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Investigating the Effect of Hydrafiber and Biochar as a Substitute for Peat-Based Substrate for Zinnia and Snap-dragon Production

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Summary

Increasing environmental and economic concerns necessitate the research for peat moss alternatives, aiming to balance ecological sustainability with cost-effectiveness. This study assessed whether biochar (BC) and hydrafiber (HF) could be a partial replacement for peat moss as substrate components. Twelve substrates were formulated by either mixing BC (20%, 40%, and 60%, by vol.) with HF (20%, 40%, and 60%, by vol.), with the remaining being peat moss or mixing BC (0%, 20%, 40%, and 60%, by vol.) with the commercial substrates (CS) to grow zinnia (*Zinnia elegans*) and snapdragon *(Antirrhinum majus)* plants in containers. Plant growth parameters included growth index (GI) and leaf greenness (indicated with SPAD), biomass, and number of flowers - measured biweekly. The results showed all the substrate mixes had similar SPAD. Treatment with 20% BC and 80% CS yielded the highest GI, biomass, and numbers of flowers in both zinnia and snapdragon. In conclusion, BC could be used to partially (20%) replace commercial substrate mix for container-grown zinnia and snapdragon.

INTRODUCTION

The escalating environmental concerns and cost of peat moss has underscored the urgency of identifying viable alternatives for container substrate. Peat moss has been a controversial substrate in greenhouse/nursery production (Yu et al., 2023). It has excellent chemical and physical properties for plant growth and development (Barrett et al., 2016). However, the extensive exploitation of peatlands for agricultural and horticultural purposes, particularly as a primary component of soilless substrates, has raised significant environmental concerns (Savvas and Gruda, 2018). These factors have led researchers to explore alternative substrates that can fulfill the role of peat moss without its associated environmental downsides (Sradnick et al., 2023).

Biochar (BC) is rich in carbon and made of a variety of renewable feedstocks that undergoes pyrolysis at 400ºC to 1200ºC with absence or limited oxygen (Barrett et al., 2016). Substituting BC from peat moss could reduce peat moss harvesting, and protect the peatland ecosystem (Page et al., 2002). Biochar enhances plant nutrient uptake by bolstering cation exchange capacity (CEC) and water use efficiency while also mitigating nutrient leaching, all at a lower cost than peat moss (Ding et al., 2016).

Hydrafiber (HF) is an innovative wood- and bark-based fiber product, as a viable alternative to peat in substrate composition ("HydraFiber Hub," n.d.). Hydrafiber is made through a specialized process that refines wood pulp into long, thin fibers using mechanical and thermal techniques, resulting in a porous, durable material ideal for horticulture ("HydraFiber Hub," n.d.). Those unique properties are highlighted by the manufacturer as reducing the risk of overwatering, an advantage that underscores its potential as a partial peat substitute (Tomczyk et al., 2020).

Researchers have tested the effect of BC or HF on plant growth separately. There are limited studies on the co-effects of BC and HF. Thus, the objective of this research was to: 1) compare BC and HF as a container substrate component; and 2) investigate the co-effects of BC and HF mixture as container substrate component for zinnia and snapdragon.

MATERIALS AND METHODS

Snapdragon (*Antirrhinum majus*, Madame Butterfly Cherry Bronze F1, hybrid Snapdragon) and Zinnia (*Zinnia elegans*, Giant Dahlia Flowered Orange) seeds (Johnny's Selected Seeds, Winslow, ME, USA) were sown in 128-cell propagation trays (cell depth: 5.7 cm; cell top length and width: 54.0 cm and 28.6 cm; volume: 25.1 cm^3) on 21 February 2023, with propagation media (Pro-Mix FPX Bio-fungicide media, Quakertown, PA, USA). Uniform zinnia and snapdragon seedlings were transplanted into 6-in. (15.2 cm) azalea pots (depth: 10.8 cm; top diameter: 15.5 cm; bottom diameter: 11.3 cm; volume: 1330 mL) on 9 March 2023, after two true leaves emerged. Plants were fertilized weekly with 400 mL of 240 mg L^{-1} water-soluble fertilizer [20 mg L^{-1} N, 8.6 mg L^{-1} P, and 16.6 mg L^{-1} K; Plantex Master Plant (Prod Inc., Leipsic, OH, USA)]. Each substrate was irrigated at the same scheduled time and with the same amount of greenhouse tap water (pH at 6.6, and EC at 20.0 mS m^{-1}) with 10–20% leaching rate and maintained at a greenhouse located at the University of Georgia, Griffin, Georgia. The average humidity and temperature during the experiment were 61% and 26.1 °C, respectively.

Twelve substrates were formulated by either mixing BC (20%, 40%, or 60%, by vol.) with HF (20%, 40%, or 60%, by vol.), with the remaining being peat moss (P) or mixing BC (0%, 20%, 40%, and 60%, by vol.) with the commercial substrate (CS). The twelve treatments were:

T1 - 20BC:20HF:60P	T7 -20BC:60HF:20P
T2 - 40BC:20HF:40P	T8 - 40BC:60HF
T3 - 60BC:20HF:20P	T9 - 20BC:80CS
T4 - 20BC:40HF:40P	T10 - 40BC:60CS
T5 - 40BC:40HF:20P	T11 - 60BC:40CS
T6 - 60BC:40HF	T12 - 100CS, control

Substrate mix components used in the study included the mixed hardwood BC (Proton Power, Inc., Lenoir City, TN, USA), HF (HF Ultra 160WB from HF Advanced Substrate, Buffalo Grove, IL, USA), P (Peat: THE GOLD Canadian Sphagnum Peat Moss by Fertilome, Worth, TX, USA), and CS (Jolly Gardener Pro-line C/25 Growing Mix, Oldcastle Lawn & Garden Inc. Atlanta, Georgia, USA). The BC was made from fast pyrolysis with a pH of 10.6 and EC of 1010 mS m^{-1}. The pH of HF, P, and CS was 4.9, 5.0, and 5.7, respectively, and EC was 112 mS m^{-1}, 179 mS m^{-1}, and 2383 mS m^{-1}, respectively, measured with pour-through methods. The CS was used as the control and consisted of 55% aged pine bark and the remaining 45% was composed of Canadian sphagnum peat moss, perlite, and vermiculite.

Plant height and two perpendicular widths were measured biweekly starting at 0 WAT. Growth index (GI) was calculated using the formula: GI= [height/2+ (width1 + width 2)/4]. Leaves greenness (SPAD) was recorded, then average from three mature leaves of each plant with a chlorophyll meter (SPAD-502 Minolta Camera Co., Osaka, Japan) measured biweekly starting at 2 WAT for zinnia and 4 WAT for snapdragon, respectively. When the plants started flowering, the numbers of flowers were recorded biweekly. Plants dry weights were determined at the end of 8 WAT for zinnia plants and 10 WAT for snapdragon plants by placing the shoots into the air-forced dry oven for 48 hours.

RESULTS

For zinnia plants, all the SPAD values were similar to or significantly lower than those of the control at 2, 4, 6, and 8 WAT (**Fig. 1a**). AT 8 WAT, all the treatments had similar SPAD values, and there was no significant difference among treatments. Similarly, for snapdragon plants, all the SPAD values were similar to or significantly lower than those of the control at 4, 6, 8, and 10 WAT (**Fig. 1b).**

For both zinnia and snapdragon plants (**Fig. 2 and 3**), all the treatments had a similar GI to the control except for T1 (20BC:20HF:60P) and T6 (60BC:40HF) for snap-dragon plants, which had a significantly lower GI than the control at 10 WAT. Snapdragon plants grown in T1 (20BC:20HF:60P) mixes had the lowest GI (14.2), while in T3 (60BC:20HF:20P), T5 (40BC:40HF:20P), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS), they had significantly higher GIs (62.0, 64.4, 59.2, 60.6, 62.2 and 63.8, respectively).

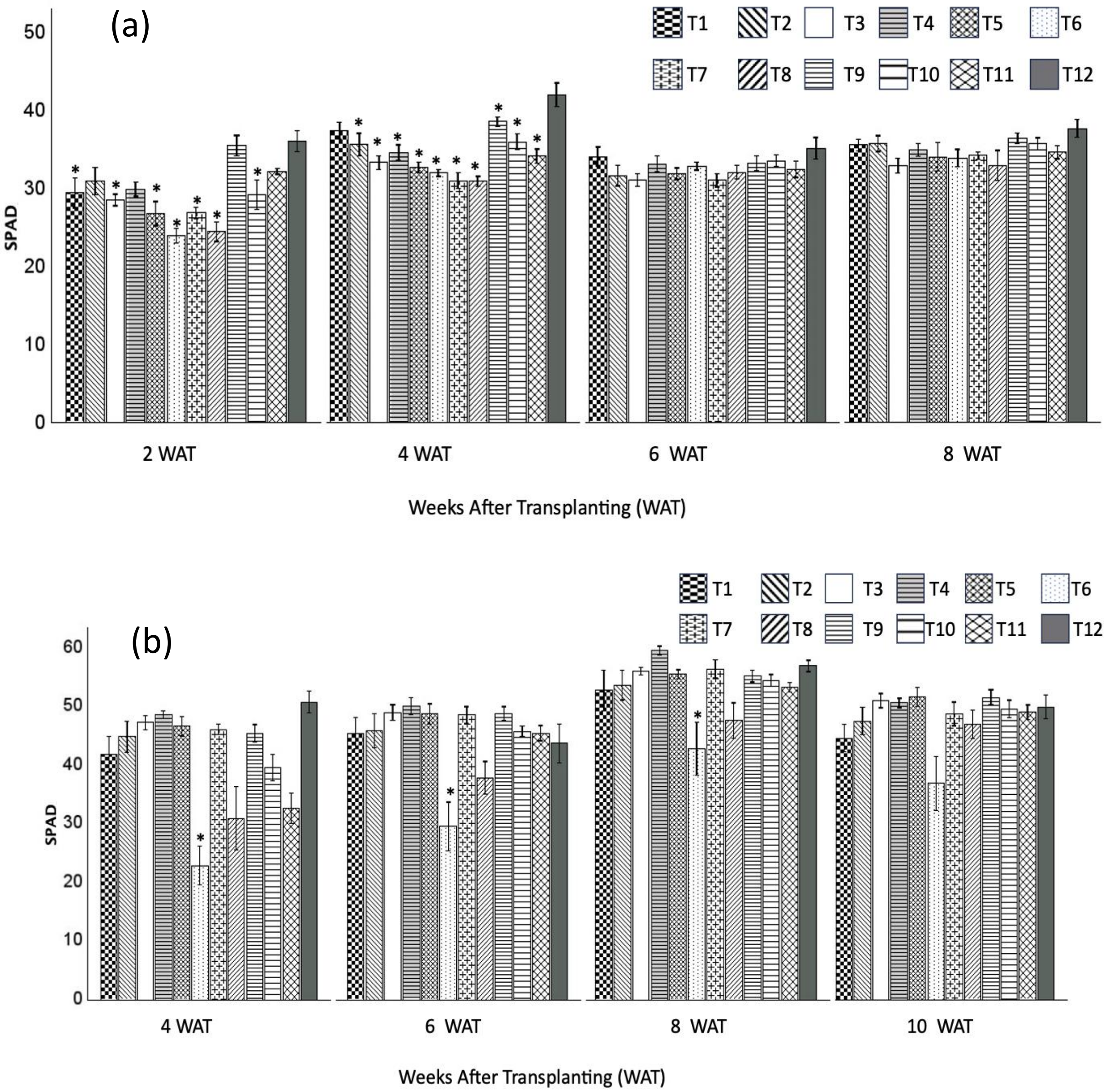

Figure 1. The SPAD values (mean ± standard error) of zinnia (**a**) and snapdragon (**b**) plants grown in twelve substrates at 2, 4, 6, 8, and 10 (snapdragon only) weeks after transplanting (WAT). Treatment 1 (20BC:20HF:60P), T2 (40BC:20HF:40P), T3 (60BC:20HF:20P), T4 (20BC:40HF:40P), T5(40BC:40HF:20P), T6 (60BC:40HF), T7 (20BC:60HF:20P), T8 (40BC:60HF), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS, control). * Indicates that means are significantly different from the control using Dunnett's test at $p \leq 0.05$.

Zinnia plants grown in T9 (20BC:80CS) mixes had the highest shoot dry weights (26.09 g), while in T7 (20BC:60HF:20P) mixes had the lowest dry weights (11.1 g, **Fig. 4a**). Snapdragon plants grown in T9 (20BC:80CS) and the control T12 (100CS) had the highest dry weights (24.0 g) while those grown in T1 (20BC:20HF:60P) had the lowest dry weights (1.5 g, **Fig. 4b)**.

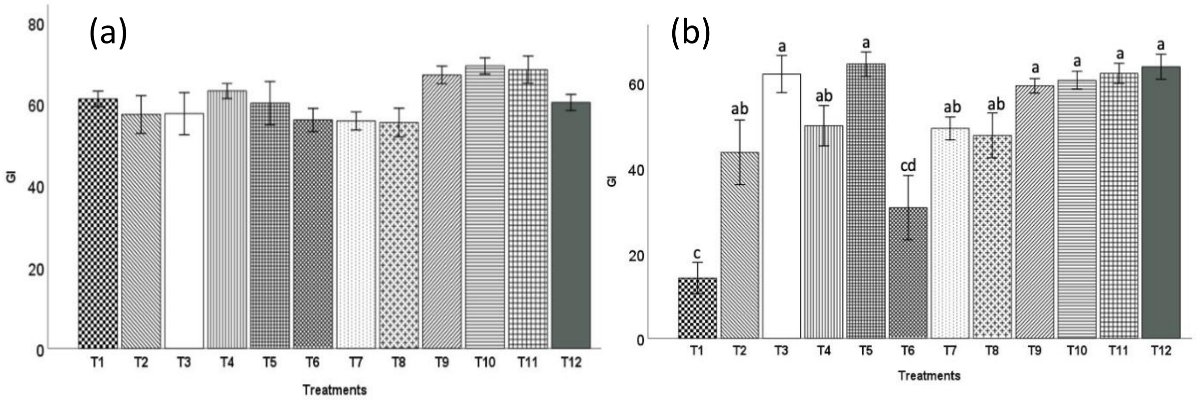

Figure 2. Growth indexes (mean ± standard error) of zinnia (**a**) and snapdragon (**b**) plants grown in twelve substrates at 8 and 10 weeks after transplanting (WAT), respectively. There were no significant differences among treatment for zinnia. Treatment 1 (20BC:20HF:60P), T2 (40BC:20HF:40P), T3 (60BC:20HF:20P), T4 (20BC:40HF:40P), T5(40BC:40HF:20P), T6 (60BC:40HF), T7 (20BC:60HF:20P), T8 (40BC:60HF), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS, control). Means indicated by the same alphabet letters are not significantly different according to Tukey–Kramer's HSD test at $p \leq 0.05$.

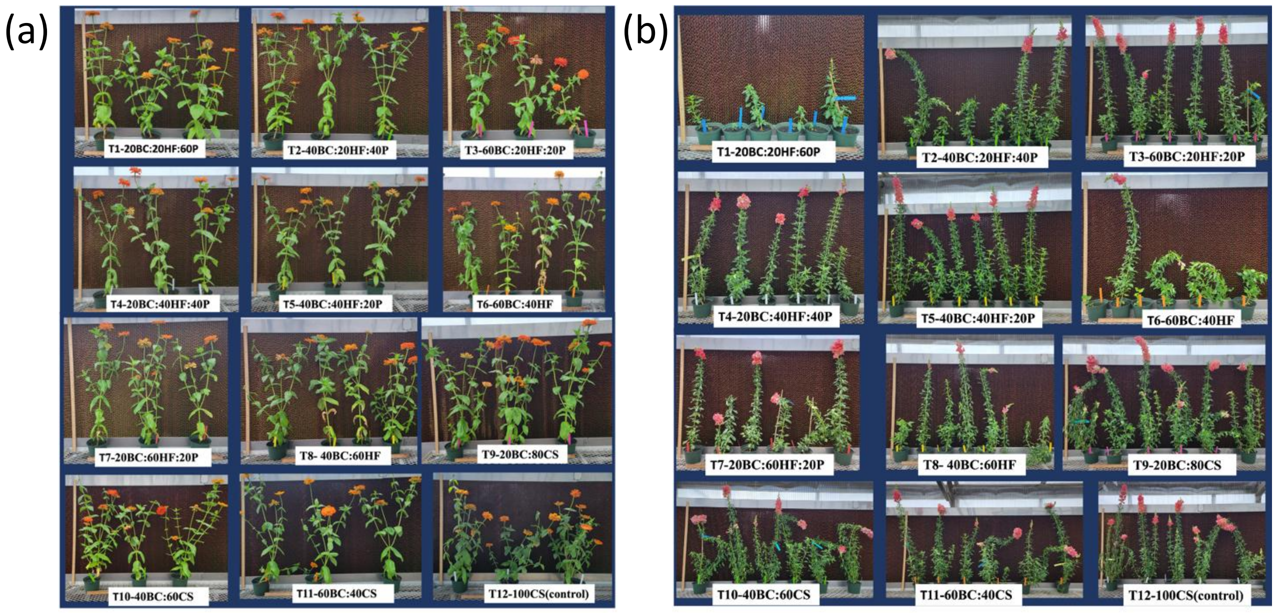

Figure 3. Plant growth of zinnia (**a**) and snapdragon (**b**) plants at 8 and 10 WAT, respectively. Treatment 1 (20BC:20HF:60P), T2 (40BC:20HF:40P), T3 (60BC:20HF:20P), T4 (20BC:40HF:40P), T5 (40BC:40HF:20P), T6 (60BC:40HF), T7 (20BC:60HF:20P), T8 (40BC:60HF), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS, control).

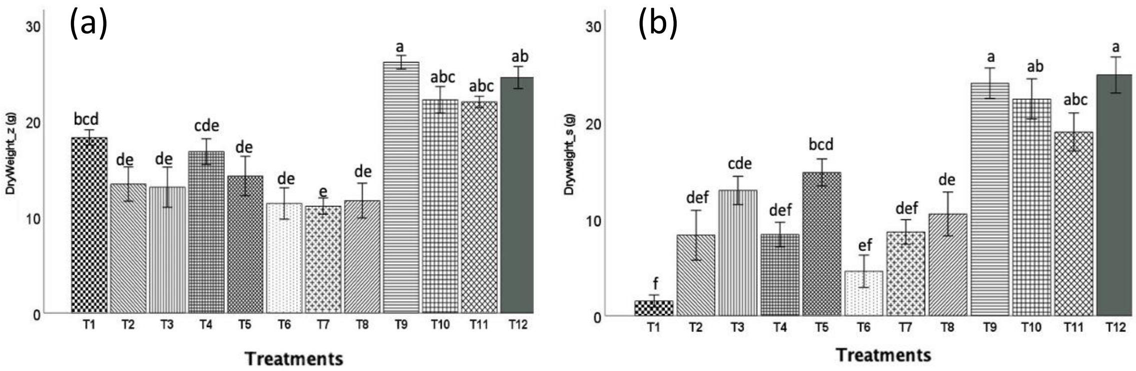

Figure 4. Shoot dry weight (mean ± standard error) of zinnia (**a**) and snapdragon (**b**) plants harvested at 8 and 10 weeks after transplanting, respectively. Treatment 1 (20BC:20HF:60P), T2 (40BC:20HF:40P), T3 (60BC:20HF:20P), T4 (20BC:40HF:40P), T5 (40BC:40HF:20P), T6 (60BC:40HF), T7 (20BC:60HF:20P), T8 (40BC:60HF), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS, control). Means indicated by the same alphabet letters are not significantly different according to Tukey–Kramer's HSD test at $p \leq 0.05$.

For zinnia plants, the control (100CS) had the highest numbers of flowers (11), whereas T6 (60BC:40HF) had the least numbers of flowers on average (3.5, **Fig. 5a**).

For the snapdragon plants, T9 (20BC:80CS) had more flowers (3.8) than the control (3.3), while T1 (20BC:20HF:60P) and T6 (60BC:40HF) had the least numbers of flowers (0.17 and 0.33, **Fig. 5b**).

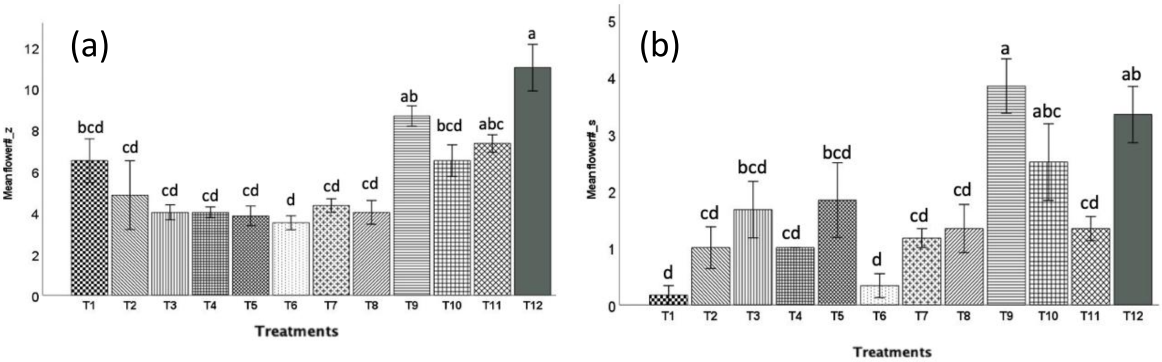

Figure 5. Numbers of flowers (unopened and opened flowers) (mean ± standard error) of zinnia (**a**) and snapdragon (**b**) plants harvested at 8 or 10 weeks after transplanting, respectively. Treatment 1 (20BC:20HF:60P), T2 (40BC:20HF:40P), T3 (60BC:20HF:20P), T4 (20BC:40HF:40P), T5 (40BC:40HF:20P), T6 (60BC:40HF), T7 (20BC:60HF:20P), T8 (40BC:60HF), T9 (20BC:80CS), T10 (40BC:60CS), T11 (60BC:40CS), and T12 (100CS, control). Means indicated by the same alphabet letters are not significantly different according to Tukey–Kramer's HSD test at $p \leq 0.05$.

DISCUSSION

This study found no significant difference in SPAD value associated with increasing HF percentage, aligning with previous research findings across various plant species and substrates. For example, HF percentage had no effect on SPAD for 'Supertunia Vista Bubblegum' petunia (*Petunia hybrida*) compared with other treatments including hammer-milled pine wood or coconut (*Cocos nucifera*) coir (Harris et al., 2020). In addition, the SPAD value was not significantly different from the control (100% peat) when treating plants with 10%, 20%, and 30% wood fiber with 90%, 80%, and 70% peat respectively in geranium (*Interspecific geraniums*)(Zawadzińska et al., 2021). However, 40% wood fiber in peat-based substrate led to smaller and fewer flowers, and lower SPAD value (Zawadzińska et al., 2021). This may be explained by two reasons. First, wood material may reduce nutrient availability and uptake, and produce phytotoxic compounds. Second, the use of wood material may need additional N fertilizer for geranium which requires substantial N to achieve optimal growth in plants (Zawadzińska et al., 2021). In our study, there were no negative effects associated with increasing HF percentage in leaf greenness because zinnia and snapdragon plants need low to medium levels of N during plant growth (Whipker et al., 2018).

Our study's findings of plant growth, plant weight, and number of flowers align with those of previous research. The study found a reduction in the fresh weight of geranium (*Interspecific geraniums*) with an increased proportion of pine wood fiber (Zawadzińska et al., 2021). Furthermore, a study discovered that a high BC concentration (70%) diminished flowering and plant growth, whereas a lower BC content (30%) did not negatively impact the flowering or growth of pelargonium plants (Conversa et al., 2015).

CONCLUSION

In conclusion, this study recommends 20% BC with CS or 100% CS for growing zinnia and snapdragon. While HF did not prove to be the most effective substrate component for cultivating zinnia and snapdragon, it still holds potential for partial peat substitution given its impact on biomass, plant growth, and floral yield.

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