

**EFFECT OF PLANT SPACING AND SEED SIZE ON THE GROWTH,
DEVELOPMENT AND YIELD OF POTATOES**

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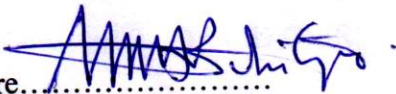
**RESEARCH DESSERTATION SUBMITTED TO THE FACULTY OF AGRICULTURE
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UNIVERSITY**

2025

DECLARATION

I, Arinaitwe Innocent, hereby declare that this dissertation entitled “Effect of plant spacing and seed size on the growth and yield of potatoes” is my original work and that no part or the whole of it has ever been submitted to any other institution for any award of Master’s Degree.

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Date: 25/04/2026

APPROVAL

This is to certify that this dissertation entitled: ‘Effect of plant spacing and tuber size on growth and yield of potatoes’ (*solanum tuberosum l*) done by Arinaitwe Innocent has been under our supervision and is now ready for submission to the Graduate School of Bishop Stuart University for examination.

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DEDICATION

This project report is dedicated to my wife Katushabe Gorettie, brothers, Owoyesigire Ronald, Tusiime Alex, Muhumuza Steven for their tender love and support offered to me towards accomplishing this research. May the almighty God bless them abundantly

ACKNOWLEDGEMENT

Much gratitude is due to the Almighty God for the protection, providence and his epic love rendered to me.

My sincere thanks unto my research supervisor, Prof. David Osiru, Dr. Wycliffe Tumwesigye for the knowledge and time they dedicated towards the writing of this dissertation to make sure it was a success;

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ABSTRACT

Potato is one of the most valuable food crops and a mainstay in the diets of people in many parts of the world. It is one of the crops that play key roles as a source of food, income, and a raw material for factories in Uganda. This study mainly focused on understanding the effect of plant spacing and seed size on the growth, development and yield of potatoes. Nakapot 1 variety of potatoes was used in this study. The experiment consisted of two factors. Plant density and seed size, the first factor involved three seed sizes; greater than 46mm, (S3) 35-45mm (S2) 20-34mm (S1) in diameter. Spacing was 75 by 40cm (P1) 75 by 30cm (P2) 75 by 25cm (P3). These were arranged in a Randomized Complete Block Design (RCBD) with three replications in each row that had three plots. Thus, there were 9 plots for each treatment. The growth factors considered were; tuber emergence, Leaf Area Index, while yield parameters were; the number of tubers per plant, weight of tubers per plant. The results showed that spacing and seed size did not have a significant effect on tuber emergence and did not influence maturity of the potato plants. However, a wide spacing of 75 by 40 cm together with bigger seed sizes greater than 46mm in diameter produced many tubers in number and which are of a bigger size compared to the spacing of 75 by 30 Cm while 75 by 25cm spacing together with 20-34mm seed size produced the least number of tubers and with very small sizes. The study concluded that a spacing of 75 by 40cm planted with seeds of 46mm produces many tubers and of a bigger size than the rest therefore farmers are advised to take it up for better results.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Potato (*Solanum tuberosum L.*) is one of the most grown crops in the world and in Uganda. (Alemayehu 2015).A number of players involved in the potato value chain that is from seed production to consumption have attained their livelihoods at different levels and this makes potato growing a significant source of income to a number of people, (Paul, 2008).

It contributes immensely to human nutrition, food security and used as a raw material for industries that produce chips, crisps and animal feeds. This makes it a source of income to those people involved directly and indirectly in its value chain, (Karim et al 2010).Potatoes contain high quality proteins and a substantial amount of essential vitamins, minerals and trace elements. They produce more edible energy and protein per unit area of land than any other crop (Paul, 2008).

It is the most important vegetable crop, currently rated as the fourth most important food crop in the world (Matto 2006, Dutches 2013). Uganda is the ninth largest producer of potato in Africa with an annual production of 327,300metric tons from the estimated 111,100 hectares in 2013 (FAOSTAT, 2014).

In Europe, potato is grown in countries like Ireland, United Kingdom, Germany, Poland and Netherlands. In North America, it is majorly grown in the United States and Canada. In South America it is grown in Peru and Bolivia, while in Africa, it's grown in Kenya, Rwanda, South Africa and Uganda.

In Uganda, the major production areas are the highlands of south-western Uganda, comprising of Kabale, Rubanda, Rukiga, Kanungu and Kisoro districts which account for 60% of total national production. (FAOSTAT, 2014). The other potato producing areas are Kapchorwa, Sironko, Bulambuli and Bududa districts on the slopes of Mt Elgon in Eastern Uganda and Nebbi district in north-western Uganda. Potato cultivation has spread to non-traditional producing areas in Central Uganda, especially Mubende, Rakai and Masaka districts.

The yield and growth of potato is influenced by a number of factors, which include; Climate, potatoes prefer cooler temperatures (15-20°C) during the day. Well drained soils with adequate nutrients and moisture to support good yields, relatively higher altitudes. Other factors majorly, seed size and spacing also affects yield, growth and development of potatoes (Barry *et al.* 1990; Arsenault *et al.*, 2001).

However, the productivity and yield of potatoes have been as low as 7.5 tons per hectare against 30 tons per hectare which is the expected yield (Barry *et al.* 1990; Arsenault *et al.*, 2001). This low production has been attributed to;

Low quality seed, most farmers (about 93%) use home saved seed from the previous season which is often of poor quality and affected by bacterial wilt disease. Therefore limited access to high quality and certified seed affects production.

Diseases and pests, Bacterial Wilt, viral diseases and pests, significantly impact negatively on the yield of potatoes. Bacterial Wilt affects 73% of ware potatoes and 50% of seed potatoes. (FAO 2010)

Among the factors that affect potato yield, plant population/spacing and seed size are probably the most important. Use of appropriate plant population/spacing and seed size ensures high yield

of tubers. Unfortunately, some of the recommendations currently being used were determined more than 30 years ago. This is so despite the fact that many new varieties have been developed. Inappropriate planting density, affects both the quality and quantity of the yield. (FAO 2010) As plant density decreases, yield per plant increases but yield per unit area decreases because there are fewer number of plants grown in a given area, however as plant density increases yield per plant decreases due to competition for light, moisture, space and nutrients this might consequently result in reduction in the total yield per hectare/acre. While use of inappropriate seed size, has made farmers use very small or too big seeds which in turn affects yield.

Generally, poor plant spacing/population and inappropriate seed size has made farmers experience low yields due to either too low or too high potato plant density. High seed rate increases production costs by 50% (FAOSTAT, 2014) and reduces yield by 25% (Forbes G 2012). High seed rate wastes seeds, requires much labor, increases fungal disease infestation therefore farmers are forced to buy expensive fungicides so as to cure these diseases. Disease infestation will definitely reduce yields if not controlled in time.

Low seed rate underutilizes the cultivated field and consequently reduces the total yield from a given acreage. Bulkiness and handling problems, large seeds increase packaging, handling and transport problems, small seeds make handling cheap and affordable. Determining the right seed size would solve the above problems. (FAOSTAT, 2014)

The above problems have affected potato production in greater Kabale area, a place that was very well known for potato production. This has affected people's livelihoods, made farmers food insecure, and reduced on the profit margin of a few farmers that have persisted in potato production. In Uganda, the above problems have affected agro industrialization, reduced government's revenue.

Uganda exports potato seed and ware to the neighboring countries of Rwanda, Burundi, Kenya among others. Any challenges that affect production equally affect the livelihoods of the neighboring countries.

From the above background, seed size and inappropriate plant population have greatly affected potato industry both locally and internationally and this makes this research very relevant since the results obtained will provide solutions to potato growing not only in Uganda but also in the whole world.

1.2 Problem statement

Potato yields in Uganda have remained low at 7 t ha⁻¹ (FAOSTAT, 2014) against a potential of about 30 t ha⁻¹. The potential yield of potatoes can be achieved when good agronomic practices are put in practice.

This research, “Effect of Plant Spacing and Seed Size on the Growth, Development and Yield of Potatoes” will provide solutions to the problems that have resulted from the use of inappropriate seed size and poor plant population/spacing. These include the following.

Reduced yields of potatoes due to either too low or too high potato plant density, increased production costs by 50% (FAOSTAT, 2014) and reduced yields by 25% (Forbes G 2012).

High seed rate wastes seeds, requires much labor, increases fungal disease infestation therefore farmers are forced to buy expensive fungicides so as to cure these diseases.

Large seeds increase packaging, handling and transport problems, small seeds make handling cheap and affordable. Determining the right seed size would solve the above problems.

The above problems have affected potato production in greater Kabale area, a place that was very well known for potato production. This has affected people’s livelihoods, made farmers food insecure, and reduced on the profit margin on a few farmers that have persisted in potato production. In Uganda, the above problems have affected agro industrialization, reduced government’s revenue. Uganda exports potato seed and ware to the neighboring countries of Rwanda, Burundi, Kenya among others. Any challenges that affect production equally affect the livelihoods of the neighboring countries.

1.3 Purpose of the study

Conventionally it is recommended that potatoes (*Solanum tuberosum L.*) should be planted at a spacing of 75cm by 30cm using tubers of 35- 45mm in diameter (Barnes, F.B., 1981) Since this recommendation was made nearly 20 years ago several changes have taken place largely in the area of variety development and the environmental conditions. However, no research has been carried out to establish if the conventional recommendations are still relevant.

The purpose of this research therefore was to determine the relevancy of the conventional and earlier recommendations on plant spacing and seed size of potato (*Solanum tuberosum L.*) in relation to tuber yield.

1.4 Objectives

The general objective of the study was to determine the effect of plant spacing and seed size on the growth, development and yield of potato. (*Solanum tuberosum L.*)

1.5 The specific objectives were;

1. to determine the effect of plant density and seed size on the number of tubers produced by the potato plant
2. to determine the effect of plant density and seed size on the weight of tubers produced by the potato plant

1.6 Hypothesis

Planting potatoes of a bigger seed size at a wider spacing produces more tubers in number compared to planting small potato seeds at a closer spacing.

Planting potatoes of a bigger seed size at a wider spacing produces tubers that weigh higher than small seeds produced at a closer spacing.

1.7Significance of the study

The findings of this research will be the basis of new recommendations for plant spacing and seed size to plant.

The findings will also add to the existing literature about seed tuber size and potato plant spacing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Effect of plant spacing and seed size on the weight of tubers produced

Plant spacing and seed tuber size are important agronomic management practices in the production of potato. (Arsenault, et al 2001) However, potato farmers in Uganda often use haphazard plant spacing and seed tuber sizes, which contribute to the low yield of the crop. A study was designed to elucidate the effect of varied plant spacing and seed tuber sizes on yield and quality of potato. (Zebenayet.al2018) Average tuber weight was significantly affected by combined effects of plant spacing and seed tuber sizes. The highest average tuber weight (119.61 g) was obtained from 35-45 mm seed tuber sizes and at 75 × 30 cm plant spacing treatment combinations. Total tuber yield and marketable tuber yield significantly affected by plant spacing and seed tuber size where the maximum marketable tuber yield (33.68 t ha⁻¹) and total tuber yields (34.38 t ha⁻¹) were obtained at spacing of 60 × 30 cm and 50 × 20 cm, respectively, while highest total and marketable tuber yields of 36.16 and 37.65 t ha⁻¹, respectively, obtained from large-sized tubers (>56 mm). The use of medium plant spacing 60 × 30 cm under seed tubers size of 35-45 mm are recommended for potato production over than other seed tubers size and plant spacing combinations, farmers can use to get maximum yield. (Zebenayet.al 2018)

Another field study was carried out with the potato (*Solanumtuberosum*L.) to determine the influence of plant population density and seed tuber size on the crop's physiological growth components and yield performance under optimal field conditions (ZebenayDagne 2018 et.al). Two factors considered were seed tuber size and population density.

The first factor involved four seed sizes; S1 (small), 200-350 mm in diameter; S2 (medium), 350-450 mm in diameter; S3 (large), 450-550 mm in diameter and S4(very large), greater than 550 mm in diameter.

The second factor was population density (E) and it was at three levels; level 1 (E1) at 90 by 15 cm, level 2 (E2) at 90 by 30 cm, level 3 (E3) at 90 by 45 cm spacing. Parameters measured included shoot emergence (germination), haulm growth and yield.

There were significant differences in mean percentage germination at 9, 10, 11 and 12 days after planting across the four seed sizes. Plants from larger seed potato tubers exhibited greater physiological growth and yield (kg/ha) compared to smaller seed tubers when the experiment was terminated at 95 days after emergence.

Large and very large seed potato tubers exhibited greater overall resource use efficiency of allocation of metabolites as measured by growth components and yield at all plant density levels compared to small and medium sized seed tubers. (Aheisibweet *al*, 2015) This had implications on the duration of the bulking, physiological growth and consequently on yields obtained at harvest.

At the same time, plant population density had no significant effect on the number of days to emergence. (ZebenayDagneet.*al*2018).

From the results obtained in this study, it was concluded that the optimum plant population density for good yield was 90 by 30 cm and that large and very large seed sets gave the best yield.

In order to maximize yield performance in potatoes, it is recommended that specific seed sizes should be planted at specific plant population densities (Entz & La Croix, 1984; Creamer *et al.*, 1999; Bussan *et al.*, 2007).

Results showed the importance of lengthening the tuber bulking period by ensuring that the crop establishes earlier in the growing season and was able to produce a superior photosynthetic surface that can support tuber growth. At the same time haulm growth should not be excessive, as this will have negative effects on normal growth of potato tubers (Baker *et al.*, 1980; MacLean, 1984). It can be recommended that preference be put on medium to large seed potato tubers that have greater meristematic capital and are able to facilitate quick haulm establishment

2.2 Effect of Seed Size on the emergence

Seed tuber size significantly influenced the number of potato tubers formed at 30 Days After Emergence (DAE). Number of tubers initiated at 30 days after emergence significantly differed depending on seed size and population density.

According to Masarirambi *et al.*, more tubers were formed from larger seed tubers and the number increased from small seed tubers to larger tubers. As a result, the bulking period was greater in larger seed across all plant densities. Similar results were previously reported by Wurr (1974) the author's study on some effects of seed size and spacing on yield, grades and bulking rate of two potato varieties. Plants from large and very large seed tubers were not significantly different in terms of the number of tubers formed at 30 DAE.

This phenomenon was attributed to more vigorous and rapid growth of larger than smaller seed potato tubers. Tuber numbers were significantly affected by plant population density, with the highest density (90 by 15 cm) plants having a lower number of tubers per plant at 30 DAE. The highest number of tubers was found from plants spaced at 90 by 45 cm, followed by plants spaced at 90 by 30 cm. Space availability has an imposing effect on number of tubers formed. The greater the space, the higher the number of tubers formed (Gulluoglu & Arioglu, 2009).

2.3 Yield and number of medium seed tuber sizes (35-45mm)

Zebenay Nigussie Wassu 2014 reported that Plant spacing and seed tuber size had significantly affected numbers and yield of medium seed tuber sizes. The result showed that plants grown at 50 x 20 cm plant spacing produced 11.82 t ha⁻¹ number and yield of medium seed tuber sizes whereas low number and yield of medium seed tuber sizes, 6.51 t ha⁻¹ was recorded at 75 x 30 cm plant spacing. 50 x 20 cm did not statistically significant difference with plant spacing of 60 x 20 cm and 50 x 30 cm to produce numbers of medium seed tuber sizes.

Closer plant spacing produced high number of tubers per plant but of smaller sizes compared to those at wider plant spacing. Closer plant spacing leads to competition for resources like; water, space, light, this limits the size of the tubers produced. This was in agreement with Tesfaye et al. 2013 who reported that the highest number of medium sized potato tubers was obtained at closer plant spacing had higher competition among plants for resources.

The highest number of medium seed tuber sizes (35-45mm) was obtained at 60 x 20 cm, 50 x 30 x 30 cm and 50 x 20 cm plant spacing. Therefore, from the results of this study, it appears that plant spacing of 60 x 20 cm is appropriate for seed tuber production by considering better seed saving and intercultural operations.

Accordingly, for seed potato production, the results of this are consistent with the established recommendation given by EARO (2004). Endale and Gebremedihen (2001) also indicated that decreasing row width below 60cm can bring in cultural problems in addition to almost doubling the seed rate cost.

2.4 Effect of seed size on the number of Stems

Stem number significantly differed among the four seed sizes (S) and the three planting density levels higher stem numbers were recorded in plants established from larger than smaller tubers. Stem number was also related to crop density with highest stem numbers being produced at 90 by 30 cm, followed by crop planted at 90 by 45 cm and was lowest at the highest density plantings of 90 by 15 cm. Differences in stem numbers progressively increased with time as there were significant differences in the means for stem number per plant at 30 to 90 DAE compared to 10 and 20 DAE. (MASARIRAMBI *et al.* / *Int. J. Agric. Biol.*, Vol. 14, No. 4, 2012)

There was a significant difference in stem number per plant across the four seed sizes and density levels as small tubers (S1) produced fewer stems per plant than large (S3) and very large (S4) tubers. This phenomenon was due to the initial difference in sprout number between the four seed sizes

The highest amount of stems with an average of 38,58 m² were observed in the treatment where plants were grown from seed tuber sizes of 45-55 mm at a plant spacing of 15 cm, followed by those established from the same size at a plant spacing of 20 cm, with statistically significant differences between them. On the other hand, the fewest stems were produced in plants established in the control treatment, without statistically significant differences with those

developed from tuber size of 30 cm at a plant spacing of 30 cm. (Fernando Almeida¹, Jorge et, al 2016)

In general, within the same seed tuber size, as plant spacing decreases, the number of stems per unit area increases; this variable was favored by larger seed tuber sizes. The best way to determine the optimal number of stems for a specific area is to experiment with different plant spacing and tuber sizes by using commonly grown varieties in the area. In this context, the importance of recognizing the influence of seed tuber sizes on the number of stems per square meter was proved; a morpho-productive indicator that defines final crop results, considering the direct relationship between stem number and tuber production that contributes to final yields. (Fernando Almeida¹, Jorge et, al 2016)

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Description of the study area

The study was conducted at Bishop Stuart University farm located at 1000 meters above sea level with a gentle slopping altitude that facilitates good drainage. The experiment was carried out from 20th September 2021 to 10th Jan 2022 and from 9th Jan to 15th June 2022. The area receives an average annual rainfall of 1,200mm with two rainy seasons, during the months of February-may and September-December. The average relative humidity of 80-90%, the soils are deep, fertile, well drained and dark in color, these characteristics make them suitable for potato growing. This site was selected because of its accessibility by both the researcher and the supervisors.

3.2 Experimental treatments and design

The experiment used two factors, Plant density and seed size. The plant spacing used was 75 by 40cm, (P1) 75 by 30cm, (P2) 75 by 25cm (P3) and the seed sizes used were; 46-55mm (S1) 35-45mm, (S2) 20-34mm, (S3) in diameter.

These treatment combinations were arranged in a randomized complete block design (RCBD) with three replications and thus there were 9 treatment combinations

A total of 27 plots were planted and a total of 54 plants were randomly selected for data collection. The details of the layout are given in table 1

Table 1: Field experimental design and layout

	Block 1	2	3
Rows			
1	P1S1	P1S2	P1S3
2	P2S1	P2S2	P2S3
3	P3S1	P3S2	P3S3
4	P1S3	P1S1	P1S2
5	P2S1	P2S2	P2S3
6	P3S1	P3S2	P3S3
7	P1S3	P1S2	P1S1
8	P2S3	P2S1	P2S2
9	P3S2	P3S3	P3S1

3.3 Experimental procedures and cultural practices

The agronomic practices in season 1 and 2 involved, primary tillage, secondary, making ridges planting, weeding, spraying, harvesting.

The experimental plots were cultivated to the depth of 15 to 20 cm. The land was leveled and ridges were made by hand hoe basing on spacing between rows. The seed was treated with an insecticide, Malathion and pre-sprouted before planting. It was sourced from Kachwekano Zonal Agricultural Research Institute (ZARDI). The variety used was the medium maturing type which takes 90 days to reach physiological maturity.

Planting was done by selecting well sprouted seed tubers in each seed tuber size category according to the specified treatments for each variety. Weeding, cultivation and earthing-up and ridging were done at 30 days after planting to facilitate root, stolon as well as tuber growth and development. Ridomil MZ 63.5% WP at the rate of 2 Kg ha⁻¹ and Mancozeb at the rate 3 Kg /ha were applied for late blight (EARO, 2019).

3.4 Description of experimental materials

The experiment was conducted using the new variety Nakapot 1, it was selected based on its adaptability, yielding potential, and preference of the producers and consumers.

Potato seed of different sizes was obtained and graded according to size in diameter. These sizes included: potato seeds above 46mm in diameter these are labeled as S3.

Seeds 35mm-45mm, these were labeled as S2 (control seed size used in the experiment)

While those seeds less than 34mm in diameter were labeled as S1.

3.5 Experimental Procedure

3.5.1 Experimental measurements

3.5.1.1 Leaf Area Index

This is the ratio of one-sided leaf area to the ground area covered by the plant. Two plants were sampled out from two inner rows of each treatment combination and their Leaf Area Index measured as illustrated hereunder. The ground area covered by the plant was estimated by measuring the area covered by the whole plant and converted to centimeters. two sampled plants

from the two inner rows were harvested, leaves removed and traced on a graph paper. The area covered by all the leaves was recorded.

The ratio of the leaf area to ground area was therefore obtained.

3.5.1.2 Number of tubers per plant

At harvesting time, the number of tubers from the three sampled plants of the two inner rows were harvested, counted and recorded. This was regardless of the size of the tubers. The average number of tubers per plant were then determined.

3.5.1.3 Weight of tubers

The counted tubers from the sampled and harvested plants above (3.7.1.2) were weighed and recorded.

3.5.1.4 Days to emergence

Through visual observation, when 50% of the total tubers had emerged from the soil, recording was done.

3.5.1.5 Days to flowering

Through visual observation, when 50% of the total plants had flowered, recording was also done.

3.5.1.6 Yield per acre

This was determined by determining the plant population of potatoes in one acre at different levels of spacing as follows;

Total area in an acre= 4000m^2

Considering a spacing of 30cm by 75cm

Conversion into square meters, =0.3m by 0.75m

Area occupied by one potato plant = 0.225m^2

Number of plants in one acre= $4000\text{m}^2/0.225\text{m}^2$

3.6 Description of symbols used

S1.....seed size less than 34 millimeters in diameter

S2.....seed size between 35-45 millimeters in diameter (control seed size used in the experiment)

S3.....seed size between 46-55mm millimeters in diameter

P1 plant spacing of 75cm by 35cm (lowest plant population)

P2.....plant spacing of 75cm by 30 cm (control plant population used in the experiment)

P3..... plant spacing of 75cm by 25cm (highest plant population)

Each treatment had $9 \times 3 = 27$ plants randomly selected for data collection.

CHAPTER FOUR

PRESENTATION OF RESULTS

Analysis Of variance was carried out for most of the parameters measured. However, only means are presented in the thesis. Details of Analysis Of Variance are presented in the appendix.

4.1 Growth parameters

4.1.1 General

In both seasons 1 and 2, the emergence and overall establishment of the crop were good. Emergence at 15 days after planting was found to be 60-70% in both seasons. This is supported by Zebeny 2018 who concluded that well sprouted potato seeds take 12-20 days to emerge after planting.

Flowering was observed to have started at about 45 days after emergence in both seasons and the number of plants that had flowered was between 60-65%. Flowering took a normal trend according to Zebeny 2018

Well sprouted potato seeds take 12-20 days to emerge from the soil (Zebenay 2018). In this experiment, 15 days after planting at least 50% of the potato seeds had emerged from the soil.

Emergence of potato seeds from the soil was recorded on the 15th day after planting. In all the treatment combinations, emergence was between 66% which was the highest and 63% as the lowest. There was no much deviation in seed emergence therefore, no further analysis was necessary.

4.1.2 Leaf Area Index

Table 2: presents the mean Leaf Area Index measured at 60 Days After Planting (DAP) for season 1

	SPACING			
Plant Population	S1	S2	S3	Population means
P1	0.9	1.4	3	1.76
P2	0.6	1.2	2.1	1.3
P3	0.4	0.7	1.8	0.96
Means for Seed size	1.03	1.1	2.3	

LSD to compare plant population=0.544

LSD to compare spacing = 0.544

LSD to compare interaction=0.77

Under normal growth environmental conditions, the average Leaf Area Index should be 3. This indicates that the figures obtained in the above experiment are considerably lower. However, despite the fact that the figures are lower than expected, there was a clear trend in the mean of the Leaf Area Index. Treatment P1 produced a significantly higher LAI than P2 which is also higher than P3.

From Table 2, it can be seen that the results obtained were generally lower than the expected.

The highest value was obtained in treatment S3 (2.3)

Table 3: means for Leaf Area Index 60 days after planting (season 2)

	SPACING			
Plant population	S1	S2	S3	Plant popn means
P1	0.9	1.5	3	1.8
P2	0.6	1.2	1.8	1.2
P3	0.5	0.9	1.7	1.03
MEAN (seed size)	0.7	1.2	2.17	

LSD to compare plant population=0.51

LSD to compare spacing = 0.51

LSD to compare interaction==0.76

In season 2 (table 3) similar trends in LAI was obtained. S3 again produced Leaf Area Index which was significantly higher than S1 and S2.

4.2 Yield parameters

4.2.1 Weight of tubers per plant

Table 4: The average weight (grams) of tubers per plant for season 1.

	P/SPACING			
PP	S1	S2	S3	Ppn means
P1	97.66	101.66	475	224.77
P2	72.93	174.33	423.33	223.53
P3	49.66	156	325	176.88
Seed size Mean	73.41	143.99	407.7	208.43, General mean

LSD to compare spacing= 37.8

LSD to compare Plant population= 37.8

LSD to compare interaction= 122.6

At the lowest population density (P1) the highest average weight of tubers was recorded (224gms) as shown in table 4 above. P2 plant population produced tubers of 223.5gm per plant while P3 produced tubers that weighed the least (176gms)

The tubers produced from the seed sizes S1, S2, S3 increase in the order $S3 > S2 > S1$. There is a great significant difference in the seed sizes produced throughout the treatment. However, S3 seeds produced tubers that weighed highest while S1 seed tubers produced the lowest.

Interaction did not have a significant difference in all the combinations above.

Table 5: Mean tuber weight in grams (season 2)

	SPACING			
PP	S1	S2	S3	Pop. Mean
P1	102	151	474.66	242.55
P2	83.66	177.8	361.5	207.65
P3	49.86	167.13	154.33	123.77
Seed size Means	78.50	165.31	330.16	191.32
				general mean

LSD to compare spacing=**15.27**

LSD to compare plant population =15.27

LSD to compare interaction= **21.60**

The average tuber weight per plant recorded in season 2 (Table 5) above showed a similar trend like that in season 1 above.

4.2.2 Number of tubers per plant

Table 6: Average number of tubers per plant (season 1)

	Spacing			
PP	S1	S2	S3	PP means
P1	8.16	10.3	21	13.15
P2	6	12.1	18.5	12.2
P3	2.16	8.5	13.1	7.9
Seed size. Means	5.44	10.3	17.53	

LSD to compare spacing= 4.7

LSD to compare plant population = 4.7

LSD to compare interaction= 6.78

Average number of tubers produced per plant is given in table 6 for season 1

P1 represents potato plants that were planted at a spacing of 40x75cm this enabled plants to produce more tubers.

Considering a Least Significant value of 4.7, S3 produced tubers which are more significant than S1 however they are not significantly different from S2

Bigger seeds (S3) produced more tubers than Medium S2 and Small seed sizes. Tuber production increased in the order of $S3 > S2 > S1$

P1S3 produced the highest number of tubers compared to the rest of the treatment combinations while P3S1 produced the lowest number of potato tubers

Table 7: Average number of tubers per plant (season 2)

	Spacing			
Plant population	S1	S2	S3	PP total
P1	9	11	24.5	14.83
P2	6.33	13.5	21.33	13.72
P3	10.66	12	22	13.08
SP means	8.66	12.16	22.61	43.43

LSD to compare plant spacing = 4.783

LSD to compare plant population = 4.783

LSD to compare interaction= 6.76

Bigger seeds (S3) produced more tubers (22.61) than medium (S2, 12.6) and small seeds (S1). S3 produced more tubers which are significantly different from S1 and S2. However the seeds produced by S1 are not significantly different from those of S2. The results from season 2 are similar to those in season 1.

P1, P2, P3 produced tubers which are almost equal in number. They are not significantly different from one another. But still, p1 has more tubers than P2 and P3

The interaction of the two factors did not have any significant effect on the number of tubers produced across all the seed sizes.

4.2.3Yield per acre

Table 8: mean yield in tones per acre (season 1)

	Spacing			
Plant population	S1	S2	S3	Popn Means
P1	1.30	2.01	6.30	3.20
P2	1.20	2.70	5.50	3.1
P3	0.89	3.03	2.70	2.20
Means for seed size	1.13	2.58	4.83	2.80

LSD to compare Spacing = 0.94

LSD to compare plant population = 0.94

LSD to compare interaction=1.23

The yield obtained from P1 and P2 are not significantly different from each other while that one obtained from P3 is significantly different from both P1 and P2.

P3 recorded the lowest yield while P1 recorded the highest one.

Mean values of seed sizes are significantly different from one another. However, S3 has the highest mean value followed by S2 and lastly S1 as shown above.

Table 9: Mean yield per acre (season 2)

	SPACING			
	S1	S2	S3	Population means
P1	1.9	4.3	6.3	4.16
P2	1.1	3.2	4.5	2.9
P3	0.7	2.8	3.9	2.4
Seed size means	1.1	2.23	6.2	

Mean yield values per acre for season 1 and 2 did not show a great deviation from one another therefore the presentation given in season 2 above, also applies to that in season 1.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Growth parameters

Days to emerge from the soil and days to flowering did not have any significant effect on the yield, growth and development of potatoes.

5.1.1 Leaf area index

The analysis of variance showed that two main factors; seed size and plant population had a high significant effect on Leaf Area Index for both seasons as shown in table 2 and 3.

However, the lowest plant population produced the highest LAI in all the seasons this is attributed to:

A wider underground space provides a wider catchment area for nutrient and mineral absorption as this supports the vigorous and strong stand canopy with leaves of a wider area Gebremedihen (2001). The wider aerial space allows free growth and expansion of leaves that increases the area of individual leaves (Gulluoglu&Arioglu, 2009).

The highest plant population, produced leaves with the lowest LAI due to limited aerial space for free growth of leaves coupled with a smaller underground space as a catchment for minerals and nutrients which limited the growth of leaves Gebremedihen (2001)

The ANOVA shows that LAI across all the seed sizes is significantly different. However, large seed has the highest LAI while the smallest seed has the lowest one.

large seeds have a relatively larger store of minerals, nutrients than medium and small seed sizes (ZebeayDagne 2018 et.al).

the nutrients and minerals facilitate the seed to establish a strong stand with wider leaves compared to seeds of smaller sizes Bussan *et al.*, 2007).

Interaction of the two factors, seed size and plant population had a significant effect on the LAI produced by the crop. P1S3 (wider spacing and large seed sizes) produced the leaves with the highest LAI across all this was attributed to a larger store of minerals and nutrients in larger seeds and a wider underground and aerial space that favored growth and development of the potato plant (Gulluoglu&Arioglu, 2009).

5.2 Yield Parameters

5.2.1 Number of tubers

Tables 6 and 7 above show that there is no significant difference in the number of tubers produced by medium and small seeds. Whereas large seeds produced more number of tubers significantly different from small and medium seed sizes. These results agree with those of Zebeay 2018. Larger seeds have a relatively more number of ‘eyes’ and buds than smaller seeds. Eyes and buds on a potato seed increase the potential of the potato plant to produce more tubers. Larger seeds also have more stored energy and nutrients than smaller seeds. The stored energy and nutrients support tuber growth

The present results also agree with those of Tesfaye et al., 2011 who found out that tuber size is an important factor which contributes much to the number of tubers produced from a potato plant in that it produces vigorous sprouts, establishes a strong stand produces more roots per plant which support more tubers to grow.

Medium and small seeds, have limited stored energy which limits tuber production. They also have fewer eyes and buds that limit the potential to produce tubers. Tesfaye et al., 2011

While different plant populations did not have any significant effect on the number of tubers produced. In both seasons, factors that favor the production of tubers are not affected by plant population

The interaction of plant population and seed size did not produce tubers which are significantly different in both seasons.

5.2.2 Average weight of fresh tubers per plant

In both seasons, large seed produced tubers that had a higher average weight higher than medium and small. This is indicated in table 5 and 4 above. The average weights of fresh tubers in table 4 for season 1 and 2 are more than two times that of medium and five times that of small seeds. large seeds produced tubers which weighed more significantly different from those of small and medium seeds. This explanation agrees with those of Gulluoglu & Arioglu, (2009).

This is because large seeds have got a relatively higher amount of stored nutrients and energy to enable the crop to establish a vigorous and strong stand that favorably competes for space suppresses weeds and improves overall plant growth (Bussan *et al.*, 2007).

The strong stand of the potato crop also has more leaves which act as the ‘factories’ for starch which is used in tuber initiation and formation

Small and medium seeds produced tubers that had a lower fresh tuber weight since they have limited stored energy and nutrients to support plant growth (Wassu 2014)

This makes the crop produce a weak canopy that is out competed by weeds, and reduces the efficiency of photosynthesis.

Different levels of plant population had a great significant difference on the weight of fresh tubers produced in both seasons the means of fresh tuber weight are so significantly different from one another with potatoes planted at the lowest spacing producing tubers with the highest fresh weight followed by medium spacing which was the control experiment and lastly those ones planted at the closest spacing.

Potatoes planted at the lowest spacing produced tubers with a higher fresh weight of tubers due to:

Reduced competition, there was less competition for space, nutrients for wider spaced potatoes.

Wider spacing allows the crop to utilize the available nutrients for yield, growth and development (Gulluoglu&Arioglu, 2009), this in turn produces a higher yield than those crops which are closely spaced.

Wider spacing improves the efficiency of photosynthesis. All most all the leaves of the plant can access sun's rays during the process of photosynthesis and this improves yield of the crop (Wassu 2014)

While a high plant population leads to increase in competition for space, nutrients and light and this reduces yield (Bussan *et al.*, 2007).

In high plant populations, the micro climate favors the growth and development of fungal diseases like Early and Late Blight if these are not controlled, they make the leaves and tubers rot

and consequently small tuber sizes leading to lower fresh weight of the tubers produced. (Wassu 2014)

The interaction of both factors seed size and plant population (P and S) produced fresh tuber weight significantly different from one another in both seasons. P1S3 produced tubers that had a higher fresh tuber weight than the rest. The interaction of large seed size and wider spacing provided better conditions for growth yield and development compared to those that had small seeds and closely spaced.

Large seeds have more nutrients and stored energy for vigorous growth and development. This was further enhanced by the available space that provided a bigger catchment area to tap and utilize nutrients to support growth development and yield. The combination of these factors enabled the potato crops to produce tubers with a higher tuber fresh weight than all the other combinations.

5.2.3Yield per acre

Tables 7 and 8 above represent the mean yield in tones for both seasons. There is a significant difference in the mean yields for both seasons across all seed sizes at varying population densities. However, potatoes planted at the lowest spacing, had the highest mean yield in both seasons while those planted at the highest spacing present the lowest mean in both seasons. Lowest spacing presents the highest mean yield in all the seasons this is attributed to:

Available aerial and underground space. Aerial space allows the leaves to position themselves well so as to capture the sun's rays during photosynthesis. Underground space provides a wider catchment area for minerals and nutrients that support vigorous plant growth yield and development (Gebremedihen, 2001)

P3 presents the lowest mean yield in both seasons; this is attributed to competition for space, nutrients and light for photosynthesis. The product of these insufficient growth and development factors in crops result in low yields (ZebeayDagne 2018 et.al).

The LSD value presents a great significant difference in the mean yield across all the seed sizes. However, large seeds produced the highest mean yield compared to medium and small seed sizes. Larger seed sizes have got a larger store for nutrients and mineral that support plant growth and development (Aheisibwe et al, 2015)

However, smaller seeds have a smaller storage for nutrients and minerals that limit plant growth, yield and development.

The interaction of both factors produced a mean yield which is significantly different from one another.

5.3 Conclusion and recommendations

Varying seed sizes have a significant effect on the yield, growth and development of potatoes.

large seed size produces tubers with a higher fresh weight, more in number and the overall yield per acre compared to medium and small.

Medium seed also performs better in terms of tuber fresh weight, number of tubers and the overall yield per acre than small seed size.

Small seed size performs least compared to the medium and large seeds

This therefore implies that, with regard to the choice of the seed size to plant with intentions of producing tubers with a greater fresh weight, more number of tubers, and a higher yield per acre, it is recommended to plant large seeds.

Farmers with intentions of producing potatoes with medium fresh weight especially those in potato seed businesses are advised to plant medium seed sizes. Farmers are discouraged from planting small potato seeds.

Large seed size produced potato plants with a higher Leaf Area Index compared to small and medium.

Different plant population densities have a significant effect on the yield, growth and development of potatoes.

Potato plants planted at the lowest plant population, produced more number of tubers with a higher fresh weight and overall yield per acre higher than those planted at medium and close spacing.

The growth, yield and development of potato plants reduced with increasing plant population densities.

This implies that farmers are recommended to plant potato plants at lower population densities.

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APPENDICES

Appendix 1: Yield Parameters

ANOVA average weight of tubers in grams per plant (season 1)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	1,780,021.44		
BLOCKS	2	21,162.88	10.581.44	3.16
T/COMBINATIONS	8	1,705,334.09	213,166.76	63.72*
PP	2	4,3716.19	2,185.59	0.65
SPACING	2	63,905.42	31,952.71	9.55
INTERACTION	4	1,637,057.48	409,264.37	122.34
ERROR	16	53,524.47	3345.2	

LSD at 5%

LSD at 5% $\sqrt{\text{error } 3345.27 \times 2 \times t}$ (at error DF)

N

$= \sqrt{743.33 \times 2.12}$

$27.26 \times 2.12 = 57.8$

LSD to compare interaction=

LSD at 5% $\sqrt{\text{error variance } 3345.27 \times 2 \times t}$ (at error DF)

N

$= \sqrt{3345.27 \times 4 \times 2.12}$

57.83×2.12

$= 122.6$

ANOVA for Average weight of tubers (grams) per plant (season 2)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	457,546.17		
BLOCKS	2	162,67	8133.5	34.79
T/COMBINATIONS	8	437,539.4	54692,42	233.98
PP	2	39,089.34	19544.67	83.77
SPACING	2	24,178.45	12,089.22	51.72
INTERACTION	4	374,271.61	93,567.9	400.32
ERROR	16	3,739.77	233.73	

LSD at 5% $\sqrt{233.73 \times 2 \times t}$ (at error DF)

N

LSD= **15.27**

LSD to compare interaction

LSD at 5% $\sqrt{233.73 \times 4 \times t}$ (at error DF)

N

LSD= **21.60**

ANOVA for yield in tons per acre (season 2)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	101.6		
BLOCKS	2	2.53	1.26	0.2
T/COMBINATIONS	8	7.28	0.91	0.1
PP	2	3.48	1.74	0.3
SPACING	2	2.1	1.05	0.1
INTERACTION	4	3.89	0.97	0.16
ERROR	16	91.79	3.13	

Correction factor= 0.94

Block ss= 2.53

Treatment ss =7.28

PP ss = 9.48

LSD to compare Spacing

LSD at 5%

LSD at 5% $\sqrt{\text{error var} \times 2 \times t}$ (at error DF)

N

LSD= 0.94

Interaction

LSD at 5%

LSD at 5% $\sqrt{\text{error var} \times 4 \times t}$ (at error DF)

N

LSD=1.23

ANOVA for Total number of tubers per plant season 1

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL SS	26	24847.1		
BLOCKS	2	16.62	8.31	0.036
T/COMBINATIONS	8	24,461.85	3,057.73	132.71
PP	2	384.17	192.08	8.33
SPACING	2	867	433.5	18.8
INTERACTION	4	23,210.68	5,802.67	860.87
ERROR	16	368.64	23.04	

LSD at 5% $\sqrt{23.04 \times 2 \times t}$ (at error DF)

27

LSD= 4.7

LSD to compare interaction

LSD at 5% $\sqrt{23.04 \times 4 \times t}$ (at error DF)

9

LSD= 6.78

Total SS=**26675.5**

Correction factor =5,662

Block SS = 25.7

PP SS= 364.17

Tt SS= 26,283.24

ANOVA for the number of tubers per plant season 2

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL SS	26	26675.5		
BLOCKS	2	25.7	12.85	0.56
T/COMBINATIONS	8	26,283.24	2,810,.20	122.66
PP	2	364.17	182.08	7.94
SPACING	2	942	471	20.55
INTERACTION	4	24,977.07	5,293.86	231.07
ERROR	16	366.56	22.91	

LSD at 5% $\sqrt{22.91 \times 2 \times t}$ (at error DF)

27

LSD= 4.783

LSD to compare Interaction

ANOVA for LAI 60 days after planting (season 1)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	21.87		
BLOCKS	2	0.57	0.285	0.31
T/COMBINATIONS	8	6.89	0.86	0.95
PP	2	1.503	0.75	0.83
SPACING	2	2.52	1.26	1.4
INTERACTION	4	2.867	0.71	0.78
ERROR	16	14.41	0.9	

LSD to compare interaction=

LSD at 5% $\sqrt{\text{error variance} \times 4} \times t$ (at error DF)

N

$=\sqrt{0.9 \times 4} \times 2.12$

27

=0.77

LSD to compare spacing

LSD at 5% $\sqrt{\text{error variance} \times 2} \times t$ (at error DF)

N

$=\sqrt{0.9 \times 2} \times 2.12$

27

0.544

ANOVA for LAI 60 days after planting (season 2)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	21.06		
BLOCKS	2	0.29	1.14	1.29
T/COMBINATIONS	8	6.57	0.82	0.93
PP	2	1.77	0.88	1
SPACING	2	1.47	0.73	0.82
INTERACTION	4	3.33	0.83	0.94
ERROR	16	14.2	0.88	

LSD to compare interaction=

LSD at 5% $\sqrt{\text{error variance} \times 4} \times t$ (at error DF)

N

$$=\sqrt{0.88 \times 4} \times 2.12$$

27

$$=0.76$$

LSD to compare spacing=

LSD at 5% $\sqrt{\text{error variance} \times 2} \times t$ (at error DF)

N

$$=\sqrt{0.88 \times 2} \times 2.12$$

27

$$=0.51$$

LSD at 5% $\sqrt{22.91 \times 4} \times t$ (at error DF)

$$9\text{LSD} = 6.76$$

ANOVA for yield in tons per acre (season 1)

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	36.7	1.4	
BLOCKS	2	3.9	1.95	1.3
T/COMBINATIONS	8	9.02	1.1	0.7
PP	2	4.3	2.15	1.5
SPACING	2	1.5	0.75	0.5
INTERACTION	4	3.22	0.8	0.5
ERROR	16	23.78	1.48	

LSD at 5% $\sqrt{\text{error} \times 2 \times t \text{ (at error DF)}}$

N

$\sqrt{1.48 \times 2 \times 2.12}$

27

LSD=0.46

LSD to compare plant population= 0.46

LSD to compare seed size=0.46

LSD to compare interaction

LSD at 5% $\sqrt{\text{error} \times 4 \times t \text{ (at error DF)}}$

N

$\sqrt{1.48 \times 4 \times 2.12}$

27

0.66

LSD to compare interaction= 0.66

ANOVA table for average yield per acre season 2

SOURCE OF VAR	DF	SS	VARIANCE(MS)	VAR.RATIO (F)
TOTAL	26	45.6	1.75	
BLOCKS	2	3.9	1.95	0.9
T/COMBINATIONS	8	7.05	0.88	0.4
PP	2	4.3	2.15	0.5
SPACING	2	1.5	0.75	0.34
INTERACTION	4	1.25	0.31	0.14
ERROR	16	34.6	2.16	

LSD at 5% $\sqrt{\text{error} \times 2 \times t}$ (at error DF)

N

$\sqrt{2.16 \times 2 \times 2.12}$

27

LSD to compare spacing = 0.8

LSD to compare plant population= 0.8

LSD to compare interaction =

LSD at 5% $\sqrt{\text{error} \times 4 \times t}$ (at error DF)

N

LSD= 1.19