Int. J. Curr. Res. Biosci. Plant Biol. 2015, 2(8): 1-6

EXCELLENT PUBLISHERS

International Journal of Current Research in Biosciences and Plant Biology

ISSN: 2349-8080 Volume 2 Number 8 (August-2015) pp. 1-6

www.ijcrbp.com

Original Research Article

Evaluation of Coal Rubble and Pine Bark Media Mixture on Germination and Growth of Tomato (*Solanum lycopersicon* L.) Seedlings

Clyde Shereni, Wendy Mutsa Chiota* and Tsvakai Mushayabasa

Department of Horticulture, Faculty of Natural Resources Management and Agriculture, Midlands State University, Gweru, Zimbabwe

**Corresponding author.*

Abstract

The main objective of the study was to determine the effect of coal rubble and pine bark media mixtures on germination and growth of tomato (*Solanum lycopersicon* L.) seedlings. The experiment was laid out in a Randomised Complete Block Design with six treatments replicated four times. Treatments consisted of varying combinations of pine bark and coal rubble with the control being 100% pine bark. Data collected included germination percentage, numbers of leaves, stem diameter, stem height and root length. Study results indicated that media combinations had a significant effect ($p< 0.05$) on germination percentage at 14 and 21 days after sowing (DAS). Root length, stem diameter, stem height were significantly ($p<0.05$) affected by combinations of pine bark and coal rubble. Growing media combinations significantly improved number of leaves on seedlings at 35 DAS. Conclusions drawn from this study show that blending pine bark and coal rubble media results in a media mixture of superior quality as evidenced by the positive emergence and growth of tomato seedlings. From the results of this study it is recommended that 60% pine bark + 40% coal rubble can be used on greenhouse tomato seedling production.

Keywords

Coal rubble

Growth

Media mixture

Pine bark

Seedling quality

Tomato

Introduction

Tomato (*Solanum lycopersicon* L.) is the second most important crop next to potatoes (FAO, 2011). Tomatoes are consumed raw, cooked or processed. In Zimbabwe tomatoes are not only cultivated commercially but are also commonly grown by subsistence and resource poor farmers. Tomato seeds generally germinate or emerge within 4 to 7 days; seedlings should from 2.5 to 5.0 cm tall with large cotyledons at 2 weeks (VanZile, 2009).

There are two common seedlings production systems used in tomatoes, the conventional system and the float system. The conventional method is the most commonly used especially by resource poor farmers. This involves suspending growing trays on benches, tables, ground and other structural components (Wyatt, 2004). The float system consists of placing growing trays that float on a nutrient-fortified water solution. The trays will have 72 to 200 cells and are kept in the solution until they reach the desired

transplanting height (Rutledge and Wills, 2011). An ideal growing media should not only supply physical, chemical and biological characteristics required by plants but also provide the conditions for practical plant production (e.g. easy to supply, suitable cost, easy processing, lightness and homogenous plant production) (Ingram et al., 2003). The quality of seedlings attained from a nursery influences re-establishment success in the field (Baiyeri, 2006).

Use of suitable growing media or substrates is important for production of quality horticultural crops. It directly affects the development and later maintenance of the extensive functional rooting system (Adad et al., 2002). Pine bark is debarked from pine logs (*Pinus radiata* L.) prior to processing into red timber and it is usually free from woody stuff and cambium. It has been used in many seedling productions as a potting medium and floating tray especially in tobacco seedlings. Coal rubble is a substrate for hydroponic media currently being used in seedling production. Coal rubble is collected from the tobacco barns after coal is burnt as a source of heat energy during tobacco leaf curing (Masaka et al., 2007).

Coal rubble can be added in media combinations to perform the functions of sand particles in media mixtures. Coal rubble is inert, sterile and neutral in pH and also adds weight just like sand particles (Pasian, 2003).Soil less substrates are a suitable replacement for soil based substrates because materials used have, when mixed in the right quantities, optimal chemical and physical properties for plant growth and development (Mazarura, 2013). According to Mazarura and Asher (2011), effective float tray seedling production depends to a greater extent on the physical and chemical characteristics of the substrate or substrate blend used. The aim of this study is to evaluate the effects of varying combinations of coal rubble and pine bark on the germination and growth of tomato seedlings.

Materials and methods

Study site

The study was conducted at Pedstock Investments in Harare, Zimbabwe in a greenhouse. The site is located in natural region IIa at coordinates of 17° 45' 25" South and 31° 4' 28" East. The minimum temperature is 17^{o}C and maximum is 26^{o}C.

Experimental design

The experiment was laid out in Randomised Complete Block Design with six treatments (Table 1) replicated four times. The treatments were blocked against temperature in the greenhouse.

The constituents of the growing media mix were composted pine bark and coal rubble collected from tobacco barns after coal was burnt during tobacco leaf curing. Coal rubble was crushed with a builder's rammer and passed through a 4 mm sieve. Coal rubble particles were washed thoroughly with water to remove excess ash. The samples of coal rubble and pine bark were analysed for pH and Electric Conductivity (EC). The prepared pine bark and coal rubble components were thoroughly mixed to generate six media combinations (Table 1).

Table 1. Summary of treatments of media mixture used in the study.

Treatments	Media mixtures
T1 (positive control)	100% Pine Bark
T2	80% Pine Bark + 20% Coal Rubble
T3	60% Pine Bark + 40% Coal Rubble
T4	40% Pine Bark + 60% Coal Rubble
T5	20% Pine Bark + 80% Coal Rubble
T6 (negative control)	100% Coal Rubble

Two hundred cell Styrofoam trays were used in the experiment. The trays were filled with media and holes were made in the middle of the cell and Star 9009 tomato certified seed was sown. The trays were randomly placed on the table 1 m above the ground surface. Micro jets were used for irrigation and nutrient supply (fertigation). The fertigation solution was applied when the seedlings produced the first true leaves. The solution constitute of Quick start fertiliser (10%: 46%: 10% NPK respectively). Application rates were 250 mg L^{-1} of water, split into three application rates of 50 mg L^{-1}. The solution was applied up to 35 days after sowing.

Data collection

Seedling emergence was obtained by counting the number of seeds that emerged from the Styrofoam trays and was expressed as a percentage of the total seedlings. The number of true leaves was obtained from counting the number of true or functional leaves from day 21 to

35 with a seven day interval. After five weeks, seedling height was obtained by measuring the stem from just above the root crown up to the part where the heart of the plant is with a ruler, stem diameter was measured using a veneer calliper just above the root crown and was measured. Root length was measured with a 15 cm ruler; the roots were washed with water to remove the growing media. Transplantable seedlings were obtained from counting the number of seedlings with a good transplantable height, stems and number of leaves after five weeks.

Data analysis

Data was subjected to one way analysis of variance (ANOVA), using Genstat 14th edition. Separation of means was done using Least Square Design (LSD) at 5% significance level.

Results and discussion

Effect of pine bark and coal rubble media mixtures on tomato seedling germination

At 14 days after sowing (DAS), germination percentages significantly differed with varying media mixtures (p<0.001). The 60% pine bark and 40% coal rubble media mixture recorded the highest seedling emergence of 86.75% and the 100% coal rubble treatment recorded the lowest germination percentage of 56.25. The remaining treatments had the following germination percentages: 100% pine bark (78.25) > 80% pine bark and 20% coal rubble (75) > 40% pine bark and 60% coal rubble (70) > 20% pine bark and 80% coal rubble (66.75). At 21 DAS germination percentages significantly differed with varying media mixtures (p<0.001) with the 60% pine bark and 40% coal rubble treatment having the highest germination percentage of 95.00 and the 100% coal rubble treatment having the lowest germination percentage of 71.75. The germination percentages for the remaining treatments were in the order: 100% pine bark (93.00) > 80% pine bark and 20% coal rubble (87.50) > 40% pine bark and 60% coal rubble (85.50) > 20% pine bark and 80% coal rubble (76.50).

At 14 and 21 DAS germination percentage generally increased as quantities of coal rubble decreased in the media mixtures from 100% coal rubble to 60% pine bark and 40% coal rubble (Table 2). Results from this study are in line with work by Masaka and Ndidzano (2008) and Mazarura (2013), where results in germination decreased with an increase in coal rubble proportions in the media mixture.

Table 2. Effect of pine bark and coal rubble media mixtures on germination percentages of tomato seedlings.

Treatments	Germination percentage (%)		
	7 DAS	14 DAS	21 DAS
100% pine bark	53.50^{bc}	78.25^{c}	93.00^{e}
80% pine bark + 20% coal rubble	53.00^{bc}	75.00^{c}	87.50^{d}
60% pine bark + 40% coal rubble	54.75^{c}	86.75^{d}	95.00^{f}
40% pine bark + 60% coal rubble	51.75^{abc}	70.00^{b}	85.50^{c}
20% pine bark + 80% coal rubble	51.75^{abc}	66.75^{b}	76.50^{b}
100% coal rubble	50.25^{a}	56.25^{a}	71.75^{a}
Grand mean	52.50	72.17	84.88
L.S.D	3.16	4.00	1.72
F-test prob	0.1	<0.001	<0.001
CV (%)	4.0	3.7	1.3

*Treatment means followed by the same letter are not significantly different.

Masaka and Ndidzano (2008) reported the lowest seedling emergence being observed in 100% coal rubble and this conforms to the findings of the current study. The trend in the treatment effects on germination percentage done by Masaka and Ndidzano (2008), where 50% pine bark and 50% coal rubble; and 60% pine bark and 40% coal rubble recorded the highest seed germination. This observation is consistent with that found in this study where the 60% pine bark and 40% coal rubble media mixture resulted in highest tomato seedling germination at 14 and 21 DAS. Mazarura (2013) reported similar results where a mix having 0 to 50% coal rubble mixed with pine bark was optimum for germination as water holding porosity was positively

correlated to germination. This suggests that coal has an unfavourable effect on water holding porosity in mixtures with more than 50% coal rubble resulting in lower germination percentages.

It was also observed that at 100% pine bark and 80% pine bark and 20% coal rubble (having least coal rubble in the media composition) germination percentages were lower than in the 60% pine bark and 40% coal rubble mixture (Table 2) at both 14 and 21 DAS. This is probably as a result of poor drainage in media mixtures high pine bark constituents. According to Van Schoor et al. (1990) when small pine bark particles are used as a growing medium, water is held in the bark and drainage is poor.

Effect of pine bark and coal rubble media mixtures on number of leaves on tomato seedlings

At 21 and 28 DAS the various media mixtures showed no significant difference (p=0.116 and p=0.147 respectively) (Table 3) on the number of leaves on seedlings. Significant differences in number of leaves (p<0.001) were observed at 35 DAS. Highest number of leaves was observed in the 60% pine bark to 40% coal rubble mixture (1.04) however it was not significantly different from the 100% pine bark (1.01). The lowest number of leaves (0.87) was noted in the 80% pine bark to 20% coal rubble mixture. In between the highest and lowest leaf numbers were 100% pine bark (1.01) > 100% coal rubble (0.99) > 20% pine bark to 80% coal rubble (0.94) > 40% pine bark to 60% coal rubble (0.90). Highest number of leaves in the 60% pine bark and 40% coal rubble are likely to have resulted from the contribution of the media constituents in these proportions in comparison to the rest. Mupondi et al. (2006) reported pine bark as having a good nutrient holding capacity due to its chemical makeup and the contribution of coal rubble is to add air to the media mix. These findings are similar to those of Blom (1993) where blending different media produces optimum physical and chemical conditions for plant growth.

Table 3. Effect of pine bark and coal rubble media mixtures on number of leaves on tomato seedlings.

Treatments	Number of leaves		
	21 days	28 days	35 days
100% pine bark	0.697^{b}	0.808^{ab}	1.010^{cd}
80% pine bark + 20% coal rubble	0.599^{a}	0.759^{a}	0.873^{a}
60% pine bark + 40% coal rubble	0.626^{ab}	0.860^{b}	1.041^{d}
40% pine bark + 60% coal rubble	0.653^{ab}	0.777^{a}	0.899^{a}
20% pine bark + 80% coal rubble	0.653^{ab}	0.795^{ab}	0.940^{ab}
100% coal rubble	0.675^{b}	0.795^{ab}	0.986^{bcd}
Grand mean	0.651	0.799	0.958
L.S.D	0.071	0.075	0.069
F-test prob	0.116	0.147	<0.001
CV (%)	7.3	6.2	4.8

*Treatment means followed by the same letter are not significantly different.

Effect of pine bark and coal rubble mixtures on stem height, stem diameter and root length.

Significant differences (p<0.01) were observed in stem height in the various media combinations. The 100% pine bark stem height differed significantly from the 80% pine bark treatment. The 100% pine barks having the longest stem length (15.27cm) and the 80% pine bark and 20% coal rubble treatment having the shortest stem length (11.15cm) (Table 4). While the 100% pine bark had the longest stem height it did not differ significantly from the 100%coal rubble treatment (Table 4). Findings of the study do not show a clear trend on effects of media composition on stem height (Table 5). However the 60% pine bark and 40% coal rubble media blend had the highest stem length following the 100% pine bark treatment. These findings can be allied to findings by Blom (1993) reporting different seedling growing media constituents generates physical and chemical components that are intermediate between qualities of the components. Therefore varying media combinations will offer various benefits in seedling growth.

Stem diameter significantly differed (p< 0.01) with various media combinations. The 100% pine bark

treatment had the thickest stem diameter (0.95cm) while the 100% coal rubble had the thinnest stem diameter (0.82cm) (Table 4). However no clear pattern of media composition and stem diameter could be established (Table 4). These results are in line with work done by Nabi et al. (2002) where best stem diameter in tomato plants grown in an array of growing media was observed in pine bark compost. Among a number of desired traits, pine bark provides good drainage and aeration within the media mix as a result of its granular particles with some bark fragments containing 45% porosity (Barnard et al., 1996).

Table 4. Effect of pine bark and coal rubble media mixtures on stem height, stem girth and root length of tomato seedlings.

Treatments	Stem height(cm)	Stem diameter (cm)	Root length (cm)
100% pine bark	15.27^{c}	0.95^{c}	13.68^{f}
80% pine bark + 20% coal rubble	11.15^{a}	0.87^{b}	11.20^{bcdef}
60% pine bark + 40% coal rubble	14.55^{bc}	0.91^{bc}	12.68^{ef}
40% pine bark + 60% coal rubble	13.40^{b}	0.92^{bc}	12.40^{cdef}
20% pine bark + 80% coal rubble	13.70^{b}	0.94^{c}	12.48^{def}
100% coal rubble	14.25^{bc}	0.82^{a}	9.18^{a}
Grand mean	13.72	0.90	11.93
L.S.D	1.39	0.04	1.67
F-test prob.	<0.001	<0.001	<0.001
CV (%)	6.7	3.2	9.3
*Treatment means followed by the same letter are not significantly different.			

Root length significantly differed ($p< 0.01$) in the 100% coal rubble treatment in comparison to all other treatments containing pine bark. The 100% coal rubble treatment had the shortest root length (9.18 cm) while the 100% pine bark treatment had the longest root length of (13.68 cm) (Table 4). The remaining treatments were in the order 60% coal rubble (12.68 cm)> 20% coal rubble (12.48 cm) > 40% coal rubble (12.40 cm) and 80% coal rubble (11.20). These findings suggest that an increase in pine bark in the media mixture results in longer root lengths in tomato seedlings. Similar results were reported by Masaka et al. (2007) and Mazarura (2013) where increasing the pine bark proportion (thus reducing coal rubble) in media mixtures resulted in higher spiral rooting in tobacco seedlings.

Conclusion

From the results of this study it can be concluded that the 60% pine bark and 40% coal rubble media mixture is an effective blend for successful germination and growth of greenhouse tomatoes grown under the float tray system. This is evidenced by the above 90% germination suggesting that the overall conditions affecting emergence were optimal. It terms of growth the 60% pine bark and 40% coal rubble had the highest number of leaves. Stem diameter, stem height and root lengths were higher than those of 100% coal rubble and compared well with the 100% pine bark treatment.

Acknowledgement

The authors would like to acknowledge Pedstock Investments, Zimbabwe, for providing the facilities and the material for the study.

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