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DEPARTMENT OF CROP SCIENCE

EFFECTS OF SEED BOMBING TECHNIQUE ON LEMON SEEDLING EARLY GROWTH USING DIFFERENT GROWING MEDIA AND DIFFERENT NUMBER OF SEEDS PER SEED BOMB

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILL OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEREE IN CROP SCIENCE

DECLARATION

Student

I, Sheron Mundozi, do hereby declare to Bindura University of Science Education that this research project is a result of my original research work. It is being submitted for the fulfilment of the Bachelor of Agricultural Science Honours Degree in Crop Science. The findings of this research project have never been submitted in any other institution.

Signature:……………………………… Date:……………………………………..

Supervisor

I have supervised the research project for the above mentioned student and I am convinced that the research project can be submitted.

Project Supervisor's Signature Date:

………………………………. …………………………………………..

I certify that I have checked the research project and I am satisfied that it confirms to the Department of Crop Science guidelines for project preparation and presentation. I therefore authorize the student to submit this dissertation for marking.

Quality Controller Signature

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DEDICATION

This research is dedicated to my father, my mother and all relatives who supported me in carrying out this research.

ACKNOWLEDGEMENTS

I thank the Lord so much for being with me through out my research. I would like to offer all the accolades to my supervisor, Mr. Mutsengi who assisted me in carrying out my research project. I also want to thank my father, Mr. Mundozi and my mother, Mrs. Mundozi, and all other family members for their financial support. Lastly I also want to express my gratitude to my friends who supported me.

ABSTRACT

Seed bombing technique was discovered by Masanobu Fukuoka, a Japanese farmer, breeder ,microbiologist and expert in plant breeding. It is a technique that involves encapsulating seeds in a growth medium and then dispersing them to germinate. The study examined the effectiveness of the seed bombing technique on lemon early growth, with a focus on comparing the performance of different growing media and the impact of different number of seeds per seed bomb. The study evaluated four media type which were manure, humus, charcoal and clay, to determine their suitability for lemon cultivation using the seed bombing technique. The research tested the effects of using one seed versus two seeds per seed bomb. The experiment was carried out at Bindura University farm and the experiment was laid out using randomized complete block design (RCBD) and it had two factors; media type and number of seeds per seed bomb. The results showed that manure-based seed bombs significantly outperformed the other growing media tested. Media type and number of seeds per seed bomb had a significant effect on chlorophyll content, height and diameter at breadth height ($p<0.05$). Media type and seed bomb size had no significant effect on leaf number($p>0.05$). There was an interaction effect between media type and number of seeds per seed bomb on germination, days to germination and leaf length ($p<0.05$). Media type and number of seeds per seed bomb had a significant effect on germination and leaf length. Lemon plants grown in manure and humus exhibited higher chlorophyll content and faster early growth rate. In terms of seed quantity, the study found that seed bombs containing a single seed performed better than those with two seeds. The one-seed seed bombs had higher germination success and better seedling establishment. Based on the research findings, seed bombing technique is a recommended and an effective method for lemon cultivation, but the choice of growing medium and the number of seeds per seed bomb are critical factors in determining the success of this approach. The insights from this study provide valuable guidance for farmers and researchers interested in exploring alternative techniques such as seed bombing which is more effective than the nursery based method.

TABLE OF CONTENTS

LIST OF ABBRIVEATIONS AND ACRONYMS

P value- Point of value

LSD- Least standard difference between the means

SED- Standard error of deviation

CV- Critical value

DBH- Diameter at breadth height

WAP- Week after planting

RCBD- Randomized complete block design

PH- Potential hydrogen

ANOVA- Analysis of variance

List of Tables

LIST OF APPENDICES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

1.1BACKGROUND OF THE STUDY

The exact origin of lemon is uncertain so it is suggested that it originated in the Punjab region of Pakistan and India, or the eastern Himalayan region of Southern China and Myanmar. The lemon was already known in China about 500 BC and reached Europe around AD 1000-1200. It is believed the lemon fruit was introduced into Australia in 1788 by Captain Cook (www.darwin.nt.gov.au). Lemon grows well in tropical and semi-tropical climate. According to (Borelli; Monastra, (2012) and (Malik and; Singh,(2006), lemon trees are an important crop in many Mediterranean and subtropical climates, but establishing new nurseries can be challenging due to factors like soil quality, water availability, and pest management. According to *(* Masterson *et al.*, 2019), seed bombing also known as direct seeding or aerial seeding is a technique that involves encasing seeds in a protective shell or bomb and then dispersing them in target areas. The seed bombing technique protects the seeds from predation, desiccation and other environmental stresses. The seed bombs are dispersed either manually or using specialized equipment across the target areas, and this allows for efficient distribution of seeds over a large area without the need for intensive site preparation or individual planting which is done in nursery grown seedlings.

Lemon (*citrus limon*) is of substantial agricultural and economic importance globally. According to Cosmetic Ingredient Database lemon can be used in cosmetics in the form of oils obtained from various organs, in the form of extracts, hydrolats, powdered parts of the plant, wax and juice (Klimek-Szczykutowicz,2020). Lemons are a versatile fruit used in the food and beverage industry. The choice of growing medium for lemon plays an important role on early growth. Nursery grown seedlings has been the primary method employed by lemon growers. In certain nurseries, seeds are first planted in a seedbed, after emergence they are uprooted and then transferred to polythene sleeves. The plants may suffer some shock during the transplanting. Some farmers will plant the seed directly into the sleeves and yet still there will be need to isolate those sleeves that would have complete failure of germination. In current years, choice and progressive strategies like seed bombing have received attention in the agricultural zone due to their potential environmental benefits and cost effectiveness.

According to (Kannan; Dhivya and; Janani, 2021), Masanobu Fukuoka was a Japanese farmer, breeder, thinker, microbiologist, and expert in plant growth. He rediscovered seed ball technique and extensively advocated for it in the middle of the 20th century. Nursery grown seedling approach is more labor-intensive and costly because it requires dedicated infrastructure, resources and labor for propagation, potting and transportation, These problems have been catered for through seed ball technology in the table crops, millets, Solanaceae, Cucurbitaceae family, and fruits crops. Seed bombing is an efficient and reliable way to cultivate with less resources and labor.

Nursery grown seedling approach involves planting lemon seeds in prepared soil beds or containers. This method promotes root development and the plants can also access nutrients, moisture, and microorganisms required for growth. According to (Smith and Jones; 2021), seedlings raised in a nursery typically have a higher rate of establishment success, as they are grown in a controlled environment and are able to develop a robust root system before transplantation. Nursery grown seedling approach has been the cornerstone of lemon cultivation, but because of its challenges such as requirement for a period of acclimation to the new environment when n transplanted, makes it a poor method compared to seed bombing technique. According to (Smith and Jones; 2021), seedlings raised in a nursery may require a period of acclimation to the new environment when transplanted, as they may not be as well-adapted to the specific site conditions.

According to (Madsen *et al.,*2016), seed bombing, or the aerial dispersal of seed has shown promise as a revegetation technique in ecological restoration efforts. Seed bombing entails encasing lemon seeds inside biodegradable capsules and dispersing them throughout the field, including distinct developing mediums. These capsules break down permitting the seeds to germinate and grow. However, its effectiveness in lemon production stays pretty unexplored.

The choice of developing medium performs an integral role in the success of seed bombing. Growers may also decide for soil, hydroponics, coco coir, or different media to residence the germinating seeds. The differences in growing media can notably influence the growth, development, and yield of lemon plants. The growers should make sure that there is a right balanced mix of media, nutrients and seed density in the seed bombs for successful germination and growth of plants. If there is too much or too little of any ingredient, then the outcomes may be affected.

Seed bombing in lemon production has the potential to make informed choices in sustainable agriculture. Evaluating the environmental implications and resource utilization associated with seed bombing in lemon production, in particular across numerous growing mediums, is integral for making sure that agriculture aligns with sustainability dreams and conservation efforts.

1.2 PROBLEM STATEMENT

The effects of seed bombing on lemon seedling production remains largely unexplored, particularly when different growing mediums are considered and also when different number of seeds per seed ball are considered. Therefore, there is need to investigate the impact of seed bombing in lemon production using various growing media which include humus, clay, charcoal and manure, and also different number of seeds per seed ball to provide insights for sustainable agricultural practices in Zimbabwe.

1.3 JUSTIFICATION

According to (Masterson *et al.,* 2019), seedlings grown from seed bombs may be more adapted to the specific environmental conditions of the target site, as they have been exposed to these conditions from the beginning. This leads to higher survival rates and better long-term establishment compared to nursery grown seedlings that may require a period of acclimation. This research focuses on different growing media, emphasizing the need for diversified cultivation options. Understanding how different media affect lemon growth can be instrumental for farmers in regions with different soil qualities, and this research offers valuable insights into adaptability. By assessing the efficacy of seed bombing, the research can potentially influence production methods and reduce costs for farmers, thereby increasing their profitability. The findings of this study can contribute to the academic literature on innovative farming techniques, thereby expanding the knowledge base in the field of agriculture.

1.4.1 MAIN OBJECTIVE

To evaluate the effects of seed bombing on early vegetative growth of lemon produced using humus, clay, manure and charcoal as growing media and different seed ball sizes.

1.4.2 SPECIFIC OBJECTIVES

To assess the effects of media type and number of seeds per seed bomb on seed bombing germination

To assess the effect of media type and seed number on seed bombing seedling chlorophyll content

To assess the effect of media type and seed number on growth of seed bombed lemon seedlings.

1.5 HYPOTHESIS

Media type and number of seeds per bomb have an effect on germination of lemon seeds in a bomb.

Media type and number of seeds per bomb have an effect on seedling chlorophyll content.

Media type and number of seeds per bomb have an effect on growth of lemon seedlings.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Seed bombing technique versus the nursery-grown seedlings

Lemon cultivation has been reliant on nursery-grown seedlings cultivation methods. However, in recent years, an unconventional agriculture technique known as seed bombing, has gained popularity as an alternative approach to nursery system. According to (Rayburn and Laca;(2013), the seed bombing technique is low-cost, as the materials and labor required to create seed bombs are generally less expensive than growing and transporting nursery-grown seedlings. The seed bombing technique allows establishment of new plants without the need for extensive site preparation like the nursery-grown seedling approach. The nursery grown seedlings usually fails to adapt to the new environment when they get transplanted. The seed bombing technique involves the dispersal of seeds encapsulated within biodegradable materials, aiming to promote seed germination and plant growth.

The need to investigate the consequences of employing seed bombing for lemon cultivation, particularly when considering different growing media, has become increasingly apparent. According to (Barry and Hodge;(2023), popular studies have focused on the growth parameters of plants using seed bombing techniques, especially in the reforestation and wildflower planting domains. These investigations often emphasize the role of seed bombing in enabling plant establishment, particularly in arid and disturbed environments. However, how these benefits translate to lemon cultivation is yet to be adequately understood. Several variables such as chlorophyll content, germination percentage, days to germination, number of leaves, plant height, leaf count, and stem diameter must be evaluated to ascertain the effectiveness of seed bombing in promoting lemon growth so this project is going to evaluate all the mentioned variables.

The choice of growing media plays a pivotal role in the success of seed bombing for lemon cultivation. Nursery grown seedlings method has been the go-to approach, but the emerging popularity of alternative growing mediums, including hydroponics and coco coir, raises questions about how these choices influence the viability of seed bombing. Hydroponics for example offers a controlled environment with precise nutrient delivery, potentially impacting plant growth. Additionally, the use of coco coir, a sustainable and eco-friendly substrate, poses an interesting avenue for exploration. According to, (MCCOY,2022), existing literature on the influence of growing mediums on seed bombing success predominantly pertains to wildflowers and native plants.

Hence, a direct application to lemon cultivation requires specific research to bridge the knowledge gap, so in this research am going to use growing mediums like humus, clay, manure and charcoal to grow lemons by seed bombing technique.

2.2 Investigations of seed bombing on agricultural production.

A study by (Gomez *et al.*, 2017), examined the effects of seed bombing on wheat production in degraded soil conditions. The researchers found that seed bombing significantly improved the germination and growth of wheat plants compared to traditional seedling methods. The clay mixture helped retain moisture and nutrients, creating a more favorable environment for seedling establishment. These results suggest that seed bombing has the potential to enhance crop yields in challenging agricultural settings.

A study by Smith and Smith (2018) investigated the effects of seed bombing on tomato production in urban gardens. The clay mixture created a protective barrier around the seeds, enhancing seedling survival rates and promoting robust plant growth. These findings indicate that seed bombing can have positive effects on crop production and ecosystem restoration.

There is limited research specifically on the effects of seed bombing on lemon production, therefore there is need to extrapolate from these studies to hypothesize potential benefits for citrus cultivation. Lemons are a valuable commodity with high demand in global markets, and any techniques that can enhance lemon production are of interest to farmers and producers.

2.3 Classification of lemon and Requirements

Table 2.1 Classification of lemon and Requirements

Common name	Citrus lemon
Scientific name	Citrus limon (L.) Burm.f / Citrus limonum Risso
Family name	Rutaceae
Type	Evergreen
Origin	Northern India, Myanmar, China
Maturity size	10-20 Feet (304-609cm)
USDA Hardness zone	9-11
Light Requirements	Full Sun
Soil	Well drained, Loam, Ph 6.0-7.0

2.4 Effects of charcoal on plant growth

According to (Lehmann; Joseph;(2015), charcoal is known to improve soil quality by enhancing soil structure, aeration, and water-holding capacity. Charcoal can also help increase soil pH and cation exchange capacity, which improves nutrient availability (Lehmann *et al.*, 2011*)*. Application of charcoal to soil as an amendment improves the availability of potassium in the soil. Potassium (K) is a macronutrient required by plants for energy production, enzyme activation, formation of cell wall, production of protein, and photosynthesis. The utilization of charcoal as a soil amendment is promising, because it provides reactive negatively charged surfaces, which enhance nutrient holding in the synchrony of crop nutrient uptake and, at the same time, chelating acidic cations such as Al^{3+} and Fe^{2+}, which have been implicated in phosphorus (P) fixation. Al^{3+} and Fe^{2+} cause H^+ build up in mineral soil, because their hydrolysis releases H^+. Upon applying charcoal to soils, it decomposes to produce organic compounds to bind Al^{3+} and Fe^{2+}. There is limited research on lemon production using charcoal as a growing medium and the seed bombing technique.

2.5 Effects of humus on plant growth

According to (Tan; 2014), the inclusion of humus in the soil greatly enhances the soil's fertility and structure, leading to improved plant growth, vigor, and overall productivity. Humus has a high cation exchange capacity that enables it to hold and exchange positively charged ions like calcium, magnesium and potassium. This improves the soil's ability to retain and supply these essential nutrients to plants. Humus in soil causes the soil to crumble allowing air and water to easily move through the loose soil. Humus is produced naturally by a process called decomposition. When people compost, they collect decaying organic material, such as food and garden scraps, that will be turned into soil. The effects of humus on lemon production using the seed bombing technique remains unexplored.

2.6 Effects of manure on plant growth

According to (Khaitov, 2019) application of organic manure increases organic elements' availability in soil, thereby improving the nutrient use efficiency (NUE) of crops and alleviating the harmful impact of climate change on crop production. Organic manure is a natural source of nitrogen (N) formation process in the soil. Livestock manure returns essential macro elements including N (2.42%), P (1.51%), and K (0.41%), as well as micronutrients such as magnesium, calcium, sulfur, and manganese to the soil while maintaining its fertility. Manure contributes to reducing soil bulk density and compaction, as well as increasing soil aggregate stability, water infiltration and retention. The effects of manure on lemon production using the seed bombing technique remains unexplored.

2.7 Advantages of Seed ball technique

According to (Zubaidah; 2022) the encapsulation of seeds in a protective clay mixture could help improve germination rates and growth of fruit and forest seeds. The seed bombing technique protects the seed from harsh climate conditions and other insects and animals. Seed bombs are good for plantation in dry and compacted soils. Seed bombs already have their own ecosystem, they are packed with nutrients already which gives their growth a head-start. Seed balls protect the seeds and keep them in one place until they receive enough water to grow, typically through rainfall. The clay and soil protect the seeds from heavy winds and extreme temperatures.

2.8 Impacts of seed ball technique globally

According to (Shono *et al.,* 2020), the seed ball technique has been employed in many regions worldwide to aid in the reforestation of Degraded or deforested areas. The seed ball technique has been embraced globally as a cost-effective and environmentally friendly way to restore ecosystem, combat deforestation and promote biodiversity. The use of seed ball has enabled individuals and organizations to easily plant seeds in degraded areas such as barren lands and eroded slopes. The seed ball technique has social and economic benefits for communities around the world. Seed ball technique helps people to connect with nature, improve their local environment, and foster a sense of community. The growth of plants from seed balls can provide food, medicine, and other resources that contribute to the well-being of people globally. The seed ball technique can also help mitigate climate change by sequestering carbon dioxide from the atmosphere. As trees and plants grow from the seed balls and mature, they absorb carbon dioxide through photosynthesis, helping to reduce greenhouse gas emissions and combat global warming. The seed ball technique is a simple yet powerful too that can help pressing down environmental challenges and create a more resilient and sustainable future.

2.9 Germination under the seed bomb technique

According to (Jones; 2018), the first step is to choose the appropriate seeds for the local climate and growing conditions. The seeds are mixed into a small ball of soil which protects the seed from harsh environmental conditions and also provides essential nutrients for growth. Germination occurs when the seed balls receive moisture from rainfall or other water sources. According to (Green; 2022), as the seeds germinate, the young seedlings begin to push through the seed ball casing and roots begins to grow in the surrounding soil. With proper growing conditions, these seedlings can then mature into full-grown plants.

2.10 Growth of seedlings under seed ball technique

The seed bomb technology provides a compact package of soil, nutrients and protection for the young plants. The growth of seedlings depend on the environmental conditions of the planting site. Areas with good soil, moisture and minimal competition from weeds tend to yield the best results. According to (Dunnett & Hitchmough; 2004), the seed bomb provides a compact package of soil, nutrients and protection for the young plants.

CHAPTER 3

3.0 RESEARCH METHODOLOGY

3.1 SITE DESCRIPTION

The research project was conducted at Bindura University of Science Education farm, located in Shamva district. The farm is located in agro ecological region 2b, which receives annual rainfall of 700-1000mm per year. The geographical coordinates of the area are, 17◦ 14’ 29’’ S, 31◦ 03’54’’ E. The soil type of the area is clay.

3.2 EXPERIMENTAL DESIGN

The experimental design used was the randomized complete block design (RCBD). There were two factors which were considered during the experiment which are media type which had four types, which are manure, humus, charcoal and clay, and number of seeds per bomb . the trial was replicated three times. Some seed bombs had one seed and some had two seeds.The blocking factor was the slope angle.

3.3 Agronomic Management

3.3.1 Land Preparation

The land was cleared with a hoe and weeds were removed to reduce competition for light, water and nutrients with the seedlings. The soil was also loosened using a hole to allow easy growth of lemon roots. Beds were made using a hoe.

3.3.2 Seed ball making and placing of seed balls on the ground

Each media type was mixed with water in different bowls and seed balls were made and they contained different number of seeds. Each media type had seed bombs with one seed and others with 2 seeds per seed bomb. The diameter of the seed balls was 1.5cm. The balls were left to dry for 24 hours. The balls were then placed on the beds. There were six seed bombs per bed.

3.3.3 Weed control watering

Weeds were removed to minimize competition for water, light and nutrients. Watering was done regularly to promote germination and growth of the seedlings.

3.4 Data collection

3.4.1 Germination percentage

Germination was calculated by counting the number of seeds that germinated over the seeds that were planted and multiplied by 100.

3.4.2 Days to Germination

Days the plants took to emerge above the ground were counted and recorded.

3.4.3 Height

The height of lemon plants was measured from the bottom to the top leaf using a string and a ruler and was recorded in centimeters.

3.4.4Stem diameter at breadth height

The diameter was measured at breadth height of the seedlings using a string and a ruler in centimeters.

3.4.5 Chlorophyll content

The SPAD-502Plus was used to measure chlorophyll content. The meter calculates a numerical SPAD value which is proportional to the amount of chlorophyll present in the leaf.

3.4.6 Leaf length

The length of leaves was measured using a ruler and it was recorded in centimeters. The plants from which data was collected were randomly selected.

CHAPTER 4

4.0 DATA PRESENTATION

4.1 Effects of media type and number of seeds per seed bomb on chlorophyll content

There were no interaction effects between media type and number of seeds per seed bomb on chlorophyll content . Media type had a significant effect on all 4 weeks after planting($p<0.05$). Number of seed per seed bomb had an effect on all 4 weeks ($p<0.05$).

4.1.1 Effects of media on chlorophyll content

Table 4. 1. Effect of media on Chlorophyll content

media	Chlorophyll 1 WAP	Chlorophyll 2 WAP	Chlorophyll 3 WAP	Chlorophyll 4 WAP
manure	7.65^{a}	15.30^{a}	30.60^{a}	50.60^{a}
humus	4.87^{b}	9.73^{b}	19.47^{b}	39.47^{b}
charcoal	4.67^{b}	9.33^{b}	18.67^{b}	38.67^{b}
Clay	4.07^{b}	8.13^{b}	16.27^{b}	36.27^{b}
Cv%	13.8	13.8	13.8	7.1
LSD	1.282	2.564	5.127	5.127
SED	0.598	1.195	2.390	2.390
Pvalue	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter are not significantly different.

Manure had the highest chlorophyll content in the first week (7.65µm) and on the last week (50.6µm). The least recordings were obtained from clay where seedlings chlorophyll content was (4.07µm) on the first week and on the last week it was (36.27µm). Media type had a significant difference on seedlings chlorophyll content on 1 WAP, 2 WAP, 3 WAP and 4 WAP ($p<0.05$). Manure had a significant difference with other media from the first week to the last week. Humus, charcoal and clay had no significant difference on 1WAP, 2 WAP, 3 WAP and 4 WAP ($p>0.05$).

4.1.2 Effects of number of seeds per seed ball on chlorophyll content

Table 4.2 Effect of number of seeds per seed ball on chlorophyll content.

Number of seed	Chlorophyll 1 WAP	Chlorophyll 2 WAP	Chlorophyll 3 WAP	Chlorophyll 4 WAP
1	6.16[a]	12.32[a]	24.63[a]	44.63[a]
2	4.47[b]	8.93[b]	17.87[b]	37.87[b]
Cv%	13.8	13.8	13.8	7.1
LSD	1.282	2.564	5.127	5.127
SED	0.598	1.195	2.390	2.390
Pvalue	<0.001	<0.001	0<001	<0.001

One seed per bomb produced more chlorophyll content than two seeds on 1 WAP, 2 WAP, 3 WAP and 4 WAP.

4.2 Effects of media type and number of seeds per seed ball on diameter at breadth height (DBH)

There were no interactions between media type and number of seeds per seed bomb. Media had a significance difference on 1 WAP, 2 WAP, 3 WAP and 4 WAP ($P<0.05$). Number of seeds per seed bomb had a significant difference on all four weeks ($p<0.05$).

4.2.1 Effects of media type on diameter at breadth height (DBH)

Table 4.3. Effect of media on diameter at breadth height (DBH)

media	DBH 1 WAP	DBH 2 WAP	DBH 3 WAP	DBH 4 WAP
manure	1.083^{a}	1.183^{a}	1.283^{a}	1.583^{a}
humus	0.900^{a}	1.000^{b}	1.100^{b}	1.400^{a}
charcoal	0.800^{b}	0.900^{b}	0.983^{b}	1.283^{b}
Clay	0.717^{b}	0.833^{b}	0.933^{b}	1.233^{b}
CV%	11.2	10.5	10.4	8.1
LSD	0.1709	0.1808	0.1949	0.1949
SED	0.0797	0.0843	0.0909	0.0909
Pvalue	<0.001	<0.001	<0.001	<0.001

Manure had the seedling with the highest DBH (1.083cm) on 1 WAP and 4 WAP (1.583cm). Humus was not significantly different from manure on 4 WAP. There was no significant difference between charcoal and clay on ($P>0.05$). There was a significant difference between charcoal and clay on DBH 3 ($p<0.05$).

4.2.2 Effects of number of seeds per seed ball on DBH

Table 4.4 Effect of number of seeds per seed ball on DBH

Number of seed	DBH 1 WAP	DBH 2 WAP	DBH 3 WAP	DBH 4 WAP
1	1.042^{a}	1.150^{a}	1.242^{a}	1.542^{a}
2	0.708^{b}	0.808^{b}	0.908^{b}	1.208^{b}
CV%	11.2	10.5	10.4	8.1
LSD	0.1709	0.1808	0.1949	0.1949
SED	0.0797	0.0843	0.0909	0.0909
Pvalue	<0.001	<0.001	<0.001	<0.001

One seed per seed bomb produced seedlings with high DBH than two seeds per seed bomb. There was a significant difference between one seed per bomb and two seeds per bomb on diameter in all weeks ($p<0.05$).

4.3 Effects of media type and number of seeds per seed ball on germination

There were interactions between media type and number of seeds per seed bomb on germination ($p<0.05$).

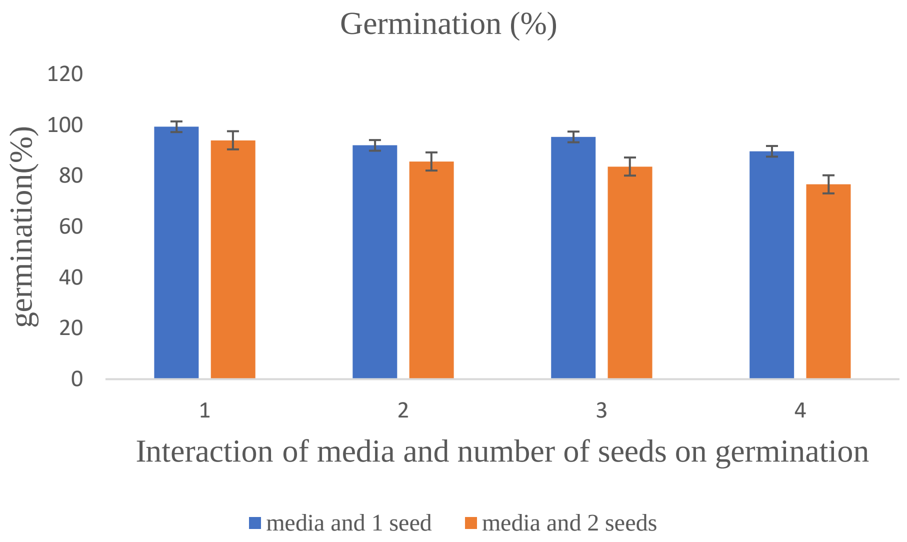

Fig 4.1 Effects of media type and number of seeds per seed ball on germination.

Manure with one seed and two seeds per ball combination was significantly different from other media ($p<0.05$). Humus and charcoal with one seed and two seeds per ball combination were not significantly different ($p>0.05$). Clay was significantly different from other media and it had the least germination mean with two seeds per combination (76,67) Manure and one seed per bomb combination had the highest germination mean (99.33). All media type and one seed per bomb combination performed better than media type and 2 seeds per bomb.

4.4 Effect of media type and number of seeds per seed bomb on height

There were no interactions between media type and number of seedlings per seed bomb on height. Media had a significant effect on height in all weeks ($p<0.05$). Number of seeds per seed bomb had a significant effect on height in all weeks ($p<0.05$).

4.4.1 Effects of media on height

Table 4.5 Effect of media on height

media	Height 1 WAP	Height 2 WAP	Height 3 WAP	Height 4 WAP
manure	2.750[a]	4.967[a]	7.175[a]	9.400[a]
humus	2.217[b]	4.450[b]	6.650[b]	8.867[b]
charcoal	2.267[b]	4.483[b]	6.650[b]	8.850[b]
Clay	1.950[b]	4.167[b]	6.383[b]	8.550[c]
CV%	6.8	3.6	3.0	1.9
LSD	0.2726	0.2834	0.3519	0.2957
SED	0.127	0.1321	0.1641	0.1379
Pvalue	<0.001	<0.001	<0.001	<0.001

Manure was significantly different from other media on all weeks. Manure had the highest height (2.75cm) recorded on the first week and on 4 WAP (9.4cm). Humus and charcoal were not significantly different in all weeks ($p>0.05$). Clay was significantly different from other media on 4 WAP and it had a mean height of (8.55cm).

4.4.2 Effects of number of seeds per seed ball on height

Table 4.6 Effect of number of seeds per seed ball on height

Number of seed	Height 1 WAP	Height 2 WAP	Height 3 WAP	Height 4 WAP
1	2.625[a]	4.842[a]	7.037[a]	9.275[a]
2	1.967[b]	4.192[b]	6.392[b]	8.550[b]
CV%	6.8	3.6	3.0	1.9
LSD	0.2726	0.2834	0.3519	0.2957
SED	0.1271	0.1321	0.1641	0.1379
Pvalue	<0.001	<0.001	<0.001	<0.001

One seed per seed bomb produced seedlings with the highest height. There was a significant difference between one seed per bomb and two seeds per bomb on all weeks ($p<0.05$).

4.5 Effect of media type and number of seeds per seed bomb on leaf number

There were no interactions between media type and number of seeds per seed bomb. Media type had a significant effect on 1 WAP and 2 WAP ($p<0.05$). Media type had no significant effect on 3 WAP and 4 WAP on leaf number ($p>0.05$). Number of seeds per seed bomb had no significant effect on 1 WAP ($p>0.05$). Number of seeds per seed bomb had a significant difference on 2 WAP, 3 WAP and 4 WAP($p<0.05$).

4.5.1 Effects of media type on leaf number

Table 4.7 Effect of media type on leaf number

media	Leaf number 1 WAP	Leaf number 2 WAP	Leaf number 3 WAP	Leaf number 4 WAP
manure	2.333^{a}	4.167^{a}	6.33^{a}	8.67^{a}
humus	2.000^{b}	3.500^{b}	5.83^{b}	7.67^{b}
charcoal	2.000^{b}	3.667^{b}	6.17^{b}	8.00^{b}
Clay	2.000^{b}	3.500^{b}	5.50^{b}	7.50^{b}
CV%	9.8	10.4	9.9	10.8
LSD	0.3575	0.6755	1.038	1.505
SED	0.1667	0.3150	0.484	0.701
Pvalue	<0.030	<0.030	<0.118	<0.138

Manure was significantly different from other media on all four weeks, it exhibited the highest mean leaf number. Humus, charcoal and clay were not significantly different on 1 WAP, 2WAP, 3 WAP and 4 WAP ($p>0.05$). Clay had the least mean leaf number in all weeks.

4.5.2 Effects of number of seed per seed ball on leaf number

Table 4.8 Effect of number of seed per seed ball on leaf number

Number of seed	Leaf number 2 WAP	Leaf number 3 WAP	Leaf number 4 WAP
1	4.000[a]	6.50[a]	8.58[a]
2	3.417[a]	5.42[b]	7.33[a]
CV%	10.4	9.9	10.8
LSD	0.6755	1.038	1.505
SED	0.3150	0.484	0.701
Pvalue	<0.002	<0.001	<0.003

One seed per seed bomb produced high leaf number than two seeds per seed bomb. There was no significant difference between one seed per seed bomb and two seeds per seed bomb on 1 WAP, 2WAP and 4 WAP ($p>0.05$). There was a significant difference between one seed per bomb and two seeds per bomb on 3 WAP ($p<0.05$).

4.6 Effects of media and number of seeds per seed ball on days to germination

There was an interaction between media type and number of seeds per seed bomb on days to germination. Media type and number of seeds per seed bomb combination had a significant effect on days to germination ($p<0.05$).

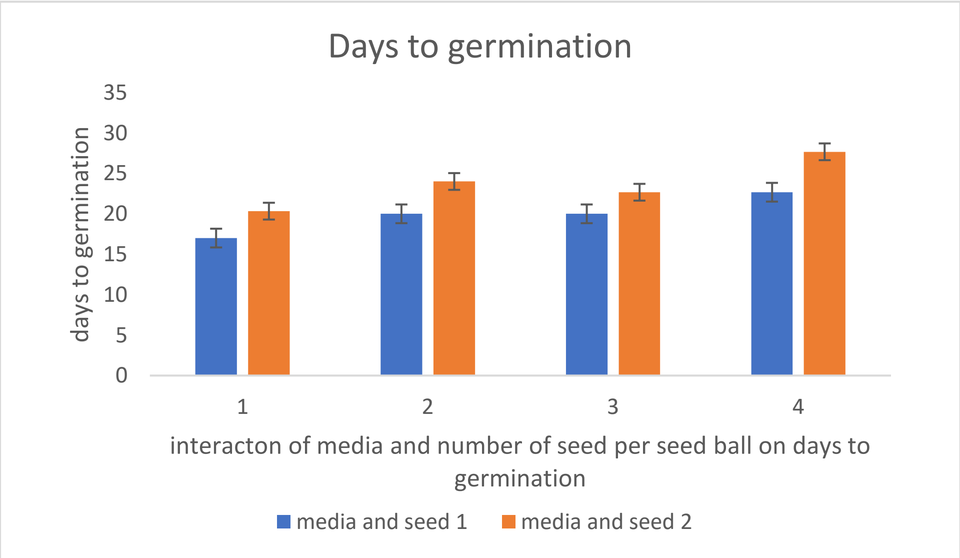

fig 4.2 interaction of media type and number of seeds per seed ball on days to germination.

Manure combinations with one seed and two seeds per bomb germinated earlier and the combinations were significantly different from other media ($p<0.05$). Humus and clay combinations with one seed and two seeds per bomb were not significantly different (p>0.05). Clay took many days to complete the germination process, it was also significantly different from other media (p<0.05).

4.7 Effects of media type and number of seeds per seed ball on leaf length

There was an interaction between media type and number of seeds per seed bomb on leaf length. Media type and number of seeds per seed bomb had a significant effect on leaf length (p<0.05).

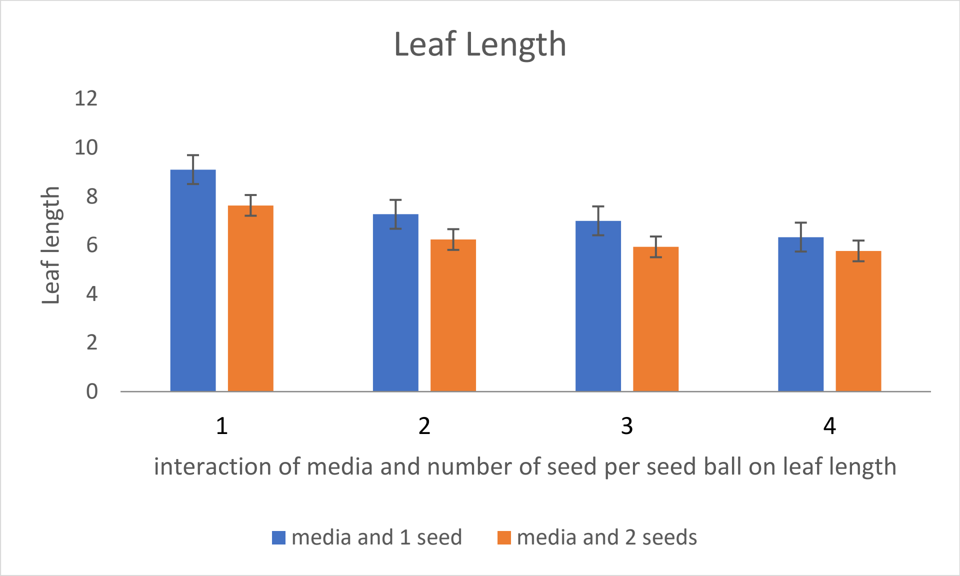

Fig 4.3 interaction of media type and number of seed per seed ball on leaf length.

Manure combinations with one seed and two seeds per seed bomb produced high mean leaf lengths, and they were significantly different from other media type combinations (p<0.05). Clay combinations were significantly different from other media (p<0.05). Charcoal and humus combinations were not significantly different (p>0.05).

CHAPTER 5

5.0 DISCUSSION OF RESULTS

5.1 Effect of media type and number of seeds per seed ball on Chlorophyll content

According to (Ying Li, 2018) Chlorophyll is an important photosynthetic pigment to the plant, largely determining photosynthetic capacity and hence plant growth. The results of the experiment showed that media (manure, humus, charcoal and clay) had a significant difference on chlorophyll content in all weeks. Manure had significantly higher chlorophyll content than other treatments with humus, charcoal, and clay for all chlorophyll types. Charcoal, humus and clay had similar chlorophyll content, with no significant differences among them. Manure is a rich source of organic matter and nutrients such as nitrogen, phosphorus and potassium. When properly decomposed and applied at appropriate rates, manure can supply these essential nutrients to plants, which are necessary for chlorophyll synthesis. Adequate nutrient availability can promote chlorophyll production and enhance the greenness of plants. Manure also improves soil structure, water retention and nutrient holding capacity. This can lead to healthier root systems and better nutrient uptake, which can positively influence chlorophyll content. Healthy plants with well-developed root systems are more likely to have higher chlorophyll levels.

Treatments with humus, charcoal and clay had similar chlorophyll content and this may be due to the fact that the growing media used might have provided similar levels of essential nutrients required for chlorophyll synthesis. The experiment may also be detecting differences in chlorophyll due to varying conditions among the treatments. Factors such as light, temperature, humidity and watering regimes can influence chlorophyll content, if the growth conditions are consistent across all media treatments and that minimized the variations in chlorophyll content observed. The experiment duration might also have affected the chlorophyll content because the experiment was conducted for a short time and chlorophyll synthesis is a gradual process so short term experiments may not capture the full effects of the growing media. There are also other factors not included in the experiment that influence chlorophyll content, such as pH, microbial activity or the presence of specific chemicals or toxins in the growing media.

One seed per seed bomb produced high chlorophyll content than two seeds per seed bomb. One seed per seed bomb had sufficient nutrients, water and light for early growth of the seedlings. Two seeds per seed ball computed for limited resources such as nutrients, water and sunlight, and that led to reduced growth and development of individual plants, resulting in lower chlorophyll content. The plants from two seeds per seed bomb grew in close proximity so they shade each other, limiting the amount of sunlight that each plant receives. Sunlight is a vital component for photosynthesis and chlorophyll production, reduced exposure to sunlight could have led to lower chlorophyll content.

These results suggest that when using seed balls for planting, it may be more beneficial to use single seed per ball to maximize chlorophyll content and potentially enhance plant growth. However, it is essential to consider other factors such as the desired plant density and available resources to determine the most suitable approach for specific agricultural practices.

5.2 Effect of media type and number of seeds per seed ball on on diameter at breadth height (DBH)

The experiment demonstrated that media type had a significant effect on diameter. Manure had the largest diameter. Humus, charcoal and clay had no much significance difference between them. The results suggest that manure had the most favorable conditions for plant growth in terms of diameter. Manure is rich in organic matter and nutrients, which can enhance soil fertility and provide essential elements for plant growth. These nutrients may have contributed to the plant’s increased diameter compared to the other media. The outcome implies that other media might not have provided the same level of nutrient availability or favorable conditions for plant growth as manure did.

The results of the experiment indicate that seed balls with one seed produced plants with a bigger diameter than seed balls with two seeds. This outcome suggests that the number of seeds in a seed ball has an impact on the growth and size of the resulting plant. There could be several factors contributing to this observation. When multiple seeds are present in a seed ball, competition for resources may occur among the seeds. This competition may result in reduced access to essential resources for each individual seed, leading to slower growth and smaller plant size compared to seed balls with only one seed. Seed balls with a single seed may have fewer resource limitations, allowing the seedling to utilize available resources more efficiently and achieve larger diameters. It is also possible that the genetic potential of the individual seeds plays a role in the observed differences. Some seeds may inherently possess characteristics that promote faster growth and larger plant size, while others may have genetic traits that favor slower growth or smaller size. The seed balls with one seed showed that they were composed of seeds with inherently superior genetic traits, and that caused the plants to exhibit larger diameters compared to the seed balls with two seeds.

5.3 Effects of media and number of seeds per seed ball on Germination

According to (Royal Duyvis Wiener), the germination process involves the activation of the dormant seed, leading to the emergence of an embryonic plant. The experiment investigated the effects of different media, namely manure, humus, charcoal, and clay, on plant emergence. The results indicated that manure and one seed per seed bomb had the highest emergence rate compared to the other combinations. The remaining media did not show a significant difference in terms of emergence. The high emergence rate observed in the manure medium suggests that it provides favorable conditions for seed germination and early plant growth. Manure is rich in organic matter and nutrients, which are essential for plant development. It contains nitrogen, phosphorus, potassium, and other micronutrients that promote plant growth and vigor. The organic matter in manure improves soil structure, water retention, and nutrient availability, creating a favorable environment for seedlings to establish and grow. Humus and charcoal did not exhibit a significant difference in terms of emergence compared to each other. This suggests that these media provided the same level of nutrients and favorable conditions for seed germination and early growth. Humus is the organic component of soil formed by the decomposition of plant and animal matter. It contributes to soil fertility by improving nutrient retention, moisture-holding capacity, and soil structure. While it may not have shown a significant difference in emergence compared to manure in this experiment, it can still provide long-term benefits to soil health and plant growth. Charcoal is a carbon-rich material produced by heating organic matter in the absence of oxygen. It has been studied for its potential benefits in agriculture, such as improving soil fertility, water retention, and nutrient availability. However, in this specific experiment, it did not show a significant difference in emergence compared to manure. Clay was significantly different from other media it had the least germination percentage due to lack of sufficient nutrients that it provided.

5.4 Effect of media type and number of seeds per seed ball on height

The results of the experiment indicate that plants grown with manure had the highest height compared to those grown with humus, charcoal, and clay. However, the plants grown with the other media humus, charcoal, and clay did not show a significant difference in height. Manure is a well-known organic fertilizer that provides plants with essential nutrients such as nitrogen, phosphorus, and potassium. These nutrients are crucial for plant growth and development. The high height observed in the plants grown with manure suggests that it effectively supplied the necessary nutrients to support their growth. Humus, charcoal, and clay are also commonly used as soil amendments or additives. Humus is the organic component of soil formed by the decomposition of plant and animal matter. Charcoal, when added to the soil, can improve its water-holding capacity and nutrient retention. Clay is a type of soil that has good water and nutrient retention properties. The lack of a significant difference in height among the plants grown with humus, charcoal, and clay could be due to various factors. It is possible that these materials provided similar levels of nutrients to the plants, resulting in comparable growth. Other factors such as watering, light availability, temperature, and the specific plant species used in the experiment could have influenced the results.

The results showed that the plants from the seed balls with one seed exhibited a higher height compared to the plants from the seed balls with two seeds. There could be several factors that contributed to this outcome and it could be competition for resources. When two seeds are present in a seed ball, they compete with each other for nutrients, water, and sunlight. This competition could limit the growth potential of both seeds, resulting in smaller plants. With a single seed, the plant can utilize all available resources for its own growth and development, leading to a higher height. Another factor that might have influenced the results is the density of the plants. The seed balls were planted at a fixed density, the plants arising from the seed balls with one seed would have more space to spread their roots and access resources. This increased access to resources could contribute to their taller stature.

5.5 Effect of media type and number of seed per seed ball on leaf number

The results indicated that there was no a significant difference in leaf number across humus, charcoal and clay. This may be due to the choice of growing media which did not have a substantial impact on the growth and development of the plants' leaves. The different media used in the experiment probably provided relatively similar conditions for plant growth. The essential nutrients, water retention capacity, and aeration properties of the media were comparable, resulting in similar leaf number across all treatment. Another possibility is that the plants used in the experiment were not particularly sensitive to variations in the growing media. Some plant species or varieties are more adaptable and less influenced by changes in the substrate as long as basic requirements are met. This adaptability could explain the consistent leaf number observed across the media. It is also important to consider that leaf number is just one aspect of plant growth and may not be the most sensitive indicator of media variations. Manure exhibited higher mean leaf number because in this experiment it provided essential nutrients.

The experiment showed there was no significant difference between one seed per seed bomb and two seeds per seed bomb. This happened probably due to the short duration of the experiment.

5.6 Effects of media type and number of seed per seed ball on days to germination

According to the results, plants grown from manure and from a single seed germinated faster compared to other media such as charcoal, humus, clay, and seed balls containing two seeds. This suggests that the growth medium and the number of seeds used can have a significant impact on the germination time of plants. The specific reasons for these differences could vary depending on several factors, including nutrient availability, moisture retention, and oxygen levels in the different media. Manure is known to be rich in nutrients, which can provide favorable conditions for seed germination and early plant growth. The use of a single seed per seed ball allows the individual seedlings to have access to more resources and space, which may contribute to faster germination and initial growth. Charcoal and humus were not significantly different and this is probably due to the supply of similar amount of nutrients in the experiment. Clay was significantly different from other media because it provided resources that are less conducive to rapid germination.

5.7 Effects of media type and number of seed per seed ball on leaf length

The results indicated that manure combinations with one seed per seed ball and two seeds per seed ball was significantly different from other media interactions, and it produced high mean leaf length than other media. Manure provided all the essential resources required by the seedlings for optimum growth. Charcoal and humus interactions with one seed and two seeds per seed bomb were not significantly different probably due to the provision of similar conditions for growth like nutrients. Clay was significantly different from other media and it produced the least mean leaf length due to provision of less nutrients for growth. The experiment was done in a short duration and the sample size was small, and that could have affected the statistical significance of the results.

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The experiment showed that the performance of the seed balls was influenced by both the type of media used as well as the number of seeds used per seed ball. Manure was superior to other tested media which are humus, clay and charcoal, on germination percentage, chlorophyll content and early growth of the lemon seedlings. One seed per seed bomb also performed better than two seeds per seed bomb. Manure likely provided more readily available nutrients that supported stronger seedling development compared to the other media. This indicates that seed ball composition and selecting the optimal growth medium is a critical factor to optimize seed ball performance. Having fewer seeds per seed ball, reduced competition for water, nutrients and space, allowing each individual seedling to thrive better. This suggests there is a tradeoff between two seeds per ball and individual seedling performance that should be considered when designing seed ball compositions. Manure also contributed to fast germination rate, highest plant height and high leaf length compared to other media which showed not much significant difference between them.

6.2 RECOMMENDATIONS

Based on the research findings, farmers are recommended to grow lemon seedlings using the seed bombing technique which circumvents the nursery-grown seedling approach by producing strong seedlings which are better adapted to the environment. Farmers should use manure as a growing medium when growing lemon using the seed bombing technique as it performed better in this experiment. Farmers are also recommended to mix clay and manure when making seed balls because clay is a binding agent. This protects the seeds and helps them adhere to the ground during dispersal. The researcher also recommends farmers to test the effect of timing on seed bombing. The researcher recommends farmers to regularly monitor the seed-bombed sites and provide any necessary maintenance like weeding to ensure the successful growth of the seed-bombed seedlings. Farmers are also recommended to use one seed per bomb, to minimize seedling competition for resources and also promote high early growth rate of lemon seedlings.

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LIST OF APPENDICES

1.1 Anovas effect of media and number of seeds per seed ball on chlorophyll contentent

Variate: Chlorophyll_1 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	12.6400	6.3200	11.80	
Block.*Units* stratum					
media	3	45.7912	15.2637	28.49	<.001
number_of_seed_per_seedball	1	17.1704	17.1704	32.05	<.001
media.number_of_seed_per_seedball	3	1.1046	0.3682	0.69	0.575
Resiual	14	7.5000	0.5357		
Total	23	84.2062			

Table of means

media	number_of_seed_per_seedball 1	2
1	8.20	7.10
2	5.90	3.83
3	5.40	3.93
4	5.13	3.00

Analysis of variance

Variate: chlorophyll_2 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	50.560	25.280	11.80	
Block.*Units* stratum					
media	3	183.165	61.055	28.49	<.001
number_of_seed_per_seedball	1	68.682	68.682	32.05	<.001
media.number_of_seed_per_seedball	3	4.418	1.473	0.69	0.575
Residual	14	30.000	2.143		
Total	23	336.825			

Tables of means

media	number_of_seed_per_seedball 1	2
1	16.40	14.20
2	11.80	7.67
3	10.80	7.87
4	10.27	6.00

Analysis of variance

Variate: chlorophyll_3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	202.240	101.120	11.80	
Block.*Units* stratum					
media	3	732.660	244.220	28.49	<.001
number_of_seed_per_seedball					

1 274.727 274.727 32.05 <.001
media.number_of_seed_per_seedball
3 17.673 5.891 0.69 0.575
Residual 14 120.000 8.571

Total 23 1347.300

Tables of means

media	number_of_seed_per_seedball	1	2
1		32.80	28.40
2		23.60	15.33
3		21.60	15.73
4		20.53	12.00

Analysis of variance

Variate: chlorophyll_4 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	202.240	101.120	11.80	
Block.*Units* stratum					
media	3	732.660	244.220	28.49	<.001
number_of_seed_per_seedball	1	274.727	274.727	32.05	<.001
media.number_of_seed_per_seedball					

3 17.673 5.891 0.69 0.575

Residual 14 120.000 8.571

Total 23 1347.300

Tables of means

media number_of_seed_per_seedball	1	2
1	52.80	48.40
2	43.60	35.33
3	41.60	35.73
4	40.53	32.00

1.2 Anovas effect of media and number of seed per seed ball on diameter

Variate: DBH_1 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.120000	0.060000	6.30	
Block.*Units* stratum					
media	3	0.448333	0.149444	15.69	<.001
number_of_seed_per_seedball	1	0.666667	0.666667	70.00	<.001
media.number_of_seed_per_seedball	3	0.016667	0.005556	0.58	0.636
Residual	14	0.133333	0.009524		
Total	23	1.385000			

Tables of means

media	number_of_seed_per_seedball	1	2
1		1.233	0.933
2		1.100	0.700
3		0.933	0.667
4		0.900	0.533

Analysis of variance

Variate: DBH2 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.13083	0.06542	6.14	
Block.*Units* stratum					
media	3	0.41792	0.13931	13.07	<.001
number_of_seed_per_seedball	1	0.70042	0.70042	65.74	<.001
media.number_of_seed_per_seedball	3	0.02125	0.00708	0.66	0.587
Residual	14	0.14917	0.01065		
Total	23	1.41958			

Tables of means

media	number_of_seed_per_seedball	1	2
1		1.333	1.033
2		1.200	0.800
3		1.033	0.767
4		1.033	0.633

Analysis of variance

Variate: DBH3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.12000	0.06000	4.85	
Block.*Units* stratum					
media	3	0.43500	0.14500	11.71	<.001
number_of_seed_per_seedball	1	0.66667	0.66667	53.85	<.001
media.number_of_seed_per_seedball	3	0.03000	0.01000	0.81	0.510
Residual	14	0.17333	0.01238		
Total	23	1.42500			

Table of means

media	number_of_seed_per_seedball 1	2
1	1.433	1.133
2	1.300	0.900
3	1.100	0.867
4	1.133	0.733

Analysis of variance
====================

Variate: DBH_4 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.12000	0.06000	4.85	
Block.*Units* stratum					
media	3	0.43500	0.14500	11.71	<.001
number_of_seed_per_seedball	1	0.66667	0.66667	53.85	<.001
media.number_of_seed_per_seedball	3	0.03000	0.01000	0.81	0.510
Residual	14	0.17333	0.01238		
Total	23	1.42500			

Tables of means

media	number_of_seed_per_seedball 1	2
1	1.733	1.433
2	1.600	1.200
3	1.400	1.167
4	1.433	1.033

1.3 Anovas effect of media and number of seeds per seed ball on Germination

Variate: Germination

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	66.333	33.167	7.07	
Block.*Units* stratum					

media 3 551.458 183.819 39.19 <.001

number_of_seed_per_seedball

1 495.042 495.042 105.54 <.001

media.number_of_seed_per_seedball

3 65.458 21.819 4.65 0.019

Residual 14 65.667 4.690

Total 23 1243.958

Tables of means

media	number_of_seed_per_seedball 1	2
1	99.33	94.00
2	92.00	85.67
3	95.33	83.67
4	89.67	76.67

1.4 Anovas effect of media and number of seeds per seed ball on Height

Variate: Height_1 WAP

Source of variation d.f. s.s. m.s. v.r. F pr.

Block stratum 2 0.40083 0.20042 8.27

Block.*Units* stratum

media 3 1.99792 0.66597 27.49 <.001

number_of_seed_per_seedball

1 2.60042 2.60042 107.34 <.001

media.number_of_seed_per_seedball

3 0.03125 0.01042 0.43 0.735

Residual 14 0.33917 0.02423

Total 23 5.36958

Tables of means

media	number_of_seed_per_seedball	1	2
1		3.033	2.467
2		2.533	1.900
3		2.600	1.933
4		2.333	1.567

Analysis of variances

Variate: Height_2 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.41333	0.20667	7.89	
Block.*Units* stratum					
media	3	1.98333	0.66111	25.24	<.001
number_of_seed_per_seedball	1	2.53500	2.53500	96.79	<.001
media.number_of_seed_per_seedball	3	0.01500	0.00500	0.19	0.901
Residual	14	0.36667	0.02619		
Total	23	5.31333			

Table of means

media	number_of_seed_per_seedball	1	2
1		5.267	4.667
2		4.767	4.133

3	4.800	4.167
4	4.533	3.800

Analysis of variance

Variate: Height_3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.31646	0.15823	3.92	
Block.*Units* stratum					
media	3	1.98031	0.66010	16.35	<.001
number_of_seed_per_seedball	1	2.50260	2.50260	61.99	<.001
media.number_of_seed_per_seedball	3	0.03281	0.01094	0.27	0.845
Residual	14	0.56521	0.04037		
Total	23	5.39740			

Table of means

media	number_of_seed_per_seedball 1	2
1	7.483	6.867
2	6.967	6.333
3	6.933	6.367
4	6.767	6.000

Analysis of variance

Variate: Height_4 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

Block stratum 2 0.38083 0.19042 6.68

Block.*Units* stratum

media 3 2.25000 0.75000 26.30 <.001

number_of_seed_per_seedball

1 3.08167 3.08167 108.08 <.001

media.number_of_seed_per_seedball

3 0.04167 0.01389 0.49 0.697

Residual 14 0.39917 0.02851

Total 23 6.15333

Tables of means

media	number_of_seed_per_seedball 1	2
1	9.700	9.100
2	9.233	8.500
3	9.200	8.500
4	8.967	8.133

1.5 Anovas effect of media and number of seeds per seed bomb on Leaf number

Variate: Leaf_number_1 WAP

Source of variation d.f. s.s. m.s. v.r. F pr.

Block stratum 2 0.08333 0.04167 1.00

Block.*Units* stratum

media 3 0.50000 0.16667 4.00 0.030

number_of_seed_per_seedball

	1	0.16667	0.16667	4.00	0.065
media.number_of_seed_per_seedball					
	3	0.50000	0.16667	4.00	0.030
Residual	14	0.58333	0.04167		
Total	23	1.83333			

Table of means

media	number_of_seed_per_seedball 1	2
1	2.667	2.000
2	2.000	2.000
3	2.000	2.000
4	2.000	2.000

Analysis of variance

Variate: leaf_number_2 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.5833	1.2917	8.68	
Block.*Units* stratum					
media	3	1.7917	0.5972	4.01	0.030
number_of_seed_per_seedball					
	1	2.0417	2.0417	13.72	0.002
media.number_of_seed_per_seedball					
	3	0.4583	0.1528	1.03	0.411
Residual	14	2.0833	0.1488		

Total	23	8.9583

Table of means

media	number_of_seed_per_seedball	1	2
1		4.667	3.667
2		3.667	3.333
3		4.000	3.333
4		3.667	3.333

Analysis of variance

Variate: leaf_number_3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.0833	1.5417	4.39	
Block.*Units* stratum					
media	3	2.4583	0.8194	2.33	0.118
number_of_seed_per_seedball	1	7.0417	7.0417	20.05	<.001
media.number_of_seed_per_seedball	3	1.4583	0.4861	1.38	0.289
Residual	14	4.9167	0.3512		
Total	23	18.9583			

Tables of means

media	number_of_seed_per_seedball	1	2
1		7.00	5.67
2		6.33	5.33
3		6.33	6.00

4		6.33	4.67

Analysis of variance

Variate: leaf_number_4 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	4.3333	2.1667	2.94	
Block.*Units* stratum					
media	3	4.7917	1.5972	2.16	0.138
number_of_seed_per_seedball	1	9.3750	9.3750	12.70	0.003
media.number_of_seed_per_seedball	3	0.1250	0.0417	0.06	0.982
Residual	14	10.3333	0.7381		
Total	23	28.9583			

Table of means

media	number_of_seed_per_seedball	1	2
1		9.33	8.00
2		8.33	7.00
3		8.67	7.33
4		8.00	7.00

1.6 Anovas effect media and number of seed per seed bomb on days to germination

Variate: days_to_germination

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	74.083	37.042	22.96	
Block.*Units* stratum					
media	3	128.458	42.819	26.54	<.001
number_of_seed_per_seedball	1	84.375	84.375	52.31	<.001
media.number_of_seed_per_seedball	3	4.458	1.486	0.92	0.456
Residual	14	22.583	1.613		
Total	23	313.958			

Table of means

media	number_of_seed_per_seedball 1	2
1	17.00	20.33
2	20.00	24.00
3	20.00	22.67
4	22.67	27.67

1.7 Anovas effect of media and number of seeds per seed ball on Leaf length

Variate: leaf_length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.65083	1.32542	26.17	
Block.*Units* stratum					
media	3	17.05792	5.68597	112.25	<.001
number_of_seed_per_seedball					

1 7.37042 7.37042 145.50 <.001

media.number_of_seed_per_seedball

3 0.29125 0.09708 1.92 0.173

Residual 14 0.70917 0.05065

Total 23 28.07958

Table of means

media	number_of_seed_per_seedball 1	2
1	9.100	7.633
2	7.267	6.233
3	7.000	5.933
4	6.633	5.767