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Growth and Nutrient Use of Ericaceous Plants Grown in Media Amended with Sphagnum Moss Peat or Coir Dust

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Abstract. **Using several different ericaceous ornamental species, we compared the growth, mineral nutrition, and composition of plants in response to growing media amended with varying proportions of sphagnum moss peat (peat) or coir dust (coir). Plants were grown for 16 weeks in media consisting of 80% composted Douglas fir bark with 20% peat, 20% coir, or 10% peat and 10% coir. Sixteen weeks after planting, decreases in extractable P were larger in peat-amended medium than the coir-amended medium, while decreases in extractable NH_4-N and NO_3-N were larger in the coir-amended medium. In general, leaf and stem dry weight, the number of leaves and stems, and total stem length increased with increasing proportion of coir in the medium while root dry weight either increased (*Kalmia latifolia*), decreased (*Rhododendron*, *Gaultheria*), or was not influenced by increasing the proportion of coir in the medium. The composition of the growing medium also influenced aspects of plant marketability and quality including: leaf greenness (SPAD), plant form (e.g., number of leaves per length of stem), and partitioning of biomass (e.g., root to shoot ratio). Nutrient uptake and fertilizer use was significantly different between the media types. Depending on the cultivar, we found that the coir-amended medium resulted in higher uptake or availability of several nutrients than peat-amended medium. Uptake or availability of N, P, K, Ca, and S was enhanced for several cultivars, while uptake or availability of Mg, Fe, and B was similar between media types. Most cultivars/species growing in the coir-amended medium had higher production or accumulation of proteins and amino acids in stems than plants growing in peat-amended medium, while the production of proteins and amino acids in roots was lower in plants growing in coir-amended than in peat-amended medium. For the cultivars/species we tested, coir is a suitable media amendment for growing ericaceous plants and may have beneficial effects on plant quality.**

The nursery industry is searching for methods to decrease the content of nutrients in effluent from production areas, reduce fertilizer consumption and costs, and maintain a level of available nutrients that does not limit productivity. The soilless media commonly used for container production of woody ericaceous plants consists of high percentages of bark and peat that have virtually no ability to adsorb and retain certain nutrients such as phosphorus (P), potassium (K), and nitrogen (N) (Bugby, 1999; Kuo et al., 1997; Marconi and Nelson, 1984; Pill et al., 1995).

Coir dust [coconut mesocarp residue (coir)] is the pith and residual fibrous material that constitutes the mesocarp of the coconut fruit (*Cocos nucifera*). Coir has been shown to have ion exchange and gas absorptive properties that can be utilized to adsorb N in its NH_4^+ and NO_3^- forms, protecting it from loss into the environment (Evans et al., 1996; Handreck, 1993a; Kithome et al., 1999a, 1999b). Coir tends to have a higher P content than peats (Evans et al., 1996; Handreck, 1993b) and coir from certain sources contains a higher number of free-living nitrogen-fixing, phosphate solubilizing, and acid phosphatase producing rhizobacteria (Linderman and Marlow, personal communication). Although coir has been reported to have a good buffering capacity (Kithome et al., 1999a, 1999b), others indicate that coir increases medium pH over time (Offord et al., 1998). Coir also has been reported to have a higher (Evans and Stamps, 1996; Stamps and Evans, 1997) or similar (Meerow, 1994) moisture holding capacity when compared to peats.

Coir has successfully been used in cutting and seed propagation (Farnesworth and Guam, 1995; Reddell et al., 1999) and for the production of a variety of annual and perennial plants (Evans and Stamps, 1996; Meerow 1994; Offord et al., 1998; Stamps and Evans, 1999). However, little literature is available on the effects of coir in the production of woody perennial plants (Evans and Iles, 1997; Knight et al., 1998; Meerow, 1994), especially those which grow best at low pH in well-drained media, e.g., the family Ericaceae. The objectives of this study were to determine whether growth, nutrient use, and storage components of ericaceous plants differ when grown in media amended with varying proportions of sphagnum peat or coir.

Materials and Methods

Plant culture and experimental treatments. Eleven different ericaceous plants from six genera were used in this study: Kinnickinnick [*Arctostaphylos uva-ursi* (L.) Spr. 'Massachusetts' (AU)], Azalea [*Rhododendron* sp. 'Strawberry Ice' (AZ)], Mountain Laurel [*Kalmia latifolia* L. 'Freckles' (KF)], 'Olympic Fire' (KO), 'Pink Charm' (KP), Salal [*Gaultheria shallon* Pursh. (GS)], Pieris [*Pieris japonica* D. Don.' Snowdrift' (PJ)], Rhododendron [*Rhododendron* sp. 'Scintillation' (RS), 'Crete' (RC), and 'Trinidad' (RT)], and Lingonberry [*Vaccinium vitis-idaea* L. 'Erntedank' (VV)]. In late February, rooted tissue culture plantlets were obtained from Brigg's Nursery (Olympia, Wash.) and transplanted into 0.64-L pots (Gage Dura Pot #GDP400) in a mix containing different ratios of composted Douglas fir bark (Whitney Farms, Independence, Ore.), sphagnum peat (Sunshine Grower Grade White; SunGrow, Hubbard, Ore.), and coir [Coco Life Blok; Coconut Palm Resources, Hillsboro, Ore. (Sri Lanka product source)] amended with 5.5 $g \cdot L^{-1}$ of a slow-release fertilizer (Osmocote Plus 15–9–12; Scotts Co., Marysville, Ohio) per pot. Equal amounts of fertilizer were mixed into media on a per-pot basis to ensure uniform distribution. Experimental treatments consisted of three different media formulations (by volume): 80/20 bark/peat mix, 80/10/10 mix of bark/peat/coir, and 80/20 mix of bark/coir. Plants were maintained in a glasshouse for 16 weeks, with supplemental light (16 h light/8 h dark), average day/night temperatures of 21/16 °C (75/65 °F), and watered using calibrated drip irrigation to ensure all treatments received the same amount of water. Watering frequency was specific to each cultivar and determined based on a substrate moisture as measured in relative units using a portable soil moisture meter (Ben Meadows Co., Canton, Ga.). When substrate moisture within a cultivar reached a level of 6 (relative units), plants were watered until water freely flowed from the bottom of the pot. Differences in substrate moisture between treatments were not detectable within the sensitivity range of the portable soil moisture meter. Periodic pest control measures were performed as needed and included diflubenzuron for fungus gnats (*Bradysia* sp.) and *Neoseiulus cucumeris* predators for thrips (*Frankiniella* sp.).

Media composition. At planting, five replicate samples of each of the three dif-

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ferent media formulations were analyzed for extractable phosphorus (mg·kg^{-1} P), calcium (meq/100 g Ca), ammonium nitrogen (mg·kg^{-1} NH_4-N), and nitrate nitrogen (mg·kg^{-1} NO_3-N) using standard methods (Berg and Gardner, 1979). Extractable P was analyzed by the Bray dilute acid-fluoride method. Extractable Ca was determined with atomic absorption spectrophotometry following extraction with ammonium acetate. The pH was also determined for all media samples. Water holding capacities determined from a 6-in (15-cm) column for similar media formulations were 23.2% for bark (100%), 35.6% for bark/coir [80/20 (v/v)], 34.5% for bark/coir/peat [80/10/10 (v/v/v)], and 34.3% for bark/peat [80/20 (v/v)].

Sixteen weeks after planting, when plants were removed from the media, substrate loosely adhering to roots was removed from plants by gentle shaking and mixed with remaining substrate in the pot. Five replicate samples of substrate were taken from pots of each media × cultivar combination and extractable P, Ca, NH_4-N, and NO_3-N were determined by the methods described above. The pH was also determined for all media samples.

Leaf greenness and mycorrhizal colonization. Fifteen weeks after planting, leaf greenness was estimated by measuring the optical density difference at 650 and 940 nm with a silicon photodiode using a SPAD502 meter (Minolta Corp., Ramsey, N.J.) on five replicate plants per treatment. Three replicate measurements from adjacent leaves were taken at five equally distributed positions in the canopy of each plant. Readings are expressed in SPAD units.

Sixteen weeks after planting, ericoid mycorrhizal colonization of fresh roots was assessed for all plant except *A. uva-ursi* on 1-cm sections after clearing and staining (Phillips and Hayman, 1970), replacing lacto-phenol with lacto-glycerin. Percentage of root length colonized by ericoid mycorrhizal fungi (hyphal coils in epidermal cells) was estimated using a light microscope (Biermann and Linderman, 1980). Mycorrhizal colonization of *A. uva-ursi* roots was assessed by counting the percentage of root tips colonized by mycorrhizal fungi (Scagel and Linderman, 1998).

Morphology and tissue composition. Sixteen weeks after planting, the aboveground portion of five replicate plants per treatment were removed, and the number of leaves, the number of stems, and stem lengths were recorded for each plant. Substrate adhering to roots was removed by washing and samples of roots were taken for assessing mycorrhizal colonization. Samples of leaf, stem, and root tissue were taken for nutrient, amino acid, and protein analyses from tissue samples pooled for each plant across all ages of tissue. The remaining roots, leaves and stems were dried to a constant weight at 60 °C and dry weights were obtained.

Stem, leaf, and root samples were analyzed for phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, zinc, carbon, nitrogen, and sulphur content using standard methods (Gaulak et al., 1997). N and S were determined after automated combustion and concentrations of the remainder of the elements determined after dry ash oxidation by ICP-AES. Total content of different nutrients in plants was calculated from the sum of the total nutrients in each tissue type (e.g., leaves, stems, and roots) based on tissue weight and nutrient concentration. Total soluble protein and amino acid content of stem, leaf, and root samples were determined colorimetrically using a BIO-RAD (Coomassie Brilliant blue) (Bradford, 1976) and ninhydrin assays respectively (Yemm and Cocking, 1955).

Experimental design and data analyses. The experiment was a randomized design with each treatment unit (pot) replicated five times for each species/cultivar grown in three different media. Growth and morphology data were analyzed using a multifactorial analysis of variance (ANOVA) and orthogonal contrasts (Statistica, Statsoft, Tulsa, Okla.). Where ANOVA indicated interactions between media and cultivar, or media and genus were significant for a variable, responses to media amendment were compared using orthogonal contrasts between genera or cultivars. Results of these contrasts were used to group plants by response to the different media. Where only ANOVA main effects were significant for a variable, responses were compared using contrasts between media. Repeated measure ANOVAs were used to assess the relative change in media composition between the beginning and the end of the experiment, and the change in leaf coloration (SPAD) within the plant canopy. Variables derived to assess changes in dry weight partitioning and plant form were square-root transformed, and percentage rooting and root colonization were arcsin transformed prior to analysis to correct for unequal variance and best model fit (Peterson, 1985). Back-transformed least squares means of actual data are reported in tables and figures.

Plant composition (nutrient, protein, and amino acid) data were analyzed using vector analysis, a technique that allows for simultaneous comparison of plant growth, nutrient concentration, and nutrient content in an integrated graphic format (Haase and Rose, 1995). Nutrient, protein, and amino acid data for plants growing in peat-amended and coir-amended media were compared after normalization using the peat-amended medium as the control treatment, similar to the vector analyses methods used by others (Swift and Brockley, 1993; Valentine and Allen, 1990). Changes in dry weight and concentration are plotted, with curved content isoclines included for interpretation. The interpretation of vector shifts due to a change in media composition is similar to that described in Valentine and Allen (1990) and shown in Fig. 3 as reference.

Results and Discussion

Media pH. Most members of the Ericaceae are calcifuge plants that grow naturally

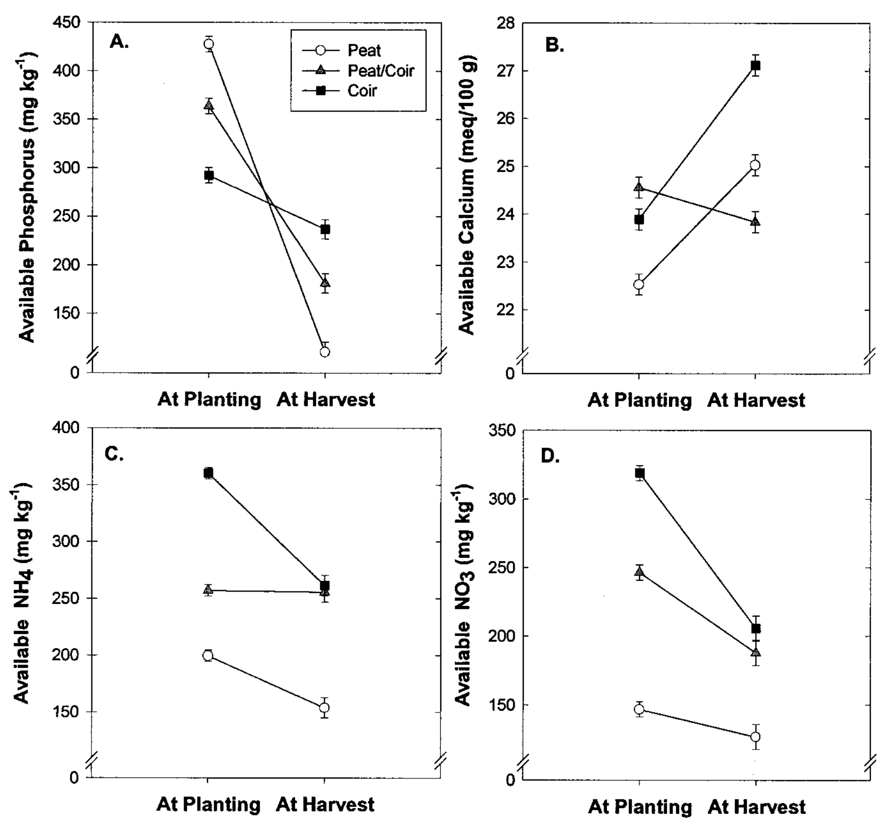


Fig. 1. Available phosphorus (**A**), calcium (**B**), ammonium (**C**), and nitrate (**D**), concentrations of media containing (by volume) 80% composted Douglas fir bark and either 20% peat (Peat), 10% peat and 10% coir dust (peat/coir), or 20% coir dust (Coir). Samples taken at the beginning of the experiment and when plants were harvested after 16 weeks. Bars on data points represent standard error of the mean pooled across treatments for Time*Media LS Means (n = 55).

in acid soils of low to moderate fertility. During this experiment, we found no differences in the pH of different media for any of the cultivars/species tested. The pH of all three media ranged from 5.6 to 6.0. In contrast, others have reported coir generally has a higher pH than peat (Kithome et al., 1999b; Meerow, 1994, 1995) and that the pH of a 50/50 coir to pine bark medium was higher than a 50/50 peat to pine bark medium (Stamps and Evans, 1997). We also found that no change in pH was detectable during the course of the experiment. Others have found that the pH of coir media to decrease over time (Argo and Biernbaum, 1997) or increase over time (Meerow, 1994, 1995; Offord et al., 1998). These researchers measured pH of media in which coir was the sole or primary medium component and used different plants and fertilizer types. In our experiment, coir was only a small proportion of the total medium and probably contributed less to total medium pH.

Available nutrients in media. A number of factors interact to affect the level of nutrients available for plant uptake from container media throughout crop production (Argo and Biernbaum, 1997) including temperature, moisture, plant uptake, losses to leaching and volatilization, microbial activity, and the physical, biological, and chemical attributes of the media. We measured decreases in extractable phosphorus (P), ammonium-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N) and increases in available calcium (Ca) in the growing media between the beginning and the end of our experiment (Fig. 1). These changes were not significantly influenced by the cultivar of plant. Also, since all plants within a cultivar received the same amount of water in our experiment and differences in moisture holding capacity of the different media was <2%, it is unlikely that the lower moisture holding capacity of the peat-amended medium could solely be accounted for by differences between the different media types.

The decrease in extractable P between the beginning and the end of the experiment was significantly different for the different media types ($P < 0.0001$). This decrease in P was larger in the peat-amended medium than the coir-amended medium ($P < 0.0001$) (Fig. 1a). Coir has been reported to have a higher initial P concentration than peat. Over time, however, peat has a higher amount of available P (Stamps and Evans, 1997). In our study, the peat-amended medium generally had a higher initial P concentration than coir, and by the end of the experiment had a lower amount of P. Plants growing in the coir-amended medium had higher P content and concentrations than plants grown in the peat-amended medium (Fig. 4), suggesting that the peat-amended medium lost more P from the pot or had a higher rate of incorporation of P into a nonavailable pool in the medium. The higher availability of P in the coir-amended medium could be a result of more P exchange sites or higher activity of P-solubilizing and acid phosphatase producing organisms (Linderman and Marlow, USDA, Corvallis, Ore., personal communication).

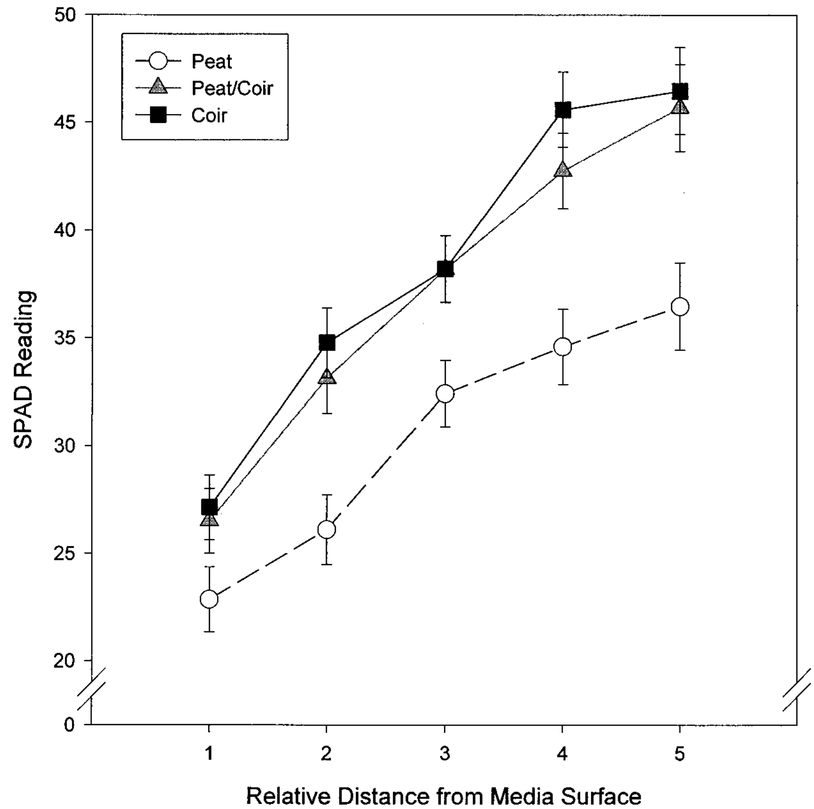


Fig. 2. SPAD reading from the bottom to the top of plants growing in media containing (by volume) 80% composted Douglas fir bark and either 20% peat (Peat), 10% peat and 10% coir (Peat/Coir), or 20% coir (Coir) 16 weeks after transplanting. Bars on data points represent standard error of the mean pooled across treatments for Distance*Media LS Means (n = 55).

Table 1. Analysis of variance (ANOVA) results for dry weight of leaves, stems, and roots of plants grown for 16 weeks in three different formulations of media.

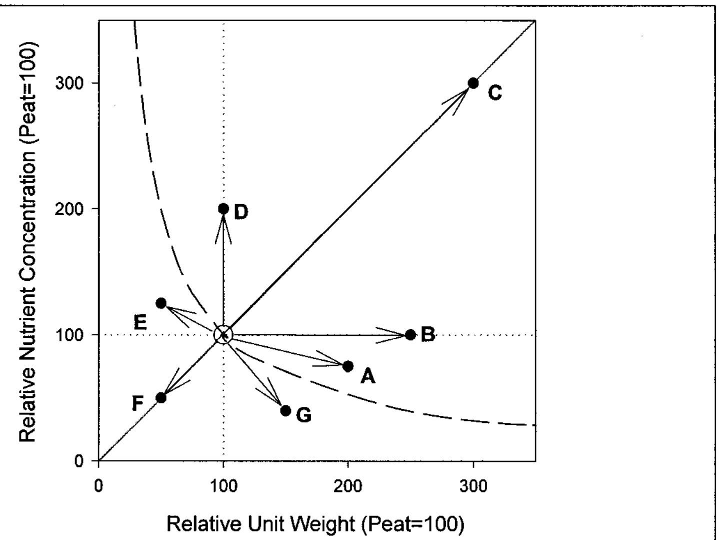
		Dry wt (g)					
Genus/species	Media[z]	Leaf		Stem		Root	
Kalmia latifolia	Peat	1.47[y]		0.161		0.044	
	Peat/Coir	2.83	b	0.257	a	0.117	a
	Coir	6.16		0.932		0.193	
Rhododendron spp.	Peat	3.05		0.694		0.347	
	Peat/Coir	5.84	a	1.533	a	0.270	b
	Coir	10.34		1.690		0.212	
Arctostaphylos uva-ursi	Peat	5.93		2.079		0.203	
	Peat/Coir	8.31	c	2.521	a	0.306	c
	Coir	9.72		2.815		0.237	
Gaultheria shallon	Peat	3.23		0.747		0.355	
	Peat/Coir	5.12	b	1.138	a	0.266	b
	Coir	7.82		1.318		0.197	
Pieris japonica	Peat	3.63		0.706		0.149	
	Peat/Coir	7.20	b	1.303	a	0.241	c
	Coir	9.05		1.893		0.167	
Vaccinium vitis-idaea	Peat	1.35		0.254		0.324	
	Peat/Coir	4.08	c	0.887	a	0.571	c
	Coir	5.05		0.943		0.314	

ANOVA summary

Variation source	df	*P*	*P*	*P*
Genus	5	<0.0001	<0.0001	<0.0001
Cultivar (genus)	5	<0.0001	<0.0001	<0.0001
Media	2	<0.0001	<0.0001	<0.0001
Genus × media	10	<0.0001	0.8796	0.0056
Cultivar (genus) × media	10	0.3251	0.2028	0.0813
(MSE)	(132)	(1.21)	(0.451)	(0.015)

[z]Growing media containing (by volume) 80% composted Douglas fir bark and either 20% peat (Peat), 10% peat and 10% coir (Peat/Coir), or 20% coir.

[y]Within a variable, genera with similar magnitude of response ($P > 0.05$) to different media formulations are followed by the same letter.



Vector Shift	Concentration	Content	Weight	Interpretation
A	Decrease	Increase	Increase	Nutrient non-limiting. Differences in concentration or content due to increase in weight (e.g. diluted due to growth).
B	Unchanged	Increase	Increase	
C	Increase	Increase	Increase	Nutrient uptake, availability, or translocation enhanced. Differences in concentration or content related proportionately to change in weight.
D	Increase	Increase	Unchanged	Nutrient uptake or availability enhanced. Differences in concentration or content have little influence on growth (e.g. luxury consumption, storage).
E	Increase	Decrease	Decrease	Elevated nutrient concentration causes decrease in growth (e.g. toxicity)
F	Decrease	Decrease	Decrease	Nutrient limiting to growth due to lower availability (e.g. deficiency)
G	Decrease	Decrease	Increase	Efficiency of nutrient use increased (e.g. more growth given less nutrient in plant).

Fig. 3. Graphical representation of interpretations comparing changes in dry weight and concentrations of nutrients between plants grown in different media types. The content isolines represent combinations of dry weight and concentration giving constant content per unit dry weight. The arrows indicate the direction in which each interpretation holds (adapted from Swift and Brockley, 1994).

The levels of extractable NH_4-N and NO_3-N measured in coir-amended media were similar to that reported elsewhere (Konduru et al., 1999; Stamps and Evans, 1997, 1999). The relative decrease in NH_4-N and NO_3-N were both significantly different for the different media types ($P < 0.0001$). Decreases in NH_4-N ($P < 0.004$) and NO_3-N ($P < 0.0001$) were larger in the coir-amended medium than the peat-amended medium (Fig. 1 c and d). Similar decreases in NO_3-N have been reported for a 50/50 bark to coir medium (Stamps and Evans, 1997). In our study, plants growing in coir-amended medium generally had higher N contents and concentrations than plants growing in the peat-amended medium (Fig. 4), suggesting that plants growing in the coir-amended medium had a higher N-uptake.

The relative increases in extractable Ca were significantly different for the different media types ($P < 0.0001$). Increases in Ca were larger in the coir-amended medium than the peat-amended medium ($P < 0.0001$) (Fig. 1b). In contrast, others (Stamps and Evans, 1997) have reported initial Ca concentrations were similar in a 50/50 bark to coir or 50/50 bark to peat medium, but over time, available Ca was higher in the 50/50 bark to peat medium when compared to the 50/50 bark to coir medium. In our study, plants growing in the coir-amended medium had higher concentrations and content of Ca than plants growing in the peat-amended medium suggesting that either more Ca was released from previously unavailable forms or less Ca was lost from the coir-amended medium than the peat amended medium. All plants within a cultivar received the same amount of water in our experiment and since differences in moisture holding capacity of the different media was <2%, it is unlikely that higher leaching of Ca in peat-amended medium accounted for the differences between the different media types.

Plant growth. Plant growth responses to the different media types were similar between cultivars/species within a genus. In general, leaf and stem dry weight of all species/cultivars increased with increasing proportion of coir in the growing media (Table 1). Leaf dry weight in different media differed significantly between genera, with genera having the largest leaves (e.g., *Rhododendron* sp.) responding the most to increased proportions of coir in the media. Root dry weight was also affected by changes in media composition and differed significantly between genera. For all *K. latifolia* cultivars root dry weight increased with increasing proportion of coir in the media, while for all *Rhododendron* cultivars and *G. shallon*, root dry weight decreased. For all other genera, root dry weight was similar for plants grown in coir-amended or peat-amended media, however the combination of peat and coir amendment significantly increased root dry weight. Others have reported positive, negative, or no response in several plant growth parameters when comparing media amended with coir or peat (Evans and Stamps, 1996; Knight et al., 1998; Meerow, 1994, 1995; Offord et al., 1998; Stamps and Evans, 1997, 1999). Some differences in plant growth in response to coir have been attributed to increased water holding capacity of the fibers in comparison to peat. Others have found that although initial media moisture holding capacity of peat-amended media is similar to coir, over time, peat can have a higher moisture holding capacity and lower air-filled pore space (Meerow, 1995). Differences in the moisture holding capacity of the different media formulations we used was initially <2%. Although it is possible that the slightly higher water holding capacity in the coir-amended media may have had some influence on plant growth, it is unlikely that the differences in initial media moisture holding capacity could solely accounted growth differences between plants growing in the different media types.

Plant morphology and form. The effects of different media components on plant biomass may not adequately represent growth differences important to commercial producers. To better gauge differences in plant growth, form, and appearance between the different media we measured several morphological parameters. Some of the differences we found in plant form between plants grown in the coir-amended medium when compared to plants grown in the peat-amended medium have the potential to influence the quality or marketability of the plants. Morphological responses to the different media types in our study were similar between cultivars/species within a genus but we found significant differences between genera in response to the different media.

In general, the number of leaves and stems and total stem length of plants increased with increasing proportion of coir in the media (Table 2), but the magnitude of the responses varied with genus. The number of leaves per plant on genera with the smallest leaves (e.g., *Arctostaphylos*, *Pieris*, and *Vaccinium*) was most responsive to increasing the proportion of coir in the media. For all genera except *Arctostaphylos*, the number of stems per plant and total stem length per plant increased with increasing proportion of coir in the media.

Media composition altered plant form and dry weight partitioning to the various plant parts

(Table 3). For all genera except *Arctostaphylos*, increasing the proportion of coir in the media decreased the number of leaves per length of stem, even though the number of leaves per stem, and the average length of each stem increased with increasing proportion of coir in the media. This means that most of the genera in the coir-amended medium had a canopy that was less dense, albeit larger than, plants grown in the peat-amended medium. This alteration of plant form in the coir-amended media could be a beneficial to growers wanting to increase salable size of a plant.

Differential partitioning of biomass between plant components in the different media types may not only affect plant form but can also influence plant function. For example, we found that the ratio of root dry weight to aboveground dry weight decreased with increasing proportion of coir in the media for all genera except *Arctostaphylos* (Table 3). This smaller ratio of root dry weight to aboveground weight in plants growing in coir-amended media could have a negative influence on the survival of the plant after transplanting.

Leaf greenness and mycorrhizal colonization. Leaf coloration is sometimes used as an indication of plant nutritional status as well as being related to marketability of a plant in retail outlets. Using a SPAD meter to quantify leaf color we found that for all genera, leaves on plants grown in coir-amended media had higher SPAD values than leaves from plants grown in peat-amended media ($P < 0.029$) and that the difference between media types was more pronounced in the youngest growth (Fig. 2). At harvest we found all cultivars/species in all media types were mycorrhizal and there were no significant differences in root colonization in the different media.

Changes in nutrient uptake and composition. Biomass of all genera increased in a similar manner with increasing proportion of coir in the medium but we found cultivar specific differences in nutritional responses to different media. In general, the total content of all nutrients was higher in plants grown in coir-amended than in peat-amended medium. When we compared differences in nutrient concentrations between plants growing in the different media, we found three types of responses. Plants grown in the coir-amended medium had higher, lower, or equal nutrient concentrations depending on the nutrient and the cultivar.

Plants of some cultivars/species growing in the coir-amended medium had higher uptake, availability, or allocation for several nutrients in comparison to plants growing in the peat-amended medium (Fig. 4). We found that uptake or availability of nitrogen (N) was enhanced in the coir-amended medium for all cultivars except *A. uva-ursi* (AU) and *P. japonica* (PJ). Phosphorus (P) and potassium (K) uptake or availability was enhanced in the coir-amended medium for eight of the eleven cultivars. Calcium (Ca) uptake or availability was enhanced by the coir-amended medium for all *Rhododendron* sp. cultivars, AU and PJ. Sulfur (S) uptake or availability was enhanced by the coir-amended medium for all

Table 2. Analysis of variance (ANOVA) results for aboveground morphological characteristics of plants grown for 16 weeks in three different formulations of media.

Genus/species	Media[z]	No. of leaves per plant (#/plant)		No. of stems per plant (#/plant)		Stem length per plant (cm/plant)	
Kalmia latifolia	Peat	23.8[y]		2.6		9.4	
	Peat/Coir	36.4	a	2.9	a	22.3	a
	Coir	57.0		4.3		37.4	
Rhododendron spp.	Peat	36.2		2.8		15.5	
	Peat/Coir	47.7	a	3.2	a	30.5	a
	Coir	53.6		3.5		33.8	
Arctostaphylos uva-ursi	Peat	131.8		15.2		140.4	
	Peat/Coir	154.2	b	12.2	b	136.2	c
	Coir	280.6		10.4		118.8	
Gaultheria shallon	Peat	65.6		10.2		85	
	Peat/Coir	87.4	a	16.4	c	144.9	b
	Coir	93.7		17.5		153.7	
Pieris japonica	Peat	119.6		7.4		45.7	
	Peat/Coir	207.0	b	8.2	a	80.4	b
	Coir	219.6		9.8		106.9	
Vaccinium vitis-idaea	Peat	93.6		11.4		38.3	
	Peat/Coir	250.8	b	15.8	c	116.7	b
	Coir	296.4		24.2		143.4	

ANOVA summary

Variation source	df	P	P	P
Genus	5	<0.0001	<0.0001	<0.0001
Cultivar (genus)	5	<0.0001	0.0124	<0.0001
Media	2	<0.0001	0.0013	<0.0001
Genus × media	10	<0.0001	0.0037	0.0408
Cultivar (genus) × media	10	0.9984	0.9997	0.9549
(MSE)	(132)	(10.1)	(4.8)	(16.7)

[z]Growing media containing (by volume) 80% composted Douglas fir bark and either 20% peat (Peat), 10% peat and 10% coir dust (Peat/coir), or 20% coir dust (Coir).
[y]Within a variable, genera with similar magnitude of response ($P > 0.05$) to different media formulations are followed by the same letter.

Table 3. Analysis of variance (ANOVA) results for plant form characteristics of plants grown for 16 weeks in three different formulations of media.

Genus/species	Media[z]	Leaves per length of stem (#/cm)		Leaves per stem (#/#)		Length per stem (cm/stem)		Root/above-ground ratio (g/g)	
Kalmia latifolia	Peat	2.5[y]		10.8		4.35		0.075	
	Peat/Coir	1.9	c	14.7	a	9.07	a	0.057	a
	Coir	1.7		18.3		10.74		0.039	
Rhododendron spp.	Peat	3.1		16.7		6.15		0.107	
	Peat/Coir	3.0	a	18.6	a	8.68	a	0.059	c
	Coir	2.8		26.2		11.13		0.034	
Arctostaphylos uva-ursi	Peat	1.8		24.0		12.19		0.030	
	Peat/Coir	1.6	b	30.6	a	16.02	a	0.036	b
	Coir	2.8		44.5		23.93		0.047	
Gaultheria shallon	Peat	0.8		5.5		8.73		0.068	
	Peat/Coir	0.6	a	5.6	a	8.85	a	0.062	a
	Coir	0.6		7.1		8.98		0.029	
Pieris japonica	Peat	2.6		16.5		6.70		0.038	
	Peat/Coir	2.5	c	25.6	a	10.59	a	0.036	a
	Coir	2.1		27.7		11.97		0.016	
Vaccinium vitis-idaea	Peat	2.9		7.6		2.75		0.142	
	Peat/Coir	2.3	c	14.2	a	6.77	a	0.113	c
	Coir	2.1		17.9		7.75		0.091	

ANOVA Summary

Variation source	df	P	P	P	P
Genus	5	<0.0001	<0.0001	<0.0001	0.0320
Cultivar (genus)	5	<0.0001	0.3129	<0.0001	0.0078
Media	2	<0.0001	0.0090	<0.0001	0.0017
Genus × media	10	0.0176	0.4990	0.2118	0.0262
Cultivar (genus) × media	10	0.2102	0.8897	0.5784	0.6473
(MSE)	(132)	(0.319)	(4.24)	(2.31)	(0.0021)

[z]Growing media containing (by volume) 80% composted Douglas fir bark and either 20% peat (Peat), 10% peat and 10% coir dust (Peat/coir), or 20% coir dust (Coir).
[y]Within a variable, genera with similar magnitude of response ($P > 0.05$) to different media formulations are followed by the same letter

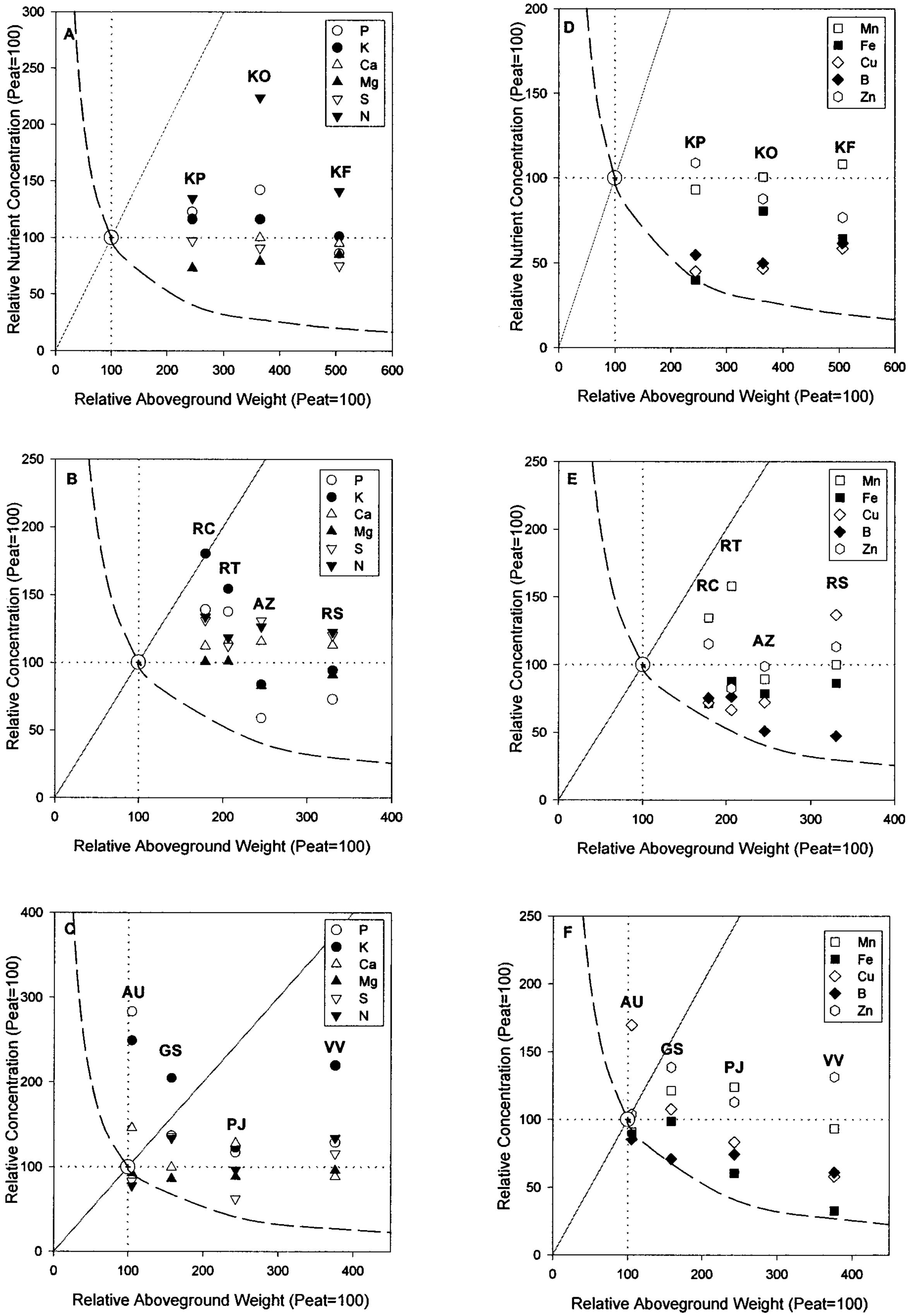


Fig. 4. Comparison of relative nutrient composition and above ground dry weight of (**A, D**) *Kalmia*, (**B, E**) *Rhododendron*, and (**C, F**) *Arctostaphylos*, *Gaultheria*, *Pieris*, and *Vaccinium* cultivars grown in composted Douglas fir bark amended with peat (normalized to 100 and shown as a single reference point) and coir dust (normalized as a percent of response compared to peat). The content isolines represent combinations of dry weight and concentration giving constant contents per unit dry weight. Acronyms above data points represent different cultivars/species (see Materials and methods for descriptions).

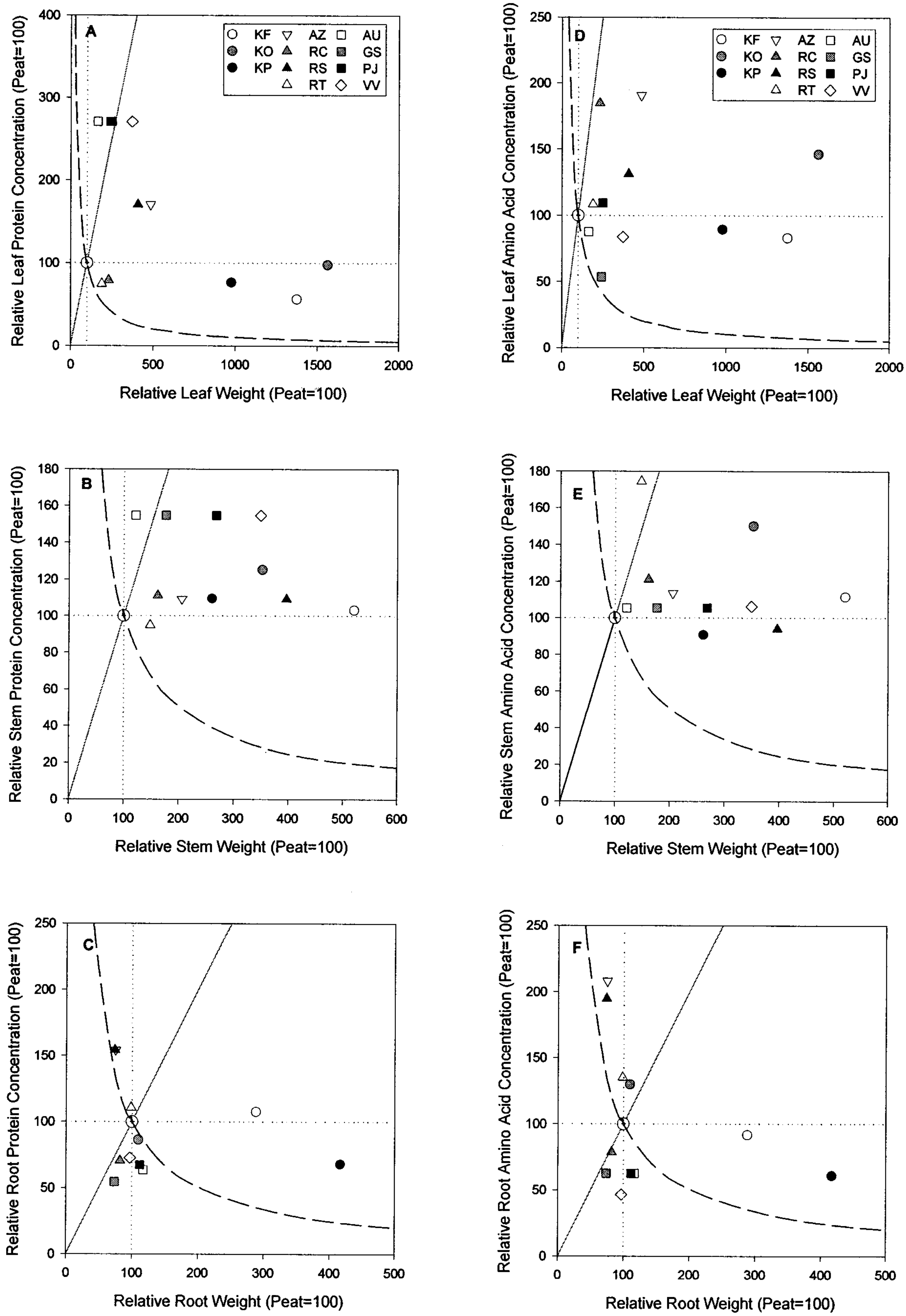


Fig. 5. Comparison of relative amino acid and protein composition of (**A, D**) leaves, (**B, E**) stems, and (**C, F**) roots of different cultivars of ericaceous plants grown in composted Douglas fir bark amended with peat (normalized to 100 and shown as a single reference point) and coir dust (normalized as a percent of response compared to peat). The content isolines represent combinations of dry weight and concentration giving constant contents per unit dry weight. Acronyms above data points represent different cultivars. (see Materials and Methods for descriptions).

Rhododendron spp. cultivars and *V. vitis-idaea* (VV). Manganese (Mn) uptake or availability was enhanced by coir amended media for KF, PJ, *G. shallon* (GS), *Rhododendron* sp. 'Crete' (RC) and 'Trinidad' (RT). Zinc uptake or availability was enhanced by coir-amended media for six of the 11 cultivars. Differences in nutrient availability to plants growing in the different media types may be a result of differences chemical properties (Bugbee, 1999; Kuo et al., 1997; Marconi and Nelson, 1984; Pill et al., 1995), physical (Evans et al., 1996; Handreck, 1993a; Kithome et al., 1999a, 1999b) of microbial activity (Linderman and Marlow, USDA, Corvallis, Ore., personal communication) between peat and coir. For instance, in our study, coir-amended media initially had significantly higher concentrations of available N that could be responsible for N content and concentrations in plants growing in coir-amended media.

If the concentration of a specific nutrient declined while the total content increased with increasing plant weight then the uptake of the nutrient is considered the same or the availability is equal in the different media types. Under these conditions differences in concentration and content between plants grown in coir- or peat-amended media were a result of increased plant weight. We found that uptake or availability of magnesium (Mg), iron (Fe), and boron (B) was similar in plants grown in peat- or coir-amended media for all cultivars (Fig. 4). Differences in the concentration of these nutrients in plants from the different media types were a result of the different plant growth rates not differential nutrient uptake between the media types. Depending on the cultivar, medium amendment with coir decreased the availability of several nutrients as a result of increased plant growth rate.

When comparing plants grown in coir-amended media to plants grown in peat-amended media, if the concentration and total content of a specific nutrient increased without appreciable increases in plant weight, then the uptake of the specific nutrient is considered to be enhanced. This increased uptake, however, does not directly contribute to increased growth (e.g., luxury consumption or storage). *A. uva-ursi* was the only cultivar to exhibit "luxury" uptake of any nutrient (P, K, Ca, and Cu).

If the concentration and the total content declined while plant weight increased then the use of the specific nutrient is considered more efficient in the different media types. We found that media composition had no influence on the efficiency of nutrient use (e.g., more growth given less nutrient) for any of the cultivars/species we tested.

Changes in protein and amino acid composition. Protein and amino acid composition of different plant parts has been related to energy storage for future growth, level of metabolic activity, rooting efficiency, photosynthesis, and other basic physiological processes which can influence the qualitative aspects of plant quality (Dong et al., 2001; Nielsen et al., 1997; Scagel, 1999; Tagliavivni et al., 1998). Stem proteins and amino acids are correlated with storage reserves for the subsequent years growth, and rooting ability of cuttings in woody perennials. High levels of leaf proteins have been correlated with increased photosynthesis.

We found that changing media components had a strong influence on the total stem protein and amino acid composition of all cultivars/species. Most cultivars/species growing in the coir-amended medium had higher production or accumulation of total protein and amino acids in their stems than plants growing in peat-amended media (Fig. 5). Leaf protein production or accumulation was enhanced in some cultivars grown in coir-amended media (e.g., AU, GS, VV, RS, and AZ). Leaf amino acid production or accumulation was enhanced for several cultivars (e.g., AZ, RC, RS, RT, PJ, KO).

If the concentration of protein or amino acids declined while the total content of protein or amino acids increased with increasing plant weight, then the production or accumulation of protein or amino acids is considered the same in the different media types. This means that differences in concentration and content between plants grown in coir- or peat-amended media are a result of increased plant weight. For example, production of leaf protein was similar for *K. latifolia* cultivars, RC, and RT when grown in peat- or coir-amended media.

When comparing plants grown in coir-amended media to plants grown in peat-amended media, if the concentration and total content of protein or amino acids increased without appreciable increases in plant weight, then the production or accumulation of protein or amino acids is considered to be enhanced. This increase, however, does not directly contribute to increased growth (e.g., storage). For example, *A. uva-ursi* produced more leaf and stem proteins when grown in coir-amended media than in peat-amended media.

If the concentration and total content of protein or amino acids declined while plant weight decreased, then the production or accumulation of protein or amino acids may be related to decreased growth or metabolic activity. For example, the production of proteins and amino acids in roots was lower in coir-amended media than in peat-amended media for GS and RC.

Conclusions

For the cultivars we tested, we found that coir is a suitable media amendment for growing ericaceous plants. Amendment of growing media for ericaceous plants with coir increased the growth and nutrient uptake of several cultivars. We also observed that coir amendment may positively influence several other aspects of plant production practices (e.g., fertilizer use), plant form, plant quality, and marketability.

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