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Effect of root substrates and seed cover materials on the germination and growth of organic tomato transplants

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Abstract

In two experiments, seeds of tomato (*Solanum esculentum* L.) cultivar 'Celebrity' were planted in four root substrates (Grower's Mix 20, Fafard 4P, Johnny's 512 Select and Sunshine Planter's) in 72-cell plastic plugs trays using different cover materials. In physical property evaluations, the four substrates had similar total porosity. However, Johnny's 512 Select had the highest container capacity and bulk density while Fafard 4P and Sunshine Planter's had the largest air space. There was some seasonal variation between the germination and growth results of the two studies. The use of root substrate, coir, or vermiculite resulted in better germination than leaving the seeds uncovered, with the exception of the seeds germinated in Johnny's 512 Select in Experiment 1. Also, in Experiment 1, tomato seedlings were the tallest and heaviest when grown in Grower's Mix 20. Using newspaper to cover seeds reduced germination in Experiment 2. Tomato seedlings grown in Grower's Mix 20 and Johnny's 512 Select were equal or greater in shoot height or weight as compared to those grown in the conventional substrate Fafard 4P.

Key words: *Solanum esculentum,* vermicompost, feather meal, kelp meal, seedlings, root media.

Introduction

U.S. demand for organic foods and beverages has increased from $1 billion in 1990 to $24.8 in 2009 (Organic Trade Association, 2010). Organic food and beverage sales in 2009 increased 5.1 percent above 2008 sales. The largest sales increase in 2009 was in organic fruit and vegetable sales, which increased 11.4 percent above 2008.

To be certified as organic, farms must use organically produced seeds and transplants (National Organic Program, 2012). However, these transplants are expensive and difficult to produce. Cantliffe (1998) concluded that optimizing seed germination is a critical step to ensure economic returns in a transplant operation, but relatively little work has been performed on optimizing germination in substrates approved for organic production.

Russo (2005) compared shoot height and dry weight of bell pepper, onion, and watermelon transplants grown in approved organic substrates to conventional substrates. Arancon *et al.* (2003 and 2004) and Atiyeh *et al.* (2000) conducted studies on the effect of vermicompost as a rooting substrate component on emergence and growth of a wide range of seedlings, including tomato. Larrea (2006) suggested that covering the seed with vermiculite might have increased germination in organic substrates containing vermicompost; however, this hypothesis was not tested in a side-by-side comparison of germination rates.

Compost and other organic materials are commonly used on organic and sustainable farms as a soil conditioner and source of mineral nutrients. One barrier to large-scale use of compost and similar soil amendments from waste materials is the need for consistent and predictable quality (Baarth, 1999). Arancon *et al.* (2004) stated that there are possible adverse environmental and economic impacts of agrichemicals on ornamental plant production and suggested a greater utilization of organic amendments such as composts or vermicompost for greenhouse production of bedding plants. With decreased use of synthetic nutrient sources, which are typically applied in a more soluble form than organic sources, the run-off of nitrogen (N), phosphorus (P) and potassium (K) could potentially be reduced.

The use of a seed cover material provides the small-scale farmer with a technique that may improve germination; however, studies on the use of cover materials other than the substrate itself to increase germination are limited. Materials with unique properties, such as coconut coir and vermiculite, need to be evaluated for cover materials in organic transplant production. Coconut (*Cocos nucifera* L.) coir dust is an agricultural waste product that is produced from the mesocarp or husk of the coconut (Evans *et al.*, 1998). There is limited research on the effectiveness of coconut coir as a seed cover material. Vermiculite is frequently used for this purpose.

This research was conducted to provide research-based results on organic transplant production to meet the growing demand for organically and sustainably-grown produce. The main objectives of this study were: 1) to compare the effects of commercial and custom organically blended substrates on tomato seed germination and growth and 2) to evaluate coconut coir and vermiculite as seed cover materials on tomato seed germination in organic transplants production.

Materials and methods

Two experiments were conducted in the Reid Greenhouse at North Carolina Agricultural and Technical State University in Greensboro, NC, USA (36° N latitude). Temperatures were set at day and night minimums of 25 and 21°C, respectively. Tomato (*Solanum esculentum* 'Celebrity') seeds were germinated and grown in 72-cell trays (Landmark Plastic Corp., Akron, OH) in both experiments. Plants were watered as needed based on the physical appearance of the substrate and seedlings.

Four substrates were selected for both experiments: a conventional, commercial transplant substrate (Fafard 4P, Conrad Fafard, Inc., Agawam, MA), two commercial organic substrates (Sunshine Planter's, Sun Gro Horticulture, Bellevue, WA and Johnny's 512 Select, Johnny's Selected Seeds, Winslow, ME), and a modified organic substrate mixed for this research (Grower's Mix 20). Fafard 4P contained 45% Canadian sphagnum peat moss combined with aged pine bark, vermiculite, Dolomitic limestone, gypsum, wetting agent, starter nutrients, and slow release nitrogen (Fafard Product Guide, 2011). Johnny's 512 Select was a blend of sphagnum and sedge peat mosses, compost, and perlite (Johnny's Selected Seeds, 2012). The Grower's Mix 20 components and mixing specifications were adopted from Larrea (2006). Grower's Mix 20 was a 4 peat: 1 perlite (v/v) amended with feather meal (Boer Commodities.Inc., Fresno, CA) and kelp meal (Algit, P.B. Ohrstrom & Sons Inc., Arlington Heights IL) at 19.53 and 8.40 $L \cdot m^{-3}$, respectively.

Tomato seeds were sown on 21 Aug. and 6 Dec. 2007 for Experiments 1 and 2, respectively. In Experiment 1, each 72-cell tray was covered with one of the four seed cover materials: vermiculite (Peaceful Valley, Grass Valley, CA), coconut coir (Down to Earth Distributors, Eugene, OR), the same substrate in which the seed were planted, or left uncovered. In Experiment 2, a single layer of wet newspaper was added as a fifth seed cover material treatment over uncovered seeds. The wet newspaper remained over the flat until ten days after cotyledons were visible (20 Dec).

Sample and data collection: Samples of the soilless substrates were collected for physical properties prior to planting. Germination data were collected on 31 Aug. and 20 Dec. in Experiments 1 and 2, respectively. Germination percentage was calculated as the total number of seedlings that emerged divided by the total number of seed sown multiplied by 100 (Bradford, 1986). Height was measured on 20 randomly selected transplants from each flat on 18 Sept 2007 (18 days after sowing) and 3 Jan 2008 (14 days after sowing) in Experiments 1 and 2, respectively.

Shoot tissue was sampled by cutting the stem at the base of 20 transplants using a hand pruner. Plant samples were collected 28 days after sowing in Experiment 1 and 18, 32 and 39 days after sowing in Experiment 2. The composited fresh weight of the 20 sample transplants was recorded. Plant samples were rinsed in distilled water for 30 s. The samples were then placed in brown paper bags and dried at 70°C in a forced air oven until a constant weight was attained (approximately 48 h). The dry weight of each sample was then recorded. Dry plant samples were ground to pass a 1 mm screen (20-mesh) using the Thomas-Wiley Laboratory Stainless Steel Mill Model No. 4 (Thomas Scientific, Philadelphia).

Substrate and tissue analyses: All substrates were analyzed for physical properties (total porosity, container capacity, air space and bulk density) in the Horticultural Substrates Laboratory at North Carolina State University using the procedures described by Fonteno (1996).

Nitrogen was determined on 10 mg plant tissue samples with a Perkin Elmer 2400 CHN elemental analyzer (Norwalk, CT). Another 0.5 mg sample was placed in the Erlenmeyer flask for dry ashing. The sample was then placed in the Muffle Furnace for eight hours at 550 °C (Mills and Jones, 1996). Nitric acid (2.5mL) was added to the ash. The Erlenmeyer flask was then rinsed twice and filtered in a 50 mL volumetric flask. The ash solution was diluted to 50 mL with deionized water. The sample was then analyzed for potassium (K), phosphorous (P), calcium (Ca) and magnesium (Mg), using an Inductively Coupled Plasma Spectrometer (ICP-OES; Perkin-Elmer Optima 3300DV, Norwalk, CT). All tissue analyses were conducted at the Analytical Services Laboratory, School of Agriculture and Environmental Sciences, NC A&T State Univ.

Experimental design and statistical analysis: Experiment 1 was a factorial design with four substrates and four cover materials arranged in a randomized complete block with four replications for a total of 64 experimental units (72-cell flats). Experiment 2 was a factorial design with four substrates and five cover materials arranged in a randomized complete block with four replications for a total of 80 experimental units (72-cell flats). Data were subjected to analysis of variance using PROC ANOVA (SAS 9.3, SAS Inst., Cary, NC). Means were separated using the Fisher's Protected LSD test at the 0.05 level of significance.

Results and discussion

Substrate physical properties: Total porosity was similar for the four root substrates (Table 1). Container capacity was greatest in Johnny's 512 Select followed by Grower's Mix 20 and least in Fafard 4P and Sunshine Planter's. Air space was greatest in Fafard 4P and Sunshine Planter's, intermediate in Grower's Mix 20, and least in Johnny's 512 Select. Bulk density varied from greatest to least in the following order: Johnny's 512 Select, Grower's Mix 20, Fafard 4P, and Sunshine Planter's.

Table 1. Total porosity, container capacity, air space and bulk density of four root substrates used for growing 'Celebrity' tomato transplants

Substrate[z]	Porosity (% by volume)	Container capacity (% by volume)	Air Space (% by volume)	Bulk density ($g \cdot cm^{-3}$)
Grower's Mix 20	88.37	76.73	11.57	0.17
Fafard 4P	87.60	70.23	17.37	0.14
Sunshine Planter's	87.37	70.40	16.97	0.09
Johnny's 512 Select	86.93	80.53	6.43	0.26
$LSD_{0.05}$	NS	2.16	2.14	0.03

[z]Grower's Mix 20, Sunshine Planter's and Johnny's 512 Select were substrates formulated to meet the National Organic Standards for transplant production. Fafard 4P was a substrate used commercially for conventional transplant production.

Transplant production practices, such as frequency of irrigation, must be adjusted based on a root substrate's physical properties and *vice versa* (Nelson, 2011). For example, root substrates with a high container capacity and low percent air space, such as Johnny's 512 Select, require less frequent watering during plant production and retain more water during plant shipping and marketing. However, greater care is required with these substrates that plants are not over-watered during production. Well-drained substrates such as Fafard 4P and Sunshine Planter's, require more frequent irrigations, which also affects the leaching of nutrients. The greater bulk density of Johnny's 512 Select may also increase the shipping cost for the bulk substrate and finished transplants.

Experiment 1: There was a root substrate x seed cover material interaction effect on seed germination. In Johnny's 512 Select, seed germination was similar for coir, vermiculite, and no cover (Fig. 1A). However, using the Johnny's 512 Select substrate as a cover resulted in a lower germination rate than with vermiculite. In Sunshine Planter's, not covering seeds resulted in the lowest germination rate. In Fafard 4P, the uncovered seeds germinated at a similar rate to those covered with coir but a lower rate than those covered with the substrate or vermiculite. In Grower's Mix 20, seeds covered with vermiculite or uncovered germinated at a lower rate than those covered with the substrate or coir. These results indicate that the best choice of cover material for germinating tomato seeds was dependent on the root substrate. Johnny's 512 Select was a heavier substrate with greater container capacity and bulk density, the germinating seedlings benefited from being covered by the lighter vermiculite or leaving the seeds uncovered in Experiment 1. Whereas, the other substrates were lighter and more prone to drying out so leaving the seeds uncovered was detrimental.

There was no root substrate x seed cover material interaction or cover material effect on the shoot height. The tallest plants were recorded in Grower's Mix 20 followed by Fafard 4P and Johnny's 512 Select (Table 2). The shortest plants were produced in Sunshine Planter's.

There was a root substrate x seed cover material interaction effect on shoot dry weight. With all four cover materials, shoots were heaviest in Grower's Mix 20 and lightest in Sunshine Planter's (Fig. 1B). Within plants grown in Fafard 4P and Sunshine Planter's, plants had similar dry weights regardless of seed cover material. In Grower's Mix 20, plants from seeds covered with vermiculite were heavier than those covered with coir or left uncovered. However, in Johnny's 512 Select, plants from seeds covered with vermiculite were lighter than those covered with substrate or coir and those left uncovered weighed less than those covered with substrate.

There was no root substrate x seed cover material interaction or cover material effect on the shoot nutrient concentrations. Nutrient concentration data is shown in Table 2. Shoot N

Table 2. Effect of root substrate on the shoot height and nutrient concentrations of 'Celebrity' tomato transplants at 28 days after planting in Experiment 1

Substrate[z]	Height (cm)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Grower's Mix 20	31.9	3.50	0.97	3.17	1.78	0.55
Fafard 4P	19.4	2.05	0.50	2.94	1.15	0.68
Sunshine Planter's	4.9	2.01	0.23	0.56	1.09	0.62
Johnny's 512 Select	19.6	3.90	0.60	2.96	1.83	0.32
$LSD_{0.05}$	1.3	1.01	0.08	0.39	0.24	0.08

[z]Grower's Mix 20, Sunshine Planter's, and Johnny's 512 Select were substrates formulated to meet the National Organic Standards for transplant production. Fafard 4P was a substrate used commercially for conventional transplant production.

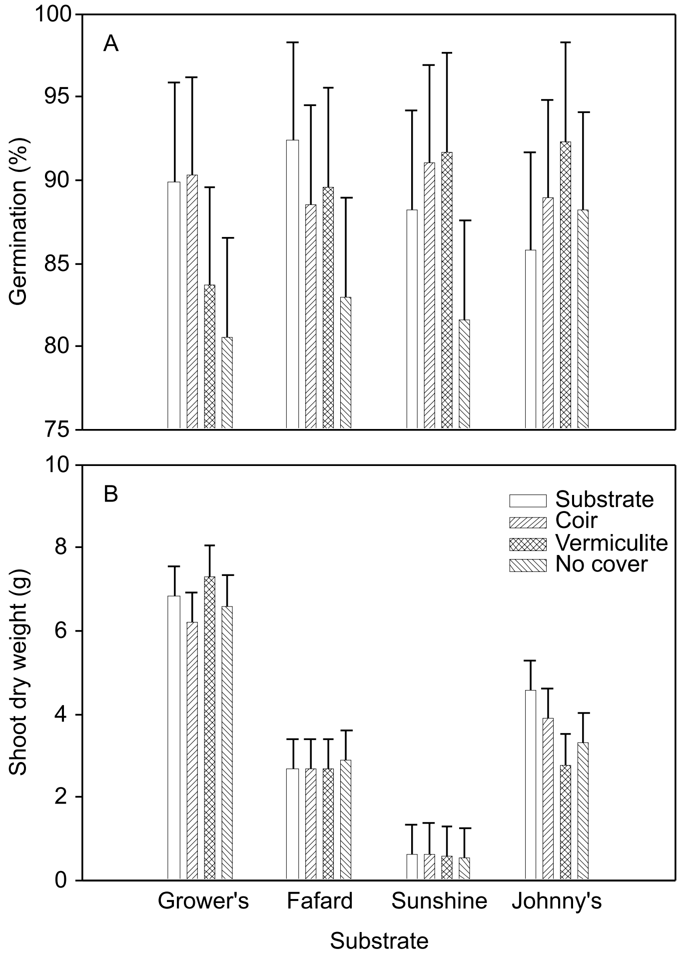

Fig. 1. Germination and shoot dry weight of 'Celebrity' tomato transplants in four root substrates (Grower's Mix 20, Fafard 4P, Sunshine Planter's, and Johnny's 512 Select) in combination with four seed cover materials in Experiment 1. Vertical bars indicate $LSD_{0.05}$ for comparing root substrate within each seed cover material or for comparing seed cover materials within each root substrate.

concentration was higher in plants grown in Grower's Mix 20 and Johnny's 512 Select than those grown in Fafard 4P and Sunshine Planter's. Shoot P concentration went from highest to lowest in the following order: Grower's Mix 20, Johnny's 512 Select, Fafard 4P, and Sunshine Planter's. Shoot K was lower in plants grown in Sunshine Planter's than the other three root substrates. Shoot Ca concentration was higher in plants grown in Grower's Mix 20 and Johnny's 512 Select than those grown in Fafard 4P and Sunshine Planter's. Plants grown in Johnny's 512 Select had the lowest shoot Mg concentration and plants grown in Gower's Mix 20 had a lower shoot Mg concentration than those grown in Fafard 4P.

Experiment 2: There was no root substrate x seed cover material interaction effect on seed germination. However, seed germination rate was greater in Sunshine Planter's and Johnny's 512 Select than Grower's Mix 20 (Table 3). Also, seed germination rate was greater using the root substrate, coir or vermiculite than with newspaper or uncovered seeds (Table 4).

There was no root substrate x seed cover material interaction effect on shoot height. However, plants grown in Sunshine Planter's were shorter than those in the other three substrates (Table 3). Also, plants were taller when seeds were covered with vermiculite than when seed were not covered and plants

Table 3. Effect of root substrate on the germination rate, shoot height, and shoot nutrient concentrations of 'Celebrity' tomato transplants at 32 days after planting in Experiment 2

Substrate[z]	Germination (%)	Height (cm)	N (%)	P(%)	K(%)	Ca(%)	Mg(%)
Grower's Mix 20	84.4	14.6	5.36	0.15	1.61	0.39	0.15
Fafard 4P	88.2	13.9	3.68	0.08	0.96	0.17	0.15
Sunshine Planter's	90.6	4.2	3.19	0.08	0.62	0.39	0.25
Johnny's 512 Select	89.8	13.4	4.55	0.13	1.61	0.71	0.16
$LSD_{0.05}$	4.3	1.4	1.96	0.06	0.63	0.21	0.05

[z]Grower's Mix 20, Sunshine Planter's, and Johnny's 512 Select were substrates formulated to meet the National Organic Standards for transplant production. Fafard 4P was a substrate used commercially for conventional transplant production.

were taller when seeds were covered with root substrate, coir or vermiculite than when covered with newspaper (Table 4).

Table 4. Effect of seed cover material on the germination rate and shoot height of 'Celebrity' tomato transplants at 32 days after planting in Experiment 2

Cover	Germination (%)	Height (cm)
Substrate[z]	92.9	12.0
Coir	89.9	12.3
Vermiculite	90.7	12.6
No cover	83.9	10.9
Newspaper	83.8	9.8
$LSD_{0.05}$	4.8	1.5

[z]The substrate used for the seed cover material was the same as the respective root substrate material.

There was a root substrate x seed cover material interaction effect on shoot dry weight (Fig. 2). Plants grown in Sunshine Planter's were lighter than those grown in the other three substrates regardless of seed cover material. Plants grown in Grower's Mix 20 and Sunshine Planter's had similar dry weights regardless of seed cover material. In Fafard and Johnny's 512 Select, plants grown from seed covered with coir or vermiculite were heavier than those with other three cover materials.

There was no root substrate x seed cover material interaction or cover material effect on the shoot nutrient concentrations (Table 3). Shoot N concentration was higher in plants grown in Grower's Mix 20 than those grown in Sunshine Planter's. Shoot P concentration was higher in plants grown in Grower's Mix 20 than those grown in Fafard 4P and Sunshine Planter's. Shoot K

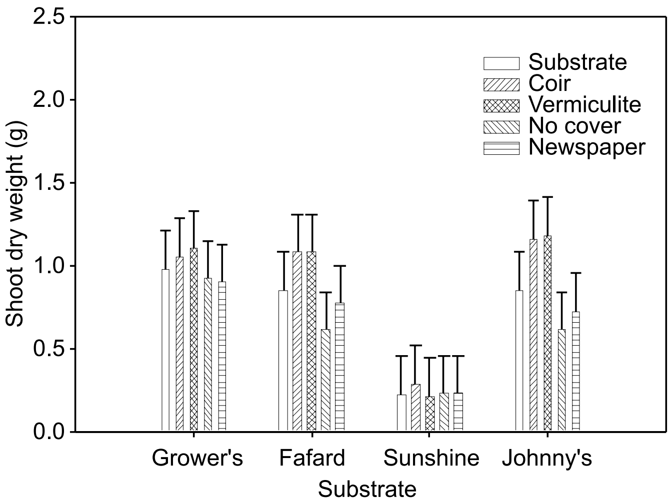

Fig. 2. Shoot dry weight of 'Celebrity' tomato transplants in four root substrates (Grower's Mix 20, Fafard 4P, Sunshine Planter's, and Johnny's 512 Select) in combination with five seed cover materials in Experiment 2. Vertical bars indicate $LSD_{0.05}$ for comparing root substrate within each seed cover material or for comparing seed cover materials within each root substrate.

concentration was higher in plants grown in Grower's Mix 20 and Johnny's 512 Select than those grown in Fafard 4P and Sunshine Planter's. Shoot Ca concentration was highest in plants grown in Johnny's 512 Select followed by Grower's Mix 20 and Sunshine Planter's and lowest in those grown in Fafard 4P. Shoot Mg concentration was higher in plants grown in Sunshine Planter's than the other three substrates.

Differences in the results between the two experiments can be attributed to seasonal variation. Experiment 1 was begun in August when daylengths were longer than 12 hours, light levels were high, and greenhouse temperatures were hot. Experiment 2 was conducted in December and January when daylengths were shortest, light levels were low, and greenhouse temperatures were cooler. Thus, tomato seedlings were taller and weighed more in Experiment 1 than Experiment 2.

Although total porosity was similar between the four root substrates tested, container capacity and bulk density were greatest in Johnny's 512 Select and air space was greatest in Fafard 4P and Sunshine Planter's. The use of root substrate, coir, or vermiculite resulted in better germination than leaving the seeds uncovered, with the exception of the seeds germinated in Johnny's 512 Select in Experiment 1. Using newspaper to cover seeds also reduced germination. Tomato seedlings grown in Grower's Mix 20 and Johnny's 512 Select were equal or greater in shoot height or weight as compared to those grown in a conventional substrate (Fafard 4P).

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