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Effect of sawdust and rice husk based growing media irrigation on growth and floral quality of zinnia (*Zinnia elegans*)

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ABSTRACT

Two pot experiments were carried out at the University for Development Studies, Tamale, Ghana, to determine the effects of feedstock specific composts as soil amendment and soilless media on growth and flower quality of ornamental Zinnia. Standardized composts were developed from co-composting of i) single species sawdust *(SS)*, ii) mixed species sawdust *(MS)* and ii) Rice husk (*RH*) feedstock with poultry manure in volumetric ratios of 2:1. In the first experiment, the three standardized compost types were mixed with soil in 1:1, 1:2 and 1:3 ratios. In the second experiment, the SS and RH based composts were each mixed with rice husk biochar in volumetric ratios of 1:0, 1:1, 1:2 and subjected to half (0.1125 mm) and full (0.225 mm) irrigation regimes. The results showed that 1 part MS compost + 3 parts topsoil improved growth of Zinnia by increasing plant height and fresh and dry biomass. The 1 part of RH compost + 2 parts topsoil increased flower diameter whiles the 1 parts of SS compost + 3 parts topsoil produced plants with the shortest flower stalk. The 1 part of RH compost + 2 parts rice husk biochar soilless media also produced the tallest plants with the widest flower head diameter. The results of our study have shown that composts and soilless media developed from variety of sawdust, rice husk and biochar can be used to improve growth and modify the flower quality of *Zinnia elegans*. These substrates, therefore, have a great potential for use in the production of quality composts and soil amendments for ornamental plant production in the tropics.

Key words: compost, soilless media, soil amendment, flower quality, *Zinnia elegans*

INTRODUCTION

Soil is the most widely used medium for potted plant production in nurseries in Ghana. As a result of the problems associated with the physical stability and soil borne diseases of natural soil, alternatives such as composted crop residues, coir and other commercially available substrates have become commercially accepted for the production of nursery and ornamental plants (Burnett *et al*., 2016). Coir and other imported commercial substrates are increasingly becoming available in

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Ghana, but they are often more expensive for urban farmers and home gardeners. Developing less expensive, nutrient rich alternative substrates such as sawdust and rice husk composts can reduce cost as well as fertilizer and water use (Wilson *et al*., 2001).

According to Grigatti *et al*, (2007), ornamental plants are cultivated in more than 140 countries and that growing flower crops at both small and large scale provide more market and income for growers compared with traditional crops. The demand for quality flowers is increasing globally and potting media is critical in producing quality flowers for the international market (Kashihara *et al*., 2011). Khan *et al*. (2012) reported that correct combination of substrates for growing media to optimize plant growth is demanding and represents about 4-6% of the cost of production for bedding plants. Municipal solid waste compost is also a good and cheaper potting media component for the production of flowering plants, but they are sometimes found to be contaminated with weed seeds, pathogens and heavy metals (Tahir *et al*., 2013). However, sawdust and rice husk feedstock are normally free from these contaminants and hence compost developed from them is safer and consistent in physical and chemical properties. Huge quantities of sawdust and rice husk are generated in Ghana annually (Duku *et al*, 2011). However, at the smaller sawmills dotted across the country, sawdust generated are usually from mixed tree species. It is only at large scale firms such as the Sokoban wood village in Kumasi, Ghana, that large quantity of sawdust can be generated from single tree species.

Knowledge about the effect of the type of sawdust on compost quality and crop response is limited in Ghana. *Daniellia oliveri*, is the most common sawdust type found across the savannah and forest areas of Ghana. Large quantities of *D. oliveri* are generated especially in the transitional zones as single species sawdust. However, it is sometimes mixed with *Chrysophylum albidum* sawdust during milling at the wood villages. The objectives of this study were to (i) determine the effects of feedstock specific compost-amended soil on the growth and quality of *Zinnia elagans* and (ii) determine the combined effects of compost and biochar soilless media and irrigation regimes on the growth and quality of *Zinnia elegans*.

MATERIALS AND METHODS

Experimental site and growing of Zinnia seedlings

The two pot experiments were carried out in a plant house at the University for Development Studies, Nyankpala campus, Ghana, from April to June, 2014. The site lies on latitude 9º 25'N and longitude 9º58'W with altitude 185 m above sea level (SARI, 1997). The temperature range in the plant house was 23-32ºC. The average relative humidity ranged from 69% to 90%.

The seeds of *Zinnia elegans*, which were obtained from Aburi Botanical Gardens in the Eastern region of Ghana, were nursed in river sand for three weeks before being transplanted into the pots.

Composts and composting of feedstock

On the basis of results of a survey reported in 2015 (Abubakari et al., 2015), single species sawdust *(SS)*, mixed species sawdust *(MS)* and Rice husk (*RH*) were selected as feedstock for co-composting with poultry manure (Table 2). The single species sawdust feedstock was obtained from *Daniellia oliveri* tree (African copaiba balsam tree) and the mixed species sawdust obtained from a mixture (1:1, v/v) of *D. oliveri* and *Chrysophylum albidum* (white star apple tree). The rice husk was obtained from Jasmine 85 rice variety. Nine different composts types were produced from three different feedstock (SS, MS and RH) in 2:1, 3:1 and 4:1 ratio (v/v) of feedstock to poultry manure (Abubakari *et al*., 2018). Out of the nine composts produced, three were used for the current studies. The three compost types selected were produced from the co-composting of the three feedstock and poultry manure in a ratio of 2 parts of feedstock to 1 part of poultry manure. The three composts compounded therefore were: i) 2 parts of single wood species sawdust to 1-part poultry manure (2SS compost), ii) 2 parts of mixed wood species sawdust to 1-part poultry manure (2MS compost) and iii) 2 parts of rice husk to 1-part poultry manure (2RH compost). The modified compost bins used and the method of composting were as described by Abubakari *et al*. (2018).

The physico-chemical properties of the individual feedstock, the poultry manure and the resulting composts were determined (Table1). Moreover, the physico-chemical properties of the soil used in the experiment was also determined (Table 1). The biochar used was produced from rice husk following the procedure used at Japan International Research Centre for Agricultural Sciences (JIRCAS, 2014). The biochar produced was characterized by Atia *et al*., (2015).

Table 1* Physico-chemical properties of poultry manure, rice husk, single sawdust and mixed sawdust

Properties	Poultry manure	Rice husk	SS	MS	LSD	*p*-value
N (%)	4.37±0.28	0.38	0.25	0.41	0.085	0.017
P (%)	1.05±0.03	0.43	0.21	0.15	0.015	0.044
K (%)	4.10±0.11	1.81	1.34	0.72	0.093	0.030
Ca (%)	4.47±0.08	0.82	1.26	1.32	0.060	0.010
Mg (%)	3.19±0.02	0.73	0.91	0.66	0.028	0.002
Moisture (%)	9.45±0.50	7.10	11.30	12.13	0.550	0.001
EC (mS/cm^3)	4.00±0.30	3.55	8.73	3.41	0.230	0.001
Density (g/cm^3)	0.50±0.01	0.25	0.28	0.25	0.015	0.003
OC (%)	25.40±1.00	40.37	42.50	45.18	1.082	<0.001
Cellulose (%)	23.87±0.08	27.74	32.75	42.11	0.093	<0.001
Lignin (%)	11.77±0.70	21.68	23.15	23.74	0.225	0.040
C:N	5.81	106.23	170	110.19		

* Adopted and modified from Abubakari *et al*., 2018.

Treatments and experimental design

In experiment 1, the three formulated composts including 2 parts of single wood species sawdust to 1-part poultry manure (2SS compost), 2 parts of mixed wood species sawdust to 1-part poultry manure (2MS compost) and 2 parts of rice husk to

1-part poultry manure (2RH compost) where used to amend pot soil in ratios of 1:1 (50 % compost added to soil), 1:2 (33 % compost added to soil) and 1:3 (25 % compost added to soil) on volumetric basis. These combinations gave the following formulations as treatments: The treatments which were arranged in a completely randomized design with four replications were as follows:

T1. Addition of 50 % 2SS compost to soil

T2. Addition of 33 % 2SS compost to soil

T3. Addition of 25 % 2SS compost to soil

T4. Addition of 50 % 2MS compost to soil

T5. Addition of 33 % 2MS compost to soil

T6. Addition of 25 % 2MS compost to soil

T7. Addition of 50 % 2RH compost to soil

T8. Addition of 33 % 2RH compost to soil

T9. Addition of 25 % 2RH compost to soil

T10. CONTROL (Top soil)

. The plastic pots used were 25 cm in diameter and 20 cm in height (Tsirogiannis, *et al*., 2010). *Zinnia elegans* seeds were nursed and transplanted three weeks later on. Watering was mostly done at two days' interval or when media conditions indicated the need for watering.

Experiment II was set up as a soilless experiment consisting of various compost or compost-biochar mixes subjected to two irrigation regimes. The experimental design was a 6 x 2 factorial arranged in completely randomized design with four replications. The first factor was compost or compost-biochar mixes at six levels; 2SS compost without biochar, 2RH compost without biochar, 2SS compost + 50 % rice husk biochar, 2SS compost + 66 % rice husk biochar 2RH compost + 50 % rice husk biochar, 2RH compost + 66 % rice husk biochar. The second factor was irrigation regimes at two levels; 0.1125 mm (half irrigation requirement per plant) and 0.2250 mm (full irrigation requirement per plant) according to Tsirogiannis, *et* *al*., (2010). All the pots were watered on the first day to volumetric moisture content to between 50 % and 60 %. Subsequently, the half (0.1125 mm water) and full (0.2250 mm water) irrigation regimes were applied per day until harvest. The treatments which were arranged in a completely randomized design with four replications were as follows:

1. 2SS compost + 0 % biochar with half irrigation ($2SS_{0char+half}$)
2. 2SS compost + 0 % biochar with full irrigation ($2SS_{0char+full}$)
3. 2SS compost + 50 % biochar with half irrigation ($2SS_{50char+half}$)
4. 2SS compost + 50 % biochar with full irrigation ($2SS_{50char+full}$)
5. 2SS compost + 66 % biochar with half irrigation ($2SS_{66char+half}$)
6. 2SS compost + 66 % biochar with full irrigation ($2SS_{66char+full}$)
7. 2RH compost + 0 % biochar with half irrigation ($2RH_{0char+half}$)
8. 2RH compost + 0 % biochar with full irrigation ($2RH_{0Char+full}$)
9. 2RH compost + 50 % biochar with half irrigation ($2RH_{50Char+half}$)
10. 2RH compost + 50 % biochar with full irrigation ($2RH_{50Char+full}$)
11. 2RH compost + 66 % biochar with half irrigation ($2RH_{66Char+half}$)
12. 2RH compost + 66 % biochar with full irrigation ($2RH_{66Char+full}$)

Data collection

For both experiment one and experiment two, data were collected on plant height (using a rule), number of leaves (by counting). and SPAD meter value (greenness by Minolta chlorophyll meter, SPAD-502), fresh and dry weights of biomass per plant (using an electronic balance). In addition, flower number (count), flower head diameter, flower stalk length (by meter rule) and flower head weight (by electronic balance) were measured.

Chemical analyses of feedstock, composts and soil

The physical and chemical composition of each of the feedstock, compost and soil samples were determined. Total N was determined using the Kjeldahl digestion method (Okelabo Gathua and Woomer, 1993). Organic C in soil was determined by the modified Walkley-Black Wet oxidation method as outlined by Nelson and Sommers (1982). Organic C in compost and feedstock was determined by the Complete Oxidation procedure adapted from Heanes, (1984). Phosphate, calcium potassium and magnesium were determined by the colorimetery method by Watanabe and Olsen, (1965). The concentrations of nutrients in compost and in soil samples (nitrate nitrogen, ammonia nitrogen) were determined using UV/VIS Spectrophotometer. Nitrate as nitrogen was determined by the Hydrazine Reduction Method (Cataldo *et al*., 1975). Ammonia as ammonia nitrogen was determined by the indophenol blue method (Koroleff, 1976). Lignin and cellulose were determined following the method by Van Soest, (1963). EC was determined by inserting the electrode of the EC meter into the compost sample suspension (Rowell, 1994). Crison Basic EC meter CM39P was used for the determination of EC. Crison

Data Analyses

Data on growth and flower quality of Zinnia were analysed using analysis of variance (ANOVA) with Gentstat version 9.2. Count data were square root transformed. Least significant difference (LSD) was used for mean separation at $p = 0.05$.

RESULTS

Growth and biomass of Zinnia in compost- soil mixes

The results of our experiment has shown that T6 produced the tallest zinnia plants of 34.9 cm ($p=0.003$), similar to those produced by T1, T2, T3, T5, T7 and T9 (Table 2). The Control produced the shortest plants of 23.1, which were similar to those produced by T4 and T8. Treatments 4 and 5 gave the highest SPAD values (36.47 % each) ($p=0.046$) which were similar to the SPAD value of other compost amended treatments whereas the control produced significantly lowest SPAD value. The T7 produced the highest fresh zinnia biomass of 15 g (p<0.00), similar to those produced by T1, T4 and T9. The control had the lowest fresh biomass of 1.65 g. The T6 produced the highest dry biomass of 6.12 g, (p=<0.001) similar to those produced by T2, T3, T5, T8 and T9. The control had significantly lowest dry biomass of 0.8 g.

Table 2. Effect of soil-compost mixes on growth and biomass of Zinnia

Treatments	Plant height (cm)	SPAD (%)	Fresh biomass (g)	Dry biomass (g)
T1	31.05	36.47	12.07	2.42
T2	34.50	34.87	8.99	5.30
T3	32.52	34.02	7.32	5.15
T4	27.22	31.77	8.64	3.20
T5	32.30	36.47	11.86	5.62
T6	34.95	35.80	13.67	6.12
T7	34.60	35.68	15.00	4.08
T8	28.40	33.97	10.57	5.35
T9	34.70	36.05	13.11	4.58
T10 (Control)	23.12	31.00	1.65	0.80
p-value	0.003	0.046	<0.001	<0.001
LSD (0.05)	5.765	3.693	4.441	1.7

T1= Addition of 50 % 2SS compost to soil; T2 = Addition of 33 % 2SS compost to soil; T3= Addition of 25 % 2SS compost to soil; T4 Addition of 50 % 2MS compost to soil; T5 = Addition of 33 % 2MS compost to soil; T6 = Addition of 25 % 2MS compost to soil; T7 = Addition of 50 % 2RH compost to soil; T8 = Addition of 33 % 2RH compost to soil; T9 = Addition of 25 % 2RH compost to soil; T10 (CONTROL) = Soil without amendment

Flower development in zinnia

There were no significant differences in flower number among the treatments. The T8 however, produced the widest (p=0.008) flower head diameter of 2.27 cm, similar to those produced by the other compost amended treatment, except T3 and the control which had significantly lower flower diameters of 1.07 and 0.3 cm, respectively (Table 4.13). The T5 produced significantly greatest flower head weight of 3.06 g, p=0.002, similar to those produced by T5 and T8. The control produced the lowest flower head weight of 0.41 g. The T2 produced the longest flower stalk length of 9.40 cm (p<0.001), similar to those produced by T3, T5, T6, T8 and T9. The control had the lowest flower stalk length of 0.5 cm (Table 3).

Table 3. Effect of soil-compost mixes on flower development of Zinnia

Treatments	Flower No.	Head diameter (cm)	Head weight (g)	Stalk length (cm)
T1	2.25	1.99	1.89	3.83
T2	1.50	1.38	1.75	9.40
T3	1.25	1.07	1.55	8.28
T4	2.50	1.76	1.56	5.25
T5	2.50	1.86	3.06	6.30
T6	2.75	2.06	2.68	7.85
T7	3.75	2.20	1.88	5.45
T8	2.50	2.27	2.33	7.35
T9	2.75	2.08	1.80	8.85
T10 (Control)	1.00	0.30	0.41	0.50
p-value	0.883	0.008	0.002	<0.001
LSD (0.05)	2.223	0.989	1.017	3.485

Growth and flower quality of Zinnia as influenced by soilless media and irrigation

The interaction effect of media and irrigation as well as the main effect of irrigation were not significant on growth and quality indices of zinnia. However, the main effect of media significantly (p=0.013) affected these parameters in zinnia (Table 4). The $2RH_{66Char}$ media produced significantly the tallest (39.2 cm) *Zinnia* plants, similar to those produced by $2SS_{50Char}$ and $2SS_{66Char}$. The $2RH_{0char}$ media produced the shortest zinnia plants of 23 cm. The $2SS_{0Char}$ and $2SS_{66Char}$ produced significantly the highest flower number of 4 each ($p<0.001$), similar to that produced by $2SS_{50Char}$. The $2RH_{50Char}$ produced plants with the least number of flowers (1.7/plant). The $2RH_{66Char}$ produced plants with the widest ($p=0.020$) flower head diameter of 4 cm, similar to those produced by $2RH_{0char}$, $2SS_{0Char}$ and $2SS_{50Char}$. The $2SS_{66Char}$ produced plants which had the least flower head diameter of 1.5 cm.

Fresh biomass was significantly highest (14.6 g; $p<0.001$) in $2SS_{0Char}$ media, which was similar to those produced by $2SS_{50Char}$ and $2SS_{66Char}$ (Table 4). Fresh biomass was lowest in $2RH_{66Char}$ plants. Dry biomass was significantly highest ($p<0.001$) in $2SS_{66Char}$, although similar to that produced by $2SS_{0Char}$. Plants produced with the $2RH_{0char}$ had the least dry biomass. Plants produced with T3The $2RH_{66Char}$ produced the longest flower stalk of 5 cm ($p=0.038$), similar to that produced by $2SS_{50Char}$. The $2RH_{50Char}$ plants had the shortest stalk length which was similar to $2SS_{66Char,}$ $2RH_{0char,}$ $2SS_{0Char}$ and $2SS_{50Char}$ (Table 4).

Table 4. Effect of compost-biochar ratio on growth & flower quality of *Z. elegans*

Treatments	Plant height (cm)	Flowers No.	Head diameter (cm)	Fresh biomass (g)	Dry biomass (g)	Stalk length (cm)
$2RH_{0char}$	23.00	2.10	2.51	5.38	0.83	3.01
$2RH_{50Char}$	29.20	1.80	2.10	7.28	0.93	2.81
$2RH_{66Char}$	39.20	1.70	4.00	4.02	1.22	5.96
$2SS_{0Char}$	29.00	4.00	2.38	14.65	1.98	3.12
$2SS_{50Char}$	35.90	3.00	3.99	11.32	1.50	4.41
$2SS_{66Char}$	32.60	4.00	1.51	10.61	2.15	2.82
p-value	0.013	<0.001	0.02	<0.001	<0.001	0.038
LSD (0.05)	8.86	1.109	1.65	4.302	0.5066	2.218

$2RH_{0char} =$ 2RH compost + 0 % biochar; $2RH_{50Char}$ = 2RH compost + 50 % biochar; $2RH_{66Char}$ = 2RH compost + 66 % biochar; $2SS_{0char}$ = 2SS compost + 0 % biochar; $2SS_{50char}$ = 2SS compost + 50 % biochar; $2SS_{66char}$ = 2SS compost + 66 % biochar

DISCUSSIONS

In compost amended soils for zinnia production, the $2MS_{25comp}$ was the best for zinnia growth and the $2MS_{50comp}$ was the worst for zinnia growth. However, addition of more compost in single species and rice husk compost led to increasing fresh and dry biomass, but did not affect plant height in the same way. In contrast, the increasing ratios of mixed sawdust compost led to increasing zinnia growth and biomass. Zinnia is known to be tolerant to higher EC and this could explain why lower ratios of single species and rice husk compost with relatively higher EC increased zinnia biomass (Carter and Grieve, 2010). With respect to zinnia as a cut flower, flower head diameter was highest in $2RH_{33comp.}$ In single species sawdust compost however, higher ratios led to smaller flower head diameter and lower flower head weight. In all 2SS, 2MS and 2RH based compost types used as amendment in the zinnia experiment, lower ratios of compost to soil resulted in shorter flower stalk which is a desirable quality attribute of good cut flower. Since the lower ratios of compost to soil contributed to higher EC than the higher ratios, the lower ratios can be used to suppress flower stalk length to improve cut flower quality without necessarily applying synthetic growth retardants (Carter and Grieve, 2010). In the soilless media, the $2RH_{66char}$ increased plant height and flower head diameter better than the other treatments but it also decreased flower number, fresh biomass and flower stalk length. The 2SS based compost increased flower number and fresh biomass better than the other treatments. The $2SS_{66Char}$ increased dry weight and stalk length but also resulted in decreased flower head diameter. In the rice husk compost-rice husk biochar soilless media, plant dry biomass increased with higher rates of biochar (or decreasing nutrient levels in compost with biochar), whereas flower number decreased with lower rates of biochar. This was in contrast to the finding of Kang and Van Iersel, (2004) who reported that dry biomass of Zinnia increased with increasing nutrient concentration in soilless media and also Zinnia flower diameter decreased with increasing nutrient concentration. These findings suggest that zinnia is less sensitive to EC and requires lower nutrient amounts; thus, it can be grown in compost with low nutrient and higher EC, which may not be suitable for plants species that require high amount of nutrients and are sensitive to EC. The growth and flower quality of zinnia as influenced by our treatments showed a huge potential for varying use of compost and biochar in soilless growing media. Biochar is carbon rich materials and compost is nitrogen rich material and the combined use of compost and biochar could optimize N and C balance in ways that can lead to better carbon sequestration in growing media (Steiner and Harttung. 2014). With reports of decreasing loamy soil availability in the urban areas for nursery production, compost use would have important application in urban horticulture (Abubakari et al., 2018). The use of soilless media can also help producers to avoid the problems associated with soils contaminated with weed seeds and soil-borne pathogens.

CONCLUSION

Soils amended with rice husk compost at 3:1 gave higher plant height and higher SPAD value. Soils amended with rice husk compost at a volumetric ratio of 1:1 gave more flowers and longer flower stalk length. The control treatment had significantly lower biomass compared to the amended soils. The 1:1 mixture of rice husk compost and topsoil promoted higher flower numbers but resulted in smaller flower diameter in zinnia. In soilless zinnia production, 1:2 sawdust compost-biochar combinations promoted higher plant height, shorter flower stalk, but reduced plant biomass. The findings of this study suggest that sawdust and rice husks which are currently seen as nuisance and causing significant disposal challenges to urban authorities can be developed into nutrient rich composts for urban greening and urban horticulture, especially for container production of ornamental plants.

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