Genetic Improvement of Early Root Vigor in Melon (*Cucumis melo* L.) to Enhance Stand Establishment

Kevin M. Crosby[1,2], John L. Jifon[1,2] and Daniel I. Leskovar[2,3]
[1] Texas Agricultural Experiment Station, Texas A&M University, Weslaco, TX 78596, USA
[2] Vegetable and Fruit Improvement Center, Texas A&M University, College Station, TX 77845, USA
[3] Texas Agricultural Experiment Station, Texas A&M University, Uvalde, TX 78801, USA

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Abstract

Root vigor is an important component of transplant health and successful stand establishment in melons and other vegetable crops. Environmental factors, which impact root traits related to vigor, have been examined in some vegetable crops, but few studies on genetic variation for these traits have been published. Greenhouse experiments were conducted to evaluate early melon root vigor in a diverse selection of melon germplasm lines and cultivars. Seven accessions, representing three horticultural groups of melons (cantalupensis, inodorous, momordica), were grown in pasteurized sand, and evaluated for key root morphology traits at four stages of development. Significant differences among cultivars were observed for total root length, fine root length and root area 7, 14 and 21 days after germination. However, by 28 days, all accessions were statistically equivalent for these root traits. The entries, 'Deltex' and 'PI × TDI,' exhibited superior root vigor during the first two weeks of development, compared to the commercial cantaloupe cultivars, 'Caravelle' and 'Magnum 45.' These two lines also exhibited superior field performance for both root and vine vigor at Weslaco, and consequently were more tolerant to infection by *Monosporascus cannonballus*. Subsequent breeding for enhanced root vigor at Weslaco has resulted in many advanced inbreds with improved stress tolerance, vine vigor and fruit quality.

INTRODUCTION

Enhanced stand establishment is critical for determining high productivity of vegetable crops. Transplant shock and other biotic and abiotic stresses are major factors that can impact transplant survival, early development, stand establishment, and subsequently yield and quality. Among stresses, water deficit is one of the major stressors responsible for transplant shock, poor survival and inadequate stand establishment. It is widely acknowledged that a vigorous root system, capable of absorbing moisture to satisfy transpiration demands, can prevent development of water deficit stress and mitigate transplant shock in trees and vegetable crops (Leskovar and Stoffella, 1995; Watson and Himelick, 1997).

Enhanced root vigor (initiation rate, elongation rate, total root length, surface area, total dry weight, regeneration capacity, etc.) are crucial components of healthy seedling development. Extensive efforts have been undertaken to develop cultural practices which stimulate rapid root development. However, the genetic component of root system development has unfortunately been overlooked in many important crops (Bohm, 1979). Environmental variance is often great for root characters (Torrey and Clarkson, 1975). Probably the most significant obstacle is the poor understanding of how root traits impact important agronomic traits such as yield and disease resistance. Efforts to identify key traits relevant to root vigor have been undertaken in some horticultural crops such as cucumbers. For instance, Walters and Wehner (1994) devised a system for cucumber root size evaluation on a scale of 1-9, from small to large, and showed that values were highly correlated with other quantitative root traits such as dry weight. Snapp et al. (2003) also found significant negative correlations between the severity of root rot in snap beans caused by *Fusarium* and root diameter and number of lateral roots. Research which may elucidate the relationships between root traits and production factors such as survival, stand establishment, disease and stress tolerance is important to guiding breeding objectives to improve root vigor. In the present study, phenotypic differences in morphological traits that ~~constitute~~ root vigor were investigated at several early development stages in diverse melon germplasm. The goal was to characterize the degree of genetic variability in these traits that could be useful in genetic improvement of root vigor to enhance soil-borne disease resistance and stress tolerance.

MATERIALS AND METHODS

Seven diverse muskmelon genotypes: 'Crème de Menthe' (Crème), 'PDI 124111 × Tam Dew Improved' (PI × TDI), 'TXC 2015', 'Magnum 45', 'Caravelle', 'Deltex', and 'Doublon' were used in this study. 'Crème de Menthe' is a commercial hybrid honeydew melon, while 'PI 124111 × Tam Dew Improved' and 'TXC 2015' are netted, ~~western shipper-type melons~~ developed at the TAES, Weslaco, Texas, and have improved tolerance to vine decline diseases. 'Magnum 45' and 'Caravelle' are both commercial western shipper cantaloupe hybrids. 'Deltex' is an ananas type hybrid, originating from white flesh Israeli melon landraces. 'Doublon' is an open pollinated Charentais type from France.

Seeds were sown in 12-L sterilized plastic pots (washed and rinsed in 5% bleach solution for 15 minutes) containing steam-pasteurized sand. Three seeds were planted in each container and later thinned to one plant per pot following emergence. There were sixteen replications (containers) of each genotype with containers spaced 20 cm apart in a completely random arrangement in a ventilated greenhouse. Plants were irrigated once or twice a day depending on the evaporative demand using an automatic drip system. Plants were fertilized once weekly using a commercial soluble fertilizer formulation (Peters 20-20-20 plus micronutrients) at a concentration of 400 mg L^{-1}.

Four plants of each genotype were harvested at ~~approximately~~ 7-day intervals starting 7 days after complete emergence. At harvest, each plant was separated into shoots and roots. The rooting medium was washed away from roots using a gentle water stream and total root length, root surface area, root volume, average root diameter, number of root tips and lengths of roots in varying diameter classes were determined after scanning (Hewlett-Packard Model HP Scanjet 4c) the entire root systems and processing the images with a proprietary software (Rhizo Pro 3.8; Regent Instruments, Quebec, Canada). An analysis of variance (ANOVA) was conducted using the general linear model procedures of the SAS System for windows, Version 9.1 (SAS Institute Inc., Cary, NC, USA) as a completely randomized design and where appropriate, mean comparisons were performed using Fisher's least significant difference test (LSD) to further evaluate the magnitude of differences between treatment means.

RESULTS AND DISCUSSION

Significant differences in root vigor parameters (total root length, very fine root length, fine root length, number of root tips and total root surface area) were evident among the genotypes within 1 week after germination (Table 1). During the first week, total root length was the highest in 'Deltex' and 'PDI × TDI' and the least in 'Magnum' and 'Caravelle'. ~~Similar~~ result was also ~~reflected in~~ fine root length, however, the lowest values for very fine root length, number of root tips and total root surface area were found in 'Caravelle'. After two weeks total root length, fine root length (0-0.5 mm) and vine length were also significantly different among the seven cultivars (data not shown). By week four, differences between genotypes in total root length were few (Table 1), but 'Deltex' still had among the highest total root length and total root surface area values. The highest number of root tips was observed in 'PDI × TDI' (Table 1), however, this was not significantly different from those of the other genotypes except TXC.

The data clearly indicate significant genetic variation among the seven genotypes for these root characteristics at least during early to midseason development. Genetic variability both within and among the genotypes may be the largest component of variation. Several of these entries are breeding lines which may contain residual heterozygosity. 'TXC 2015' and 'PI 124111 × TDI' fall into this category. 'Doublon' is an open-pollinated line which is uniform. 'Magnum,' 'Deltex,' 'Caravelle' and 'Creme de Menthe' are all commercial hybrids which should be highly uniform for horticultural traits. However, root traits have had little selection pressure during development of melon hybrids or any melon lines. In addition, levels of inbreeding in melon are not great as most breeding is carried out with the intention of fixing qualitative genes for fruit quality and disease resistance (McCreight et al., 1993). This situation favors heterozygosity, particularly in unselected traits such as root characters. Because the exact levels of heterozygosity and segregation for root traits is not known, this experiment cannot reveal how environmental variation compares to genetic variation. It does provide support that there is genetic variation for root traits among these diverse melon types. In addition, it reveals trends among the genotypes for specific root traits.

The total root length, fine root length and root area may be the most important traits examined here because they represent the capacity for the plant root system to interact with the soil environment. Uptake of water, nutrients and gas exchange should increase as root length and area increase (Torrey and Clarkson, 1975). Fine roots are the primary regions of absorption, thus their total length should directly impact the plant's capacity for water and nutrient uptake. It is clear that some of these cultivars develop greater total root length and fine root length than others from the time of germination and through the length of the growing period. Two cultivars, 'Deltex' and 'PI 124111 × TDI', demonstrated superiority for these two traits throughout the experiment (Table 1; Fig. 1). 'Deltex' also produced significantly greater root tip numbers and root area for the first two weeks, but the other cultivars caught up in weeks three (data not shown) and four. 'Creme de Menthe' showed the greatest variability for all traits throughout the experiment (data not shown). This cultivar may be extremely sensitive to environmental fluctuations or it may have more genetic variability for the traits examined. The latter may be more likely since this hybrid is a fairly consistent performer across various environments in commercial fields in south Texas. 'Caravelle' exhibited poor root development during the first two weeks but then quickly caught up with the others during weeks three (data not shown) and four (Fig. 1). The slower initiation of root development in this cultivar may be a clue to its poor performance under the stress of diseases which destroy roots, such as *M. cannonballus*. This may also be true of 'Magnum' which also performed poorly in the first two weeks but improved during the last two weeks (Fig. 1). Since *M. cannonballus* infection takes place within the first 10 days after germination, the early advantage in root development demonstrated by 'Deltex' and 'PI × TDI' could be a contributing factor in their greater field tolerance to the disease (Mertely et al., 1991; Crosby et al., 2000). In previous investigations, extensive root vigor, particularly lateral root development, has been associated with field tolerance to vine decline (Crosby, 2000). Thus, because of its excellent root vigor, 'PI × TDI' has been selected for the inoculated experiments in both the greenhouse and field as a potential rootstock to reduce transplant shock and enhance stand establishment in melon.

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Tables

Table 1. Early developmental root components of seven melon cultivars.

Cultivar	Total root length (cm)	Very fine root length 0-0.5 mm (cm)	Fine root length 0.5-1.0 mm (cm)	Number of root tips	Total root surface area (cm^2)
			Week 1		
Deltex	366 a	197 a	148 a	336 a	67 a
PDI x TDI	352 a	189 a	146 a	260 ab	62 ab
TXC	279 b	164 ab	107 ab	189 bcd	47 bc
Crème	244 bc	137 ab	104 ab	200 bc	44 c
Doublon	225 bcd	145 ab	76 b	142 cd	37 cd
Caravelle	188 cd	95 b	73 b	114 d	25 d
Magnum	173 d	101 b	57 b	156 cd	31 cd
			Week 4		
Deltex	2751 a	1758 a	607 ab	1994 a	358 ab
PDI × TDI	2706 ab	1829 a	549 abc	2049 a	348 ab
TXC	1932 c	1350 c	482 c	1331 b	261 c
Crème	2421 b	1507 bc	581 ab	1630 ab	349 ab
Doublon	2397 b	1711 ab	529 bc	1798 ab	342 b
Caravelle	2648 ab	1741 ab	600 ab	1909 a	345 ab
Magnum	2597 ab	1669 ab	645 a	1624 ab	406 a

Means separated by LSD at $P \leq 0.05$. Means with the same letter are not significantly different within each week.

Figures

Fig. 1. Root development of four melon cultivars at one week growth stage.