Yield of Two Hydroponically Grown Tomato Cultivars as Affected by Transplanting Stage or Direct Seeding

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Abstract. Direct seeding or transplanting younger seedlings should reduce costs in hydroponic systems. A 2-year study (2011–12 and 2012–13) was conducted to determine yield of two hydroponically grown tomato cultivars using transplanted seedlings at different growth stages vs. direct seeding. An open bag, using 10-L plastic bags filled with sawdust, was used for direct seeding and transplanting of seedlings at two-, four- or six-leaf stages. Data were collected on early marketable, early total, total, total marketable and cull yield as well as plant fresh and dry mass. In 2011–12, there was increased early marketable and total yields from direct-seeded plants or plants transplanted at the two- or four-leaf stage. Cultivar FA593 produced a higher early marketable yield and total yield compared with ‘Linares’. In 2012–13, the highest early marketable and total yields were for plants developed from those transplanted at the two-leaf stage or from those developed from direct seeding. There was no difference between cultivars on marketable and total yield. Cultivar Linares produced the highest plant fresh and dry mass. Early yield can be induced by direct seeding or transplanting seedlings at the two-true leaf stage with no significant effect on total yield and marketable yield. Direct-seeded plants, or transplanting seedlings at the two-leaf stage, will benefit growers by producing tomatoes earlier for the market while eliminating or reducing transplant shock.

Direct seeding of hydroponically grown tomatoes (*Solanum lycopersicum*) is not a common practice in South Africa, and most growers use transplants. Seedlings for hydroponic production of fresh market tomatoes are commonly transplanted at 6 to 7 weeks after sowing or at the six-leaf stage (Niederwieser, 2001). Some advantages of transplants, compared with direct seeding, include more efficient use of costly hybrid seed, avoidance of unfavorable cool soils, increased crop uniformity, and early harvest (Liptay et al., 1982; NeSmith, 1997, 1999; Orzolek, 1996).

Effects of transplant age on growth and development have been reported for several vegetable species under soil cultivation. Kratky et al. (1982) reported similar yield for Chinese cabbage (*Brassica rapa* L. ssp. *pekinensis*) plants developed from transplants of 3 to 6 weeks old. Tomato transplants of among 4, 5, or 6 weeks old did not exhibit significant differences in growth (Leskovar and Cantliffe, 1991). Hall (1989) reported that transplants produced higher late and total yields than direct-seeded plants for

one of two watermelon (*Citrullus lanatus* Thunb.) cultivars. Transplants of bell pepper (*Capsicum annuum* L.) resulted in increased basal roots, advanced maturity, increased shoot allocation, improved fruit set, and fruiting efficiency compared with direct-seeded plants (Leskovar and Cantliffe, 1993). Leskovar and Cantliffe (1994) also reported that transplants of fresh-market tomatoes resulted in earlier and higher yields compared with direct-seeded plants when grown in soil.

Various studies have been conducted in open-field cultivation on direct seeding vs. transplants (Leskovar and Cantliffe, 1991, 1993), but there is limited information for tomatoes grown hydroponically. The selection of a planting system depends on the economics of plant establishment, plant performance after establishment, and the value of subsequent yield (Hall, 1989; Leskovar and Cantliffe, 1993, 1994). The effect of transplant stage and direct seeding on yield and biomass production of hydroponically grown tomatoes has not been reported. This study was conducted to determine the yield of two locally produced tomato cultivars as affected by transplant stage and direct seeding.

Materials and Methods

The study was conducted during Oct. 2011 to Feb. 2012 and repeated in Sept. to Feb. 2013 at the Agricultural Research Council—Vegetable and Ornamental Plant Institute, Roodeplaat, South Africa (lat. 25°59' S, long. 28°35' E; altitude 1 200 m.a.s.l.).

A temperature-controlled plastic tunnel was used equipped with a pad and fan (2 × 1.1-kW fans, 1300 mm in diameter) cooling system. Ambient temperature in the tunnel during 2011–12 and 2012–13 ranged from 13 to 35 °C and 11.6 to 36 °C, respectively. Two indeterminate fresh-market tomato cultivars, FA593 and Linares, were either directly sown in 10-L plastic bags or transplanted as seedlings at two-, four-, and six-leaf stages (21, 35, and 46 d old, respectively). Sawdust was used as the growing medium. A randomized complete block design with four replicates was used. Tomato seed was sown in 200-cavity polystyrene trays filled with the commercial growing medium Hygromix® (Hygrotech Pty. Limited, Pretoria, South Africa) and covered with a thin layer of vermiculite after sowing. Each cavity had a volume of 24 mL. With direct seeding, the same volume of growing medium used in seedling trays (24 mL) was placed in 10-L bags filled with sawdust by making a cavity in the sawdust. Seeds were planted in the seedling medium and also covered with a thin layer of vermiculite. Seeds that were directly sown were irrigated twice a day using drip irrigation with a discharge rate of 70 mL for 2 min daily. All seedlings were fertigated with Multifeed® (Plaaskem Pty. Limited, Johannesburg, South Africa) at a rate of 1 g·L⁻¹ of water once daily from the two-leaf stage until the six-leaf stage.

Trials were conducted in tunnels (10 m width × 30 m length) covered with a 200-μm light diffusive plastic (Evadek green tint; Chris Hefer Construction, Johannesburg, South Africa). The floor of the tunnel was covered with 200-μm white plastic. Plants were established at a density of 2.5 plants/m² with 10 plants used to collect data in each replication.

Plants were irrigated using one dripper per plant (discharge rate of 35 mL·min⁻¹) at 2-h intervals seven times daily. The irrigation volume was gradually increased as plants enlarged to ensure that 10% to 15% of the applied water leached out of the bags to reduce salt buildup in the growing medium. The composition and chemical concentration of locally recommended fertilizers used were: Hygroponic® (Hygrotech Pty. Limited, Pretoria, South Africa) comprised of nitrogen (N) (68 mg·kg⁻¹), phosphorus (42 mg·kg⁻¹), potassium (K) (208 mg·kg⁻¹), magnesium (30 mg·kg⁻¹), sulfur (64 mg·kg⁻¹), iron (1.254 mg·kg⁻¹), copper (0.022 mg·kg⁻¹), zinc (0.149 mg·kg⁻¹), manganese (0.299 mg·kg⁻¹), boron (0.373 mg·kg⁻¹), and molybdenum (0.037 mg·kg⁻¹); calcium nitrate [Ca(NO₃)₂] comprised of N (117 mg·kg⁻¹) and calcium (166 mg·kg⁻¹); and potassium nitrate (KNO₃) comprised of K (38.6 mg·kg⁻¹) and N (13.8 mg·kg⁻¹). When all seedlings were 6 weeks old (including direct-seeded seedlings), the irrigation water was supplemented with 800 g Hygroponic and 600 g Ca(NO₃)₂ per 1000 L water until the first flower truss appeared. During development of the first to third flower trusses, fertilizer application was adjusted to 900 g Hygroponic

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and 700 g Ca(NO₃)₂ and from the third flower truss to the end of the experiment to 1000 g Hydroponic, 900 g Ca(NO₃)₂, and 200 g KNO₃ per 1000 L of water.

Plants were trellised to a single stem by twisting trellis twine around the main stem and fixing it to a stay wire 2 m aboveground to support the plant. Side shoots or suckers were removed weekly to maintain a single stem system. When plants had reached the horizontal wire at 2 m, the growing point was removed.

Fruit were harvested weekly at the breaker stage in midsummer from January to February (2011–12 experiment) and December to February (2012–13 experiment). Yield data were collected from 10 plants for each treatment and replicate. The performance of treatments was evaluated using total yield, marketable, and cull yield. Fruit were regarded as cull when they exhibited cracking, zippering, rotting, blossom-end rot, rain control, cat face, or when extra small (less than 40 mm fruit diameter) (Maboko et al., 2011). Early marketable and total early yields were recorded from the first four harvests, i.e., 84, 91, 98, and 105 d after transplanting. At the end of the experiment, the above-ground plant fresh and dry mass were determined by cutting the plant at the growing medium level. Plants stems and leaves were dried in an oven at 70 °C for 48 h for dry mass determination.

Data were subjected to analysis of variance using GenStat®, Version 11.1 (Payne et al., 2008). Means were separated using Fisher's protected *t* test least significant difference (Snedecor and Cochran, 1980).

Results

The cultivar and transplant stage interaction was not significant for growth and yield. Only the main factors, cultivar and transplant stage, are presented in this experiment. The 2011–12 experiment was ended early (126 d after transplanting) as a result of a high infestation of tomato rust mite (*Aculops lycopersici*).

Effect of cultivar. In 2011–12, cultivar FA593 produced significantly higher early and total yield as well as cull yield compared with cultivar Linares (Table 1). Total marketable yield and number of marketable fruit were not significantly affected by cultivar (Table 1). However, cultivar FA593 produced a higher early yield than 'Linares'. In 2012–13, cultivar did not affect yield. 'Linares' produced significantly higher plant fresh and dry mass than cultivar FA593 (Table 2).

Effect of transplant stage. In 2011–12, directly sown seeds and seedlings transplanted at the two- or four-leaf stages produced significantly higher early marketable and total yields than seedling transplanted at the six-leaf stage (Table 1). Total yield and

total marketable yield for direct-seeded and transplanted tomato were similar (Table 1). In 2012–13, sowing seed directly into the sawdust or transplanting seedlings at the two-leaf stage produced plants that had the highest early number of marketable fruit and early total and marketable yield (Table 2). Total yield or total marketable yield was unaffected by transplant stage or direct seeding (Table 2).

Discussion

Differences in yield among the cultivars are in agreement with a previous study (Maboko et al., 2012) in that cultivars performed differently in terms of yield and quality. The higher plant fresh and dry mass on cultivar Linares (Table 2) is in agreement with Luitel et al. (2012) who reported that tomato cultivars varied in terms of vegetative growth.

Transplanting seedlings at the two-leaf stage or by direct seeding in sawdust may reduce costs in hydroponic production systems. Furthermore, early harvests from directly seeding or transplanting at the two-leaf stage should provide an advantage of supplying tomatoes early to the market. These results differ from Leskovar and Cantliffe (1991), who found that early total and total fruit yields of tomatoes were similar for 2-, 3-, 4-, or 5-week-old transplants when grown in soil. Leskovar and Cantliffe (1993) reported

Table 1. Effect of transplanting stage on yield of two tomato cultivars (2011–12).^z

Treatment	Early marketable yield (g/plant)	Early total yield (g/plant)	Early number of marketable fruits/plant	Total marketable yield (g/plant)	Total yield (g/plant)	Number of marketable (fruit/plant)	Cull yield (g/plant)
<i>Cultivar</i>							
FA593	1904 a	2223 a	16.00 a	3388	4384 a	29.28	995 a
Linares	1492 b	1765 b	12.19 b	3123	3673 b	27.61	550 b
LSD 0.05	230.3	217.8	1.70	NS	411.9	NS	190.7
<i>Transplant stage</i>							
2 leaves	1956 a	2300 a	16.46 a	3730	4528	31.22	798
4 leaves	1717 a	2001 a	13.26 bc	2985	3789	26.07	804
6 leaves	1309 b	1592 b	11.33 c	3049	3868	27.80	819
Direct seeding	1810 a	2083 a	15.34 ab	3258	3929	28.69	671
LSD 0.05	325.7	308.0	2.41	NS	NS	NS	NS

^zValues in a column followed by the same letter are not significantly different $P \leq 0.05$, Fisher's protected *t* test.

NS = nonsignificant; LSD = least significant difference.

Table 2. Effect of transplanting stage on yield of two tomato cultivars (2012–13).^z

Treatment	Early marketable yield (g/plant)	Early total yield (g/plant)	Early number of marketable fruit/plant	Total marketable yield (g/plant)	Total yield (g/plant)	Percent marketable yield	Number of marketable fruit/plant	Cull yield (g/plant)	Percent cull yield	Plant fresh wt (g/plant)	Plant dry mass (g/plant)
<i>Cultivar</i>											
FA593	1027	1125	6.29	5942	6734	87.95	41.5	792	12.05	1694 b	226.8 b
Linares	1130	1300	6.88	5889	6684	87.88	37.2	795	12.12	1935 a	266.5 a
LSD 0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	207.3	31.12
<i>Transplant stage</i>											
2 leaves	1433 a	1598 a	8.74a	6122	7048	86.57	39.1	926	13.43	1846	259.9
4 leaves	886 b	1019 b	5.17b	5918	6731	87.68	38.7	813	12.32	1880	248.0
6 leaves	695 b	810 b	4.51b	5734	6394	89.26	39.5	660	10.74	1786	246.2
Direct	1301 a	1425 a	7.91a	5888	6664	88.15	40.1	776	11.85	1747	232.4
LSD 0.05	257.5	279.9	1.71	NS	NS	NS	NS	NS	NS	NS	NS

^zValues in a column followed by the same letter are not significantly different, $P \leq 0.05$, Fisher's protected *t* test.

NS = nonsignificant; LSD = least significant difference.

that bell pepper transplants had significantly higher and earlier yields than direct-seeded peppers when grown in soil. In this study, the delay in harvest for plants developed from transplants of either the four- or six-leaf stage was compensated for by higher yields during the late harvests.

Plants developed from direct seeding or from transplants established at the two-leaf stage might have performed better than plants developed from seedling transplanted at four- or six-leaf stages as a result of unrestricted taproot development and greater root proliferation in the larger sawdust volume in a 10-L planting bag (Leskovar and Stoffella, 1995). The early yield might be the result of early root growth, improved water and nutrient uptake, and less competition for light as might have occurred in higher density seedling trays. Commercial seedling growers produce seedlings in seedling trays with small cavities to reduce the amount of growing medium and produce more seedlings per unit area. This might result in seedlings competing for sunlight as the leaf canopy becomes crowded. Seedlings that were allowed to grow to the six-leaf stage might have increased root restriction as a result of a small cavity size (NeSmith and Duval, 1998). When seed is directly sown or transplanted at a young stage, i.e., two-leaf stage, into 10-L plastic bags, seedling roots are not be restricted (NeSmith and Duval, 1998). Peterson et al. (1991) reported that increased root mass and decreased rooting space lead to competition for available oxygen, further reducing the amount of pore space.

In conclusion, direct-seeded plants, or transplanting seedlings at the two-leaf stage, will benefit growers by producing tomatoes earlier for the market while eliminating or reducing transplant shock. Direct seeding or transplanting seedlings at the two-leaf stage would reduce production costs in hydroponic production systems.

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