Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 12 Article 6

Fall 2011

Comparison of growing media for container grown plants

Paul Harris
University of Arkansas, Fayetteville

David Longer
University of Arkansas, Fayetteville

Derrick Oosterhuis
University of Arkansas, Fayetteville

Dimitra Loka
University of Arkansas, Fayetteville

Comparison of growing media for container grown plants

Paul Harris*, David E. Longer†, Derrick Oosterhuis§, and Dimitra Loka‡

ABSTRACT

Greenhouse and growth chamber experiments are conducted worldwide in efforts to produce solutions that would increase yields of agronomic crops. However, the results of those experiments vary due to the many growth media being used. An experiment was conducted in the fall of 2010 to identify a broadly acceptable growth media that would produce uniform stands and optimum results in greenhouse and growth chamber settings. A total of six growth media were tested on cotton (*Gossypium hirsutum*) at the Arkansas Agricutural Research and Extension Center's Altheimer Lab in Fayetteville. The plants grown in each medium were harvested six weeks after planting and the measurements performed included plant height, plant dry matter, leaf area, and nutrient analysis. The results indicated that a positive, significant difference ($P < 0.05$) existed between "Sunshine" mix (MIX1) and the other media. Plants grown in MIX1 experienced greater plant height, dry matter, leaf area, and also experienced higher leaf tissue levels of N, P, and S. "Sunshine" (Mix1) is a readily available growth medium that produces optimum plant growth and uniform results in growth chamber and greenhouse experiments.

* Paul Harris is a 2011 graduate with a major in Crop Management.
† David Longer is a professor and faculty mentor in the Department of Crop, Soil, and Environmental Sciences.
§ Derrick Oosterhuis is a distinguished professor in the Department of Crop, Soil, and Environmental Sciences.
‡ Dimitra Loka is a graduate assistant under the tutelage of Dr. Derrick Oosterhuis.

MEET THE STUDENT-AUTHOR

Paul Harris

I am a native of Kennett, Mo., and a 2006 graduate of Kennett High School. After graduation, I began my education as an undergraduate student at the University of Arkansas. After three years of pursuing a degree in chemistry, I came to the realization that this particular area of study was not for me. Coming from a strong agricultural background with a passion for the agricultural industry, I made the decision to change my major to crop management in the department of crop, soil and environmental sciences (CSES), with a minor in pest management. After only a few classes, I realized that switching to agriculture was the right decision.

In the fall of 2010, I was given the opportunity to conduct experimental research under the direction of Dr. Derrick Oosterhuis, distinguished professor of cotton physiology and Dr. David Longer, professor of agronomy in the CSES department. In the spring of 2011, I was given the opportunity to conduct additional undergraduate research under the guidance of Dr. Jason Norsworthy an associate professor of weed science in the CSES department. Also, in 2011 I was selected for the Who's Who Among Students in American Universities and Colleges. I plan to graduate from the University of Arkansas in the fall of 2011, and I will pursue my career in agriculture with my wife Bethany, and her family at Wildy Family Farms in Manila, Ark.

I would like to thank Dr. Derrick Oosterhuis and Dr. David Longer for their guidance and assistance with this project and their ongoing support for my education.

INTRODUCTION

With the world's population on a steady increase, pressure has been placed on crop scientists from around the world. To date, much research has been directed to help keep up with the high demand for food. Whether the research focus is testing new cultivars with improved genetics, chemical treatments, or growth techniques, many experiments are performed in controlled environmental chambers. By controlling all environmental factors (temperature, water, humidity, nutrients, etc.) it is fairly simple to determine whether a particular treatment is affecting a plant's growth. However, although experimenters worldwide are able to set environmental factors at a constant value, the potting media often varies, making meaningful comparisons difficult. Corporate and academic researchers prefer a certain growth media that performs best in their laboratory. For example, agricultural researchers at Texas A&M University perform experiments using fritted clay as the growth medium. Researchers at Utah State University as well as the NASA research lab at the Kennedy Space Center use calcined clay, while University of Arkansas CSES personnel use a peat moss based media called "Sunshine" marketed by Sun Gro Horticulture Canada Ltd. (pers. comm. with Dr. D. Oosterhuis). With the growth medium varying across the world, problems arise when the results are analyzed because nearly identical experiments can vary and are unable to be compared due to the differing mediums used for plant growth. Soilless cultures, often used in greenhouse experiments, will present a different range of physical and hydrological properties compared with natural and agricultural soils (Casadesus et al., 2007); this may explain why soilless substrates have experienced a rapid expansion over the last decade (Raviv, et al., 2002). Thus, the desired uniformity between container cultures and between container and field cultures will continue to elude researchers if a universally reliable and accepted medium is not developed.

Growing media differ in many ways such as nutrient availability, water holding capacity, pH, bulk density, etc., and they all determine how certain plants grow in certain medium. Clays, for instance, are made up of very fine particles which decrease the pore size, available soil water and oxygen while increasing the pore space (Brady and Weil, 2009). The very fine particles of clay, according to Asli and Neumann (2009), may accumulate at the external root surfaces of transpiring plants, thereby reducing root hydraulic conductivity and plant availability of external water sources. Clayey soils are notoriously difficult to manage. The window of opportunity between too wet and sticky (gummy, adhesive) and dry and hard is short compared to loamy soils (Popp et al., 2003). However, expanded clays (natural clays heated at 1050 °C) contain large amounts of air because the porosity is increased after heating, and physical characteristics of the clays are unchanged after 5 years of intensive cropping (Raviv, et al., 2002), indicating sufficient soil consistency. Also, fritted clay, often referred to as "kitty litter," is a material that has been found suitable for growing experimental plants because it holds 31% by volume of plant-available water which is excellent for plant growth purposes (Van Bavel et al., 1978).

Sand cultures are often the opposite of clays in regards to agricultural soil physical and chemical properties. Sand particles are smaller than 2 mm but larger than 0.05 mm and primarily consist of quartz which means sands generally contain fewer plant nutrients (Brady and Weil, 2009). Because of sand's inability to hold water or nutrients, it is normally not the medium of choice by most agricultural researchers. However, sands can be used as a component of various growth media mixtures (Raviv et al., 2002). When working with a either a drought-tolerant plant or one sensitive to large amounts of water, a sand based-culture is the medium of choice because of the large particle size and resultant large pore spaces, which help to make water management easier.

Soilless media, sometimes called artificial soils, offer the plant several advantages. They are readily available, easy to handle, and produce uniform plant growth from year to year (Boodley and Sheldrake, 1977). Peat-based media usually contain large amounts of nutrients and other minerals supportive of plant growth and are known for high water-holding capacities. Peat mixes also contain methane-oxidizing bacteria that reduce methane emissions to the atmosphere and supply carbon dioxide for photosynthesis (Szafranek-Nakonieczna and Bennicelli, 2010). A different type of "soilless" media commonly used in laboratory experiments would be hydroponic solutions that date back to the mid 18th century (Jones Jr. and Benton, 1982). Hydroponics can be broadly defined as the practice of growing plants in a mineral nutrient solution without the presence of soil.

With the increasing demand for new crop growth technology, higher yields, and wise use of resources, comes the increasing demand for accurate and uniform agricultural experimental designs and comparable results. For convenience and cost savings, many experiments have been and will continue to be carried out in a climate-controlled setting and will involve container-grown plants. Those plants will be grown in media that vary in chemical and physical properties and will produce data that will also vary, no matter how similar the experiment. It is important that a growth medium not restrict plant growth to an artificially low level and bias the experimental results. Therefore, the objectives of this research were to define both the benefits and the disadvantages of various growth media and to find a broadly adaptable growth medium that will produce optimum and meaningful results while producing uniform stands, across media, in the greenhouse or growth chamber setting.

MATERIALS AND METHODS

Planting Materials and Growth Conditions. The experiment was conducted at the Arkansas Agricultural Research and Extension Center's Altheimer Laboratory, University of Arkansas, Fayetteville. The plant species chosen for this trial was cotton (*Gossypium hirsutum L.*), cultivar Stoneville 5288B2R. Six different plant media were chosen and included a Calloway silt loam soil from Marianna, Arkansas (SOIL and SOILH – Hoagland's solution added), sand with added nutrients (SAND), fritted clay (FC), calcined clay (CC), and two different peat moss-based media named "Sunshine Mix 1" (MIX1) and "Sunshine NB1" (NB1). Each medium was analyzed at the University of Arkansas Fayetteville Soil Testing Laboratory where the following chemical properties were measured: (1) Mehlich-3-extractable nutrients; (2) pH and electrical conductivity (EC); (3) total N and C. Mehlich-3-extractable P, K, Ca, Mg, Na, S, Fe, Mn, Zn, Cu and B were analyzed by SPECTRO CIROS ICP using a 1:10 soil to extractant (wt/vol.) ratio (Table 1). The pH was measured using a 1:2 soil to water (wt/vol.) ratio (Table 1).

Each treatment was replicated 10 times and placed in 1.5-L pots. Each pot was filled with a certain media approximately 2.5 cm from the upper rim of the pot. Five cotton seeds were planted in each pot about 2.5 cm below the surface of the media. All treatments were subjected to 14-hour photoperiods at a constant humidity of 60%. The plants were watered daily using 200 mL of deionized water per pot. At two weeks, the plants were thinned to one plant per pot. After thinning, the daily watering schedule consisted of watering on alternate days with 150 mL Hoagland's solution per pot and a onetime rinse with deionized water. Also, half of the pots containing field soil were watered daily with 200 mL deionized water only. Hoagland's solution was not added to these five pots so that observations could be taken on how the representative field soil would compare to the other media under more field related circumstances. This treatment, designated as "SOIL" was set as the experimental control.

Measurements and Data Analysis. At six weeks after planting, plant height (cm), the number of nodes, leaf area (cm^2), plant dry weight (g), leaf symptoms of deficiencies/toxicities and nutrient analysis of the leaves were determined. Plant height was measured from the base of the plant at the soil surface to the apical meristem. Leaf area was calculated using a LICOR Leaf Area Analyzer (LI-COR Biosciences, Lincoln, Neb.). Harvested plant biomass was placed in a forced-air oven at 60 °C for 72 h to remove moisture and then weighed to determine plant dry weight. Leaf tissue nutrient analysis was performed by the University of Arkansas-Fayetteville Soil Testing Laboratory. A statistical analysis of the six growth media treatments, with 10 replications, was conducted using JMP software, version 9.1 (SAS Institute; Cary, N.C.). Analysis of variance and conventional LSD ($\alpha = 0.05$) post hoc analysis were used to compare significance between mean values. The main effects of growth media on plant growth factors were separated by LSD comparisons of the treatment means at the ($P < 0.05$) level.

RESULTS AND DISCUSSION

Plant Height. Significant treatment differences existed in plant height (Table 2). The greatest average plant height was found in MIX 1 and averaged 29.55 cm. In addition, MIX 1 contained the highest concentrations of nutrients (Table 1) while still existing in the cotton-preferred pH range of 6-7 (Table 1). The FC medium also consisted of relatively high levels of most nutrients while resulting in the smallest average plant height. Short plant height may have been due to the pH level of 8.68, which is considered by most to be too high for cotton. Also, the electrical conductivity level of 22,200 umhos/cm (Table 1) indicates high salinity. Growth and yield of cotton are severely inhibited in salinity levels higher than 10,000 umhos/cm at the germination and emergence stages (Ashraf, 2002). In regards to the two field-based soil media referred to as SOIL and SOILH, addition of Hoagland's solution (SOILH) significantly increased plant height by nearly 2.5 cm (Table 2).

Nodes Per Plant. In comparison with plant height, the number of nodes per plant experienced a similar ranking, however with fewer significant differences among media (Table 2). The MIX 1 medium contained plants with the greatest plant node number, averaging 9.3 nodes per plant. The NB1 medium and the two field soil media (SOIL and SOILH) had 7.5 nodes per plant average and were not significantly different from one another. The fewest nodes per plant was 5.3 and occurred when using FC growth medium.

Leaf Area. In addition to the greatest leaf dry matter (Table 3), the MIX1 treatment had the highest leaf area with an average of 730.5 cm² (Table 2). This is likely due to the higher levels of nutrients contained in MIX1 in comparison with the other types of media (Table 1). The next largest average leaf area was 470.05 cm² belonging to the plants in SOILH; however, leaf area was not significantly different than NB1 with an average leaf area of 454.29 cm². Similar to previous data, leaf area was significantly smaller in FC than for plants growing in other media (Table 2).

Plant Dry Matter. The MIX 1 medium and the field soil that received Hoagland's (SOILH) had the largest total plant dry matter respectively and were not significantly different from one another (Table 3). Plants in SOILH and MIX 1 were significantly different from the plants in other mixes in terms of stem dry matter, but they were not significantly different from each other. Plants in SOILH and MIX1 were significantly different in leaf dry matter. The two clay media, FC and CC, exhibited the lowest total dry matter (Table 3).

Nutrient Analysis. The data (Table 4) showed that the greatest uptake and retention of N occurred with MIX 1 and CC and were not significantly different from one another. The MIX 1 medium also featured the highest levels of P. The water retention capacity of these two media may have contributed to higher plant nutrient uptake because water films in the soil support nutrient transport from soil solids to plant roots. The plants in MIX1 and CC media contained the highest percent N with no significant difference (Table 4). As expected, SOIL contained the lowest percent N due to the absence of Hoagland's solution. Plants grown in MIX1 possessed the highest percentage of both P and S and were not significantly different from NB1; and both were significantly higher than all other mixes except CC in terms of S levels. The FC medium contained a significantly lower percent P than the other media, but the cause for this is unknown. It should be noted that FC had an extremely high value for electrical conductivity, but no cause and effect relationship seemed apparent. The CC plants possessed the highest percentages of Mg and K and these were significantly greater than the nutrient levels found in the other media (Table 4).

In addition to macronutrients, micronutrient analysis was also performed (Table 5). Not only did plants grown in CC contain the highest concentrations of Mg and K, but they also contained the largest amounts of Fe, Mn, and B. However, CC plants contained the lowest amounts of Cu and a relatively low amount of Zn compared to MIX1 plants, which contained at least 32% more Zn than the other media. As expected from the soil test, plants grown in FC contained the largest amount of Na. The high Na concentration may be one reason why plants were negatively affected by the FC treatment in terms of plant height, plant dry matter, and leaf area. High amounts of Na in media solution can be detrimental to plants. The damage of salinity to plants is mainly caused by Na ion accumulation which alters ion transfer across cell membranes and can be toxic to non-halophytes (Wu et al., 2004).

Overall, leaf-based nutrient analysis of the plants grown in MIX1 points to a positive treatment influence on the plants nutrient uptake and the plant growth parameters tested. Plants grown in MIX1 were significantly greater in leaf dry matter than plants grown in the other media. In stem dry matter, the MIX 1 grown plants were not significantly different than plants grown in SOILH, but greater than all the other growth mediums. Total plant dry matter was highest in the MIX1 and SOILH media, which did not differ from one another (Table 3). In addition to MIX1, NB1 ranked second in percent P, K and S which could result from peat-based media water holding capacities, nutrient retention and reduced leaching. Due to the water-holding capacity and rewetting ability of calcined clay, CC plants contained high percentages of nutrients. Rewetting ability refers to how rapidly a root medium absorbs water, and thus reaches its potential for maximum available water-holding capacity, with minimal leaching (Argo and Fisher, 2007). Calcined clay or vermiculite can be added to a root medium to increase rewetting because both absorb and distribute water independently of their moisture content prior to water being applied (Argo and Fisher, 2007). However, the physical plant growth properties of CC showed negative, significant differences when compared with MIX1 or SOILH. In addition to the plant growth properties found in CC, FC also produced plants that were significantly lower in height, dry matter, and leaf area.

Our research showed that MIX1 produced plants that attained greater aboveground biomass and leaf area along with improved plant nutrient uptake as evidenced by improved levels of overall plant nutrition (Fig. 1). Also, peat-based media such as MIX1 may require less water than other media because of the retentive nature of peat, but we did not test this. All other media, besides MIX1, demonstrated some level of restricted plant growth. For future research involving plant growth media, it is important to understand that limiting the growth of the plants because of the growth media used, could possibly mask any positive effects caused by the treatment. The MIX1 medium is an economical, available medium that is ideal for producing uniform cotton seedlings in greenhouse and growth chamber settings. Additional research should focus on similar studies conducted with other plant species.

ACKNOWLEDGEMENTS

I would like to extend my appreciation to Dr. David E. Longer, Professor of Agronomy, University of Arkansas-Fayetteville and Dr. Derrick Oosterhuis, Distinguished Professor of Cotton Physiology, University of Arkansas-Fayetteville for the financial support and opportunity to perform this project. Also, I would like to thank Dimitra Loka, a graduate student under the tutelage of Dr. Oosterhuis, who assisted in maintaining this experiment as well as performing statistical analysis of the data at the experiment's conclusion.

LITERATURE CITED

Argo, B. and P. Fisher (2007). Improving rewetting. Greenhouse Grower Magazine. Mar., p. 112-116.

Ashraf, M. (2002). Salt tolerance of cotton: some new advances. Critical Reviews in Plant Sci. 21 (2002):1–32.

Asli, S. and P. M. Neumann (2009). Colloidal suspensions of clay or titanium dioxide nanoparticles can inhibit leaf growth and transpiration via physical effects on root water transport. Plant Cell Environ. 32:577-584.

Boodley, J.W. and R. Sheldrake Jr. (1977). Cornell "Peat-Lite Mixes" for commercial plant growing. Cornell Cooperative Extension Publication. p. 1-7.

Brady, N.C. and R.R. Weil (2008). The Nature and Properties of Soil. 14th ed. Upper Saddle River, New Jersey: Pearson Education, p. 123-125.

Casadesus, J., O. Marfa and R. Caaceras (2007). Dynamics of CO_2 efflux from the substate root system of container-grown plants associated with irrigation cycles. Plant Soil. 300.1-2:71-82.

Herrera, F., J.E. Castillo, R.J. Lopez-Bellido, and L. Lopez-Bellido (2009). Replacement of a peat-lite medium with municipal solid waste compost for growing melon (*Cucumis melo L.*) transplant seeds., Compost Sci. Utiliz. 17.1 (2009):31-39.

Jones Jr., H., J. Benton (1982). Hydroponics: its history and use in plant nutrition studies. J. Plant Nutr., 5.8:1003-1030.

Popp, M. P., P.M. Manning, L.R. Oliver, T.C. Keisling, P.C. Counce, and E.C. Gordon (2003). Analysis of a novel bedded planting system for dry clay soil management of full-season and double-crop soybeans. Comm. Soil Sci. Plant. Analysis., 34.19:2925-2950.

Raviv, M., R. Wallach, A. Silber, and A. Bar-Tal (2002). Hydroponic productions of vegetables and ornamentals. Athens, Greece: Embryo Publications, p. 25-101.

Siri-Prieto, G., D.W. Reeves, J.N. Shaw, and C.C. Mitchell (2006). World's oldest cotton experiment: relationships between soil chemical and physical properties and apparent electrical conductivity. Comm. Soil Sci. Plant Analysis. 37:767-786.

Szafranek-Nakonieczna, A. and R.P. Bennicelli (2010). Ability of peat soil to oxidize methane and affect temperature and layer deposition. Polish J. Environ. Studies. 19.4:805-810.

Van Bavel C.H.M., R. Lascano, and D.R. Wilson (1978). Water relations of fritted clay. Soil Sci. Soc. Amer. J., 42:657–659.

Wu, Chang-Ai, G.D. Yang, Q.W. Meng and C.C. Zheng (2004). The cotton *GhNHX1* gene encoding a novel putative tonoplast Na+/H+ antiporter plays an important role in salt stress. Plant Cell Physiol. 45:600-607.

Table 1. Standard soil test analysis of plant nutrient levels found in selected plant growth media. pH levels and electrical conductivity levels are also presented.

Media Types[a]	pH	EC	…………					mg/kg	…………				
		(μmhos/cm)	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
FC	8.68	22200	7.5	754	7389	823	527.6	4253.5	132.8	26.2	6.5	1.1	1.9
CC	6.52	81	40.5	839	449	372	25.7	47.6	113.3	5.5	1.5	0.4	2.2
SAND	10.24	128	<0.6	26	405	26	16	15	70.6	7.8	0.9	0.3	0.2
MIX1	6.58	582	309.7	1232	8188	3078	729	308.2	247.2	21	11.7	2.5	1.4
NB1	7.02	312	8.9	209	7654	3209	835.2	206.2	203.4	9.4	3.9	1	0.4
SOIL	7.1	142	74.5	248	1310	313	24.9	23.5	259.7	138	2.2	2.1	0.3

[a]Abbreviations for media types are: FC (Fritted clay), CC (Calcined clay), SAND (sand with nutrients added), MIX 1 ("Sunshine" commercial peat mix), NB1 (commercial peat mix), SOIL (Calloway silt loam soil), and SOIL H (Calloway silt loam soil with Hoagland's nutrient solution).

Table 2. Mean physical properties of cotton plants grown in different plant growth media.

Media[1]	Plant Height (cm)	# of Nodes	Leaf Area (cm²)
MIX1	29.55 a[2]	9.33 a	730.5 a
NB1	25.96 b	7.66 b	454.29 b
SOILH	22.42 c	7.8 b	470.05 b
SOIL	19.94 d	7.2 bc	290.64 c
SAND	19.63 d	6.5 cd	277.44 c
CC	18.15 de	6.33 d	251.66 c
FC	16.96 e	5.33 e	200.95 d

[1] Abbreviations for media types are: MIX 1 ("Sunshine" commercial peat mix), NB1 (commercial peat mix), SOIL H (Calloway silt loam soil with Hoagland's nutrient solution), SOIL (Calloway silt loam soil), SAND (sand with nutrients added), CC (Calcined clay), FC (Fritted clay).

[2] Means in the same column with the same letter are not significantly different at the 0.05 alpha level.

Table 3. Mean plant dry matter components of cotton plants grown in different plant growth media.

Media[1]	Leaf Dry Matter (g)	Stem Dry Matter (g)	Total Dry Matter (g)
MIX1	2.99 a[2]	1.53 a	4.52 a
NB1	2.16 c	1.22 b	3.38 b
SOILH	2.51 b	1.62 a	4.13 a
SOIL	1.80 d	1.13 b	2.93 b
SAND	1.42 e	0.81 c	2.23 c
CC	1.14 e	0.56 d	1.70 d
FC	1.29 e	0.52 d	1.81 cd

[1] Abbreviations for media types are: MIX 1 ("Sunshine" commercial peat mix), NB1 (commercial peat mix), SOIL H (Calloway silt loam soil with Hoagland's nutrient solution), SOIL (Calloway silt loam soil), SAND (sand with nutrients added), CC (Calcined clay), FC (Fritted clay).

[2] Means in the same column with the same letter are not significantly different at the 0.05 alpha level.

Table 4. Plant macronutrient leaf tissue analyses from plants grown in different plant growth media.

Media[1]	N	P	K	Ca	Mg	S
MIX1	5.63 a[2]	0.81 a	3.34 b	3.17 bc	1.18 b	1.18 a
NB1	4.51 b	0.63 b	3.29 b	3.15 bc	1.30 b	1.12 ab
SOILH	4.62 b	0.34 c	2.15 c	2.65 d	0.70 c	0.83 c
SOIL	2.57 c	0.22 d	1.49 d	2.61 d	0.59 c	0.38 d
SAND	4.25 b	0.20 d	2.99 b	3.43 b	0.67 c	0.83 c
CC	5.50 a	0.34 c	4.38 a	2.89 cd	1.58 a	1.04 b
FC	4.39 b	0.13 e	1.78 cd	4.17 a	0.57 c	0.85 c

[1] Abbreviations for media types are: MIX 1 ("Sunshine" commercial peat mix), NB1 (commercial peat mix), SOIL H (Calloway silt loam soil with Hoagland's nutrient solution), SOIL (Calloway silt loam soil), SAND (sand with nutrients added), CC (Calcined clay), FC (Fritted clay).

[2] Means in the same column with the same letter are not significantly different at the 0.05 alpha level.

Table 5. Plant micronutrient tissue analysis from plants grown in different plant growth media.

Media[1]	Na	Fe	Mn	Zn	Cu	B
MIX1	374 c[2]	105 c	6 e	51.8 a	2.9 c	59.5 c
NB1	545 b	128 b	4 e	20.6 c	1.1 e	42.6 de
SOILH	312 c	97 c	19 e	20.1 c	4.9 b	36.5 e
SOIL	189 d	62 d	51 d	11.6 d	3.6 c	47.6 d
SAND	582 b	106 c	162 b	35.3 b	5.7 a	62.8 c
FC	795 a	99 c	86 c	6.5 e	2.6 d	72.7 b
CC	755 a	183 a	266 a	12.8 d	1.1 e	97.6 a

[1] Abbreviations for media types are: MIX 1 ("Sunshine" commercial peat mix), NB1 (commercial peat mix), SOIL H (Calloway silt loam soil with Hoagland's nutrient solution), SOIL (Calloway silt loam soil), AND (sand with nutrients added), CC (Calcined clay), FC (Fritted clay).

[2] Means in the same column with the same letter are not significantly different at the 0.05 alpha level.

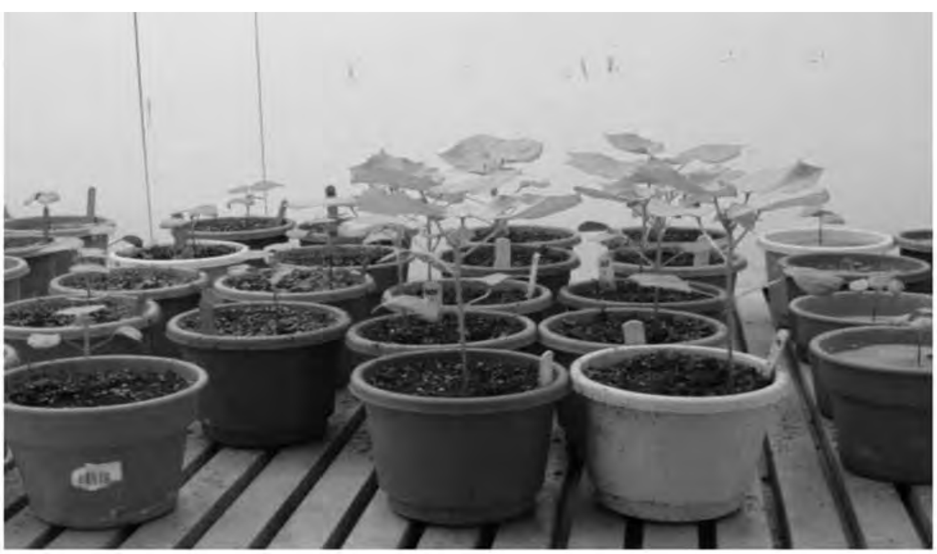

Fig. 1. The difference of physical properties and appearance of plants grown in NB1 (left) and MIX1 (right).