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Watermelon Transplanted by Chisel, Strip-Tillage and Bedding Methods Produce Similar Yield and Quality

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ABSTRACT

Watermelon plants grown in semi-arid, subtropical south Texas (Lat. 26° N) are affected by wind and high solar loads. To provide an environment that would reduce wind-related sand blasting, early transplant desiccation, vine damage and reduce soil temperatures, watermelon seedlings were transplanted into chisel- and strip-tilled high surface residue (14 t/ha) Raymondville silt-loam soil and compared to the standard method of plowing and bedding. Diploid 'Jamboree' and triploid 'Tri-X 313' watermelon varieties were used as sub-plots in a transplant establishment (main-plots) experiment with four replications. Maintaining high soil residue reduced average daily soil temperatures in the chisel and strip-tilled establishment plots at 5 (P=0.03), 10 (P=0.20), and 30 cm (P=0.01) depths compared to bedded melons. Daily maximum surface temperatures were lowest in the bedded plots, suggesting that soil cooling by water loss might lower temperatures. Seasonal moisture at 30 cm was influenced only by date and not by transplant method. Rainfall for the experimental period was unseasonably high (52% of ET). Plant establishment method did not influence transplant survival rate, average fruit weight, marketable fruit weight, or marketable fruit number, but planting into high residue soil increased marketable yield (%) and the percent of marketable fruit with 'Jamboree' showing the greatest response to a high residue environment. Fruit objective color and firmness were not affected by plant establishment method, but 'Tri-X 313' soluble solids (%) were higher than that of 'Jamboree' (12.0 vs. 11.5 %). Cultivars differed in fruit weight, marketable fruit, and marketable yield (%), and marketable fruit number (%). Reducing tillage inputs to establish watermelon transplants had no negative effect on fruit yield or quality.

Additionalo Index Words. *Citrullus lanatus* L., conservation tillage, transplanting methods, WUE

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Conservation tillage practices are in widespread use in agronomic crop production. Adapting traditional no-till practices to horticultural row crops in the past, particularly warm-season vegetables, were not always successful (Grenoble and Bergman, 1980; Knavel et al. 1977; Mullins et al.; 1988). In Puerto Rico, watermelon, tomato (*Lycopersicon esculentum* Mill.) and pigeon pea (*Cajanus cajan* L.) yield were not affected by no-till, minimum tillage (chisel plowing), conventional tillage (plowing to 15 cm) or deeper disc plowing to 45 cm, suggesting that these crops could be grown by minimum or no-till methods (Lugo-Mercado, et al. 1987). More recently, Morse (1999) ascribed the successes of no-till planted vegetables to improved field planting equipment, better management of cover crops and integrated weed control. Winter cover crops, in some cases in conjunction with strip tillage and/or herbicidal destruction of the cover crop, has been more effective, particularly in temperate climates, in assuring both economic and ecological sustainability (Hoyt et al., 1994; Russo and Kindiger, 2007). Late summer no-till broccoli (*Brassica oleracea* L.) planted into previously mowed soybean (*Glycine max* L.) and soybean + millet (*Pennisetum americanum* (L.) K. Schum.) cover crops has produced yields equal to clean cultivation (Abdul-Baki et al., 1997) and reduced tillage sweet corn yields were comparable to those of conventionally grown sweet corn when vigorous cultivars were selected (Makus, 2002). Brassicas (cabbage, cauliflower, and broccoli) were evaluated for adding income to grazed hill lands in cow-calf operations in the mid-southern USA. Yields of 63 cwt/ac from strip-rototilled broccoli grown on these grazing sites are possible before returning the land to grazing the following spring (Makus, 1993). In Northern Queensland, subsurface-irrigated tomatoes grown in glyphosate-killed cover crop systems (*Centrosema pubescens* 'Cavalcade' and *Bothriochloa pertusa* 'Keppel' and 'Hatch') had yields comparable to conventional methods with polyethylene film; but no-till systems benefited from less soil compaction, improved soil aggregates and presence of earthworms (Rogers et al., 2004). In an organic system, use of Sudex [(*Sorghum bicolor*) X (*Sorghum sudanensis*) hybrid, cv. Hay Grazer] as a hay and cover crop for fall planted cabbage reduced yield and average head weight, perhaps due to uncontrolled re-growth of the sorghum sudangrass cover crop (Finney, et al., 2009). Use of strip-tillage in an organic managed system resulted in soil disturbance levels similar to those of conventional tillage systems in the row (tilled strip) and properties of no-till in the inter-row (between rows); suggesting that organically managed production systems are less biologically stratified than conventional input systems under strip-tillage management (Overstreet and Hoyt, 2008).

Constraints to watermelon production in south Texas (Lat. 26º26'N) typically include wind (-blown soil erosion and vine desiccation / movement), intense solar radiation, and timely water application. Transplanting into high-residue fields should improve edaphic factors by reducing wind-blown soil (sand blasting), soil surface temperatures and water depletion. The study was undertaken to evaluate the impact of trans-planting watermelon into high residues, using relatively low disruptive methods and compare with the use of standard soil disruptive methods. Vine phenology, soil temperature and moisture, and the agronomic attributes of fruit yield and quality were used to quantify differences in these trans-planting methods.

MATERIALS AND METHODS

<u>Cover crop</u>. On 23 Feb 2009, sudex cv. Hay Grazer was planted at a rate of 22 kg/ha, followed later with an application of 112 kg/ha N and sickle mowed, without residue removal, three times over the course of the season. A final shredding by rotary mower was in spring 2010 followed by a burn down application with glyphosate on 22 Mar.

<u>Cultivars.</u> 'Jamboree' (a diploid) and 'Tri-X 313' (a triploid) were started in 128-cell Speedling trays on 23 Feb 2010.

Description of the tillage methods used follow:

<u>Chisel.</u> A Yetter disc-opener with residue fingers (Yetter Mfg Inc., Colchoster, IL) was attached to a diamond bar with a 3-point hitch was set up. The unit was run once down the center of the planting row.

<u>Strip-tilled</u>. A FPSR 81 cm Multivator head (Mitchell Equip. Inc., Dublin, OH) was set to till a 23 cm wide strip by removing ½ of the tines and centering the remaining three tines on the row center. One pass was made down the center of the row.

<u>Bedded.</u> A John Deere model 660 tiller (John Deere Co., Moline, IL) was passed twice over the row. A Lilliston cultivator was run over each row three times to raise the bed height to a 30 cm.

After each of the above operations, a 2.5 x 7.5 cm chisel shank with a drip-tape applicator was set to bury trickle tape (type 508-12-450-TSX, T-Systems Int., San Diego, CA) at a 15 cm depth. Double disc hillers were run to cover the opening, followed by a 10 cm press wheel. A Holland Rotary-One cone transplanter (Holland Transplanter Co., Holland, MI) was used for transplanting 6 week-old watermelon transplants.

Main plots (36 m) consisted of rows on 2 m spacing which had either been chiseled, strip-tilled or established in the traditional way of plowing / rototilling and bedding. Sub-plots (cultivars) were 18 m long and randomized within main-plots. Seedlings were planted at 1 m intervals with the Rotary-One planter on 3 Mar into a Raymondville silt loam soil. There were four replications. Weeds and sudex were controlled by 'Select' (clethodim) (21 Apr) and by hand (12 May). A season total of 80 kg/ha (N-P-K) was applied by fertigation and broadcast application between 29 Mar and 21 May. 'Cabrio' (pyraclostrobin) was applied for control of alterneria (11 Jun). Six irrigation applications between 25 Mar and 2 Jun supplied 113 mm of water. Average conductivity of the irrigation water was 236 mS/cm.

Meteorological data were collected by a weather station adjacent to experimental plots. Evapotranspiration (ET_o) was measured by a Model E ET gauge (ETgauge Co., Loveland, CO). Twelve Watermark 200 moisture sensors (Irrometer Co, Riverside, CA) were installed vertically at 30 cm from the soil surface in the center of each main plot treatment in all replications on 13 Apr and soil water content measured weekly between 1300 and 1400 hrs from 23 Apr to 18 Jun. A T-type thermocouple was centered on the moisture sensor body to provide for both soil moisture computation (Thompson and Armstrong, 1987) and a 30 cm soil temperature value. Soil temperatures at 5 and 10 cm were measured hourly in replications two and three by thermisters connected to Hobo data loggers (model H8, Onset Computer Corp., Bourne, MA) at six locations in the 'Jamboree' sub-plots. Surface temperatures were recorded hourly by interrogating infrared thermocouple sensors (1:2 aspect) (model IRTS, Apogee Instruments, Logan, UT) with a data logger (model CR10, Campbell Scientific, Logan, UT) (see Table 1 for dates). The three IR sensors were

Table 1. Average and maximum soil temperatures at 5 and 10 cm from 15 Apr to 14 Jun 2010. Average temperatures at 30 cm taken weekly between 1300 and 1400 hrs from 23 Apr to 18 Jun. Surface temperatures (unreplicated) obtained hourly by IR thermometry between 15 Apr to 20 May (row closure).

Treatment	Avg. Temperature (°C) at 5 cm	10 cm	30 cm	Max/ Temperature (°C) at Surface	5 cm	10 cm
Bedded	27.6 a[z]	26.7 a	27.7 a	32.7	38.1 a	29.5 a
Strip-tilled	26.4 b	26.1 a	27.0 b	35.6	31.1 b	29.0 a
Chiseled	26.7 b	25.5 a	27.0 b	36.4	32.9 b	28.5 a
Prob. > 'F'	0.03	0.20	<0.01	--	0.07	0.45
Contrast:						
Bedded vs. others	0.02	0.13	<0.01	--	0.04	0.30

[Z] LSMEANS separation at P=0.05. Values in a column followed by the same letter are not significantly different.

moved sequentially from replication one to replication four every two weeks until row closure.

Fruit quality. Two uniformly-sized fruit were sub -sampled from each plot after the first 'Jamboree' and 'Tri-X 313' harvests on 14 Jun and 15 Jun, respectively. Melon fruit flesh objective color characteristics (lightness, chroma and hue angle), fruit firmness (kg/ cm), and soluble solids (%) were measured with a Minolta CR-200 (Minolta Corp., Ramsay, NJ), an Effigi Model FT 011 (McCormick Fruit Tech. Yakima, WA), and an Atago Model PR-32α (Atago USA, Inc., Kirkland, WA), respectively. Fruit was cut vertically in half; three sampling locations per fruit were used for color and firmness determinations and three (x 2 fruit) core samples were used for soluble solids determination.

The design was a split plot with transplant method as the main plot and cultivar as the sub-plot. Analysis of variance was done with SAS (ver. 9.1, SAS Institute, Cary, NC) using the PROC GLM procedure. Means separation was by LSMEANS, usually at P=0.05. Where appropriate, single degree orthogonal contrasts were made between bedded and minimum tilled transplant methods.

RESULTS AND DISCUSSION

Rainfall during the experimental period was 124 mm. The experimental plots received 113 mm of supplemental trickle irrigation. Water replacement, both supplemental and by rainfall, was 63% of ET_o (not ET_c). At the 30 cm depth there were no soil water potential (kPa) differences between transplant methods but there were date differences (data not shown). Mean monthly air temperature for April, May, and June (until the 25th) in 2010 was 26.0, 33.8, and 32.5 ° C, respectively. Corresponding monthly radiation values were 128.9, 178.5, and 148.3 kW/m^2.

Seasonal soil temperatures were significantly highest at the 5 cm depth and numerically higher at the 10 cm depth in bedded plots (Table 1). Maximum daily seasonal soil temperatures followed the same trend. Soil temperatures at the 30 cm depth, which were taken at the same time of day but only at weekly intervals, were also significantly higher in the bedded vs. high residue transplanting methods. Seasonal maximum daily average surface temperatures, which were not replicated but where the sensors were relocated every two weeks, were higher in the high residue plots typically by 3° C compared to bare soil plots. Stubble residue appears to act as an insulator, reducing the downward temperature flux into the soil. Bare ground may also reduce the resistance to upward soil water movement which in turn provides for soil surface evaporative cooling.

Transplant survival assessed on 14 Apr was nominal and not influenced by establishment method. Vine length measured on 23 May was significantly higher in plants transplanted by the chiseled method (Table 2). Lateral vine development was reduced in the strip-tilled plants on this date, but initial plant (staminate) flowering was not affected by establishment method. 'Tri-X 313' had less branched vines compared to 'Jamboree' in all establishment methods except the chisel method, giving rise to the branching cultivar x method interaction. The high degree of anchorage of the vines that were planted in high residue and secured by plant tendrils was not quantified. High winds early in the season, typical in south Texas, required repositioning of the vines grown on bare ground. Reposi-

Table 2. Transplant loss on 14 Apr based on 23 plants per plot and phenological plant development on 23 May of five representative plants per plot.

Effect	Transplant loss (%)	Vine length (cm)	Lateral branches (no.)	Plants in bloom (no.)
Cultivar:				
Jamboree	0.4 a[z]	60.0 a	1.8 a	3.5 a
Tri-X 313	2.5 a	58.0 a	1.8 a	5.1 a
Prob. > ‘F’ value	NS	NS	NS	NS
Establishment method:				
Chisel	1.6 a	63.5 a	1.9 a	4.4 a
Strip-tilled	1.1 a	57.4 b	1.6 b	4.2 a
Bedded	1.6 a	56.6 b	1.8 a	4.2 a
Prob. > ‘F’ value	NS	0.01	0.02	NS
Interaction:				
Cultivar X method	NS	0.28	0.056	0.62

[z] LSMEANS separation is at *P*=0.05. Values in a column followed by the same letter are not significantly different.

tioning adds to cost of production and generally sets back vine length development (Table 2).

Yields. ‘Tri-X 313’ fruit were harvested on 14 and 21 Jun and ‘Jamboree’ fruit on 15 and 22 Jun 2010. ‘Jamboree’ fruit were larger in size, but produced fewer marketable fruit, and a lower percent of marketable fruit in weight and number than ‘Tri-X 313’ (Table 3). Transplanting method had no significant effect on average fruit size, marketable fruit weight and number. The marketable yield and fruit number, as a percent of total yield, was significantly reduced in the bedded treatment. A high proportion of culled fruit from plants grown in the bedded treatment were cracked (split along the pistilate end) probably caused by late season rains. Residue-grown fruit did not seem to have problems with split ends. The larger-fruited ‘Jamboree’ was much more susceptible to split ends and this is probably what accounted for the percent marketable yield interaction between cultivar and establishment method. The split-end problem also reduced the number of marketable fruit in ‘Jamboree’ compared to ‘Tri-X 313’.

In Brazil, marketable and total yield of *Cucumis melo* L. were not influenced by either tillage depth in conventional plots (chiseling to 20, 30 40 and 50 cm) or strip-tillage using the same chisel depths (Miranda, et al., 2003). Although weed control was adequate in the experimental plots, persistent weeds such as yellow nutsedge (*Cyperus esculentus* L.) can be controlled in watermelon with metam-sodium fumigation using incorporation by a narrow-width power tiller, resulting in consolidating two field operations, chemical weed control and strip tilling (Johnson and Webster, 2001). Alterneria became systemic near harvest because of rain and high levels of morning dew. The spread of *Phytophthora capsici* in bell peppers, particularly between rows, was greatly reduced when stubble from no-till wheat cover crop was present compared to bare soil or black plastic management (Ristaino et al., 1997). Reduced disease spread in watermelon production systems may benefit by the presence of stubble and/or high residue.

Fruit quality. Fruit selected for quality determinations represented the average weight range of harvested fruit within a given plot. Fruit size did influence fruit quality attributes (Table 4). In order to adjust for this influence, fruit size was used as a covariate in the analysis of fruit quality attributes. Neither flesh color (‘L’, chroma, hue angle) nor fruit firmness was significantly affected by either cultivar or transplant establishment method (Table 5). The average TSS concentration of ‘Tri-X 313’ (12.0%) fruit was higher than those of ‘Jamboree’ fruit (11.5%).

Table 3. Season average melon weight, fruit weight and number per plot, and the marketable yield (%) and fruit number (%) of 'Jamboree' and 'Tri-X' watermelon cultivars grown under minimum inputs or traditional raised beds. Pre-plant field sudex residue was14 t / ha.

Effect	Avg. fruit wt. (kg)	Mkt. fruit wt.[z] (kg)	Mkt. Fruit[z] No.	Mkt. yield (%)	Mkt. fruit (%)
Cultivar:					
Jamboree	8.17 a[y]	63.0 a	7.8 b	74.0 b	70.0 b
Tri-X 313	6.36 b	80.8 a	13.5 a	96.1 a	94.2 a
Prob. > 'F' value	<0.01	0.12	<0.01	<0.01	<0.01
Establishment method:					
Chisel	7.06 a	71.7 a	10.7 a	86.9 a	83.6 a
Strip-tilled	7.28 a	75.9 a	11.2 a	89.4 a	87.0 a
Bedded	7.46 a	68.1 a	10.1 a	78.8 b	75.5 b
Prob. > 'F' value	NS	NS	NS	0.02	0.03
Contrast:					
Bedded vs. others	0.50	0.63	0.68	0.03	0.04
Interaction:					
Cultivar X method	NS	NS	NS	0.03	0.03

[Z] Based on 19.4 m^2 plots.
[Y] LSMEANS separation at *P*=0.05. Values in a column followed by the same letter are not significantly different.

Table 4. Simple correlation matrix between flesh color, fruit firmness, soluble solids, and fruit weight of subsampled 'Jamboree' and 'Tri-X 313' melons.

Attribute	CDM 'L'	CDM Chroma	CDM Hue angle	Fruit firmness	Soluable solids
CDM Chroma value	NC				
CDM Hue angle value	0.596*[j]	0.628**			
Fruit Firmness (kg/cm2)	NC	-0.463*	-0.643*[t]		
Soluble Solids (%)	NC	NC	NC	-0.723**[j]	
Fruit weight (kg)	NC	0.734**	0.692**[t]	-0.669**	0.585*[j]

J= Jamboree, only; T= Tri-X 313, only. NC = not correlated (*P*>0.05).
*, ** = significant at *P*=0.05 and *P*=0.01, respectively.

Table 5. Raw product quality from 'Jamboree' and 'Tri-X 313' melons harvested 14 and 15 Jun 2010, respectively. Sub-sampled fruit weight (see Table 4) used as a covariate in PROC GLM.

Effect	'L'	CDM values Chroma	Hue Angle	Firmness (kg/cm)	Sol. solids (%)
Cultivar:					
Jamboree	36.3 a[z]	35.9 a	28.2 a	82.4 a	11.5 b
Tri-X 313	36.2 a	32.2 a	28.2 a	88.1 a	12.0 a
Prob. > 'F' value	NS	NS	NS	NS	0.04
E Establishment method:					
Chisel	35.6 a	33.2 a	28.1 a	89.2 a	11.8 a
Strip-tilled	36.5 a	35.7 a	28.6 a	83.8 a	11.8 a
Bedded	36.6 a	33.2 a	27.9 a	82.8 a	11.7 a
Prob. > 'F' value:	NS	0.22	NS	NS	NS
Interaction:					
Cultivar X method	NS	NS	NS	0.13	0.08

[Z] LSMEANS separation when $P \leq 0.05$. Values in a column followed by the same letter are not significantly different.

CONCLUSIONS

Transplanting watermelon seedlings into a high surface residue soil, either by chiseling or strip-tilling, resulted in watermelon yields and quality comparable to the standard field preparation methods which require higher energy inputs of fuel and equipment (capital) to form transplant beds. Fertility, water, and pest control inputs were similar in all three transplant methods. There were no differences in water use efficiency (data not shown), but soil temperatures beneath the residue were reduced in the chisel and strip-tilled plots compared to bare ground beds. The diploid cultivar 'Jamboree' performed better on high residue treatments compared to bare ground beds by producing a higher percentage of marketable fruit. The smaller-sized triploid, 'Tri-X 313' produced more marketable fruit than 'Jamboree', probably due to reduced splitting when high rainfall events occurred late in the growing season.

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