicate significant differences between treatments.

Table 1. Changes in plant parameters in response to increasing concentration of NaCl, indicating a tolerance/adaptive mechanism to salt stress by wheat plants.

Plant Parameters	0 NaCl	3 NaCl	6 NaCl	Significance
Number of tillers (incl. main stem)	5.1	4.8	4.3	*
Main stem length (mm)	572.0	554.0	610.0	***
Flag leaf length (mm)	138.0	171.0	227.0	***
Flag leaf width (mm)	14.2	14.0	15.6	**

*, $P \leq 0.05$; **, $P \leq 0.01$; and ***, $P \leq 0.001$.

Generally, wheat plant responded to increasing salt stress by decreasing the number of tillers (16%), increasing the main stem length (7%), and increasing the flag leaf length (65%) and width (10%) when added salt concentrations increased from 0 to 6 g NaCl/kg dry soil (Table 1). Increased flag leaf area may have contributed to a greater dry matter production and partitioning to productive tillers (including main stem tiller) and a greater grain yield per plant. These changes in plant morphology and physiology apparently highlighted inherited mechanisms of tolerance to salt stress by wheat plants. It is important to note that the reductions in the number of total tillers and total plant water use did not necessarily decrease the total shoot dry matter rather WUE and grain yield increased significantly with increasing salt stress. Evidence from field studies in QLD and NSW (Subsoil Constraint Project, SIP08, GRDC; unpublished) also indicated that significant reductions in soil water use by wheat crop due to subsoil salt constraints may not necessarily suggest significant reductions in grain yield, highlighting an increased WUE for wheat plants under such conditions.

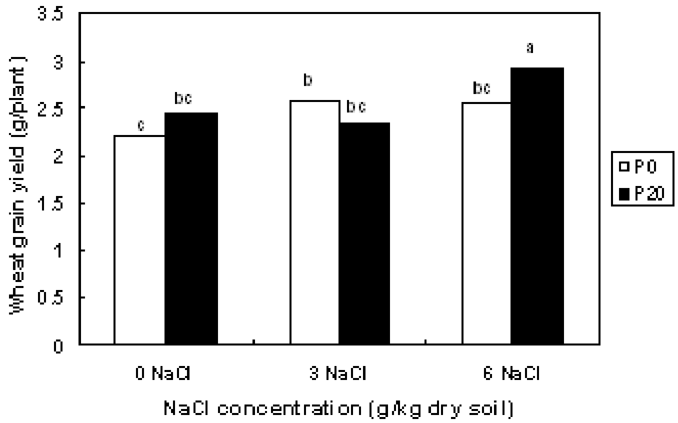

Fig.3. Effect of NaCl on wheat grain yield at different P applications. Different letters on top of the bars indicate significant differences between treatments.

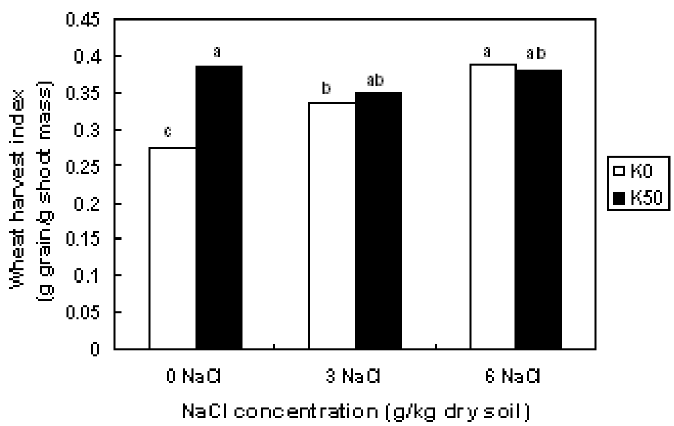

Fig.4. Effect of NaCl on wheat harvest index at different supply of potassium. Different letters on top of the bars indicate significant differences between treatments.

On average, increased supply of P from 0 to 20 kg P/ha equivalent increased the wheat grain yield. This increase in yield was more marked (15% increase) at the higher concentration of NaCl (6g/kg dry soil) (Fig. 3). Similarly, an increased supply of K resulted in an improved wheat harvest index (HI), but this response to K was only marked (40% increase) in the absence of any added salt at 0 NaCl (Fig.4). However, varieties responded differently to P and K nutrition in response to increasing salt concentrations in soil, this complicated the result analysis and conclusion drawn for P and K response. For example, increased P supply increased the WUE for Baxter and Moti, but had no effect on Sunco and Jimbour, whereas, an increased K supply (50 kg K/ha equivalent) increased the grain yield for Baxter, but decreased the grain dry yield for Sunco at higher salt concentrations (data not presented). These interactions effects involving varieties are being closely examined in another paper.

Nevertheless, it has been reported previously that increasing salt concentration in soil may increase the requirement of P and K due to likely membrane leakage and P and K deficiency in plants (Awad *et al*. 1990, Adams 1991, Mohammad *et al*. 1998, Kaya *et al*. 2003). However, supplementary P in our study was not only able to restore any P deficiency (if there was any) due to salt stress, but it also increased the grain yield significantly, particularly at the higher salt concentration (Fig. 3). This result may indicate some sort of Na and/or Cl deficiency for an optimal response to supplemented P in this study. Possibly Na in the added NaCl was able to successfully replace the requirement of K for the wheat plant. Na can be beneficial to the plant in K-deficient soils (Marschner 1995), as also noted for the barley, and to some extent for wheat, in a previous study (Dang et al. 2006).

Conclusion

This study has demonstrated that an imposed salt stress under the experimental conditions and the soil used may result in a greater grain yield for wheat, and severe reduction in yield for chickpea. Increased yield for wheat is likely to result from a greater WUE and an increased flag leaf area contributing to a greater dry matter production and partitioning to productive main stem tillers. This may be due to an inherited tolerance mechanism for wheat in response to increasing Cl toxicity through the added salt. Additionally, an increased concentration of Na through the added salt may have also benefited the wheat plant in the absence of adequate levels of K nutrition in the soil. Supplementary P is most likely to increase the wheat grain yield at higher salt concentrations due to a better response to P in the presence of Na or balanced nutrition for an optimal response, at least for the soil used in this study.

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