Research Application Summary

Development of aluminium toxicity tolerance system for sorghum in agro ecological region three of Zambia

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Abstract

The overall objective of this study was to characterize selected sorghum varieties for Aluminium (Al) tolerance. The specific objectives were to determine performance of selected sorghum varieties grown in Al prone environments, identify root characteristics associated with Al tolerance and to develop a selection criterion for Al tolerance in sorghum.Twenty sorghum genotypes were evaluated in the field at three sites with high soil Al levels and in the laboratory for aluminium tolerance were characterized. Based on the results obtained in the laboratory and field analysis, the top 10 entries that showed Al toxicity tolerance and high grain yield were entries 1,2,3,6,8, 11, 12, 16, 17 and 20. Among these, the top seven in the laboratory analysis were entries 2, 3, 12, II, 17, 16 and 20. The top seven in the field analysis were entries 1, 6, 8, II, 17, 16 and 20. Therefore the best perfomers in both the laboratory and field analysis were entries 11, 17, 16 and 20 score.

Key words: Aluminium toxicity, *Sorghum bicolor,* Zambia

Résumé

L'objectif global de cette étude était de caractériser des variétés choisies de sorgho pour la tolérance en aluminium (Al). Les objectifs spécifiques étaient de déterminer la performance des variétés choisies de sorgho développées dans les environnements enclins d'Al, identifier les caractéristiques de la racine liées à la tolérance en Al et d'élaborer un critère de choix pour la tolérance en Al dans le sorgho. Vingt génotypes de sorgho ont été évalués sur terrain à trois emplacements avec les niveaux élevés d'Al du sol. Dans le laboratoire, ils ont été caractérisés pour la tolérance en aluminium. Basées sur les résultats obtenus en analyse de laboratoire et sur terrain, les 10 entrées principales qui ont montré la tolérance de toxicité d'Al et le rendement élevé de grain étaient les entrées 1, 2, 3, 6,8, 11, 12, 16, 17 et 20. Parmi ces dernières, les sept principales dans l'analyse de laboratoire étaient les entrées 2, 3, 12, II, 17, 16 et 20. Les sept principales dans l'analyse sur terrain étaient les entrées 1, 6, 8, II, 17, 16 et 20. Par conséquent, les plus performantes dans l'analyse de laboratoire et celle sur terrain étaient les entrées 11, 17, 16 et 20.

Mots clés: Toxicité de l'aluminium, *sorgho bicolore*, Zambie

Background

The future of sorghum (*Sorghum bicolor)* production in Zambia is threatened by low productivity resulting from cultivation in low pH soils. Small scale farmers who grow sorghum in region III use unimproved varieties which have low yield potential, and are tall and nonresponsive to improved management (MACO, 2002). In order to increase production levels of sorghum in acidic soils of Zambia a number of strategies need to be adapted. Application of agricultural lime to soils having low pH of less than 5 is one way of restoring soil fertility. However, liming is often not economic or practical because of the slow movement of lime especially in the deeper layers of sub soils. Developing cultivars with improved tolerance to acid soil stress offers an alternative solution to address the problem of low yields in sorghum. The study aimed at identifying important plant characteristics under Aluminium (Al) stress to be used in developing an objective basis of selecting for Al tolerance in sorghum.

Literature Summary

Sorghum is relatively undeveloped and has a remarkable array of untapped variability in grain type, plant type, adaptability and productive capacity. It probably has more undeveloped and underutilized genetic potential than any other major food crop (Lost crops of Africa, 1996). Certain sorghum varieties have been reported to tolerate high aluminium concentrations found in acidic soils (Mohammadi *et al.*, 2003). However, most sorghum cultivars are not tolerant to high concentrations of Al because sorghum improvement programmes have been conducted at locations with near neutral pH soil.

Aluminum (Al) phytotoxicity is one of the biggest agronomic problems in acid soils. Aluminium (Al) is a major constituent of most soils but only when it moves into soluble or exchangeable form can it affect plants. Exchangeable aluminium values may be high in soils with pH below 5.5 but may occur at pH values as high as 6.0 in heavy textured soils (Matsumoto *et al.*, 2001).

The main symptom of Al toxicity is the rapid inhibition of root growth, which may translate to a reduction in vigour and crop yields (Kochian *et al.*, 2005). Shoot growth is also inhibited due to limiting supply of water and nutrients. Aluminium (Al) mainly affects plants by inhibiting radical growth which can be seen in the primary and lateral root apexes, which become thick and turn brownish-gray (Rout *et al*., 2001).

Study Description

Twenty sorghum genotypes were screened for aluminium tolerance both in the field and laboratory. The field experiment was conducted in the Al prone areas of Masaiti, Mpongwe and Mansa in region III in Zambia. The RCBD was used with 3 replications at each site. Soil samples were collected and tested for pH and Al levels. Parameters that were recorded included days to 50% flowering, Plant height, plant count, head wt/plot, grain weight, head harvest index, agronomic score, disease score, pest score and grain yield. The laboratory assessment was done at the University of Zambia where 20 sorghum varieties were tested in nutrient solutions of varying Al concentrations (0, 4, 8, 12, 16 and 20 ppm). The pH was initially adjusted to 4.2 and left unadjusted thereafter. The CRD was used with 4 replications for each genotype. Measurements of interest were shoot length, root length, number of lateral roots per plant, root and shoot biomass.

The analysis of variance (ANOVA) was used to detect statistical differences among different levels of parameters of interest for both the field and laboratory experiments using GenStat Release 7.22. Means were separated using Duncan's Multiple Range Test (DMRT). The conventional path analysis based on the method developed by Dewey and Lu (1959) was used to partition the correlations. MSTAT-C statistical software (MSU, 1988) was used to obtain the correlation coefficients and standard partial regression coefficients. The standard partial regression coefficients from multiple regressions were used as path coefficients and the indirect effects were determined by multiplying the correlation by the respective path coefficients (Ssango *et al*., 2004).

Research Application

Genotypes, concentrations and interaction effects were different for root length, shoot length, number of lateral roots, shoot and root biomass. Laboratory attributes correlated positively with grain yield. Direct effects were 0.5 for lateral roots and 0.7 for shoot length, while indirect effects of root length and root biomass were 0.6 and 0.5, respectively via shoot length. Indirect effects through other variables were not significant. The field study showed significant interactions for plant height and grain yield. Genotypes were different for all parameters tested except plant count, pest score and agronomic score. Significant differences

($P \leq 0.05$) were observed for locations on days to 50% flowering, plant height, pest score, head weight and grain yield. Positive correlations were observed between parameters and yield.

Head weight had a significant ($P \leq 0.001$) direct contribution of 1.4 towards yield. Plant height, pest score and agronomic score had significant indirect effects of 0.7, 0.7 and 0.5, respectively via head weight. It was concluded that under laboratory conditions, head weight and head harvest index contributed highly directly to yield and can be used as a selection criteria. Genotypes 1, 2, 3, 6, 8, 11, 12, 16, 17 and 20 showed Al toxicity tolerance and high grain yield. Among these, the top seven were genotypes 2, 3, 11, 12, 16, 17 and 20 while, in the field they were 1, 6, 8, 11, 16, 17, and 20. The superior genotypes recommended for high rainfall areas were 11, 17, 16 and 20.

Recommendation

The genotypes that performed well in both the lab and field studies should be screened again to validate their performance.

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