Efficacy of Cork Granulates as a Top Coat Substrate Component for Seed Germination as Compared to Vermiculite

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SUMMARY. A top coat is a lightweight substrate component used in seed germination. The seeds are typically placed on a substrate such as peat and then the seeds are covered with a layer of the top coating substrate. The top coat serves to maintain adequate moisture around the seeds and to exclude light. Vermiculite and cork granulates (1 mm) were used as top coat substrates for seed germination to determine if cork granulates could be successfully used as an alternative to vermiculite. The cork granulates had a bulk density of 0.16 g·cm⁻³, which was higher than that of vermiculite that had a bulk density of 0.12 g·cm⁻³. Cork granulates had an air-filled pore space of 22.7% (v/v), which was higher than vermiculite which was 13.2%. The water-holding capacity of vermiculite was 63.4% (v/v), which was higher than that of cork granulates that was 35.1%. Seeds of 'Rutgers Select' tomato (*Solanum lycopersicum*), 'Dazzler Lilac Splash' impatiens (*Impatiens walleriana*), 'Orbital Cardinal Red' geranium (*Pelargonium × hortorum*), 'Better Belle' pepper (*Capsicum annuum*), and 'Cooler Grape' vinca (*Catharanthus roseus*) were placed on top of peat and covered with a 4-mm top coating of either vermiculite or cork granulates. For tomato, impatiens, and vinca, days to germination were similar between seeds germinated using vermiculite and granulated cork as a top coat. Days to germination of geranium and pepper were significantly different with geranium and pepper seeds coated with cork granulates germinating 0.7 and 1.5 days earlier than those coated with vermiculite. For tomato, impatiens, and geranium, the number of seeds germinating per plug tray was similar between the top coats. Number of seeds germinating per tray for pepper and vinca were significantly different. Pepper had an average of 2.8 more seeds germinating per tray, and vinca had an average of 2.4 more seeds germinating per tray if seeds were germinated using granulated cork vs. vermiculite. For all species, dry shoot and dry root weights were similar for seedlings germinated using cork and vermiculite top coats.

Vermiculite is a naturally occurring sheet silicate mineral, formed by hydrothermal alteration of minerals such as biotite and phlogopite (Brindley and Brown, 1980). Flakes of unprocessed vermiculite are mica-like and contain interlayer water within their structure. When the flakes are heated rapidly, above 870 °C, the water flashes into steam and the flakes expand into accordion-like particles. This process is called exfoliation, and the resulting material is lightweight, fire resistant with excellent insulating and absorption properties (Potter, 2000). Vermiculite has been widely used as a horticulture substrate component

because of its lightweight and its capacity to hold water and mineral nutrients (Nelson, 1998). Most commonly, vermiculite has been blended with peat as a component to increase substrate water-holding capacity (Boodley and Sheldrake, 1977; Stamps and Evans, 1999). Additionally, vermiculite has been commonly used as a top coating material because it is sterile, holds significant water in its layers, and seedlings can easily emerge through it upon germination (Dana and Lerner, 2001). Walker et al. (1984) reported

that watering was less frequent when a top coating was used in seed germination. A vermiculite top coat was also shown to prevent surface packing of the substrate, reduce the incidence of tipping over of seedlings, and increase the seedling rating as compared with no top coating (Walker, 1984).

Cork oak (*Quercus suber*), native to southwestern Europe and northwestern Africa, is a forest tree species grown in the Mediterranean basin countries, where it is exploited for cork production (Manzanera et al., 1993). Cork is produced by the cork cambium in the outer bark of the cork oak, and it is considered a natural and renewable raw product (Silva et al., 2005). Cork consists essentially of suberin, lignin, and cellulose (Kolattukudy, 1978) and also contains a small amount of fatty acids, terpenes, long chain aliphatic compounds, and saccharides (Pereira, 1988). These compounds give cork unique properties such as high elasticity and low permeability to liquids. Because of these physical properties, cork has a wide range of traditional applications, such as in green buildings and handicrafts, but cork stoppers for wine bottles remains the primary use and the highest value market (Silva et al., 2005). Waste cork from the cork-based products industry, low-quality cork, and virgin cork (rough and irregular cork bark coming from the cork tree the first time it is harvested) are all used to produce cork granulates (Gil, 2009). This granulated cork material, discarded and unsuitable for cork products production, can be used in a variety of applications and different task such as in industrial components, various fillers, insulators, or as compounds to be mixed with other materials.

Limited research has been reported regarding granulated cork in substrates. Bazzocchi and Giorgioni (1987) reported that nephthytis (*Syngonium*

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
28,350	oz	mg	3.5274 × 10 ⁻⁵
1.7300	oz/inch ³	g·cm ⁻³	0.5780
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

podophyllum) grown in cork oak bark had slower growth than when grown in a peat-based substrate. In this case, the lower growth rate was attributed to nutritional and water deficiencies. Aguado et al. (1993) reported that geranium plants grown in substrates with cork had lower dry shoot weights than plants grown in peat-based substrates without cork. The reduced growth rate was attributed to a possible phytotoxic effect of phenolic compounds in the cork. However, other researchers have reported that cork oak bark was a suitable substrate for growing plants. Carmona et al. (2011) reported that particle density, bulk density, effective porosity, container capacity, and aeration capacity of cork was within the requirements for nursery substrates as recommended by Carmona and Abad (2008). Additionally, Ortega et al. (1996) reported a study in which they examined the growth of different species in a phytotoxicity bioassay of cork bark substrates and found that radicle growth of chinese cabbage (*Brassica pekinensis*), lettuce (*Lactuca sativa*), pepper (*Capsicum annuum*), and radish (*Raphanus sativus*) plants was higher in water-washed cork than in vermiculite. The authors speculated that the hot water wash technique used to wash the cork before use removed phytotoxic compounds.

Despite the benefits reported for using vermiculite as a top coating in seed germination, the relatively high costs of vermiculite as a result of mining, transportation, and heating, reported environmental and health concerns (Bandli and Gunter, 2006), and the desire to use byproducts in substrates have resulted in an interest in alternatives to vermiculite in horticulture substrates. The objective of this research was to compare the efficacy of vermiculite and granulated cork as a top coating for seed germination and seedling production.

Materials and methods

PHYSICAL PROPERTIES OF VERMICULITE AND CORK GRANULATES. Vermiculite (1-mm diameter) was obtained from Sun Gro Horticulture (Bellevue, WA). Cork granulates (1-mm diameter) were obtained from Amorim Cork Composites (Chicago, IL). Vermiculite and cork were packed into 345-mL porometers (7.5×7.5 cm), and bulk density (grams per cubic

centimeter), total pore space (percent v/v), air-filled pore space (percent v/v), and water-holding capacity (percent v/v) were determined using procedures described by Bilderback and Fonteno (1993) and Evans and Gachukia (2007). Five replications of each material were conducted. Significant differences in physical properties between cork and vermiculite were determined using a *t*-test.

GERMINATION AND SEEDLING GROWTH USING VERMICULITE AND CORK GRANULATES AS TOP COATS. Sphagnum peat (Sun Gro Horticulture) was amended with calcitic limestone to adjust the pH of the sphagnum peat (peat) to 5.8. Five-cell-by-five-cell mini-plug trays (round 273 with a volume of 5 mL per cell) were filled with the amended peat up to 4 mm from the rim of the plug cells. Seeds of 'Rutgers Select' tomato, 'Dazzler Lilac Splash' impatiens, 'Orbital Cardinal Red' geranium, 'Better Belle' pepper, and 'Cooler Grape' vinca were sown onto the surface of the peat, and the seeds were covered with a 4-mm top coating of either vermiculite or cork granulates. The mini-plug trays were placed on expanded metal benches in a polycarbonate-glazed greenhouse. Temperature set points were 65 °F for heating and 75 °F for cooling. Light levels during the trial period averaged 350 to 450 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at 1200 HR. Initially, the seeds were misted four to five times per day with clear water to maintain a moist top coat. After they developed two true leaves, plants were irrigated as required to maintain a moist substrate with a nutrient solution containing 25 ppm nitrogen using 15N-2.2P-12.5K fertilizer (Excel 15-5-15 Cal Mag; Everris International, Geldermalsen, The Netherlands).

Days to germination were recorded for each plug cell, and the average days to germinate and the number of seeds germinating per plug tray was recorded. After 5 weeks, the seedlings were harvested and the roots were washed. Shoots and roots were placed in a drying oven at 70 °C, and after drying, the dry shoot and dry root weights per plug tray were measured. The dry shoot and dry root weights of each tray were divided by the number of plants germinated in the tray to obtain the average seedling dry shoot and dry root weight.

A five-cell-by-five-cell mini-plug tray served as an experimental unit. The experimental design was a complete randomized block with six blocks and each species and top coating appearing once per block. The experiment was repeated three times.

For each species, the *t*-test was conducted to determine if significant differences in days to germination, number of seeds germinating per tray, average dry shoot weight, and average dry root weight occurred between seeds germinated with a cork granulate or vermiculite top coat.

Results and discussion

PHYSICAL PROPERTIES OF VERMICULITE AND CORK GRANULATES. The bulk density of cork granulates was $0.16 \text{ g}\cdot\text{cm}^{-3}$ and was higher than vermiculite that had a bulk density $0.12 \text{ g}\cdot\text{cm}^{-3}$. Cork granulates had a total pore space of 57.8% (v/v) and a water-holding capacity of 35.1%, which were significantly lower than those of vermiculite at 76.5% and 63.4%, respectively (Fig. 1). However, the air-filled pore space of cork granulates was 22.7% and was higher than that of vermiculite which was 13.2% (Fig. 1).

The physical properties of substrates have been reported to be largely determined by the size of the particles of the substrate components (Buck and Evans, 2010). Larger particles tend to result in the creation of larger pores (macropores) in substrates. Larger pores tend to drain after irrigation and provide the air-filled pore space of the substrate (Bunt, 1983; Raviv and Leith, 2008). Conversely, Tilt et al. (1987) found that increasing the number of fine particles in a substrate increased the number of smaller pores (micropores) and increased water-holding capacity of the substrate. In this experiment, vermiculite and cork granulates had similar particle sizes but different physical properties. When vermiculite is thermally treated, the macroscopic plate layers were spread apart in an accordion-like structure. The space between the layers reduced the particle density of the vermiculite, which in turn resulted in a lower bulk density than the granulated cork. Additionally, water was absorbed in-between the layers of the vermiculite. This allowed vermiculite to hold water not only in the micropores but

also in the particle layers, and this gave vermiculite a higher water-holding capacity than the granulated cork that held water only in the micropores created by the particles. Additionally, although the vermiculite and granulated cork were both an average 1 mm across in size, the cork had more of an angular structure than the vermiculite. This would have resulted in the two materials packing in the porometers differently. Angular materials tend to pack less densely and create more macropores. This would explain why although particle sizes were the same, the granulated cork had a higher air-filled pore space.

GERMINATION AND SEEDLING GROWTH USING VERMICULITE AND CORK GRANULATES AS TOP COATS. Tomato seeds germinated after 8.1 d when top coated with vermiculite, which was not different from the 8.3 d required for tomato seeds coated with cork granulates to germinate (Table 1). An average of 23.4 tomato seeds germinated per tray when top coated with vermiculite, and this value was not different for seeds germinated with cork granulates, which had an average of 22.8 seeds germinated per tray. Tomato seedlings had similar dry shoot weights of 49.1 and 48.5 mg when germinated with vermiculite or cork granulate top coat, respectively.

Fig. 1. Total pore space, water-holding capacity, and air-filled pore space (percent v/v) of 1-mm (0.04 inch) granulated cork and 1-mm vermiculite. The combined value of water-holding capacity and air-filled pore space was the total pore space. *Values for cork granulate were significantly different from that of vermiculite at $P > F$ of 0.05; $1 \text{ g} \cdot \text{cm}^{-3} = 0.5780 \text{ oz/inch}^3$.

Table 1. Time to germination, number of seeds germinated per tray, average seedling dry root weights, and average seedling dry shoot weights of tomato, impatiens, geranium, pepper, and vinca germinated and grown with a top coating of either vermiculite or granulated cork.^z

Species	Top coat ^y	Time to germination (d)	Seeds germinated (no./tray)	Shoot dry wt (mg) ^x	Root dry wt (mg) ^x
Tomato	Vermiculite	8.1	23.4	49.1	20.7
	Cork	8.3 NS	22.8 NS	48.5 NS	20.5 NS
Impatiens	Vermiculite	9.6	24.1	27.4	11.7
	Cork	9.6 NS	24.4 NS	28.4 NS	11.5 NS
Geranium	Vermiculite	5.4	22.7	83.9	23.8
	Cork	4.7*	24.5 NS	60.6 NS	14.9 NS
Pepper	Vermiculite	14.1	19.7	25.9	9.6
	Cork	12.6*	22.5*	26.2 NS	10.1 NS
Vinca	Vermiculite	12.4	19.3	16.6	7.0
	Cork	11.8 NS	21.7*	15.9 NS	6.2 NS

^zSeeds were sown in five-cell-by-five-cell mini-plug trays [round 273 with a volume of 5 mL (0.17 fl oz) per cell] onto the surface of amended peat and covered with 4 mm of respective top coating; 1 mm = 0.04 inch.

^yVermiculite was 1-mm "fine" vermiculite, and cork was 1-mm cork granulate.

^xThe dry shoot and dry root weights of each tray were divided by the number of plants germinated in the tray to obtain the average seedling dry shoot and dry root weight; $1 \text{ mg} = 3.5274 \times 10^{-5} \text{ oz}$.

NS, *Nonsignificant or significantly different from vermiculite within species at $P > F$ of 0.05, respectively.

Tomato dry root weights were 20.7 and 20.5 mg when germinated using a vermiculite and cork granulates top coat, respectively, and were not different between the two top coats.

Impatiens seeds germinated after 9.6 d when top coated with either vermiculite or cork granulates (Table 1). An average of 24.1 impatiens seeds germinated per tray when top coated with vermiculite, and this value was not different for seeds germinated with cork granulates, which had an average of 24.4 seeds germinated per tray. Impatiens seedlings had similar dry shoot weights of 27.4 and 28.4 mg when germinated with vermiculite or cork granulate top coat, respectively. Impatiens dry root weights were 11.7 and 11.5 mg when germinated using a vermiculite and cork granulate top coat, respectively, and were not different between the two top coats.

Geranium seeds germinated after 5.4 d when top coated with vermiculite, which was significantly longer than the 4.7 d required for geranium top coated with cork granulate (Table 1). An average of 22.7 geranium seeds germinated per tray when top coated with vermiculite, and this value was not different for seeds germinated with cork granulate, which had an average of 24.5 seeds germinated per tray. Geranium seedlings had similar dry shoot weights of 83.9 and 60.6 mg when germinated with vermiculite or cork granulate top coat, respectively. Geranium dry root weights were 23.8 and 14.9 mg when germinated using a vermiculite and cork granulate top coat, respectively, and were not different between the two top coats.

Pepper seeds germinated after 14.1 d when top coated with vermiculite, which was significantly longer than the 12.6 d required for impatiens top coated with cork granulate to germinate (Table 1). An average of 19.7 pepper seeds germinated per tray when top coated with vermiculite, and this value was significantly lower than for seeds germinated with cork granulate, which had an average of 22.5 seeds germinated per tray. Pepper seedlings had similar dry shoot weights of 25.9 and 26.2 mg when germinated with vermiculite or cork granulate top coat, respectively. Pepper dry root weights were 9.6 and 10.1 mg when germinated using a vermiculite and cork granulate top coat, respectively, and were not different between the two top coats.

Vinca seeds germinated after 12.4 d when top coated with vermiculite, which was not different from the 11.8 d required for impatiens top coated with cork granulates to germinate (Table 1). An average of 19.3 vinca seeds germinated per tray when top coated with vermiculite, and this value was lower than for seeds germinated with cork granulate, which had an average of 21.7 seeds germinated per tray. Vinca seedlings had similar dry shoot weights of 16.6 and 15.9 mg when germinated with vermiculite or cork granulated top coat, respectively. Vinca dry root weights were 7.0 and 6.2 mg when germinated using a vermiculite and cork granulate top coat, respectively, and were not different between the two top coats.

Although Bazzocchi and Giorgioni (1987) reported reduced growth of nephthytis grown in cork oak bark, they attributed reduced plant growth in cork to nutritional and water deficiencies as a result of the physical properties of the cork substrate. Although Aguado et al. (1993) reported reduced growth of geranium grown in a cork oak-based substrate, they proposed that reduced growth was because of phytotoxic phenolic compounds in the cork. We observed no reduced germination and no reduced seedling growth for species germinated with a top coating of granulated cork as compared with vermiculite. The results in our experiment may have been different because only a small amount of cork was used and the cork was applied only to the surface of the substrate as a top coat and not incorporated into the peat. By only using a small amount of granulated cork and only using it as a top coat, the developing seedling rooted into the peat substrate below the top coat and, therefore, may not have experienced phytotoxic levels of phenolic compounds and would have had adequate moisture retained by the peat to not have experienced water stress.

Interestingly, we observed reduced days to germination and/or increased germination numbers for several species tested when a cork granulate top coating was used as compared with vermiculite. This may have occurred as a result in the changes in physical properties that occurred in the vermiculite top coat over time. Vermiculite has been reported to collapse over time as a result of irrigation

(Dole and Gibson, 2006). The layers of the vermiculite particles collapse and the water-holding capacity and air-filled pore space decreases. This is in contrast to the granulated cork which was rigid and suberized and had no apparent changes over the experimental period. Therefore, the cork top coat provided adequate moisture and air space but also maintained a more constant environment during germination and seedling growth. The more constant germination environment provided by the cork top coat may have resulted in a reduction in days to germination and a higher germination number for some of the species tested. Interestingly, the two species that displayed increased germination numbers were pepper and vinca. This would be expected if the collapse of the vermiculite over time were resulted in reduced germination numbers since the longer germination time provided a longer time period for the vermiculite particles to collapse and negatively affect seed germination.

Conclusion

No deleterious effects related to days to germination, number of seeds germinating, seedling dry shoot weight, or seedling dry root weight were observed for species tested in this study using cork granulate as a top coating as compared with using vermiculite as a top coating. Therefore, although cork granulate had held less water and had a higher air-filled pore space than vermiculite of a similar particle size, its physical properties were appropriate to allow it to be used as a top coat substrate for seed germination and plug production. In some species, decreased days to germination and increased number of seeds germinating were observed when cork granulate was used as the top coating. This may have occurred as a result of vermiculite particles collapsing over time and a concomitant reduction in the vermiculite's ability to hold water and provide for air-filled pore space around the seed. Therefore, cork granulates were successfully used as an alternative to fine vermiculite as a top coating for seed germination and plug production.

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