Genetic Variability for Root Development in Cotton

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ABSTRACT

Cotton root system development is under genetic control and continuously influenced by the environment. Root architectural diversity can influence the overall productivity of the plant since both uptake and distribution of water and nutrients are impacted by the size and distribution of the root system. The impact of various environmental factors on the phenotypic expression of exotic accessions and modern cotton cultivar root systems was evaluated. Plants were grown in aeroponic, hydroponic, and soil systems and the development of root mass, root length, root extension rates and root architecture were measured. Significant differences in root length development and root architecture were observed among the cotton lines evaluated. Genetic diversity in the rooting response to pruning and temperature were also observed. These findings should aid in developing germplasm for improved response to adverse environments and increased plant productivity.

Introduction

Cotton root system development has been described by Balls (1919), Collins and Warner (1926), Baranov and Maltzev (1937), Hayward (1938) Brown and Ware (1958), Pearson (1974), and Taylor and Klepper (1978). The depth of penetration of the primary root and the formation, number, and depth of penetration of lateral roots are under genetic control. Genetic variability in root length and specific root length in several cotton genotypes was described by Eissa *et al.* (1983). McMichael *et al.* (1985) showed genetic diversity in the number of vascular (xylem) bundles in cotton taproots and suggested that variability in lateral root production was associated with bundle number. Additional research by McMichael *et al.* (1987) supported that hypothesis. McMichael and Quisenberry (1991) showed variability for root weight and root/shoot ratios in a number of exotic cotton accessions. The purpose of the present study was to identify a range of genetic variability for root development among cotton genotypes and to evaluate the impact of various environmental factors on the phenotypic expression of root development.

Material and Methods

Germplasm from exotic accessions of the World Cotton Collection and modern cultivars were evaluated. Plants were grown aeroponically, as described by Waisel (1996); in soil (polyvinyl chloride columns 20 cm in diameter and 110 cm deep, McMichael and Quisenberry (1991)); and in polyethylene growth pouches under hydroponic conditions (McMichael *et al.*, 1985). To determine the ability of various genotypes to regenerate new roots following root pruning, selected sections of the soil columns containing roots were removed and replaced with soil containing no roots. New roots were allowed to grow into the replaced soil for a period of seven days after which the roots were washed clear of soil and measured.

Roots were processed by separating them from shoots. Soil was washed from the roots of the soil-grown plants and the roots were collected on screens. Root length was measured by hand using rulers, by Newman's grid method (Newman, 1966), or with scanning equipment and appropriate image analysis software. Following length measurements both roots and shoots were placed in forced draft ovens and dried at 80C for 24 hours to obtain dry weights.

Results and Discussion

Genetic differences were observed in the development of root/shoot relationships among three exotic genotypes and one commercial cultivar grown in either aeroponics or soil (Table 1). In general root/shoot dry weight ratios were higher in aeroponically-grown than in soil grown plants.

There were also differences noted in the development of root/shoot relationships among genotypes growing in the same culture system (data not shown). T25 grown in soil showed a progressive decrease in root/shoot ratios over time, primarily due to a reduction in root development as reproductive growth increased. T50, however, maintained relatively constant root/shoot ratios.

The heritability for root architecture was investigated by crossing a genotype with relatively few lateral roots (Lubbock Dwarf) with a genotype having a more extensive lateral root system (T25). The results provide the rooting data and heritability estimates for the parents, F1 and F2 progeny (Table 2).

The results indicate the highest heritability to be for lateral root development, especially for lateral root initiation. As a result, total lateral root length also

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exhibited a high heritability. The F1 and F2 progeny exhibit intermediate root architectures with similar tap and lateral root lengths. This data suggests the potential for modification of root architecture through traditional breeding.

Differences in lateral root initiation and development among genotypes can have a significant impact on the growth and productivity of cotton plants. A study was conducted to determine the impact of observed genotypic differences in lateral root production on the ability of cotton root systems to re-explore a soil volume following pruning (Table 3).

The results indicate that cotton roots could re-explore the 60-80 cm depth but not the 80-100 cm depth during the seven day post-pruning period. Genetic variability in the total root length and in the rate of re-exploration was observed. Whether the roots exploring the 60-80 cm soil zone arose from new roots appearing at the cut root ends, or represent other lateral roots moving into the soil zone was not determined in this study. The genotype T25 which has been shown to have an extensive lateral root system in other studies (McMichael *et al.*, 1985) showed the highest rate of root appearance in the new soil zone. The results suggest an advantage in having an extensive lateral root system under conditions where mechanical pruning may exist.

Finally, a study investigating genetic diversity in the temperature dependence of root development revealed similar temperature characteristics among cotton lines (Figure 1). Although similar temperature characteristics were observed for root development among lines, the temperature characteristics of taproot and lateral root development were different within a line. Taproot development occurs across a broader temperature range than that observed for lateral root development. A possible explanation for the observed differences is that taproot development occurs during the period of rapid seed reserve mobilization, while lateral root development occurs after the period of peak reserve mobilization. Although the temperature providing maximum lateral root development was similar among lines, the range of temperatures supporting lateral root development differed among the lines.

Conclusion

These studies demonstrate genetic diversity in existing cotton germplasm for root growth and development. This diversity can directly influence overall plant development by impacting both water and nutrient uptake and utilization. With the current advances in molecular biology, the possibility now exists for genetic engineering the root system for maximizing the cotton root system form and function for enhanced productivity under a wide range of environmental conditions.

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Table 1. Comparison of root/shoot dry weight ratios 13 weeks after planting for four cotton genotypes grown either aeroponically or in soil.

Entry	Aeroponics	Soil
T25	0.35	0.17
T169	0.30	0.17
T50	0.20	0.19
DPL90	0.30	0.20

Table 2. Heritability for root traits in cotton germplasm.

Entry	Taproot Length cm	Lateral Root Length cm	No. Laterals	Total Root Length cm	Mean Lateral Root Length cm
Lubbock Dwarf	12.61 a	2.41 c	8.50 c	15.02 a	0.246 c
F1	8.09 b	7.46 b	20.25 ab	15.55 a	0.437 b
F2	9.56 b	8.24 ab	25.58 a	17.78 a	0.312 bc
T25	4.43 c	11.15 a	16.00 b	15.58 a	0.699 a
Heritability (%)	35.2	54.0	57.0	36.4	----

Table 3. Removal and regeneration of roots at two depth increments from 58-day old cotton plants grown in soil columns.

Genotype	Depth Increment	Total RootLength (m)		Root Regeneration Rate
	cm	Removed	Regenerated	m/day
T50	60-80	57.2 ± 5.5	1.14 ± .5	.16
	80-110	148.5 ± 35.0	0.0	.00
T169	60-80	61.2 ± 21.5	3.1 ± 1.5	.44
	80-110	94.5 ± 35	0.0	0.0
DPL90	60-80	147.7 ± 45	2.0 ± .8	.30
	80-110	198.5 ± 104	0.0	0.0
T25	60-80	87.4 ± 6.0	8.0 ± 3.8	1.14
	80-110	242.4 ± 23	0.0	0.0

Figure 1. Temperature response of taproot and lateral root development 10 days after planting.