

**Effects of pine bark amended with goat manure as tomato (*Solanum lycopersicon L*)
seedlings growing media using the float system.**

By

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Abstract

Pine bark is locally available in Zimbabwe and is widely in vegetable seedling production. However, it lacks essential nutrients for seedling growth. Goat manure was used to supplement nutrients when pine bark is used as growing media. The main object of the study was to determine the effect of pine bark amended with goat manure on tomato seedling emergence and seedling quality parameter which were stem diameter and stem length. The study was carried out at the Tobacco Research Board which is located 15 kilometers East of Harare at an altitude of latitude $17^{\circ} 55'$ S and longitude $31^{\circ} 08'$ E. The experiment was laid out in a 3 X 3 Factorial in a Completely Randomized Design with three replicates. The experiment had nine treatments with three different growing media which were un-amended pine bark, pine bark amended with goat manure and pine bark amended with Calcium carbonate (CaCO_3). It also had three fertilizer rates which were 0 ppm, 75 ppm and 150 ppm float fertilizer. Results from this study showed that the different media and fertilizer combinations had a significant effect ($P < 0.05$) on seedling emergence, stem diameter and stem length. From the results pine bark amended with goat manure significantly increase seedling emergence, stem diameter and stem length compared to un-amended pine bark and pine bark amended with CaCO_3 . A combination of pine bark amended with goat manure and 75 ppm float fertilizer had a significantly high emergence percentage, stem length and stem diameter compared to other media and fertilizer combinations.

Dedication

This project is dedicated to my parents Mr and Mrs Madziwa.

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I would like to express my most profound gratitude to God Almighty who have guided and strengthened me through this study. I am hugely indebted to my research supervisors, Ms W. Chiota, Mr C. Koga, Dr D. Rukuni, Dr L.T Mupondi and my lecturers for their selfless and untiring support and guidance. I appreciate that, their co-operation and courage was enough to inspire me towards this study. Most of all, I wish to thank my family for always standing by my side and to my father's soul whom I loved so much.

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CHAPTER ONE: INTRODUCTION

In Zimbabwe, horticulture contributes about 3–3.5% to the gross domestic product (Nyamupingidza and Machakaire, 2003). Tomato (*Solanum lycopersicon*. L) is the most grown horticultural crop which forms a vital component of the diets, proving essential nutrients in raw or relish recipes. Production and marketing of the crop provides occupation and income for many people (Saunyama and Knapp, 2009). It is also one of the most important vegetable crops grown throughout the world owing to its high nutritive value and diversified use (Esfahani, 2009). Tomato production is however associated with a number of diseases in the seedbed.

Tomato plants require a liberal supply of water. However, overwatering will encourage development of diseases. Diseases like, *Fusarium wilt*, *Rhizoctonia* dumping off, bacterial diseases and pests like nematodes and termites are devastating to the vulnerable seedlings (Brooke *et al.*, 2006). Conventionally, these diseases have been curbed through soil fumigation with methyl bromide (Mazarura, 2004).

Methyl bromide however has been banned because of its ability to deplete the ozone layer, contaminating water bodies and having a residual effect in the soil (Zasada *et al.*, 2010). A number of useful chemicals are also being banned because of the environmental effects they have. As a result yearly losses in vegetable production are attributed to less-than-ideal weather conditions, soil-borne diseases and high incidence of pests. Among the alternative agricultural systems, the float system appears to be a popular and acceptable solution for production under conditions of space restrictions or unavailability of soil and reduce incidences of soil borne diseases (Santos and Ocampo, 2005).

The float tray system involves the use of floating trays filled with a suitable growing media such as composted pine bark. It has been used extensively and successfully to raise *Nicotiana Tabacum* seedlings and infrequently vegetable seedlings (Rideout, 2004). Seedlings produced this way have a uniform growth and adequate nutrient storage for good crop establishment after transplanting. Advantages of the float system include reduce soil borne disease, reduced labour costs, reduce input and chemical use, reduced wetting of plant foliage thus reducing diseases, more efficient use of water and nutrients and also eliminates leaching of nutrients to ground water (Hajer *et al.*, 2006).

1.1 Justification

Pre-composted pine bark is commonly used as growing media in Zimbabwe for *Nicotiana Tabacum* float seedling production because it is well drained, well-aerated and light weight (Mazarura, 2004). Pine bark is however acidic with a pH between 4 and 4.5 and requires liming to a pH of 5.5 (Mazarura, 2004). It also lacks essential nutrients required for seedling growth and hence forth requires fortification (Mupondi *et al.*, 2010). Calcium carbonate has been used to amend pine bark but this has resulted in very high amounts of fertilizer used.

Tomato seedling production however requires good nutrition but the fertilizers currently being used in the float system are expensive and have been associated with problems such as salt injury (Zhang *et al.*, 2006). In a quest to find cost-effective ways of fortifying pine bark, in a tray suspended-system, Mupondi *et al.*,(2010) observed that amendments of pine bark with goat manure is promising in crop production. This study therefore seeks to evaluate the suitability of goat manure amended pine bark as seedling growing media for tomatoes in float tray seedling production system.

1.2 OBJECTIVES

1.3 Main Objective

To evaluate suitability of goat manure as a pine bark amendment for tomato seedling production under the float system.

1.4 Specific Objectives

1. To determine the effect of pine bark amended with goat manure on tomato seedlings emergence.
2. To determine the effect of goat manure as pine bark amendment on tomato seedling stem diameter.
3. To determine the effect of pine bark amended with goat manure on stem length of tomato seedlings.

1.5 Hypotheses

H₁: Pine bark amended with goat manure has a significant effect on tomato seedling emergence using float system.

H₁: Pine bark amended with goat manure significantly improves tomato seedling stem diameter grown under the float system.

H₁: Pine bark amended with goat manure has a significant effect on stem length of tomato seedlings grown using the float system.

CHAPTER TWO: LITERATURE REVIEW

2.1 Biology of tomatoes

Tomato is a vegetable which belong to the genus *Lycopersicon* of the *Solanaceae* family (Tanni *et al.*, 2010). It is native to Peru in South America where it used to grow wildly and was consumed by local people until then, latter spread to Central America primarily by migrating birds (Singh, 2004). It then became a cultivated vegetable in Central America and Europe. Tomato is now the most important warm season fruit vegetable grown throughout the world. It is the second most grown crop after potatoes and is edible and usually grown for commercial use (Mehdizadeh *et al.*, 2013). Cultivated tomatoes are tender to cold but are very tolerant to extremely hot or dry weather. The vegetable is consumed in various ways, as element in many dishes and drinks (Varela *et al.*, 2001).

2.2 Nutrition of tomatoes

Tomato is a vegetable which is sometimes considered a fruit. It is popular for its diversified use as well as its nutritional value (Tanni *et al.*, 2010). Tomatoes can be described as diverse in terms of their colour, flavor, use and nutrients (Psota, 2014). They can be red, green, orange or purple in colour. Tomatoes have a wide range of use, they can be eaten as boiled, roasted or baked (Nakia *et al.*, 2005). Tomatoes add flavor in meals as well as supplying nutrients to the body. Tomatoes contain 94 to 95 % water and 5 to 6 % is constituted by inorganic compound, ascorbic acid, pectin among others (Kalibbala, 2011), Tomatoes are a major source of Vitamin A, vitamin C, carotenoids, potassium, thiamin, vitamin B6, lycopene and good source of dietary fibers (Visioli *et al.*, 2009). Vitamin A is a fat which is good for eye sight as well as cell development and vitamin C which plays a vital role in mineral absorption as well as cellular functions. In addition tomatoes contain lycopene which help prevent prostate and breast cancer.

2.3 Tomato production in Zimbabwe

Zimbabwe's economy is dominated by agriculture with horticulture contributing about 3–3.5% to the gross domestic product (Nyamupingidza and Machakaire, 2003). Tomato is the most popular vegetable grown throughout the country. It is grown by both small holder and large scale farmers for its edible fruits both for export and local consumption. Tomato provides income to about 75% of the country's 13 million populations (Nyamupingidza and Machakaire 2003).

2.4 Tomato seedling production system

Two methods can be used in tomato seedling production. These methods are the conventional or soil culture and the float system also known as the soilless culture (Gonzales *et al.*, 2010). The conventional system involves growing of tomato seedlings in a soil plot whereas the float system is a soilless system where plant roots grown in different growing media such as artificial soil mixtures, pine bark, sand, sawdust, and vermiculite among others (Awad, 2010).

2.4.1 The conventional system

This method involves growing tomatoes using soil as the growing media. However, this method is associated with a number of soil borne pests and pathogens which include *Phytophthora capsici* and *Fusarium oxysporum* as well as diseases like, *Fusarium wilt*, *Rhizoctonia* (dumping off) and pests like nematodes and termites are devastating to the vulnerable seedlings (Gleason and Edmund, 2006). Several methods such as crop rotation, resistant varieties, fallowing and chemicals have been used to manage these soil borne pests and pathogen. Chemical method is widely used in commercial production. Diseases have been curbed through soil fumigation with methyl bromide. Methyl bromide however has been banned because of its ability to deplete the ozone layer, contaminating water bodies and having a residual effect in the soil (Zasada *et al.*, 2010). A number of useful chemicals are also being banned because of the adverse

environmental effects they have. As a result yearly losses in vegetable production are as a result of less-than-ideal weather conditions, soil-borne diseases and pests' occurrence (Santos and Ocampo, 2005). Among the alternative agricultural systems, the float system appears to be a popular and acceptable solution for production under conditions of space restrictions or unavailability of soil there by eliminating problems of soil borne diseases (Santos and Ocampo, 2005).

2.4.2 The float system

Briefly the float system involves constructing shallow ponds using bricks on greenhouse floors. The bricks are covered with plastic sheeting which will be filled with a nutrient solution to a depth of 10 cm (Rideout, 2004). The seed is then sown into polystyrene cell trays which can easily float on the nutrient solution. No irrigation is requires such both nutrients and water move by capillary movement to the seedling root zone.

The float system is now the most applicable method of raising seedlings without the risk of nematodes that caused serious economic damage to tobacco seedlings (Mazarura, 2004). Rideout and Overstreet (2003) states that, tomato seedlings can be raised successfully using the float system. Also tomato seedling production using the conventional method requires a lot or labour. The float system is less labour intensive and has been adopted as an alternative to the conventional method. It also eliminates a number of diseases such as septoria leaf spot which are caused by wetting foliar. Use of this technology improves plant growth and productivity. The system has been used extensively in tobacco seedlings production but is infrequently used in vegetable seedling production such as tomatoes (Rideout, 2004).

Tomato is a fast growing vegetable and requires a lot of water during early growing phase. The float system ensures continuous water supply to the seedling and reduces abscisic acid synthesis caused by water stress which results in a reduction of shoot: root ratio (Leskovar, 1992). At vegetative phase, water is required for the plant to produce and accumulate a lot of reducing sugars which will be used in fruit development as well as vegetative growth. Sinha *et al.*, (2004) states that it takes a considerable amount of water to convert sunlight into energy for tomatoes to produce branches and blossom.

2.5 Seedling growth

Tomato seedlings grow very well in growing media with a pH between 6.0 and 6.5. The seed should be sown to a depth of 3mm. This will help seed absorb adequate moisture for the germination process. Germination starts from as early as 5 up to 10 days after sowing. The required temperature for germination is 21 to 27 °C. At 5 days after sowing, the seed would have imbibed adequate water for initiation of the germination process. The seed will then sprout with the seed coat still attached and this is accompanied by development of radicle from which roots develop followed by plumule which will later develop into the shoot (Walls, 1982). The hypocotyl of the seed elongates while carrying the cotyledon above the growing media surface. The plumule grows on a bent shape which is called epigeal germination. At 7 days after sowing cotyledon leaves appears followed by development of true leaves. Photosynthesis starts just after leaf formation and growth proceeds. Vanzile, (2009) states that tomato seed germination is delayed by low temperatures and is accelerated by high temperatures. A temperature of 18 °C is then required during the growth phase.

2.6 Types of growing media

2.6.1 Composted pine bark

Composted pine bark is commonly used in Zimbabwe for vegetable float seedling production due to its availability locally, good physical properties and low cost. It is obtained from the Eastern Highlands of the country. It will be pre-composted for at least 4 years before use. Pine bark has physical properties which are different to those of other growing media such as sand, peat and vermiculite. Its chemical properties also differ from those of mineral soils (Tucker, 1995). Pine bark have physical and chemical properties which include a low water holding capacity and low nutrient availability as a result amendments with other growing media and organic matter is essential (Harrelson *et al.*, 2004). Also these different chemical and physical properties influence the amount of lime and fertilizers which are needed for optimum seedling growth (Tucker, 1995). However pine bark is well drained, well-aerated and light weight (Mazarura, 2004). Though it contains some minor elements required for plant growth (Gartner and Williams, (1977) in Mupondi *et al.*, 2006), pine bark has a high nutrient holding capacity due to its chemical makeup.

Pine bark has nutrient retention sites which contain the organic fractions (R-COO-H) (Tucker, 1995). Tucker (1995) states that, these R-COO-H sites hold positively charged ions which include magnesium, potassium and calcium and repel negatively charged specifically phosphates ions (H_2PO_4^- and HPO_4^{2-}). As a result phosphate ions are unavailable to seedlings growing in pine bark medium thereby affecting seedling growth as metabolic reactions such as photosynthesis and respiration will be hindered. In addition, phosphorus unavailability will result

in an increase in amounts of fertilizers needed in seedling production. Pine bark is however acidic with a pH between 4 and 4.5, have low electrical conductivity and requires liming to a pH of 5.5 (Mazarura, 2004). Calcium carbonate (CaCO_3) has been used to increase pH in pine bark but very high amounts of fertilizers are required. Pine bark also lacks essential nutrients required for seedling growth and hence forth requires fortification (Mupondi *et al.*, 2010). Fertilizers currently being used in the float system are expensive and have been associated with problems such as salt injury and there are no float fertilizer recommendations in tomato float seedling production.

2.7 Advantages of amendments

Amending a growing media with another component such as organic manure can result in physical and chemical properties which are intermediate between properties of the combined components (Masaka *et al.*, 2007). In a study by Ryszard and Marcin (2010), an addition of wool to different growing media from mixes with composts and other organic amendments improved air filled porosity and water holding capacity and improved production of pepper and tomato seedlings. Health seedlings are produced when different growing media are fertilized through use of amendments together with fertilizers that adds essential nutrients such as nitrogen, potassium and phosphorus to optimize seedling growth (Ngouajia and Bierabaum, 2011). Use of these amendments can also reduce amounts of fertilizers used hence reducing seedling production cost.

2.8 Fertilizer use

The use of fertilizer implies to supplementing the natural nutrient supply of the growing media. This is important for seedling development stages and establishment after transplanting. Without essential elements such as N, P and K the seedlings will not survive (Wolfe and Kipps, 2004).

2.8.1 Role of nitrogen

Tomatoes are heavy nitrogen feeders though they cannot supply it on their own. Nitrogen is the most needed nutrient compared to other nutrients in seedling production. It is absorbed in its inorganic form and these include as ammonium (NH_4), nitrates (NO_3^-) and also as amino (NH_2^+). Nitrogen uptake is influenced by anaerobic and aerobic conditions. Under anaerobic conditions, tomatoes take up nitrogen in form of nitrates and as ammonia ions under anaerobic conditions (Tolanur, 2004). Tomato seedlings require nitrogen for synthesis of amino acids, chlorophyll, proteins, coenzymes and nucleic acids. Nitrogen enables seedlings to produce a good leaf and stem development (Wolfe and Kipps, 2004). Nitrogen is important for a number of processes therefore it should be available in growing media for growth of the seedlings. Oversupply of nitrogen in tomato seedlings will result in very thin stems with dark green soft leaves. Yellowing of older leaves and a very slow growth rate indicate nitrogen deficiency. Brown, (2011) concludes that, nitrogen and phosphorus ensures seedling growth.

2.8.2 Role of phosphorus

Phosphorus is available to plant in two forms which are inorganic phosphorus and organic phosphorus. Very high amount of available phosphorus are in inorganic forms, organic phosphorus is available to plants in the form of phospholipids and nucleic acids (Tolanur, 2004). Phosphorus is absorbed by plants in ionic forms which are the H_2PO_4^- and HPO_4^- . The availability of these ionic forms of phosphorus is depended on pH, ions are available at pH below 7.22 while HPO_4^- ions dominates at pH above 7.22 (Brady, 1980). Under acidic soils or media mixes can combine with ions such as iron, aluminium, magnesium and calcium resulting in phosphorus forming insoluble phosphate compounds making it unavailable to plants (Walls, 1982). Tomatoes requires phosphorus for strong root development and to build disease resistance

during early growing stages. Phosphorus is also used in all metabolism processes in a tomato seedling and these processes include photosynthesis and respiration. It is also used in metabolic transfer processes of Adenosine triphosphate (ATP) and Adenosine diphosphate (ADP). Besford (2009) states that, phosphorus is an immobile nutrient which should be applied directly to plant roots. A deficiency in tomato seedlings is associated with thin fibrous stems with a dull purple discoloration. Also any shortage of phosphorus especially during the seedling growth stage will result in reduced crop growth and nutrient uptake and affects the crop establishment after transplanting (Wyatt, 2004).

2.8.3 Role of potassium

Tomato seedlings take up potassium in solution as potassium oxide (K_2O). Potassium helps promote growth and improves disease resistance in tomato seedlings. According to Grubinger, (2012) potassium promotes growth and should be applied at planting. In tomatoes seedling potassium is responsible for transport of sugars, stomata control thereby controlling photosynthesis as well as transporting cofactor of many enzymes. It is also used in carbohydrate metabolism and also promotes water use efficiency in tomato seedlings as it regulates transpiration rate by stomata. Potassium also delay senescence of seedling leaves thereby promoting canopy cover for photosynthesis. Deficiency symptoms are mainly on leaves, they will have a bronzance with orange and yellow patches with woody stems.

2.9 Goat manure

Different livestock manure is being used throughout the world as this reduces amounts of fertilizer used thereby promoting organic agriculture which does not contaminate the environment. These organic manures have several advantages over inorganic manure. These organic manures are cheap as no processing is required, they environmentally friendly, protect

health of humans as well as the ecosystem. Many studies on manure use have only focused on yield response of most vegetables and field crops but very little effort have been done in relating these yield responses with nutrient availability (Maerere *et al.*, 2001).

Brady *et al.*, (1980) states that organic manure have a functional R-OH group which react with the hydrogen ions (H^+) in the soil thereby reducing acidity in the soil. Also organic manure form composts can improve the biological, physical and chemical properties of the amended soil or growing media (Ghorbani *et al.*, 2008). This was supported by a study carried out by Mupondi *et al* (2010), such pine bark physical properties as air filled porosity; water holding capacity and pH were enhanced when pine bark was composted with goat manure. According to Kalibbali, (2011) using different sources of organic manure reflected that a higher level of available phosphorus in poultry manure influenced tomato plant growth. Goat manure contains 0.65% nitrogen, 0.5% phosphorus and 0.03% potassium (Tolanur, 2004).

Small holder farmers in Zimbabwe mainly use cattle and goat manure is used as soil fertility amendments (Wuta *et al.*, 2012). Goats form an integral component in agriculture, in Zimbabwe goat population is 4.7 million and 97% of these goats is owned by smallholder farmers (Kusina and Kusina, 2001). Goat manure is locally available in Zimbabwe and often underutilized. In a study by Mupondi *et al.*, (2006) concluded that goat manure contain desirable nutrients required in vegetable seedlings production when composted with pine bark. Use of goat manure for vegetable seedlings was also supported by Tiamiyu *et al.*, (2012) where different sources of organic manure were used in okra production and obtained impressive results. In addition in a study carried out by Khaple *et al.*, (2012), different manure sources including vermin compost, goat manure and pig manure were used to raise *Grevillae robusta* seedlings. Results from this study showed that goat manure increased seedling height by 307% as well as stem diameter.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study site

The trial was carried out in a greenhouse at Tobacco Research Board which is located 15 km east of Harare at latitude 17° 55`S and longitude 31° 08`E with an altitude of 1479 m above sea level.

3.2 Growth media

Pine bark which was used in this study was obtained from the Eastern Highlands of Zimbabwe. It was composted for at least 4 years before use. Three different growing media were used in this study (Table 1).

Table 1: Pine bark amendments of the 3 different growing media

Different growing media used	Amendment ratio
Pine bark amended with goat manure	1:3 (pine bark: goat manure)
Un-amended pine bark	Nil (pine bark)
Pine bark amended with calcium carbonate	1:50 (pine bark: calcium carbonate)

Dry samples of the three different media were ground to less than 1 millimeter and parameters such as electrical conductivity, pH, available nutrients, and water holding capacity and air filled porosity were determined as shown overleaf:

Table 2: Chemical analysis of the three different growing media

Pine bark	pH											
	(CaCl ₂)	EC ds/ m	CEC mmole/ kg	WHC %	AFP %	N mg/k g	H ₂ PO ₄ ⁻ mg/kg	Mg meq/100 g	Na mg/k g	K mg/k g	Fe pp m	Zn ppm
Un-amended	4.00	1.3	495	53.9	15	110	33.6	2.26	200	345	3.0	0.5
with CaCO ₃	6.08	1.0	580	53.9	15	245	66.0	7.06	315	345	2.7	0.6
with goat manure	6.78	0.9	830	65.8	20	950	132	7.24	438	2013	2.5	0.6

1.5.1 Methods used to determine the chemical properties

A 1 kilo gram (kg) sample was taken from the three different growing media. Media pH was measured using the Potentiometer method. Each growing media had a sample of 20grams of the growing media which was mixed with 50mililiters of distilled water. The suspension was stirred intermittently for 30 minutes and continuously for 10 minutes. A neutral solution of Calcium Chloride was added to the suspension to decrease the pH values. pH was then measured using a pH meter electrode which was first dipped in distilled water to calibrate it. When the calibration was satisfactory, the electrode was rinsed in distilled water and latter inserted in the media suspension and the pH reading was recorded.

Soluble salts concentration was determined by measuring electrical conductivity of the media water extracts. 20gram sample was mixed with 50mililiters of distilled water. The suspension was mixed intermittently for 30 minutes and was allowed to settle for an hour when a

supernatant solution was formed. The solution was then filtered using a filter paper and the electrical conductivity of the filtrate was measured using the electrical conductivity bridge.

Available Nitrogen in the growing media was determined using alkaline Potassium Permanganate method. 20 grams samples of the different growing media were air dried and sieved through a 2mm sieve in a Kjeldhal flask. 20 milliliters of distilled water were added to the flask to moisten the soil. 1 milliliter of liquid paraffin was also added to avoid frothing. 100 milliliters of 0.32% KMnO_4 was also added followed by addition of 100 milliliters of 2.5% sodium hydroxide (NaOH) to oxidize the organic matter in the different growing media. The mixture in the flask was then distilled and the nitrogen ions were collected in a flask containing Boric acid mixed with an indicator. Titration of the distillate (green) was done until the colour changed to pink.

Available phosphorus was determined using the Olsen's method. 2.5 grams of media was weighed and put in a 250ml conical flask. 0.5 grams of Dacro-G-60 which are phosphorus free was added to the flask. 50 milliliters of sodium bicarbonate was also added to the flask and the mixture was shaken in a mechanical shaker for 30 minutes. Filtering of the solution was done after 30 minutes; a 50 milliliter volumetric flask was then used to pipette 5 milliliters of the filtrate. 5 milliliters of chloromolybdic acid solution was added to the filtrate, which was then shaken for 5 minutes. After shaking, 1 milliliter of stannous chloride working solution was added and shaken again. The intensity of the blue colour read after 10 minutes. The concentrations of phosphorus were then determined using the standard curve.

Available potassium was determined using the flame photometry. 50 milliliters of 1.0N neutral ammonium acetate solution was added to 10 grams of air dried soil in a conical flask and shaken

for 10 minutes. The growing media suspension was filtered through a What-man number 40 filter paper afterwards the suspension was leached with the addition 50 milliliters of ammonium acetate. The standard of potassium ions were fed to the flame photometry and the readings were recorded as well as drawing the standard curve of photometer readings against the different concentrations. After drawing the standard curve, the ammonia acetate extract was fed to the flame photometer. The available potassium ions were then recorded.

The standard versenate method was used to determine exchangeable magnesium in the growing media. 50 milliliters of 1N neutral ammonium acetate was added to 10 grams of air dried soil in a 250 milliliter conical flask. The suspension was filtered using a filter paper and latter leached with the addition of 50 milliliters of ammonium acetate. The cations in the leachate were determined in mill equivalents per 100 gram of soil.

Micronutrients such as zinc and iron were extracted using Diethylene triamine penta acetic acid (DTPA). DTPA combines with free metal ions in medium solution forming soluble complexes. A medium suspension was made from 20gram air dried soil and 40 milliliters of DTPA. The suspension was shaken on a horizontal mechanical shaker for 2 hours. The mixture was filtered using a What-man number 50 filter paper. A cathode lamp was then used to read the cations in the filtrate using the standards in atomic absorption spectrophotometer.

3.3 Fertilizers used in the study

Kutsaga float fertilizer was used in this study (Table 3.3), it is a liquid fertilizer used in tobacco seedlings production. It contains the following mineral compositions in percentage:

Table 3: Mineral compositions for Kutsaga float fertilizer

Nutrient	Percentage
Nitrogen	4.5%
Phosphorus	2.1%
Potash	4.7%
Calcium	0.05%
Magnesium	0.1%
Sulphur	7.5%
Boron	0.04%
Copper	0.03%
Iron	0.09%
Manganese	0.05%
Zinc	0.01%

3.4 Experimental design used in the study

The trial was laid out in a 3 x 3 factorial in a completely randomized design with 3 factors of different growing media compositions and 3 fertilizer levels replicated 3 times. The growing media were pine bark amended with goat manure, pine bark amended with CaCO₃ and un-amended pine bark. The fertilizer rates of 0, 75, and 150 ppm were applied to the different

treatments. The fertilizer treatments were randomized within each plot and the experiment was replicated 3 times.

3.5 Treatments

Table 4: Treatments combinations used in the study

Treatment	Media combinations	Fertilizer rate
1	Pine bark amended with goat manure	0 ppm
2	Pine bark amended with goat manure	75 ppm
3	Pine bark amended with goat manure	150 ppm
4	Un-amended pine bark	0 ppm
5	Un-amended pine bark	75 ppm
6	Un-amended pine bark	150 ppm
7	Pine bark amended with CaCO ₃	0 ppm
8	Pine bark amended with CaCO ₃	75 ppm
9	Pine bark amended with CaCO ₃	150 ppm

3.6 Seed material

Tomato, Moneymaker variety was used in this study. The tomato seeds were obtained from East West Seeds International (Zimbabwe).

3.7 Procedure

Tomato seeds were sown using the float tray system. 27, 242 cell polystyrene trays were filled by hand with three different growing media which were un-amended pine bark, pine bark amended with CaCO_3 at a ratio 1: 50 and pine bark amended with goat manure at 1:3 ratios. Sowing was done with each cell of the tray containing one seed and was left uncovered. The trays were then floated in three tray ponds (1.05m x 0.675m) with a water depth of 10 cm. Fertilizer treatments of 0 ppm, 75 ppm and 150 ppm were applied at sowing.

Weekly sprays with Copper oxychloride and dithane M 45 were done to prevent fungal infections on the tomato seedlings. Good sanitation was practiced in the greenhouse to prevent disease occurrence. Practices included a foot bath at the green house entrance, washing hands before entering the green house. Green house day and night temperatures were maintained at 20 °C and 28 °C respectively.

3.8 Data collection

Emergence and survival counts were done at 7 days after sowing. With newly emerged shoots recorded up to 21 days after sowing. Seedlings were considered as emerged when there was protrusion of the radical. The emergence percentage of the seedlings was later determined at 28 days after sowing.

At 28 days after sowing, seedlings from the 50 center cells for each treatment were pulled for sampling. Data collection involved calculating the pullable seedling percentage, measuring stem length and stem diameter. Stem diameter was measured using a veneer caliper and stem length was measured using a meter rule.

3.9 Data Analysis

Data on seedling emergence and pullable percentages were transformed using the square root method. This was done because the data did not normally distributed. The data on stem diameter and stem length as well as transformed data on seedling emergence was subjected to analysis of variance using Genstat statistical package, 14th edition. Means were separated using Duncan's multiple range at 5% significance level.

CHAPTER FOUR: RESULTS

4.1 Tomato seedling emergence percentage at 28 after sowing

At 28 days after sowing, fertilizer and media interaction showed a significant effect ($P < 0.001$) on tomato seedling emergence. Pine bark amended with goat manure had a significantly high seedling emergence (95% average) compared to un-amended pine bark and pine bark amended with CaCO_3 . Pine bark amended with goat manure and 75 ppm fertilizer showed the highest emergence percentage of 97% compared to other treatments (Fig 4.1). Un-amended pine bark and 0 ppm fertilizer showed the lowest emergence percentage of 70%.

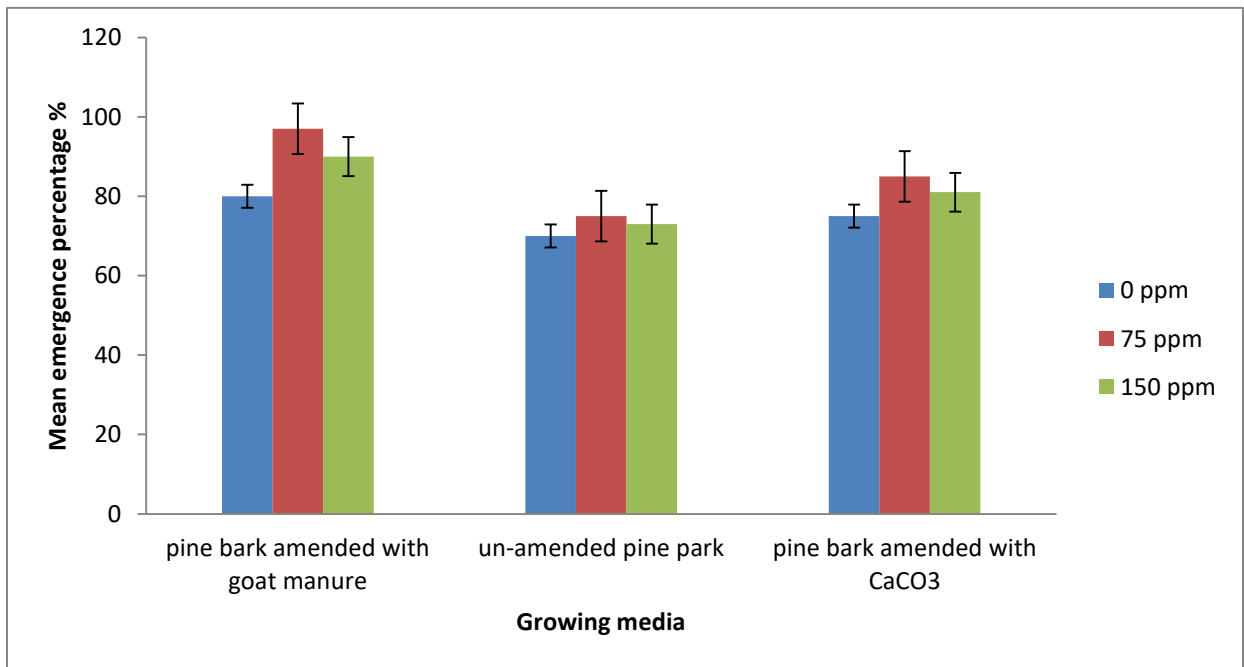


Figure 1: Effects of media and fertilizer combinations on seedling emergence at 28 days after sowing

4.2 Effects of different growing media and fertilizer combinations on stem diameter

There was a significant interaction ($P < .001$) between fertilizer and media on stem diameter (Fig 4.2). Pine bark amended with goat manure had a significantly high stem diameter compared to un-amended pine bark and pine bark amended with CaCO_3 . When no fertilizer was added, un-amended pine bark and 0 ppm float fertilizer had a significantly lower stem diameter while there were significant differences in pine bark amended with goat manure and pine bark amended with CaCO_3 . When 75 ppm float fertilizer was added, un-amended pine bark had a significantly low stem diameter compared to the other two different growing media; however there were no significant differences between pine bark amended with goat manure and CaCO_3 . Pine bark amended with goat manure and 75 ppm float fertilizer had the greatest stem diameter of 0.53 mm followed by pine bark amended with CaCO_3 and 75 ppm float fertilizer which had 0.44 mm while a treatment with un-amended pine bark with no fertilizer had the least stem diameters of 0.14 mm.

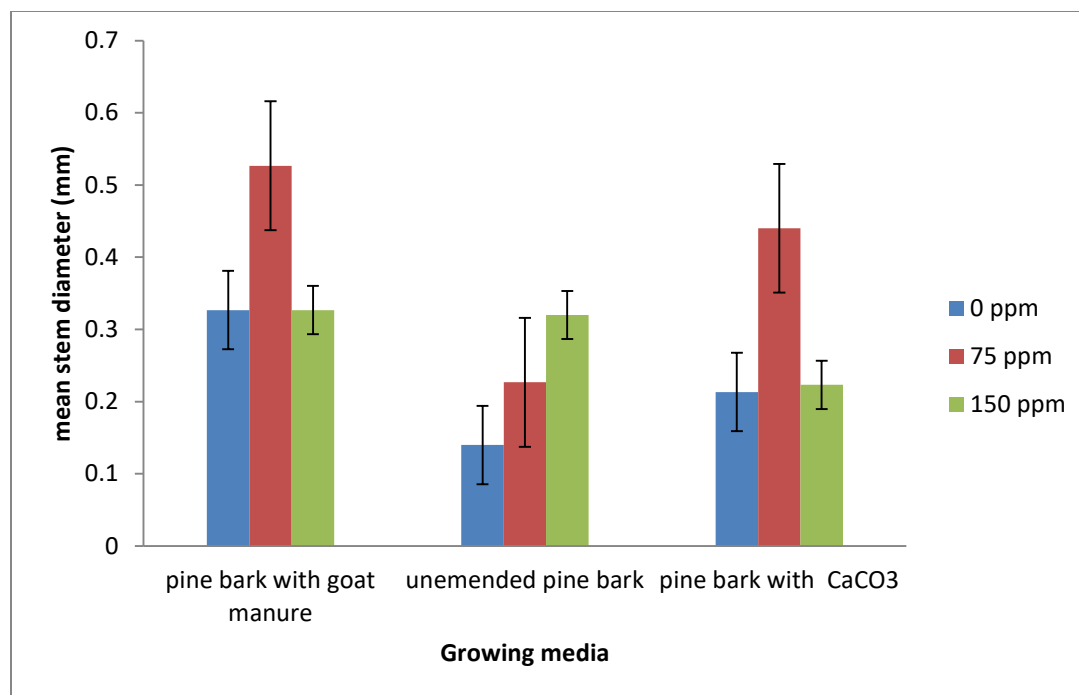


Figure 2: Effects of media and fertilizer combinations on stem diameter

4.3 Effects of different growing media and fertilizer combinations on stem length

There were no interactions ($P < .001$) on the different media and fertilizers used however media and fertilizer significantly increased stem length (Fig 2). Un-amended pine bark had a significantly lower stem length and there were no significant differences between pine bark amended with goat manure and pine bark amended with CaCO_3 . 150 ppm float fertilizer also obtained significantly high stem length of 21.19 cm while there were no significant differences when 0 ppm and 75 ppm float fertilizers were added to the different growing media.

Table 6: Effects of media and fertilizer rates on seedling stem length

Media type	Mean stem length (cm)
Unamended pine bark	8.40 ^a
Pine bark amended with CaCO₃	13.83 ^b
Pine bark amended with goat manure	18.62 ^b
Grand mean	13.38
CV	18.4
P Value	<.001
LSD	3.37

Fertilizer rate	Mean stem length (cm)
0 ppm	9.80 ^a
75 ppm	13.18 ^a
150 ppm	19.19 ^b
Grand mean	13.38
CV	18.4
P Value	<.001
LSD	3.37

Means with the same letter(s) are not significantly different from each other

CHAPTER FIVE: DISCUSSION

5.1 Effect of goat manure on seedling emergence

Pine bark amended with goat manure had a significantly high emergence percentage compared to un-amended pine bark and pine bark amended with CaCO_3 . When no float fertilizer was added, pine bark amended with goat manure had a significantly high emergence percentage compared to un-amended pine bark and pine bark amended with CaCO_3 . This might have resulted from goat manure amendments which improved pine bark physical properties such as air filled porosity (AFP) thereby increasing aeration of the media. Improving aeration of growing media resulted in increased oxygen availability for the emerging seed. A higher seed emergence percentage is attributed to mainly availability of oxygen and water, seed vigor as well as required temperature for seed emergence (Bewley and Black 1994 in Guodong *et al.*, 2012; Boddy *et al.*, 2012).

However there were no significant differences on seedling emergence when no fertilizer was added to un-amended pine bark and pine bark amended with CaCO_3 , this might be because the growing media had low air filled porosity hence low oxygen levels to the emerging seed. This is constant with work done by Masaka *et al.* (2007) who concluded that poorly aerated soils contain a variety of partly oxidized products accumulation such as ethylene gas, alcohols and organic acids which are toxic to tomato seed and disturb seedling metabolic processes. Also in a study by Mupondi *et al.*, (2010) when goat manure was added to pine bark using suspension method it resulted in an increase in water holding capacity and air filled porosity of the growing media.

When 75 ppm and 150 ppm float fertilizer was added, pine bark amended with goat manure showed a significantly high seedling emergence compared to un-amended pine bark and pine bark amended with CaCO_3 which showed no significant differences. This might be because

Nitrogen fertilizers increase ammonia ions concentration in the growing media. These ions cause damage to the seed as they can inhibit germination and result in very low seedling emergence. If a growing media have higher Cation Exchange Capacity (CEC) ratio, it can adsorb large amounts of these ammonia ions and reduce seed damage. Goat manure increased the CEC ratio of the pine bark hence facilitated ammonia ion adsorption. A mean emergence percentage 72 and 80 % was obtained in un-amended pine bark pine bark amended with CaCO_3 respectively which had a CEC of 495 and 580mmoles/kg, this might have been caused by ability of media to adsorb a small amount of the produced ammonia ions thereby inhibiting germination. In a study on cucumber seedlings, emergence was low due to presence of ammonia ions and Ellis *et al.*, (1991) concluded that the amount of ammonia in any growing media is influenced by CEC.

5.2 Effect of goat manure on seedling stem diameter

Un-amended pine bark had a significantly low stem diameter compared to pine bark amended with goat manure and CaCO_3 . This might be because pine bark is acidic in nature having a pH of 4.0; it reduces nutrient availability to the seedling hence reducing seedling growth. However there were no significant differences on stem diameter of pine bark amended with CaCO_3 and goat manure when 75 ppm float fertilizer was added. This might be because the growing media had pH values of 6.08 and 6.78 respectively which promoted nutrient availability to the seedlings and facilitated production of hormones such as cytokines which promotes cell growth. When 150 ppm float fertilizer was added to the three different growing media, no significant differences in stem diameter were noted and low stem diameters was recorded. This might be because high applications of Nitrogen in tomato result in rank growth whereby the seedlings will have excessive stem elongation a result of overproduction of gibberellins which stimulates shoot elongation at the expense of cytokines which promotes cell enlargements. This is consistent with

findings by Rideout and Overstreet, 2003 who found that high nutrients supply in tomato seedlings result in rapid stem elongation at the expense of stem diameter.

5.3 Effect of goat manure on seedling stem length

Un-amended pine bark had a significantly low stem diameter of 8.40 cm compared to pine bark amended with goat manure and pine bark amended with CaCO_3 . This might be because un-amended pine bark at low pH, have retention sites with organic fraction (R-COO-H) group which hold positively charged ions and repel negatively charged ions such as phosphorus making it unavailable to plant (Tucker, 1995). Low pH affects availability of essential nutrients such as phosphorus, magnesium, calcium, manganese and molybdenum to the plant and at the same time such elements such as aluminum and iron become readily available causing toxicity to the seedlings. A study by (Zhang *et al*, 2006) concluded that phosphorus unavailability mainly affect shoot growth by reducing leaf expansion in tomato seedlings. There were no significant differences on stem length in pine bark amended with CaCO_3 and goat manure which obtained higher stem lengths of 13.83 cm and 19.19 cm respectively which are within the transplantable range of 10.5 to 20cm. This might be as a result of pH values which promoted availability of phosphorus. When phosphorus is absorbed into the plant system, it is transformed into organic forms and is incorporated in organic compounds such nucleic acids, phospholipids, sugar phosphates and enzymes which can be used in cell membrane formation and cell division. ATP and sugars are used as energy sources for other reactions and for as building blocks for new cells respectively.

150 ppm float fertilizer had a significantly high stem length compared to treatments where 75 ppm and no float fertilizer. High fertilizers increased reducing sugar deposition which promoted

excessive stem elongation. Also high fertilizer rates result in a decrease in the amount of carbon thereby reducing stem expansion.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

1. Pine bark amended with goat manure improves pine bark physical properties hence promoting tomato seedling emergence
2. When pine bark is amended with goat manure, 75ppm float fertilizer is required to for seedlings to reach recommended height and stem diameter.
3. High fertilizer rate of 150 ppm in pine bark amended with goat manure resulted in excessive stem elongation and thin stem diameter.

6.2 Recommendations

1. Goat manure can be used as pine bark amendment
2. A combination of pine bark amended with goat manure and 75 ppm float fertilizer is required for tomato seedlings to reach the recommended stem diameter and height.
3. There is need for further research on effect of goat manure on yield and growth parameters after transplanting.
4. Trails of different manure ratios should be carried out on tomato seedlings.
5. A trial with different liquid fertilizers should be carried out to get recommendations on different fertilizer ratios.

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APPENDICES

Appendix 1: ANOVA table for emergence percentage

Emergence percentage at 28 Days after sowing

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Media type	2	47.109463	23.554732	4325.97	<.001
Fertilizer rates	2	3.005734	1.502867	276.01	<.001
Media type*Fertilizer rates					
	4	2.328871	0.582218	106.93	<.001
Residual	18	0.098009	0.005445		
Total	26	52.542078			

Appendix 2: ANOVA for stem diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Media type	2	0.0442741	0.0221370	38.31	<.001
Fertilizer rates	2	0.1791630	0.0895815	155.04	<.001
Media type*Fertilizer rates					
	4	0.2078815	0.0519704	89.95	<.001
Residual	18	0.0104000	0.0005778		
Total	26	0.4417185			

Appendix 3: ANOVA for stem length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Fertilizer rates	2	256.78	128.39	11.10	<.001
Media type	2	566.92	283.46	24.50	<.001
Fertilizer rates*Media type					
	4	18.37	4.59	0.40	0.808
Residual	18	208.29	11.57		
Total	26	1050.37			

