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Effects of Seed Tuber Size on Growth and Yield Performance of Potato (*Solanum Tuberosum L*)

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Abstract - This research was conducted in Kasiya agricultural camp of Pemba district of southern province of Zambia. Latitude 16.531 and longitude 27.275 (according to the GPS from TSB, DACOs office). The aim is to determine the effect of tuber seed size on the growth and yield performance of Irish potatoes (Solanum tuberosum) in the agricultural camp. The data was generated through the experiment and complete randomized design with three treatments which were used with three replicates in the plots. Each plot was three (3) meter by two point twenty-five (2.25) meters per treatment. The treatments tested in this study were categorized as follows; treatment three (3) (T3) was the local seed from the farmers; treatment two (2) (T2) was certified seed from farmer's burn, Lusaka town center outlet. Treatment one (1) (T1) was small certified seed also from farmer's burn, Lusaka town center outlet. All the treatments were replicated in 3 beds which are 3.3 meters by 2.25 meters, planting was done on the same day at the recommended spacing of 75 x 30cm. Fertilizer was applied at the rate of 0.185 kg per plot (1.67kg for the 9 plots) basal at planting and 0.111kg per plot (1kg for all the 9 plots) ammonium nitrate top dressing was applied at flowering stage. Numbers of rows per plot were 4 and number of plants per row was 11 that add up to 44 plants per plot. That is making a total plant population of 396 plants for 9 plots. Data collection was done every Sunday from the day of planting; Data collected was subjected to complete randomized block design (CRD), analysis of variance (ANOVA) using Gen start 12th edition computer software. The treatments statistical mean was separated from one another by least significance difference (LSD) test at 5% significance level. The results from this study reveal that there is a significant difference among treatments. T_2 had the highest average yield. The average yield per hectare was 3.64tones, 9.79tones and 6.53tones for T_3, T_2 and T_1 respectively. The results of T_2 indicate 169% more than T_3 and 89.6% higher than T_1. This concludes that medium certified tubers have the potential to increase yield and income among small scale farmers. And there is still need for more research to be done, as the soils were not tested for their levels of nutrition, acidity, insect and diseases attack. Water holding capacity. The results did not consider tests which were not done.

Key Words: *Irish potatoes, Fertilizers, Complete random block design, Analysis of variance, Pemba, Mine, least significance difference, Treatments Certified seed, Local seed, Kasiya*

Introduction

Irish Potato (Solanum tuberosum L.) is an important food and cash crop in world over; serving, as a food security crop due to its nutrition content, wider adaptability and early maturing behavior. However, the yield of the crop is constrained by a number of factors. Among which unspecified tuber seed size and limited availability and distribution of improved varieties are among the important limiting factors. Potato (*Solanum tuberosum* L.) is the main crop among those producing roots and tubers. It is harvested in more than 125 countries, besides being consumed by over a billion people. Cultivars Tropicales, (2016) vol 37, no 2, pp 88-95 April-June It is widely accepted and many families depend on it as a primary and secondary source of food and nutrition. It is very nutritious, as it is rich in protein, calcium, potassium and vitamin C, in addition to a good amino acid balance. It is very productive and produces more food per capita in time and space than wheat, rice and maize. China, India and the Russian Federation are among the highest potato-producing countries in the world; however, top yields are between 41 and 45 t ha, mainly concentrated in the Netherlands, Germany and the United States. Particularly in Africa, over the latest decades, marketable potato production has increased from 2 million tons in 1960 up to near 16.7 million tons in 2007, with an average yield of 10, 8 t ha-1, despite being developed in a wide range of soil and climatic conditions, Egypt, Malawi, South Africa and Algeria provide 59 % of the entire potato produced in Africa. Within the African continent, Zambia contributes 30,000 metric tonnes per year on 1200 ha (ZNFU weekly report March (2017). They are still very low if compared with those obtained in South Africa, which are from 24 to 34 t ha. Several factors could have influence on low yields of potato production in Pemba and Zambia as a whole. Crop management is one of them, which is not fully applied by small scale farmers; planting frames are very diverse as each grower uses any tuber size, time of planting and spacing according to his own criteria. A field experiment was conducted to study the effects of tuber seed size on growth and yield performance of Irish potato at Kasiya Agricultural camp field during 2018 farming season. The treatments consisted of two potato varieties the first being land pent dell certified tubers which had small and medium tuber size and the second being local variety which had small tubers which farmers use to plant, So two tuber sizes, medium and small from land pent dell and (for local) small seed tubers. That is adding up to three treatments.

Potato (Solanum tuberosum L.) belongs to the nightshade or Solanaceae family and originated in South America (Asfaw, 2016). Globally, potato is the third most important food crop in terms of consumption after rice (De Jong., 2011; Birch, 2012; Hancock, 2012). The global cultivation exceeds 19.34 million hectares of land in more than 158 countries across the world with an estimated annual production of 364 million tons (FAOSTAT, 2014). It is an important tuber crop grown widely in the humid tropics and used as a source of carbohydrates for many people in tropical and sub-tropical regions (Bilate and Mulualem, 2016). Potato is a high potential food security crop in Africa due to its high yield potential and nutritional quality tuber, short growing period, and wider adaptability (Ayalew., 2014). Potato plays a major role in national food security, nutrition, poverty alleviation and income generation (Ayalew, 2014; Gedif. 2013). The crop also provides employment opportunity in the production, processing and marketing sub-sectors (Menza. 2014). It is grown in over 3.5 million smallholder farmers in the highland areas and known to buffer food deficit during the months of limited food supply (November - march) before the grain crops are being harvested (Tebabal, 2014). Zambia is among the potato producing countries in Africa, with 70% of the arable land suitable for potato production

(FAOSTAT, 2008). Potato production and productivity is low due to several constraining factors such as inappropriate planting materials, prevalence of disease and pests, in some instances poor soil fertility (Menza, 2014), variability in climatic patterns, shortage of water, shortage of agricultural inputs, and poor post-harvest handling practices (Tesfaye, 2011).

Similarly, in some instances, absence of improved certified varieties, dependency on traditional management practices and unproper tuber seed size are among the important factors challenging our small-scale potato producing farmers in Kasiya camp and the country Zambia as whole. The productivity of potatoes by small scale farmers in Africa is less than 11.8 tons per ha (CSA, 2014). Among the factors contributing to this low production and productivity is the use of local varieties that are low in yield and susceptible to disease (Asefa, 2015). And also seed tuber size is a limitation for potato production in the area. Therefore, there is an urgent need to determine proper seed tuber size for potatoes grown in the area. In general, potato seed tuber size and varieties in the Southern province of Zambia have not been sufficiently evaluated for increasing higher yields. Considering the above limited research work, it is important to identify optimum tuber size and varieties for maximum potato production. Therefore, the objective of this study is to evaluate the growth performance and yield response of potato varieties to variable seed tuber sizes.

Potatoes are indigenous to the Andean regions of Peru, Chile and Bolivia, extending northward to the southern Rocky Mountains. (Gugerli, 2018 and Martinez, 2018). Cultivated potato, *Solanum tuberosum* L., is a highly heterozygous tetraploid (4x = 48), belongs to the Solanaceae family together with other crops like tomato and peppers (Kuzuo, 2015) Potatoes are adapted to an array of climates and are utilized in many ways. The potato tuber is not only the principal mean for potato propagation, but also a major human food source. Potatoes are mainly propagated by vegetative methods (cloning). (Krystyna, 2015). Potato tubers have nodes or (eyes) from which the new growth begins. The new stems growing from each (eye) are called sprouts which give rise to the new plant. Vegetative seed can be either a whole tuber or a cut tuber. Physiological age of seed is influenced by growing conditions, handling, storage and cutting procedures, and it has an impact on how the new crop grows. Sexual propagation occurs by means of botanical or sexual seed. Most potato cultivars produce fruit; each seed will develop into a plant with unique characteristics. This is a process very useful in crop improvements in breeding programs, but its genotypic variation is of little value to growers. (National Science Foundation (NSF. 2008) Tissue culture is another method which permits a very rapid propagation. This method is used to maintain disease free seed stock, which can be then stored (in vitro) and be used when is needed. Potato is an annual dicotylendon when grown for botanical seed, but is treated as a perennial because the vegetative propagation from tuber for commercial purposes. (Yancheva S. and Kondakova V. 2016) Potatoes are adapted to an array of climates and are utilized in many ways. There are potato cultivars developed for different environments and end users. (Vilela. 2009) Because of the wide adaptation and many species, a vast genetic resource can be called upon for introgression of resistance to disease and insect pests, stresses, as well as improvement of quality traits. Vegetative reproduction ensures a uniform crop, contraire to what would happen with sexual propagation. Sexual propagation of potato is accomplished by planting its (true seed), but a high variability exists between this seed and that is why is not commonly used. However, sexual seed is becoming more and more popular; especially in places were disease pressure is very high and maintaining disease free seed is becoming a problem. (*Royal Horticultural Society Propagation Techniques 2013 and* Thompson, Peter. 2005.)

When potato growers talk about seed, they are talking about the tuber and not the botanical or sexual seed. (De luca and Dr Lee 2016). De luca and lee continue, Potato tubers are actually a modified stem with approximately 70-75% content of water and a remaining 25-30% of dry mater. They have nodes or eyes from which the new growth begins. The new stems growing from each eye are called sprouts. Sprouts grow from the tuber after a period of dormancy after they are harvested, this varies largely between cultivars. After this dormancy is broken, sprouts grow and when planted, they give rise to the plant stems and from there all the vegetative part of the plant. Underground, lateral shoots called stolons are formed, from which the new tubers will be formed. Vegetative seed can be either a whole tuber or a cut tuber. The standard seed piece used by growers is 2 by 2 or 2 oz. (ibid).

Research has shown that a seed piece this size (see appendix) has the adequate amount of carbohydrates levels for shoot initiation and growth (De luca and Dr Lee 2016). If the tubers are cut, the usual procedure is to let the cut pieces to suberize or cure, for about 10 days. Suberization in tubers allows them to develop a corky layer around the seed piece that prevents the seed piece decay by the entrance of several kinds of pathogens. Physiological age of seed is not the chronological age of the seed piece; instead, is the influence of the growing environment of the seed. Physiological age of seed is influenced by growing conditions, handling, storage and cutting procedures. Physiological age of the seed will have an impact on how the new crop grows.

For higher final yield in a long season it is very important to manage the physiological age of the seed because it has a big impact on how the new crop is going to look like and it will probably, along with many other factors, determine whether the crop will be of a high quantitative and qualitative value**. (**William. 2017)

De luca and Dr Lee 2016, continues to emphasize that other than seed age, there are some pros and cons when talking about vegetative reproduction, some of them include the fact that cloning assures genetic purity and product uniformity, it also favors high yields. Some of the disadvantages are that cloning favors disease spread (e.g. viruses, bacteria, fungi), and also a significant amount of storage space, transportation and heavy planting equipment is required. Most potato cultivars produce fruit but some are pollen sterile or fail to set fruit for other reasons. If fruit is established, they usually are small, up to 1.25cm in diameter and are green colored, resembling a small tomato. The fruit contains the true seeds of potato plants, containing approximately 300 seeds per fruit. When the potato plant reproduces, usually through self-pollination, the chromosomes (along with the genes they carry) are randomly distributed to the seeds. Each seed will develop into a plant with unique characteristics. (Bruins, 2018) This is a process very useful in crop improvements in breeding programs, but its genotypic variation is of little value to growers because a new plant could be totally different to the mother plant and no uniformity would be seen in the field. Some of the advantages that true potato seed have, are that they don't carry any diseases and that seed can be stored in small places contraire to what happens with tubers. Tissue culture permits a very rapid propagation. (Mohaidib, M.S. 2009). Under traditional propagation, one tuber yields approximately 8 daughter tubers in one growing season, while with tissue culture, 100,000 identical plantlets can be produced in eight months, that when transferred to the field, could produce 50 metric tonnes of potatoes.

The process of this technique is very simple says De luca, C and Dr Lee, C. 2018, D e luca and Dr lee said their research that, disease free plantlets are

grown in test tubes on a nutrient media. Each plantlet is cut into 3 to 10 nodal sections after 18-60 days. Each new cutting is planted in a new test tube. This can be repeated until the desired number of plantlets is obtained. Plantlets are then removed from the tubes and grown in sterile soil and let them complete their entire growth cycle. Tubers produced are collected and stored to later be sold to growers. This is also the process followed to obtain certified seeds. This first seed lot would be called nuclear seed and then after harvesting the product of this seed you get Generation 1(G1) and so forth. Meristem have no vascular system, therefore are less prone to viral, fungal and bacterial infections. For this reason, this method is used to maintain disease free seed stock, which can be then stored in vitro and be used when is needed. Any potato variety can be propagated vegetatively by planting tubers, pieces of tubers, cut to include at least one or two eyes, or also by cuttings, a practice used in greenhouses for the production of healthy seed tubers. Some commercial potato varieties do not produce seeds at all (they bear imperfect flowers) and are propagated only from tuber pieces.

Tubers are commonly used as planting materials. However, the medium sized tubers are commonly used as propagates amongst small scale farmers. (Hulse. 2019) Hulse continues, “Increased seed size, produces larger total harvestable tuber numbers. Yield increases as the seed size increases as a result of adequate nutrient reserves for the growing plant”. From the research conducted, yield varies with the tuber size used. The effect of tuber seed size on yield and tuber number per sprout varied between years but mini tubers gave lower yields per stem than larger seed tubers. As sets size increased, sprouts/ha and stems/station increase. Using larger seed pieces, will not necessarily produce larger tubers, but may have the opposite effect, as the feeds off the seed and does not produce underground stems on which the tubers develop. The Irish potato seed size has an effect on the harvestable tuber sizes. Increased seed size produces large progeny while the planting depth has little effect on the harvestable tuber sizes. (Barry, 2002) Large tuber seed size emergences faster than small tubers. It provides ground cover soon after emergency, higher dry matter yields and high fresh tubers yields. The mini tubers produce only one primary stem. Reduced stem number is often associated with small tuber sets and a large tuber size produces more stems. Sprouting of eyes on stems of small tubers delays or may not occur. (Dainello.J and Roland. 2006)

Irish potatoes supplements or replaces grain-based diets where rice, wheat, or maize availability has lessened or price has become unaffordable. Potato is also inexpensive to buy and easy to grow. It can give stable yield under conditions where other crops might fail, suitable to grow where land is limited and labor is plentiful. Its plasticity to environmental conditions and yielding capacity also make it the best crop for food and nutrition security. (Hailu. 2017)

Despite of high demand of Irish potatoes and profitability of the crop, the problem is low Irish potato production in Zambia (as above stated in the graph) more especially amongst small scale farmers, in Pemba district of southern province. In the province, potatoes being consumed are being imported from Malawi and Tanzania supplying eastern and Northern provinces which then trickles to southern province. (Zambia daily mail, 2015). Buyabamba farms and few local small-scale farmers from Chikankanta district (Smart Zambia institute,2019) are trying their best to come into play as producers but still failing to meet the demand due to low production as compared to mouths to feed. For someone to access the tuber for home consumption then they have to incur transport costs of ferrying the produce to the district in this scenario Pemba district. Despite Zambia being a blessed nation with all the resources required to produce her own potatoes at affordable price. Small scale farmers use their own local seed for potato production. Which results in

poor yields, this might be due to the reason that, small scale farmers do not know the exactly or recommended size of tubers to be used as planting materials in order to yield the intended goal. It has been observed that when farmers harvest Irish potatoes, they tend to sell off the harvest at low prices due to the size of tubers and if there are any slightly bigger ones, they are selected and sold off first. The crop performance and yield has been very poor (low) for the small-scale famers leading to low levels of participation in the market there by low income levels. (Chanda. 2013) the demand for potatoes continues to increase in conjunction with expanding diet diversity, requests for prepared food items, and a need for inexpensive foods. The ability to grow potatoes in a wide range of climates and their adoption by a broad range of cultures has increased potato consumption worldwide. (Agriculture *& Food Secure (2017).* Therefore, potato is currently the predominant vegetable in terms of sales, production, and consumption. It is the most important crop in developing countries, and its production is expanding more rapidly than other food crops. As a result, it is becoming an increasingly important source of rural employment, income, and food for growing populations

With the above advantages the crop has on the farming community, still there is low production, the researcher thought it is important to carry out a research on the planting material the farmers are using and determine whether there are effects of tuber seed size on the growth and yield performance of Irish potatoes in Pemba district.

The aim of this research was:

1. To determine whether the tuber seed size has any effect on the growth and yield performance of potato *[Solanum tuberosum]*.

The Main objective was:

1. To determine whether there are effects on the tuber seed size (medium, small) on the growth and yield performance of Irish potatoes.

In order to achieve the above objective, the study had the following specific objectives were;

1. To determine the number of shoots per station
2. To determine the average stem diameter
3. To determine the average harvestable tuber size
4. To determine the yield

Materials and Methods

The field study was conducted during 2018 and 2019 farming season or rainy season at the farm in Kasiya camp, Pemba district in southern province of Zambia. The soil profile was well drained with a saturated with good water holding capacity. The site was under bucket irrigation and rain fed.

Treatments included three cultivars (local, certified medium and certified small), one planting configuration (4 rows /plot), and three in-row plant spacings for each planting configuration. Plant spacing for the planting configurations were based on published recommendations (4RC) (Tarkalson, 2011) and best scientific judgment (5RB and 7RB) since no research has been conducted to determine the optimum in-row plant spacings in order to give a potential range around the optimal population for production. For the 4RC planting configuration, the middle plant spacing treatment for each cultivar was based on recommendations from Tarkalson. (2011), the widest in-row plant spacing was set to equal the plant population given by the middle in-row plant spacing treatment of the 4RC planting configuration for each treatment. The middle and narrowest in-row plant spacings for the bed planting configurations were established by decreasing the widest in-row plant spacing by approximately 13 and 30%. The same was done by the researchers David. D (2011) in their research using cultivars, Russet Burbank and Russet Norkotah, the in-row plant spacing produced plant populations (plants ha−1) ranging from 26,900 to 53,800 for the 4RC planting configuration and 35,900 to 46,600 for the 5RB and 7RB planting configurations. For Ranger Russet the in-row plant spacing produced plant populations (plants hectare) were ranging from 28,700 to 61,500 for the 4RC planting configuration and 39,100 to 50,900 for the

5RB and 7RB planting configurations. A systemic insecticide treatment (imidacloprid) was added to the seed pieces prior to planting. Each treatment combination was replicated four times in a randomized complete block factorial design. Each plot was 3.7 m wide and 7.6 m long. Prior to planting in 2008 and 2009, soil samples were collected at depths of 0 to 30 and 30 to 60 cm across the study locations to determine nutrient input requirements. Subsamples from each site and depth were composited; air dried, ground to pass through a 2 mm sieve, and analyzed for bicarbonate extractable Phosphorus and potassium (Ayelew.2016. Motsara and Roy.2008), and nitrate nitrogen and Ammonium nitrogen (Motsara and Roy.2008). Based on the soil test results, nutrients were applied over the entire study area in fertilizer based on the University of Idaho recommendations for Russet Burbank potatoes and a yield goal of 49 Mg per hectare (Hopkins.2015 Stark .2004). In 2008, N, P (as Phosphorus pent oxide), and manganese (Mn) were applied at rates of 258, 202, 11 kg hectare, respectively. Nitrogen was split applied with 155 kg ha−1 (urea, 46% Nitrogen) applied prior to planting and 56 kg Nha−1 (urea ammonium nitrate, 32% Nitrogen) applied through irrigation water on July 11 and 28. In 2009, Nitrogen, Phosphorus, and manganese were applied at rates of 134, 280, 8 kg ha−1, respectively. Nitrogen was split applied with 44 kg ha−1 (urea, 46% Nitrogen) applied pre plant and 45 kg N hectare (urea ammonium nitrate, 32% Nitrogen) applied through irrigation water on July 1 and 22. Phosphorus fertilizer consisted of ammonium polyphosphate (10-34-0).

Plots were hand planted on May 6 and 11 in 2008 and 2009, respectively to ensure precise plant spacing. A toolbar with adjustable harrows was used to mark rows for the three planting configuration treatments. After marking rows, a push harrow was used to make the seed furrow. Precise seed piece placement was accomplished using marked PVC pipes. The seeds were then covered with the soil to a depth of approximately 15 cm. For the 4RC configuration a toolbar with large furrow shovels was used to make the hills. The plots were irrigated to meet the estimated crop evapotranspiration rate for potatoes. The crop was calculated using the U.S Bureau of Reclamation AgriMet System) based on climatic conditions measured within 4 km of the study site. Average irrigation rate was 50 mm h−1 and peak rate was 100 mm h−1. Total individual irrigation times were less than 30 min. University of Idaho recommended weed control practices were used in 2008 and 2009.

Prior to harvest, potato vines were killed with a desiccant spray (diquat dibromide) on September 15 and 11 in 2008 and 2009, respectively. Tubers from this study were harvested with a conventional 4-row potato windrower on September 25 and 23 in 2008 and 2009, respectively. An area 3.7 m wide by 4.9 m long was harvested from each plot, bagged by hand and stored until graded. Plot samples were graded (U.S. No. 1 and No. 2 tubers) and passed through an automated potato sizing machine that weighed and recorded the weight of each tuber on October 9 and 6 in 2008 and 2009, respectively. Total tuber yield was the sum of U.S. No. 1 and No. 2 tubers. Average tuber size was calculated as total tuber yield divided by the number of tubers harvested. Large tuber yield was the U.S. No. 1 tubers ranging from 213 to 510 g in size. Statistical Analysis Plant spacing comparisons of production variables (total tuber yield, U.S. No. 1 tuber yield, tubers per ha, average tuber size, and large tuber yield) were conducted within each cultivar and planting configuration. Comparisons of planting configuration production variables were conducted within each cultivar at a plant spacing that produced the same plant population on an area basis (plant spacing treatments 30, 38, and 53 cm for the 4RC, 5RB, and 7RB planting configurations, respectively in Russet Burbank and Russet Norkotah, and 28, 35, and 49 cm for the 4RC, 5RB, and 7RB planting configurations,

respectively in Ranger Russet. All production variables were tested for homogeneity of variances using Hartley's F max test (Rhoades 2018). All production variables variances were found to be homogeneous. The least significant difference (LSD) method was used for mean separations. Significance was determined at the p=0.05 probability level for all statistical analysis, and for this experiment it was planted on 1st February 2019 under rain fed and bucket irrigation. The systematic randomized complete block design (RCBD) was used with three treatments each consisting three replicates.

All cultural practices were done on the day of planting as mentioned above. Soil preparation, such as planting, weeding, pest control and harvesting were developed by hand, according to vegetable production rules from the Ministry of Agriculture hand book for Mount Makulu. Crop water demands were satisfied depending on rainfall occurrence during the experimental period. The morpho-productive variables evaluated were:

Stem height (cm):

22 plants per plot of the middle lines were evaluated 55-65 days after planting (dap) by choosing the highest stem and measuring it from its base to the apical bud with a ruler.

Main stem diameter (mm):

22 plants per plot were evaluated 55-65 days after planting by taking the highest stem and measuring it at 10 cm soil surface digitally measured with ± 0,1 mm error.

Stem number m-2:

22 plants per plot and stem number per sprout were recorded 55-65 dap by visual counting; determining the area occupied by each plant, according to plant spacing and calculating stem number per m2.

***Total estimated yield (t ha-1)*:** it was obtained from dividing the total tuber mass by 1000 kg (one ton) and the results were divided by the harvested area (in hectares). A statistical analysis was performed on the information of evaluations, taking into account the design used, so that data was processed through a two-way classification variance analysis (ANOVA) and the multiple comparison of mean were subjected to GenStat 12th edition

Materials narrative

The seed used in this research was pent land dell which was certified seed and farmers own seed uncertified. Fertilizers, Ammonium nitrate top dressing and D Compound as basal dressing, while for termites, an insecticide Chlopyrifos (termigun) was used at a rate of one liter to two hundred liters of water. Fungicides Mencozeb copper plus was used at two milliliters to one liter of water

Treatments

The tubers were selected and measured using a Vernier caliper and only those tubers falling within the below stated millimeters were selected

T1 – small certified seed tubers = 23 – 31 mm.
T2 – medium certified seed tubers = 32- 45 mm
T3 – farmer own seed = 23- 31 mm

Procedure

The selected tuber were exposed to dark light, they were put in a dark room for a period of four weeks and they were being monitored every Sunday from 2nd of January 2019.by the end of the fourth week they started sprouting which indicated that they are ready for planting in the main bed, With care of not breaking the sprouts, they were taken to the main bed for planting

Soil quality

Potatoes grow best in loose, well-drained loam soil. Heavy clay soil retains too much moisture and tends to become hard as it dries, which can eventually slow water absorption and make it difficult for tubers to grow. Sandy soil drains too quickly, which can result in drought stress unless you water often. Garden soil with a pH between 5.0 and 5.5 provides for the healthiest potatoes and minimizes potato scab disease. (Agro consultancy and conservation, 2015) Pegging poles were cut

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with a marchet and demarcating of the land was done using twine rope on 1st February 2019. The area was prepared by hand digging using a hoe then planting furrows and spaces were opened and marked.

A. *3.7 Spacing*

Irish potato seed can be planted as soon as the ground is worked on, making sure to choose a sunny location. The tubers need room to grow, so planting them about 3 inches (7.62 cm) deep and 12 inches (30.48 cm) apart within the rows, leaving about 3 feet (90cm) of space between the rows. When planting, it should be made sure that the soil is moist. (Mwansa. 2011)

Mwansa. 2011, in his similar research conducted in Chilanga at Mt Makulu in 2011, and Fernando.2015 used similar spacing as below:

Inter-row 75cm (range 60cm to 90cm), Intra-row 30cm (range 20cm to 30cm) and Depth 8 cm

The expected plant population was 37 000 plants/ha but it ranges from 32 000 to 46 000 plants/ha.

Plot size 3.3m x 2.25m x 9 plots

Numbers of rows/plot were 4.

Numbers of plants /row were 11.

44 plants per plot

Total plant population was 396 plants for 9 plots.

As for a hectare spacing can be calculated by

Total area (T) divided by plant density (PD) multiplied by row width (RD) in cm = seed space in a row (SSR)

$$\frac{T}{PD \times RD} = SSR$$

(Mathematical model courtesy of potato council, 2009)

Fertilizer

Fertilizer supplies any nutrients lacking in the soil. A 5-10-5 or 10-10-5 blend provides ample nutrition when applied at the rate of 1½ pounds (0.68kg) per 50 square feet (1500cm2) of bed before you plant. The main nutrients required by potatoes are nitrogen, phosphorus and potassium, or N-P-K. The first number on the fertilizer label is the percentage of nitrogen, which is followed by the phosphorus and potassium percentages. A second application 1-pound (0.45kg) of fertilizer per 50-foot (1500cm) row, made after the potatoes reach a 4 to 6-inch (10.16-15.24 cm) height, provides the remainder of the nutrients needed. Sprinkle this fertilizer on the soil about 6 inches (15.24 cm) away from the plants and water immediately so it soaks in. (Motsara and Roy. 2008)

Soil moisture

Proper soil moisture ensures healthy growth, but overly moist conditions can result in rot problems. Good soil amended with compost or organic matter retains moisture well, but it may still dry out during hot or dry weather. Deep irrigation prevents the soil from drying out too quickly, so provide about 1 inch of water weekly so it can penetrate at least 6 inches (15.24 cm) into the soil. Covering the soil with 2 to 4 inches (5.08-10.16 cm) of straw mulch further retains soil moisture, while also protecting potatoes that form near the soil surface from sun exposure, which can ruin them. (Fernando, M. (2015) and homeguides.sfgate.com)

The trial was applied with 2.4kg basal dressing at planting at the rate of 250kg/ha and weeds were first controlled in the second week after emergence which was combined with ridging. 1kg top dressing was applied at flowering stage at the rate of 150kg/ha of ammonium nitrate.

T2	**Path**	**T3**	**Path**	**T1**
Path	**Path**	**Path**	**Path**	**Path**
T1	**Path**	**T2**		**T3**
Path	**Path**	**Path**	**Path**	**Path**
T3	**Path**	**T1**	**Path**	**T2**

Layout for the research project

Weeding

In this research weeding was done by hand hoe and on three occasions ensuring a free weed area while hilling was done on six occasions to avoid tuber exposure to light and parasites.

Harvesting

It's best to let the plant and the weather to tell you when to harvest potatoes. There is need to wait until the tops of the vines have died before one can begin harvesting. Potatoes are tubers and if you want your plant to store as much of that flavorful starch as possible. Temperatures of both the air and soil should also factor into when to dig. Potatoes can tolerate light frost, but when the first hard frost is expected, it's time to get out the shovels. In areas where the fall is cool, but without frost, soil temperature will dictate when to pick potatoes. Your soil needs to be above 45 F (7 degree Celsius.). When to dig potatoes for dinner is much easier. Wait until late in the season and take only what you need, carefully resetting the plant so the smaller tubers have a chance to mature Rhondes, (2018).

In this research, the crop was harvested when the leaves had dried up; digging was done using a hand hoe on 25th May, 2019.

Results and Discussions

The source of data was from the experiment conducted at home (farm). Parameters such as plants per station and the stem diameter were collected during the plant growth while tuber diameters and yield after harvesting. The researcher collected information himself by random sampling, the parameters related to yield components was measured which included; number of plants per station, stem diameter, tuber diameter and yield. Data on growth performance, yield and quality were recorded from twenty-two sample plants per plot.

Phonological parameters Days to 50% emergence: Days to emergence was recorded when 50% of planted tubers were emerged from the soil. Days to flowering: Days to flowering was recorded when 50% of the plant population in each plot produced flowers. Days to maturity: Days to maturity were recorded when 90% of the plants in each plot become ready for harvest as indicated by the senescence of the haulms. The days were counted from emergence to maturity.

Growth parameters

Plant height (cm): Was measured from the soil surface to the top most growth point of the plant at physiological maturity.

Number of stems per hill: Actual number was recorded at 50%flowering. Then an average was taken. Only stems that emerged independently above the soil as single stems were considered.

Total tuber yield (ton ha): The whole tubers harvested from the two central rows were weighed and converted in to ton ha. Unmarketable tuber yield tonnes per hectare: Including diseased, deformed tubers and weighing less than 25 g and converted into ton ha. Number of tubers per plant: Was recorded as counting of the actual number of tubers collected from five plants at harvest.

Sample size

The sample size was from three treatments twenty-two per plot from plant population of 44plants where only the middle rows were considered when collecting data with plant population of 22 plants on average from two middle rows; hence the sample size was a representative because it represents 50% of the population.

Methods and instruments for data collection

The tools used during data collection were measuring tape, a rule, Vernier calipers, strings to get tuber circumference of tubers and scale.

After digging the potatoes, each sample (tubers) was bagged and labeled there after they were cleaned by washing with water to remove dirty, then each tuber was measured that is its

circumference using a string then the string measure was subjected to the measuring tape and recorded on a sheet of paper

Stems diameter was collected using the Vernier calipers from 22 plants from the middle of each plot from the three treatments and mean collected using mathematical computation, the mean is subjected to GenStat software.

Data analysis

The statistical analysis on the research results was done by the use of analysis of variance (ANOVA) with the GenStat 12th edition (a statistical analysis software computer package).

B. ***4.4 Findings of the study***

C. ***4.4.1 Results and interpretation***

The findings of the research have been tested at 5% level of significance and their differences among treatments were compared using the least significant difference.

Table 17: showing the average number of plants per station from the given treatments below.

Treatment	Number of Plants per station
Farmer own seed	2.93 [a]
Certified medium seed tubers	4.53 [b]
Certified small seed tubers	4.13 [b]

l.s.d. = 0.840.
CV % = 29.4%
P-value < 0.001

All means followed by the same letter are not significantly different at 5% level of significance.

T_3 and T_2 = 1.60. The means are significantly different.

T_3 and T1 = 1.20. The means are significantly different.

T_2 and T_1 = 0.67. Not significantly different

Table 18: showing the average stem diameter in millimeters from the given treatments below.

Treatment	Stem diameter (mm).
Farmer own seed	5.95 [a]
Medium certified seed tubers	9.57 [b]
Small certified seed tubers	7.42 [c]

l.s.d. (0.05) = 0.879
CV% = 15.60
P-value < 0.001

All values of the treatments followed by the different letters are significantly different at 5% significant level.

T_3 and T_2 = 3.62. There means are significantly different.

T_3 and T_1 = 1.47. There means are significantly different.

T_2 and T_1 = 2.15. There means are significantly different

Table 19: Showing the average harvestable tuber diameters in millimeters

Treatment	Tuber diameters (mm)
Farmer own seed tubers	37.1 [a]
Medium certified seed tubers	44.9 [a]
Small certified seed tubers	40.5 [a]

l.s.d. = 8.380.
CV% = 27.80
P-value < 0.001

All the values of the treatment mean followed by the same letter are not significantly different at 5% significantly level.

T_3 and T_2 = 7.80. The means are not significantly different.

T_3 and T_1 = 3.40. The means are not significantly different.

T_1 and T_2 =4.40. The means are not significantly different.

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Table 20: showing the average yield in tonnes per hectare

Treatment	Yield per hectare (tones)
Farmer own seed tubers	3.64 [a]
Medium certified seed tubers	9.79 [b]
Small certified seed tuber	6.53 [c]

l.s.d. = 1.695

CV% = 11.20

P-value < 0.001

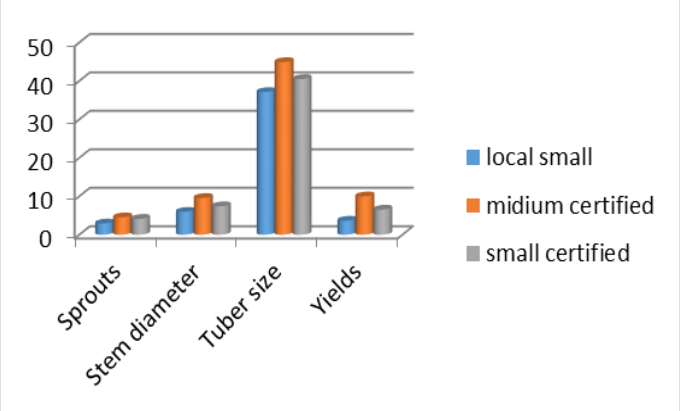
T_3 and T_2 = 6.15. The means are significantly different.

T_3 and T_1 = 2.89. The means are significantly different.

T_2 and T_1 = 3.26. The means are significantly different.

All values of the treatment mean followed by different letters are significantly different at 5% significance level.

Figure 3: Graph presentation of results for the treatments



D. 4.4.2 Tables of averages

Table 21: Average number of plants per station

Analysis of variance. **Variety**: number of plants per station

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
block stratum	3	6.533 3.267 2.52	3.267	2.52	
Treatment	3	20.800	10.400	8.02	0.001
Residual	40	51.867	1.297		
Total	44	79.200			

Table 22: Mean plants per treatment

Treatment	Plants per station mean
Local	2.93
Medium certified	4.53
Small certified	4.13
Grand mean	3.87
Least significant difference of means	(5% level)
rep.	3
d.f	44
l.s.d. (0.05)	0.840

Table 23: Stratum standard error and coefficients of variation Variety: plants station

Stratum	d.f	S.E.	CV%
Treatments	3	0.467	12.1
Residual	44	0.467	29.4

Table 24: Average stem diameter

Analysis of variance Variety: stem diameter mm

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
block stratum	3	2.146 3.267 2.52	1.073	0.76	
Treatment	3	99.233	49.617	34.95	<.001
Residual	40	56.785	1.420		
Total	44	156.165			

Table 25: Mean stem diameter per treatment. Variety: stem diameter (mm)

Treatment	Tuber size mean
Local	5.95
Medium certified	9.57
Small certified	7.42
Grand mean	7.65
LSD of means	(5% level)
Rep.	15
d.f	44
l.s.d.	0.879

Table 26: Stratum standard error and coefficients of variation Variate: stem diameter (mm)

Stratum	d.f	S.E.	CV%
Treatments	3	0.267	3.5
Block units	44	1.191	15.6

Table 27: Average tuber diameter

Analysis of variance: Variate: tuber sizes mm

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
block stratum	3	260.2	130.1	1.01	
Treatment	3	455.1	227.6	1.77	0.184
Residual	40	5154.8	128.9		
Total	44	5870.2			

Table 28: Mean tuber per treatment

Treatment	Tuber size mean
Local	37.13
Medium certified	44.89
Small certified	40.45
Grand mean	40.83
LSD of means	(5% level)
Rep.	15
d.f	44
l.s.d.	8.378

Stratum standard error and coefficients of variation Variate: tuber sizes mm

Stratum	d.f	s.e.	CV%
Block	3	2	7.2
block. *Units*	44	11.352	27.8

Average yield per hectare

Analysis of variance Variate: yield in tonnes

Source of variation	d.f	s.s.	m.s.	v.r.	F pr.
block stratum	2	7.0640	3.5320	6.32	
Treatment	2	56.8183	28.4091	50.81	0.001
Residual	4	2.2365	0.5591		
Total	8	66.1188			

Mean tuber yield per treatment

Treatment	Tuber size mean
Local	3.64
Medium certified	9.79
Small certified	6.53
Grand mean	6.66
Least significant difference of mean	(5% level)
Rep	3
d.f	44
l.s.d (0.05).	1.695

Stratum standard error and coefficients of variation Variate: yield in tonnes

Stratum	d.f	s.e.	cv%
Block	2	1.085	16.3
block. *Units*	4	0.748	11.2

Yield is the most vital parameter of all where all other parameters are components of it. The study showed significant differences among treatments. T_2 had the highest average yield. The average yield per hectare was 3.64tones, 9.79tones and 6.53tones for T_3, T_2 and T_1 respectively. The results of T_2 indicate 169% more than T_3 and 89.6% higher than T_1. This concludes that medium certified tubers have the potential to increase yield and income among ssf. The low yield of T_3 might have been due to high vegetative and fruiting. The recycled seed produces low yields due to either seed borne diseases which may be transmitted through seed and it is important to use free disease certified seed potatoes to improve on yield. The differences might have been caused due to different seed tubers which were used because medium tubers are commonly used as planting materials. The tuber seed size has effect on yield, tuber number per stem, plants per station and stem sizes in which mini tubers give lower results than larger seed tubers. As set size increased, stems/ha and

stems/plant increases. The temperature might have as well contributed on low yields among treatments not reaching average standard yield of 20 – 50t/ha this is because potatoes does well between 15^0 C to 24 ^{0} C and temperatures of above 30 ^{0} C little or no tuber formation may occurs and the area where research was conducted has temperature range of 20 ^{0} C – 35 degrees Celsius. Martinez. (2018).

Conclusion

Although there is still need for more research to be done, the study results showed significant differences among treatments, where T_2 gave the highest yield of 9.79t/ha, 6.53t and 3.64t/ha for T_1 & T_3 respectively. The local gave 169% & 79.4% lower than T_2 and T_1 respectively. From the results obtained it indicates that tuber seed size has an effect on the establishment and performance of Irish potatoes. The medium certified tubers have the potential to increase yield among small scale farmers despite of ns in other parameters.

The ns among treatments on harvestable tuber sizes might have been due to inadequate rainfall received and high temperatures experienced during the research period, hence the results might have been altered due to these limitations.

Other limitations that might have contributed to alterations of results are soil type which has poor drainage system, the soil pH; the levels of soil fertility, topography was not taken into consideration and were not tested.

Since the farmers' interest is to plant seed that gives high yield, the medium should be used as planting materials to increase yield among small scale farmers (ssf) hence as shown from the graph tabulation.

Due to some limitations during the research work, the results might have been altered. From these findings, the researcher feels that higher yields can be obtained in areas with adequate rainfall and in soils with high organic matter. This will help increase potato production and income for farmers and rectify malnutrition and income problems.

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REFERENCES

[1] Agriculture in Zambia 2019. How to grow Irish potato 16/06/19
[2] Ashwani, S, 2013 Potato mini-tuber production through direct transplanting of in vitro plantlets in green or screen houses - A review
[3] Barry (2002). Potato research.
[4] Boyetchko, S.M. and Audy, P. (2015). "Soil bacteria may offer weapon against late blight in potatoes. 13/05/2019
[5] Bruins. M, 2018.Starch Trek: What it Takes to Breed a New Potato Variety
[6] Bussan AJ., (2007) Evaluation of the effect of density on potato yield and tuber size distribution. Crop Science. 2007; 47(6):2462–72.
[7] Buyabamba 2019. seed varieties 16/06/19
[8] Caddie. B, (2013).” Why the future belongs to the potato”. *Australian Broadcasting Corporation*. Retrieved Friday, May 13, 2019.
[9] Carrasco A.et al (2009) Marker-assisted breeding for disease resistance in potato. Potato Res. 52: 245–248. (Google scholar)
[10] Chanda, M.M, (2013). Participation of small-scale farmers in supplying Irish potatoes to the local market (case study): Lusaka district.
[11] Cornell University Extension Service, (2010). Growing Potato in the Home Garden
[12] Dainello J. and Roland Roberts – (2006) Cultural Practices in Potato Production
[13] Dr Wang, F,2015, The importance of quality potato seed in increasing of quality potato production in Asia and the pacific region
[14] Ebrahim. S, et al 2018, Effects of seed tuber size on growth and yield performance of potato (Solanum tuberosum L.) varieties under field conditions
[15] El-Hamady, M.M. 2017 Canadian journal of Agriculture. Online science publishing .com
[16] Fernando, M. (2015) effects of different plant spacing and seed tuber sizes on some morpho-productive characteristics of potato in Huambo, Angola
[17] Gachango Easter 2008. Effects of light intensity on quality of potato seed tubers
[18] Gitonga, Z.M. 2014. Agro ecological zones and provinces in Zambia with population.
[19] Heather M. & Turner S. (2004), Agricultural Science of Potato Breeding Experiment
[20] Hopkins, B.G. 2018 Russet Burbank potato phosphorus fertilization with dicarboxylic acid copolymer additive
[21] Hulse. G.W. (2019). How to plant potatoes in containers, Irish Journal of Agriculture Research, volume 24, No. 2/3 [1985] page 213-219
[22] Islam S.M.D. et al 2017, Studies on seed size and spacing for optimum yield of potato in northern region of Bangladesh
[23] Kakuhenzire.R,2015 Strategies to Improve Seed Potato Quality and Supply in Sub-Saharan Africa: Experience from Interventions in Five Countries
[24] Kassam, 2015.Overview of world widespread of conservation Agriculture
[25] Kumar.P.et al. 2015 Effects of seed cutting and treatment methods of potato on yield, quality and profitability Effects of seed cutting and treatment methods of potato on yield, quality and profitability of French fry variety Kufri Frysona
[26] Lawrence D.H. (1981-1997) Growing your own Fruits and Vegetables.
[27] Liu. B, et al (2012). Identification of differentially expressed genes in potato associated with tuber dormancy release. Molecule Biology Rep. 39(12):11277-87.
[28] Luthra, S.K, et al 2018. Genetic analysis of tuber yield, processing and nutritional traits in potato (Solanum tuberosum)
[29] Mahmoudpour A,.2018 Effects of Different Sizes of Mini-tuber on Yield and Yield Components of Potato Variety Agria
[30] Martinez. A (2018).” The potato Whisperer. *Atlas Obscura*. Retrieved Friday, May 10, 2019.

[31] Mathani P.J. 2001. Potato Production in Tropical Regions.
[32] Mohaidib, M.S. 2009. Corn and potato starch as an agar alternative for (Solanum tuberosum L.) micropropagation. African Journal. Biotechnol. 9(1):12-14.
[33] Motsara, M, R, and Roy, R.N. 2008.soil analysis- FAO
[34] Muliokela, S.W, PhD Seed Specialist. 1995. Zambia Seed Technology Handbook.
[35] National Science Foundation (NSF) Potato Genome Project. n d. Tuber formation *National Science Foundation*. Retrieved October 7, 2008.
[36] Ostroshy .M and Struik P.C 2008. Effects of Size of Normal Seed Tubers and Growth Regulator Application on Dormancy, Sprout Behaviour, Growth Vigour and Quality of Normal Seed Tubers of Different Potato Cultivars
[37] Pevek. M.J et al 2018 Improving Land Use Efficiency and Grower Revenue by Reducing Potato Row Width
[38] Prof Mazarura.U, 2014. Influence of Main Stem Density on Irish Potato Growth and Yield: A Review
[39] Qasim, M. 2013. Effects of different planting systems on yield of potato crop in Kaghan Valley: A mountainous region of Pakistan
[40] Rhoades Jackie 2018.How and When to Harvest Potatoes
[41] Royal Horticultural Society Propagation Techniques, *2013. Octopus Publishing Group Ltd, London.*
[42] Rurinda. J, (2014). Vulnerability and Adaptation to Climate Variability and Change in Smallholder Farming Systems in Zimbabwe
[43] Rydberg, P. (2002) Potato Production in Canada
[44] Salin, A.et al, 2015 The Effects of Plant Density and Eye Number per Seed Piece on Potato (Solanum tuberosum L.) Tuber Yield
[45] Schonbeck, M. et al 2013, Grow Vigorous, Competitive Crops—the First Line of Defence Against Weeds
[46] Shayanowako, A et al, 2014. Effect of stem density on growth, yield and quality of potato variety amethyst
[47] Shayanowako, A et al, 2014. Influence of Main Stem Density on Irish Potato Growth and Yield: A Review
[48] Situmbeko Sitwala, Zambia daily mail, 2nd June, 2015 pp 3
[49] SR, Fuller J, (2014). Physiological, biochemical and molecular responses of the potato (*Solanum tuberosum* L.) plant to moderately elevated temperature. Plant Cell Environment 37:439-450
[50] Tadele.Z, 2017. Raising Crop Productivity in Africa through Intensification https://doi
[51] Tarkalson.DD et al, 2011.Evaluation of In-Row Plant Spacing and Planting Configuration for Three Irrigated Potato Cultivars
[52] Thompson, P., 2005. *Creative Propagation.* 2nd ed. Portland, Oregon: Timber Press, Inc.
[53] USDA Plants database checklist dataset 2019/08/21
[54] Vilela X.M. (2009) Potato clones with multiple copies of the Ry_{adg} allele conferring resistance to PVY. Crop Breed. Appl. Biotechnology vol. 9: pp 286–292.
[55] William. E. et al (2017) Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments. journal of experimental botany vol 68, iss 4.pg 843-856
[56] Yancheva S. and Kondakova V. (2016) Plant Tissue Culture Technology: Present and Future Development. In: Pavlov A., Bley T. (Eds) Bioprocessing of Plant in Vitro Systems. Reference Series in Photochemistry. Springer, Cham