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ORIGINAL RESEARCH

Reuse of peanut shells and Azolla mixes as a peat alternative in growth medium of *Dieffenbachia amoena* 'tropic snow'

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Abstract

Purpose An experiment was designed to introduce a substitute for peat, which is used in the production of bedding for the cultivation of ornamental plants and is imported and expensive. For this reason, the usability of peanut shells and Azolla, whose accumulation in the environment causes environmental problems, is a major research question.

Methods In this work, *Dieffenbachia amoena* was grown in a growing medium that had substituted peanut shells and Azolla mixes composts (0, 15, 30, 45, 60, and 100 v/v %) for peat. The controls received only peat: perlite (2:1 v/v) without composts.

Results It was found that, as the substitution of compost increased, nutrients also increased in the growing medium. Nonetheless, the nutrients led to minor changes in the leaves. As compost increased, the bulk density of the growing media decreased (0.17, 0.16, 0.15, and 0.15 g cm^{-3}). The range of substrate physical properties, such as container capacity, air-filled porosity, and total porosity, was within the recommended range. The 15–100% substitution of compost increased the electrical conductivity and pH of the growing media. The 30% compost treatment led to significant differences in the final height (32.06 cm), trunk diameter (11.66 mm), stem and leaf fresh weight (57.52 g), and stem and leaf dry weight (5.10 g) in comparison with the controls.

Conclusions Considering the high price of peat in comparison with compost, replacing peat with 30% compost is economically preferable. Compost was thus found to be a good alternative to peat as an ornamental plants growing medium.

Keywords Compost · Foliage plants · Nitrogen · Ornamental plants · Physical characteristics

Introduction

Peanut shells are a waste remaining from the cultivation of peanuts in considerable amounts. The compost of this waste can be used as an available and inexpensive material for use in the production of ornamental plants' growing media. In Iran, peanut is cultivated in an area of 3218 hectares, with 2718 hectares located in Gilan Province (Torkashvand et al. 2015). Aquatic fern Azolla (*Azolla filiculoides*) is not native to Iran and entered the northern provinces of the country in 1991 and was quickly developed in paddy fields and wetlands and created many problems for rice farmers and the environment.

Azolla performs well in terms of Azolla production and is a good natural fertilizer in ecological terms (Pabby et al. 2003). Collecting and commercializing its use, therefore, not only help solve some of the existing environmental problems, but may also have economic benefits (Khomami and Dehkaei 2010). In addition to its local production, a considerable amount of peanut is imported to the country with shell. Due to the limited and inadequate peat resources in Iran and the heavy costs of peat importation from abroad, investigating the possibility of replacing peat with new and inexpensive resources is a must. Soilless growing media are crucial to the production of potting plants. In addition to their desirable physical, chemical, and biological characteristics, suitable growing media should also be economically

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accessible, affordable, sustainable, and lightweight, so that they are easier to work with and have an effective cost of transport (Davidson et al. 1998). Rauch et al. (1997) used manure and wood chips and waste paper with a mixture of volcanic materials as a growing medium for potted Crotone, Cordyline, Chrysanthemum, and Ligustrum and concluded that these materials can be used as an organic substrate for this plant. Khomami et al. (2015) concluded that a mixture of cow manure and sawdust is appropriate for feeding earthworms and its outcome is quality vermicompost, and reported that this vermicompost provides an inexpensive, high-quality, peat-like substitute for *Dieffenbachia amoena* production (Khomami and Mohammadoov 2014). The study of the physical properties of compost is an important factor in evaluating the efficiency of compost in growing media. Cristiano et al. (2018) concluded that replacing peat with sewage sludge-based compost at 30 and 60% doses yields the poorest results in terms of the diameter of the plant, shoot, leaves, flowers, and fresh and dry masses, which likely decrease due to the physical composition of compost. Baran et al. (2001) used a grape waste compost instead of peat in the growing media of the houseplant Hypoestes and concluded that, as an alternative to peat, grape compost should take up 50% of the mix. The present experiment was designed to investigate the possibility of using Azolla peanut shell compost as an alternative to peat.

Materials and methods

This study was conducted in the Flowers and Ornamental Plants Research Station in Lahijan (37°11′44″ and 50°01′03″). To develop a suitable growing media, peanut shells were collected from peanut-drying workshops in Astaneh, Gilan Province, and Azolla was collected from the wetlands of this province. After mixing the peanut shells and Azolla with an equal volume ratio (1:1), they were dumped in 1-cubic-meter (1 × 1 × 1) wooden boxes with pores for providing aerobic conditions and microbial activity (Figs. 1, 2). The temperature was measured in the center of the compost mass by a thermometer every 3–5 days, and the material was removed from the boxes and adjusted to create a good ventilation, and the moisture content of the mass was adjusted; this operation continued for 4 months until the temperature stability and maturity of the compost mass was sustained.

Considering the importance of this ornamental foliage plant in the manufacturing of ornamental plants in Iran and its role as an experimental plant, *D. amoena* was selected for this experiment. Rooted cuttings of the plants were prepared in almost equal sizes. After transferring the plants to pots containing growing media (with a diameter of 10 cm), the plant was grown over 5 months in a fiberglass covered greenhouse at the Ornamental Plant Research Station of Lahijan, Iran. The average night and daily temperatures were 18 ± 2 and 27 ± 2 °C, respectively, and the relative humidity was 65–75% and the average light was equal to that produced by 75–150-foot candles. This experiment was carried out using a completely randomized design with six treatment substrates, including peat substrate and perlite (2:1) and five substrate compositions with 15, 30, 45, 60, and 100% of peanut shells + Azolla compost, which have replaced peat (Table 1), with three replications and four plants per treatment. To enable the plants' adaptation to the new conditions, they were watered right in the pot a week before giving them the nutrient solution. For each pot, 200 ml of Omex fertilizer containing 18% nitrogen, 18% phosphorus and 18%

Fig. 1 Used wooden box to produce peanut shell + Azolla compost

Fig. 2 Provided peanut shells + Azolla compost

Table 1 Composition of the growing media

Percent of compost (%)	Combination
0	2 peat + 1 perlite (control)
15	1.7 peat + 1 perlite + 0.3 peanut shells + Azolla compost
30	1.4 peat + 1 perlite + 0.6 peanut shells + Azolla compost
45	1.1 peat + 1 perlite + 0.9 peanut shells + Azolla compost
60	0.8 peat + 1 perlite + 1.2 peanut shells + Azolla compost
100	0 peat + 1 perlite + 2 peanut shells + Azolla compost

potassium was added every 7 days. At the end of the growing season, plant-growing factors such as height, diameter, stem and leaf fresh weight and stem and leaf dry weight were measured. To measure the dry weight, the stem and leaf samples were dried for 48 h at 75 °C in an oven (Khomami and Mohammadoov 2014).

The total nitrogen was determined by the procedure proposed by Bremner and Mulvaney (1982) after digesting the samples with concentrated H_2SO_4 and HC_lO_4 (9:1 v/v). Each ground sample was ashed in a muffle furnace at 550 °C to determine the other nutrients (Horwitz 1980).

Total P was analyzed according to Murphy and Riley (1962) by a spectrophotometer (CECIL 2041). According to Houba et al. (1989), the total K was analyzed by a flame photometer (JENWAY PFP7). The total organic carbon was measured according to the method proposed by Nelson and Sommers (1982). According to the method proposed by Munter and Grande (1981), Ca, Mg, Fe, Cu, and Zn were determined in the plants and substrate samples by inductively coupled plasma atomic emission spectroscopy. Physical properties such as total porosity, bulk density, air-filled porosity, and container capacity were measured using Fonteno's (1996) method and EC and pH were measured using the method proposed by Verdonck and Gabriels (1992). The data were analyzed in the SAS software (SAS Institute Inc 2001) and the means of the data were statistically compared using Tukey's multiple-range test.

Results and discussion

The physicochemical characteristics of growing media have a great impact on plant quality. The results in Table 2 show that, due to the high C/N ratio of peanut shells and the low ratio of Azolla, their composition has a balanced ratio of C/N and improved compost quality compared to raw materials.

The results in Table 3 show that increasing the amount of peanut shells + Azolla compost led to an increased nitrogen, phosphorus, and potassium in the growing medium compared to the controls, and the highest content was reached with 100% peanut shells + Azolla compost. These findings are consistent with the results obtained by Khomami and Moharam (2013), who reported an increase

Table 2 Some physicochemical properties of peanut shells + Azolla compost, peanut shells, Azolla, and peat

Physicochemical properties	Peanut shells + Azolla compost	Peanut shells	Azolla	Peat
Total nitrogen (%)	2.9	0.87	2.8	0.63
Available phosphorus (mg kg^{-1})	4000	1190	5100	300
Available potassium (mg kg^{-1})	19,300	18,700	23,800	3100
Organic carbon (%)	21.8	30	38.8	21.2
C/N ratio	4.1	34.5	13.9	10.1
PH (1:5)	6.03	5.89	7.4	5.52
EC (dS m−1)	2.5	1.38	5.47	0.62

Table 3 Some chemical properties of growth media

Treatment	Total nitrogen (%)	Available phosphorus (mg kg^{-1})	Available potassium (mg kg^{-1})	Organic carbon (%)	C/N ratio
Control	0.6f	300f	3100f	37.8a	63.0a
15% peanut shells + Azolla compost	1.9e	1900e	14,400e	29.2b	15.3b
30% peanut shells + Azolla compost	2.0d	3100d	14,800d	28.5b	14.2b
45% peanut shells + Azolla compost	2.3c	4300c	17,700c	24.3bc	10.5c
60% peanut shells + Azolla compost	2.4b	4600b	19,000b	24.3bc	10.1c
100% peanut shells + Azolla compost	2.8a	4900a	19,900a	22.1c	7.6c

The means of the same letters do not significantly differ ($p \leq 0.05$)

in the amount of nitrogen, phosphorus, and potassium by an increase in sugarcane bagasse vermicompost in the growing medium. The highest nitrogen content was reached with 100% peanut shells + Azolla and the lowest nitrogen content belonged to the controls. The amount of phosphorus also increased with an increase in the replacement rate of peanut shells + Azolla compost, and the highest amount of potassium (19,900 mg kg^{-1}) was reached with 100% peanut shells + Azolla and the lowest potassium content (3100 mg kg^{-1}) belonged to the controls. The results showed that, in comparison with peat, a significant amount of potassium was present in peanut shells + Azolla compost, which is consistent with the results reported by Grigatti et al. (2007). Due to the high amounts of potassium in peanut shells + Azolla compost (Table 4), its addition to growing media led to an increase in the available amount of potassium. Due to the low nitrogen content in the controls, the C/N ratio was also shown to be higher. The C/N ratio reduced as the compost surface increased in the growing media, which is consistent with the results obtained by Jayasinghe et al. (2010). The C/N ratio was lower than the permitted standard for the growing of ornamental plants (C/N = 30) in the growing media containing peanut shells + Azolla compost. Davidson et al. (1994) reported that compost with a C/N ratio less than 20 is ideal for plant production. The highest pH and EC values were reached with the 100% peanut shells + Azolla compost substrate and the lowest pertained to the controls.

Plant nutrient analysis

The leaf analysis of the plants (Table 4) grown in potting mixtures containing 30% peanut shells + Azolla compost showed a significant increase in the nitrogen concentration compared to the controls, which could explain the increase in the growth of the plants after replacing peat with 30% peanut shells + Azolla compost (Table 3). The elemental composition of the leaves for other elements shows slight differences in nutrient concentrations between the treatments (Table 4).

The average nutrient content obtained is in line with the values given by Uchida (2010) for good-quality plants. The differences in plant growth between the treatments appear to not have been a direct result of excessive or deficient nutrients. The fact that the plants were fertilized every 10 days with a nutrient solution supports this interpretation. In substrates, where peanut shells + Azolla compost has replaced peat, other factors seem to have also affected plant growth in addition to the nutritional value of compost, and these factors need to be further investigated.

Plant growth factors

The mean comparisons shown in Table 5 suggest that the highest final height of the plant (32.66 cm) pertained to 30% peanut shells + Azolla compost, which had a significant difference with 100% peanut shells + Azolla compost.

Table 4 Nutrient element concentration analyses of *Dieffenbachia amoena* leaves

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (ppm)	Zn (ppm)	Fe (ppm)
Control	2.14ac	0.69	4.16b	1.58	0.80	12	61	184ab
15% peanut shells + Azolla compost	2.43ac	0.71	5.23ab	1.10	0.88	12	67	215a
30% peanut shells + Azolla compost	2.70a	0.79	5.08ab	1.10	1.00	10	67	225a
45% peanut shells + Azolla compost	2.24ac	0.76	5.73a	0.96	0.86	12	61	201ab
60% peanut shells + Azolla compost	2.39ac	0.75	5.83a	1.22	0.91	12	58	205ab
100% peanut shells + Azolla compost	2.08bc	0.72	4.84ab	1.23	0.90	13	59	194ab

The means of the same letters do not significantly differ ($p \leq 0.05$)

Table 5 *Dieffenbachia amoena* growth characteristics measured in the various potting mixtures at the end of the growth period

Treatment	Final height (cm)	Trunk diameter (mm)	Stems and leaves fresh weight (g)	Stems and leaves dry weight (g)
Control	28.58ab	8.34ab	43.70c	3.42cd
15% peanut shells + Azolla compost	29.83ab	7.88b	54.67b	3.67c
30% peanut shells + Azolla compost	32.06a	11.66a	57.52a	5.10a
45% peanut shells + Azolla compost	28.83ab	8.74ab	50.64ab	4.33b
60% peanut shells + Azolla compost	28.22ab	9.66ab	50.24ab	4.27b
100% peanut shells + Azolla compost	25.95bc	7.65b	43.17c	3.77c

The means of the same letters do not significantly differ ($p \leq 0.05$)

The lowest final height of the plant (25.95 cm) was reached with 100% peanut shells + Azolla compost, which did not show any significant differences with the controls. The highest trunk diameter (11.66 mm) pertained to 30% peanut shells + Azolla compost, which differed significantly from the 15% and 100% peanut shells + Azolla compost.

The lowest diameter (7.65 mm) was observed in the 100% compost treatment, which showed only a significant difference with 30% peanut shells + Azolla compost. The highest stem and leaf fresh weight (55.7 g) was associated with 30% peanut shells + Azolla compost, which did not show significant differences with the 45% and 60% peanut shells + Azolla composts, but was significantly different from the other treatments. The lowest stem and leaf fresh weight was 43.17 g and was associated with the 100% peanut shells + Azolla compost, which did not show a significant difference with the controls. The highest stem and leaf dry weight (10.5 g) was associated with 30% peanut shells + Azolla compost, and showed a significant difference with the other treatments. The least amount of leaf dry weight (3.42 g) was observed in the controls, which was not significantly different with the 15% and 100% peanut shells + Azolla composts.

Physical characteristics

The study of the physical properties of growing media showed that an increase in the amount of peanut shells + Azolla compost in growing media reduced the bulk density compared to in the controls (Table 6). According to Yeager et al. (2007), the ideal bulk density of a growing medium is 0.1–0.7 g cm^{-1}. The bulk density in compost-containing growing media is thus ideal. The porosity of the substrates increased as the peanut shells + Azolla content increased in the growing media. As peat was replaced with peanut shells + Azolla, the bulk density of the substrates decreased, resulting in a gradual increase in the total porosity and a change in porosity distribution in the substrates. The result was a reduced air-filled porosity and an increased container capacity (Table 6).

Taylor and Ratliff (1969) argued that the number of large pores in the growing medium and the root strength for deformation, replacement in the growing medium and longitudinal growth decreased with an increased bulk density. Increasing the amount of peanut shells + Azolla compost in the growing media increased porosity more than in the controls. Air and water contents are very crucial physical parameters of growing media (Marfà et al. 1998). Water should be available in the substrate with minimum energy levels, but at the same time, there should be sufficient air in the root zone (Inbar et al. 1993; De Boodt et al. 1974). Verdonck and Gabriels (1992) declared the ideal air-filled porosity as 20–30% of the plant growth in a growing medium. In this experiment, the percentage of air-filled porosity in the growing medium containing 15% compost was slightly more than the ideal, while it was ideal in the other substrates. Yeager et al. (2007) argued that the ideal total porosity is 50–80% in growing media. The total porosity of the substrate containing 15%, 30%, and 45% compost is within this ideal range. A high total porosity was found in 100% peanut shells + Azolla and the lowest in 15% and 30% compost. As estimated by Verdonck and Gabriels (1992), the ideal container capacity for growing media is between 55 and 75%; it thus seems that the container capacity is less than optimal in all growing media. In this experiment, the highest container capacity was observed in the control medium and the lowest in the growing media containing 15% peanut shells + Azolla compost. By increasing the amount of peanut shells + Azolla compost in the growing media, air-filled porosity decreased. The highest air-filled porosity was observed in the growing medium of 15% compost and the lowest in the growing medium of 100% compost. With the increase in the peanut shells + Azolla compost content in the growing media, pH and EC increased. Grigatti et al. (2007) reported an increase in pH and EC in plant-growing media after increasing the amount of green waste compost to 25%, 50%, 75%, and

Table 6 Physical characteristics of substrates

Treatment	Bulk density (g cm^{-3})	Total porosity (%)	Air-filled porosity (%)	Container capacity (%)	pH (1:5)	EC (dS m−1)
Control	0.23a	73.60c	24.20c	52.30a	5.55bc	0.67e
15% peanut shells + Azolla compost	0.17b	65.53e	30.47a	37.79d	5.67b	1.06d
30% peanut shells + Azolla compost	0.16b	67.44d	28.56b	38.37d	5.27c	1.70c
45% peanut shells + Azolla compost	0.15b	72.67c	23.33c	41.28c	5.65b	1.92c
60% peanut shells + Azolla compost	0.15b	85.47b	15.53d	41.86cb	5.80b	2.10b
100% peanut shells + Azolla compost	0.15b	89.53a	10.47e	43.02b	6.05a	2.60a
	0.19–0.70[a]	50–85[a]	10–30[a]	45–65[a]	5.5–6.5[b]	0.76–1.25[b]

[a]Rang values are recommended physical characteristics (Yeager et al. 2007)

[b]Cavins et al. (2000)

100% volumes for peat substitution. The highest EC content (2.6 dS m^{-1}) was observed in the medium containing 100% peanut shells + Azolla compost and the lowest EC (0.62 dS m−1) in the controls. Cavins et al. (2000) proposed the ideal pH as 5.5–6.5 and EC as 0.76–1.25 dS m−1 for optimal plant growth. Accordingly, in this experiment, pH was in the proper range in all the compost replacement treatments. At levels higher than 30% peanut shells + Azolla compost, the EC was higher and fell out of this range. In general, the combination of compost and peat in plant-growing media increases the pH (Bustamante et al. 2008). The highest pH was obtained in the treatments containing 100% peanut shells + Azolla compost and the lowest pH in the controls. Chen et al. (1988) considered the physical characteristics of growth media as the most important factor that affected potted plants' yield. They also reported that the best plant growth compared to the controls (20% vermiculite + 80% peat) was in the growing medium containing 50% peat + 50% compost (including animal manure or compost grape pulp).

Conclusion

The results showed that the highest growth was observed in the treatments containing 30% peanut shells + Azolla and the lowest growth rate in the 100% peanut shells + Azolla compost. Examining the physical properties of growing media in relation with plant growth showed that plant growth was lower with 100% peanut shells + Azolla compost than with the other growing media, and in terms of growth factors, the yielded plant was poor. Peanut shells + Azolla compost has a reduced C/N ratio and appropriate pH, EC and growth characteristics, such as height, trunk diameter, stem and leaf fresh weight and stem and leaf dry weight compared to the controls. The observations made in this experiment showed that peanut shells + Azolla compost can be used to substitute peat in the growing media of *D. amoena*.

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