EVALUATION OF NEW IRISH POTATO (*Solanum tuberosum L.*) VARIETIES FOR YIELD POTENTIAL IN ZIMBABWE

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Declaration

I hereby declare that the research described in this thesis is the result of my own efforts and all the additional sources have been acknowledged by means of Reference.

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Date

Certification of Thesis

I declare and certify that I have supervised Tapiwa Ronald Mpemba R132632M thesis with the topic Evaluation of new Irish potato (*Solanum tuberosum L.*) varieties for yield potential in Zimbabwe.

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Name of Supervisor

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Abstract

Irish potato (*Solanum tuberosum L.*) is an important crop in Zimbabwe due to its nutritional and economic worth. The upgrading of its status to a strategic food crop by the government in 2012 has created the need for research to increase production, increase germplasm and diversify staple food crops. A study to investigate the yield potential of new Irish potato varieties was carried out at the Scientific Industrial Research and Development Centre between June and November 2015. Aim of the study was to evaluate new varieties to introduced and released in Zimbabwe. The varieties BRI1, BRI2, BRI3, BRI4, BRI5, BRI6 and BRI7 were grown with the controls being locally released varieties Amethyst and BP1 which are long and short season varieties respectively. The experiment was laid out in a randomised complete block design with 9 treatments and slope as the blocking factor. Analysis of variance was done using Genstat 14th edition. Data on yield, number of days to 50 % flowering and number of days to 95 % maturity was recorded. Analysis of variance showed that there was a significant difference ($P<0.05$) in the yield of potatoes, number of days to 50% flowering and number of days to 95% physiological maturity due to variety. BRI6 and BRI3 achieved the highest yields of 69.63 and 58.89 t/ha respectively. BP1 and BRI7 had the lowest yields of 13.22 and 9.89 t/ha respectively. Amethyst and BRI7 took the highest number of days to 50 % flowering of 30.33 and 29 respectively. BRI6 and BRI1 took the least number of days to 50 % flowering of 17 and 16.67 respectively. BRI7 and BRI5 took the longest number of days to reach maturity with 139.3 and 136.7 respectively. BRI1 and BP1 took the least number of days to maturity with 100 days each. The research concluded that the new varieties had a higher yield potential. BRI6 had the highest yield followed by BRI3, BRI2, BRI2, BRI4, BRI5, Amethyst, BP1 and BRI1. The varieties BRI7, BRI5, BRI3, BRI4, BRI2, BRI6 and Amethyst are long season varieties while BRI1 and BP1 are short season varieties. A multi locational trial is required to determine the yield potential of the varieties in the different farming regions of the country. The varieties should also be screened for drought tolerance as well as pest and disease resistance.

Dedication

This project is dedicated to my late father who set an example that gave me the desire to one day reach academic excellence.

Acknowledgements

I would like to thank my mother and brother for being my pillars of strength and for guiding me through life. A special thank you goes to my family and friends who have been there for me throughout my college life. I pray that the friendship we have built last till the end. I would like to acknowledge the Scientific Industrial Research and Development Centre for the opportunity to conduct my research and for the exposure to the field agricultural research. Finally to my academic supervisor much gratitude is extended for the guidance that was provided in writing this thesis.

All glory is to God.

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Abbreviations

SIRDC	Scientific Industrial Research and Development Centre
CIP	International Potato Centre
CBI	Crop Breeding Institute
DR&SS	Department of Research and Specialised Services
BRI	Biotechnology Research Institute
GDP	Gross Domestic Product
RDI	Recommended Daily Intake
ANOVA	Analysis Of Variance
LSD	Least Significant Difference
Kg	kilogramme
Mm	millimetre
m	metre
Mg	milligram
t/ha	Tonnes per Hectare

CHAPTER 1

1.0 INTRODUCTION AND JUSTIFICATION

The Irish potato (*Solanum tuberosum L.*) is the fourth most important staple food crop in world after rice, wheat (*Triticum aestivum*) and maize (*Zea mays*) (Li, 1985). It was ranked first in the world's root and tuber crop production followed by sweet potato (*Ipomoeas batatas*). In terms of yield, potato is the third crop in the world and first in root and tuber crops followed by sweet potatoes (CIP, 2008). Potatoes were introduced in Zimbabwe in the early 20th century. The most common varieties grown in Zimbabwe include BP1, Amethyst, Mont Claire, Opal, Emerald and Jacaranda (www.drss.gov.zw). Potato is a cool season crop that requires bright and sunny days and cool nights. Potatoes grow best in tempratures 15 – 20 ^{o}C and should not be grown in areas where temperatures above 32 ^{o}C are experienced (Lombia et al. 1988). In Zimbabwe, potatoes can be grown 3 times a year for the short season varieties such as BP1. This is very attractive to farmers as potato production is a very lucrative industry. This is however not common due to frost, fluctuating demands in the market and the need for crop rotation cycles to control pests and diseases such as Potato tuber moth and blights (Fusire, 2001). High production costs and the difficulty faced in obtaining loans also add to the constraints of potato production while pests and diseases greatly affect yield (Lutaladio et al. 2009). Lack of diversity in potato varieties reduces the ability to overcome problems of drought, diseases, pests, climate change and decreasing yields in marginal lands (FAO, 2008).

Potatoes have the widest genetic diversity amongst all cultivated crops which have traits for high yield, resistance to pest and diseases, high nutritional value and tolerance to harsh environments. The multiple varieties in the center of origin (South America) of potatoes provide a gene pool that can be exploited to provide new and improved varieties for farmers

(Lutaladio et al. 2009). The Crop Breeding Institute (CBI) under the Department of Research and Specialist Services (DR&SS) is responsible for variety development, maintenance and provision of seed in Zimbabwe. The institute has released seven varieties namely Pimpernel, Montclare, Amethyst, Jasper, BP1, Garnet and Diamond since it started potato breeding in 1957 (Majaju, 2010). The last two varieties were released in 1998 and 2008 respectively (FAO, 2009). The financial constraints faced by the CBI due to a continuous reduction in the government's expenditure the mid-1980s have reduced the institutes technology output. The formation of Biotechnology Research Institute of the Scientific Industrial Research and Development Centre (SIRDC) should pave the way for partnerships between the two institutes to work to overcome the problem (Woodend, 1995).

In Zimbabwe the average yield for potatoes is 20 tons per hectare while the world average is 17.4 tons and in developed countries such as USA yields can reach 44.3 tons per hectare. In Zimbabwe there is a lot of attention paid to maize as it is the staple crop but there is need for focus on other crops such as potatoes which can be alternative sources of starch. There is need to invest more in research towards better production practices of potatoes. Special attention has to be put into new potato varieties that give higher yields. In Zimbabwe there are only eight potato varieties as compared to 80 white hybrids, 18 yellow hybrids and eight open pollinated varieties for maize (FAO, 2009). Potatoes produce more dry mass per unit area than any cereal, contain minimal fat and have a low energy density like legumes (Donnelly and Kobow, 2011). This means that potatoes and their processed products could replace their cereal counterparts in cooking and processing. It is also not wise for a nation to rely heavily on one crop for their survival as failure of that crop would result in starvation. This was the situation in Ireland where one and half million people died after late blight wiped out most of the potato crop causing famine in the mid-19th century. This was so disastrous it led to the crop being known as the "Irish Potato," (Pavlista, 1997).

Since Irish Potatoes were declared to be a strategic crop by the Zimbabwean government in 2012 there has been low response by seed companies to release new varieties of the crop that can outperform the previously released varieties or increase to the germplasm available in the country (Svubure et al. 2015). The main limitation to production of seed tubers in Zimbabwe is the strictness in production agronomy that aims to prevent spread of viral diseases through vegetative propagative material such as tubers. Biotechnology has led to production of virus free potato propagules to be possible in areas other than the quarantine zone in the Eastern Highlands. There is therefore need to release new potato varieties into the market that address the different needs of farmers and the consumers at large (Haverkort et al. 2015). According to Mori et al. (2015), one way of improving potato germplasm is to bring in new varieties. This is followed by testing the varieties for adaptation to the new (Harahagazwe et al. 2012). Therefore this study was aimed at evaluating new potato varieties for yield potential to release a new variety in Zimbabwe.

1.1 Main objective

To evaluate the yield potential of new potato varieties introduced from Peru when grown in Zimbabwe.

1.2 Specific objectives.

- To evaluate the agronomic traits: days to 50% flowering and days to 95% physiological maturity of the different potato varieties.
- To evaluate tuber yield and yield parameters (number of tubers per size class) of the different potato varieties

1.3 Hypotheses

- There is a significant difference in tuber yield of different potato varieties.

- There is a significant difference in the number of days to 50% flowering and 95% physiological maturity of different potato varieties.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Economic importance of Irish potatoes in Zimbabwe

Potato farming is a very lucrative venture in Zimbabwe. For the highest yields, it requires a high capital investment. Potatoes can have returns of up to 55 % initial input and therefore provide a source of income for many families. The potato industry allows people to earn as it comprises of a long chain of individuals who specialise in selling seed, farmers, farm workers, marketer's etc. the potato industry therefore contributes to the GDP of Zimbabwe. Potatoes very nutritious and can form an important part of the diet. Potatoes can be prepared in various ways and add to the daily requirement of humans. According to Dixon et. Al. (1997), an unpeeled 100 g potato tuber contains 7.7 g water, 20.13 g carbohydrates, 87 kcal of energy, 1.87 g protein, 0.1 g fat, 5 mg protein, 379 mg potassium, 44 mg, 0.31 mg iron, 1.44 mg niacin, 0.106 mg thiamine and 0.02 mg riboflavin when boiled.

Potatoes also contain carotenoids and phenolics which are effective antioxidants. Different varieties of potatoes can have other important nutrients such as white fleshed cultivars which have 50-100 µg/100 g carotenoids and up to 30 µg/100 g flavinoids. Purple fleshed potatoes can have approximately 60 µg/100 g flavinoids and deep yellow to orange fleshed cultivars can have 200 mg/100 g phenolic compounds, (Brown, 2005). According to Donnelly and Kobow (2011), potatoes can also play an important role in disease prevention as antioxidants protect tissues and cells from destruction by reactive oxygen species. These are species that cause development of ageing and inflammatory diseases such as arthritis, cancers, diabetes, atherosclerosis and neurodegenerative diseases. Some of the phenolics found in potatoes (caffeic and chlorogenic acids) are believed to prevent type 2 diabetes (Donnelly and Kobow, 2011). According to Donnelly et al. (2012), one serving of potato a day provides 30-48 % of the recommended daily intake (RDI) of macro minerals save from calcium and sodium and 6-82 % of trace element required in the RDI. The Irish potato is therefore an important part of the human diet as its nutritional value shows its ability to contribute to the country's food security.

2.2 Uses of Irish potato

Potatoes are used for many food and non-food purposes with a few cases where it is used as stock feed. The potato can be cooked when fresh by boiling and served when mashed or fried to produce French fries. This is a major part of the fast food industry especially in Zimbabwe. Potato is used to produce soups, gravies and sauces. Common potato servings are potato crisps, mashed potatoes, french fries and salad. The starch acts as a thickener and binder when cooking (Gopal and Khurana, 2006). Potato starch is also used to produce flour (Martin et al. 2006). Potatoes are used in the beverage industry to produce vodka when fermented. They can also be used in the production of ethanol which is added to fuels to reduce air pollution (Guenthner, 2001). Potato juice can be used to treat sprains, sciatica, heartburn and bruises (www.care2.com). Other uses of potatoes include making of adhesives, paper and boards.

2.3 Potato varieties in Zimbabwe and their characteristics

Basic classification of potato varieties can be done by shape, skin and flesh colour. According to Martin et al. (2006), white or light skinned potatoes that have and round to oblong shape are mostly used in chipping and boiling. Russet skinned potatoes with long flattened cylindrical shape are frequently used for baking and french fries while red skinned varieties with round tubers are mostly used in the fresh market. These morphological classifications are however not accurate especially with new varieties being released all over the world, modern methods are more discriminating and specific. These include Image analysis, Gel Electrophoresis and DNA Profiling (Cooke, 1999).

2.3.1 The varieties available in Zimbabwe

2.3.1.1 **Montclare**: This is a late maturing variety which produces large to extra-large tubers which have white skin and flesh. They have deep eyes and are resistant to blights. They can yield up to 60 tons per hectare (t/ha).

2.3.2.1 **BP1**: early maturing (sometimes medium) in 14-15 weeks with white skin and flesh. Tubers have shallow eyes and an oval shape. Variety is resistant to late blight and has an expected yield of 13.5 to 20 t/ha

2.3.3.1 **Pimpernel**: late maturing (17-19 weeks) with red skin and yellow flesh which is mainly used in processing. Produces small to medium oval tubers with deep eyes and has an expected yield of up to 20t/ha and is mainly used in processing.

2.3.4.1 **Amethyst**: late maturity (17-19 weeks) variety which produces flat oval tubers with white skin and flesh. They have rough skin, shallow eyes and yield 35-60 t/ha.

2.3.5.1 **Garnet**: late maturity (17-19 weeks) variety which produces tubers that have white skin and yellow flesh. Tubers are medium sized and round. Produce up to 26 t/ha.

2.3.6.1 **Jasper**: a late maturing variety (127 days in winter) with white skin and flesh. Tubers are oval shaped and it yields up to 30 t/ha. It tolerates Late blight and grows vigorously.

2.3.7.1 **Diamond**: medium maturity with white skin and white fleshed tubers that have an oval shape. Yields up to 60 t/ha (www.drss.gov.zw).

In Zimbabwe, Irish potato breeding is done by the CBI at the Nyanga Research Station and this is where development and maintenance of lines is done (FAO, 2009).

2.4 Potato production factors

2.4.1 Soil Requirements

Potatoes are best grown in sandy to medium loam soils that have high organic matter. Good seedbed preparation is required to make sure the soil is well aerated and drained. This is because friable light textured soils with a lot of organic matter commonly have uniform temperature and are well aerated resulting in better tuber development (Panda, 2012). Extremes in pH hinder root activity and can lead to diseases such as common scab (*Streptomyces scabies*). In a three to four year rotation, the soil should be limed before planting to avoid occurrences of the scab disease (Martin et al. 2006)

2.4.2 Nutrient Requirements

Potatoes require very fertile soils as they are heavy feeders of soil nutrients. For the best tuber yield, potatoes may require up to 1.5 tons of well decomposed organic matter in a single hectare. Nitrogen, phosphorous and potassium increase yield by increasing number of medium sized tubers and it is vital that these elements be applied at planting (Anonymous, 2013). Fertilization is also very crucial to potato production and is usually done in split applications to cater for the vegetative growth phase and the tuber initiation and filling. In a single hectare the crop will require 120 kg of nitrogen (N), 80 kg of phosphates (P_2O_5) and 100-120 kg of potassium (K_2O). Micronutrients are also required and they are zinc sulphate 25 kg, manganese sulphate 25 kg, ferrous sulphate 10 kg, copper sulphate 10 kg, ammonium molybdate 10 kg and sodium borate 1 kg in one hectare. The micronutrients can be applied as solids, in water solution or by the tuber soaking method (Panda, 2012).

2.4.3 Moisture Requirements

Water management is very important as it has to be manipulated to ensure the critical stages of Potato development do not coincide with water stress. The stages are germination, tuber initiation and tuber enlargement (Panda, 2012). Water stress during the germination period results in poor plant stand as the sprouts may fail to grow and have the ability to emerge from the soil. Water stress during tuber initiation result in the roots developing fewer tubers while tuber filling is poorly done as the plant needs water to photosynthesis and translocate the solutes from the leaves to the tuber. All these stages are vital to high yield as they contribute either by producing many tubers or better enlarged tubers (Cooke, 1999). According to Panda (2012), potatoes require light and frequent irrigation irrespective of the varieties but this is not advisable in Zimbabwe due to the frequency of blights. To ensure that uniform moisture is available for the crop at all times, supplementary moisture can be applied using furrow irrigation to prevent the leaf diseases (Acquaah, 2005).

2.4.4 Weed management

Weeds result in reduced tuber yields by using nutrients and soil moisture meant for the crop, by harboring pest and diseases and by having non symbiotic relationships with the crop (Dallyn, 1971). Herbicides can be used in the control of weeds. An example of one such is alachlor which is applied as a pre-emergence herbicide. Other classes of herbicides include pre-planting and post emergence. With the growing concern of the need to reduce chemical use in the environment it is best to make use of an integrated weed management program. An ideal program includes chemical, cultural, mechanical, physical, biological and manual weed control measures. This method harnesses the merits and demerits of each of the methods to create a synergy where the effect of the control methods combined is greater in the long run (Panda, 2012).

2.4.5 Pest management

Pests and disease attack are also a major problem that results in reduced yield in Zimbabwe. Pests of economic importance in Zimbabwe include the potato tuber moth (*Phthorimaea operculella*), potato leaf hopper *(Empoasca fabae)*, leaf miner (*Liriomyza spp.*), aphids

(*Macrosiphum euphorbiae*) and cutworms (*Agrotis* spp.). Chemical control is usually done and this begins soon after emergence as pests like cutworms affect young seedlings which are still tender. Spraying is done regularly to control these pests as they can also affect the tuber in such a way that it cannot be marketed due to decrease in quality (Herverkortc et al. 2015).

2.4.6 Disease management

Diseases of economic importance in Zimbabwe include early blight (*Altenaria solani*), late blight (*Phytophtora infestans*), potato viruses (X and Y), common scab (*Streptomyces scabies*), rhizoctonia canker (*Rhizoctonia solani*) and ring rot (*Corynebaterium sepedonica*) (Herverkortc et al. 2015). Control of these diseases is using different methods such as chemical and cultural. Crop rotations exclude solanaceous crops as they can lead to continuation of pathogen life cycles and vectors such as nematodes. Control of blights is done using fungicides which are sprayed regularly on the leaf surfaces to prevent fungal development.

2.5 Potato Growth Stages

Potatoes are grown from tubers that are planted to develop into full plants. After harvesting the tubers enter a dormant state where they will not sprout even in ideal environmental conditions.

According to Struik and Wiersema (2012) the dormancy of the tuber is a physiological state where autonomous growth of the sprouts is hindered for some time despite the presence of conditions that support their growth. The induction of dormancy in the tubers is caused by the plant hormones abscisic acid and ethylene while maintenance of the dormancy is due to abscisic acid alone (Suttle, 2004). Before the tubers are planted they are sprouted. Sprouting of potato tubers is when they develop shoots that form plant stems when grown (Struik and Wiersema, 2012). The tuber will have overcome bud dormancy when they are removed from storage and placed in diffuse light at high temperatures. The tubers begin to develop short and stout shoots from the 'eyes' (Kipps and Wolfe, 2004). Sprouting of potatoes is done by placing them in chitting trays and exposing them to light which can be from the sun or a fluorescent light (Rhoades, 2016). Sprouting can also be done by dipping the tubers in acetyline solution or enclosing the tubers in a room with acetyline gas. Gibberilic acid can also be used to initiate sprouting of potato tubers (Gopal and Khurana, 2006).

When the sprouted tubers are planted, the shoots develop and grown until they emerge from the soil. Adventitious roots begin to develop at the base of the shoot where the shoot is attached to the tuber. Lateral buds then begin to grow in a horizontal direction and these develop into elongated and etiolated stems. This is known as the stolon initiation phase. The stolons continue to grow in the presence of auxins and gibberilins. Production of a tuber inducing substance in the plant suspends lateral growth of the stolon and the subtropical regions begin cell enlargement and division. This is the tuber initiation phase and it is a result of a tuberisation regulatory protein that is produced in the leaves and the mother tuber (Davies et al. 2002). Therefore a tuber is a result of a modified underground stem (Fernie and Willmitzer, 2001). The tuber initiation phase is very important to yield as this is where most of the marketable tubers are formed.

Initiated tubers begin to grow and develop and this marks the beginning of the tuber bulking phase. This phase is where adequate potassium is required as it is responsible for delaying leaf senescence thus allowing more time for photosynthetic products to be translocated to the tubers during tuber bulking (Grewal et al. 1996). The tuber bulking or tuber filling phase is due to the tuber becoming the largest sink of the plant leading to storage of most of the photosynthates produced. Photosynthesis leads to production of sucrose which is translocated to the tubers and is converted to starch which is the storage carbohydrate. This constitutes tuber growth (Fernie and Willmitzer, 2001). Other nutrients such as proteins are also stored in the tuber. The metabolic activity of tubers is drastically reduced as it will be acting as a storage sink. (Davies et al. 2002).

After the tuber bulking phase, senescence of the plant begins to occur and the haulms begin to wilt. A mature tuber will have approximately 20 % of its weight as starch. The haulms dry off and the skin of the tuber hardens and becomes thicker so as to prevent damage to the tuber and entry of pathogens (www.geochembio.com)

2.6 Potato Seed production in Zimbabwe

Production of seed tubers in Zimbabwe is done in the Nyanga Eastern Highlands. This is a quarantine area where potato seed multiplications and breeding activities are done (Haverkort et al. 2015). Nyanga is located in the Natural Farming Region I. Production of table potatoes and seed multiplication is done in the subsequent Regions IIa and IIb. The elevation of the whole region is between 1 200 and 1 800 m above sea level. Breeding activities are done at the Nyanga Experiment Station which is at an elevation above 1 800 m above sea level (Svubure, 2015). This is where virus-free planting material is produced by the Zimbabwe Potato Seed Association as the cool and high altitude areas of the country ensure that transmission of viral diseases is non-existent (Woodend, 1995). The concentration of potato seed and breeding activities in high altitude areas is done to exclude vectors of viral diseases such as Aphids (Family *Aphididae*) (Nganga and Shideler, 1982). In Zimbabwe, the production of seed potatoes is done according to the regulations set by the law. Multiplication of seed tubers is done in the 259 hectares of isolated land in Nyanga. This legislation is meant to control pest and disease occurrences in Zimbabwe. This is necessary to curb diseases which are associated with vegetatively propagated crops. Of particular importance are viral diseases which are difficult to control once they infect the crop (FAO, 2009). Producers of potato seed are required by law to be registered.

In the Eastern Highlands potatoes can be grown throughout the year but the most favourable periods are between November and March while February to June is done for the early winter crop. The late winter crop tends to vary due to the sensitivity of potatoes to frost. Planting starts between June and August depending on the probability of frost occurring. Production of potatoes is done in loam, medium textured soils. Even though the area is recommended for seed tuber production for disease control reasons, this does not mean it is totally free of all pests and diseases. There is need for crop guards to regularly ward of baboons that habitat in the nearby mountains. Nematicides and fungicides are applied in the field to nematodes and fungal diseases such as early and late blight. Irrigation is done to supplement the rain in periods of low precipitation. It can also be done to avoid frost effects on the plants. The production of seed tubers follows the same practices for table potato with special attention to plant protection. The plant spacing can be reduced to prevent production of oversized tubers or alternatively early destruction of the haulms can be done (Svubure et al. 2015).

2.7 Potato propagation

Potatoes are vegetatively propagated because it is a tetraploid and this is normally associated with increased sterility. In cases where there is a significant level of sterility the seed produced by the potato plant does not produce plants that are true to type. The seed results in offspring different from the parent and usually produces tubers that are too small for economically viable farming (Pierce, 1987).

Potatoes can be propagated from different materials with most common being tubers. According to Davies et al. (2002), tubers can be planted whole or cut into sections. When the whole tuber is to be used for planting the tuber is sprouted before planting. The eyes on the tuber are dormant buds which produce shoots when the dormancy is broken or overcome. The dormancy of the potatoes is due to low temperature or growth regulators such as maleic hydrazide and chloro-IPC (Pierce, 1987). When propagating using cut tubers, the cut sections should have at least one auxillary bud where sprouts will develop. The sections can range from a through section of the whole tuber to a small piece with an auxillary bud commonly referred to as the eye. According to Struik and Wiersema (2012), these are known as sprout cuttings. Each eye should carry with it a sizeable portion of the starchy part of the tuber so the developing shoot will have enough food reserves (Davies et al. 2002). The open surface left exposed after the tuber has been cut should not be too large such that the suberisation process cannot cover the wound in time before infection or desiccation occurs. Organisms that facilitate decaying are likely to enter the flesh of the tuber when the cut surface is left exposed for an extended period of time (El-Helaly, 2012).

Potatoes can be propagated from mini tubers. These are small tubers that have a diameter of 9 to 15 mm. They are produced by micropropagated plants when they are transferred to the soil after 70-150 days. The in micropropagated plants (in vitro plantletes) are produced using the tissue culture process. The plantlets may produce micro tubers whilst still in vitro. These are even smaller tubers that have a diameter of 2 to 10 mm and they are grown in a glass house or sterile greenhouse to produce mini tubers (Struik and Wiersema, 2012). The plantlets can also be transferred to a hydroponic environment where they can also produce min tubers. When grown out in the field under normal irrigation and fertilisation, the mini tubers will produce large sized tubers (Ahloowalia, 1994). This is a fast method of producing potato propagules that are disease free and less bulky. Tissue culture may also be used to produce plantlets that are transferred to a nursery to produce seedlings. The seedlings are then transplanted to the field.

2.8 Structure of the potato tuber

The potato tuber is defined as a modified stem with lateral buds commonly known as the eyes (Martin et al. 2006). It develops from behind the apical hook at the end of the stolon. Botanically the stolon is a rhizome and it has auxiliary and lateral buds which later develop into the eyes of the tuber. The buds are in a dormant state during the period which the tuber is attached to the plant and a short period after it is detached (Fernie and Willmitzer, 2001) and this is known as apical dormancy. The tuber is similar to a typical stem in its structure but it is enlarged for the purpose of storing food. The tuber has a terminal, apical or bud end and on the opposite is the stem end which is point of attachment to the plant stolon. The eyes are indentations in the tuber that contain at least one bud and they are arranged in a spiral manner starting from the terminal end of the tuber. The skin or periderm is the outer layer of the tuber which is immediately followed by the cortex. The flesh of the potato tuber consists of the phloem, xylem and pith (Pierce, 1987). The structure of the tuber is shown in Figure 2.1.

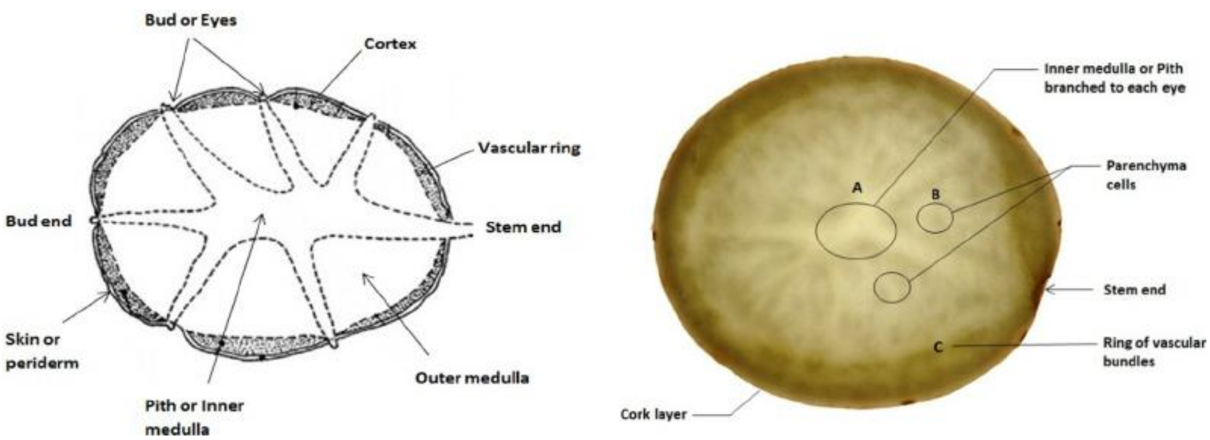

Figure 2.1 Structure of the potato tuber (Picture courtesy of Bremer et. Al. 2015.)

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out at the Scientific Industrial Research and Development Centre in Harare, Zimbabwe. It is situated in the Northern part of the city and has a latitude of 17.8^{o}55’S and a longtitude of 30 ^{o} 7’Ewith an altitude of 1488.35 m above sea level. The area falls under Natural Region IIa which receives 750 – 1000 mm of rain annually. The rainfall is fairly reliable and is received from November to March. In summer average temperatures during the day and night are 26.1 ^{o}C and 15.7 ^{o}C respectively. In winter the average temperatures during the day and night are 22.2 ^{o}C and 6.3 ^{o}C. The experiment was carried out on field B on the centre which has clay loam soil and a slight slope to the East.

3.2 New potato varieties used in the experiment

Seven new potato varieties were obtained from the International Potato Centre (CIP). These varieties came as micro propagules that were multiplied by the tissue culture process to produce mini tubers. These were named after the institute’s Biotechnology Research Institute. The varieties were BRI1, BRI2, BRI3, BRI4, BRI5, BRI6 and BRI7.

3.3 Experimental Design and Treatments

The experiment was laid out in a Randomised Complete Block Design with nine treatments, namely BRI1, BRI2, BRI3, BRI4, BRI5, BRI6, BRI7, Amethyst and BP1, replicated three times. Varieties currently being grown in Zimbabwe served as controls and these were short and long season varieties BP1 and amethyst, respectively. The plant spacing was 90 X 30 cm. The treatments were planted in a 3 m row with a 1 m gap between rows. The blocking factor was slope.

3.4 Trial management

3.4.1 Land preparation

Tillage was done using a power tiller which creates a fine tilth by ploughing to a depth of 20 cm. the land was cultivated previously therefore there was no need for deep ploughing. The rows were marked perpendicular to the direction of slope. A line was stretched across the field and used to mark straight rows which were 90 cm from each other. Furrows were opened in the rows using hoes to represent the plots in which each treatment was to be planted.

3.4.2 Planting

Planting was done on the 29th of June 2015. The mini tubers were sprouted and planted by hand with an intra row spacing of 90 cm and an in row spacing of 30 cm which gave 10 tubers in each plot. The tubers were covered with soil to a depth twice the size of the tubers.

3.4.3 Fertilisation

Compound D was applied as the basal fertiliser at a blanket rate of 1500 kg/ha. The fertiliser was covered with soil to prevent direct contact with the tuber as this may cause burn of the tubers. The top dressing was split into two dresses. Each dressing was applied at 350 kg/ha of ammonium nitrate and sulphate of potash.

3.4.4 Crop Protection

For control of nematodes Nemacur was applied during planting by banding the powder over the tubers before covering. Control of early and late blight was done by spraying copper oxychloride fungicide every 2 weeks at a rate of 200 g/100 litres. For control of pests such as the potato tuber moth and cutworms Lambda was sprayed at a rate of 500 ml per hectare. Weeding was done twice using a hoe.

3.4.5 Irrigation

Irrigation was done to prevent water stress as this has negative effect on yield. The most sensitive growth stages potatoes most sensitive to water stress are flowering, tuber initiation and bulking. Therefore water had to be applied artificially using an overhead irrigation system.

3.4.6 Ridging

This is the placing of soil at the base of the potato plant to cover the lower parts of the stem. This was done until the top four leaves of the plant are left uncovered. It was done to improve tuber development, prevent cases of potato tuber moth and to protect developing tubers from direct sunlight which causes them to turn green.

3.4.7 Harvest

Harvesting was done after 18 weeks. The haulms of the potato plants had began to wilt and this was an indicator of maturity. The haulms were slashed when 95 % of the haulms had dried and the tubers left to cure in the soil for a week. Harvesting was done using a garden fork and a pick. The tubers were collected in perforated sacks according to their plots.

3.4.8 Sorting and weighing

The tubers were graded into 4 categories (extra-large, large, small and charts) based on their size. The weight of the harvested tubers was obtained using an electronic scale.

3.4.9 Notable pests and diseases

Regular scouting was done to take note of infestations, signs and symptoms of pests and diseases.

3.5 Data Collection

3.5.2 Days to 50 % flowering

The number of days it took the potato plants to flower from the day of planting were observed and recorded. Flowering was determined as the appearance of a flower bud on any one of many stem from a single tuber.

3.5.3 Days to 95 % maturity (wilting)

Wilting of the haulms of potato plants is a characteristic of physiological maturity. The number of days to physiological maturity was from the day of planting to the day when 95% of the leaves had dried.

3.5.4 Number of tubers in each size class

Potatoes are grouped into categories depending on their size and these are extra-large, large, small and charts and the diameters for the different size categories are shown in Table 3.1. To grade the tubers by size, sample tubers were cut to measure the diameter. The diameter of the tuber is the distance across the tuber perpendicular to the stem end and bud end. The number of tubers in each of the classes was counted.

Table 3.1 Standards for classification of tuber classification according to size

Size	Diameter of tuber
Charts	<56 mm
Small	56 – 63.9 mm
Medium	64 – 75.9 mm
Large	76- 83.9 mm
Extra large	>84 mm

Source: Explanatory Guide to The Seed Potato Classification Scheme and Approved Stock Scheme for the 2016/17 season (2016)

3.5.5 Yield

The yield was recorded in kilogrammes per hectare. An electronic scale was used to measure the mass of the yield from each plot.

3.5.6 Data analysis

One way analysis of variance (ANOVA) was done using GenStat 14th edition to analyse data from the treatments. Treatment means were separated using LSD at 5 % level of significance.

CHAPTER 4

4.0 RESULTS

4.1 Effect of Variety on number of days to 50 % flowering

There was a significant difference (P<0.05) on the number of days it took for 50 % of the plants in a plot to flower. Amethyst and BRI7 took the highest number of days to reach 50 % flowering with no significant difference between them. BRI1, BRI6 and BRI2 took the least number of days to 50 % flowering with no statistical difference between them (Figure 4.2).

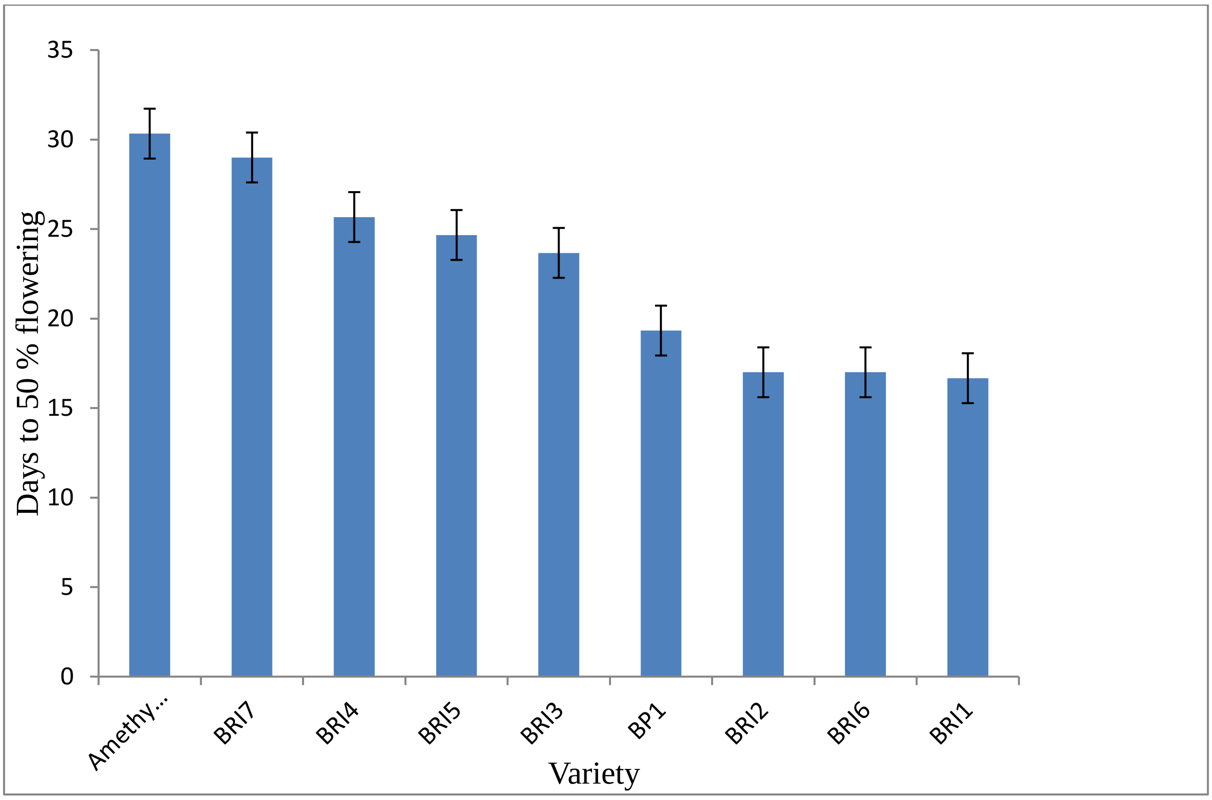

Figure 4.1 Number of days to 50% flowering

4.2 Effect of variety on number of days to 95 % maturity

There was a significant difference ($P<0.05$) on the number of days it took the varieties to reach 95% maturity. BRI7 and BRI5 had the highest number of days to reach 95% maturity with no significant difference between them. BP1 and BRI1 had the least number of days with no statistical difference between them (Table 4.1).

Table 4.1 Number of days 95 % maturity

Variety	Number of days to 95 % maturity
BRI 7	139.3a
BRI 5	136.7ab
BRI 3	134.7bc
BRI 4	131.7cd
BRI 2	130de
BRI 6	126.7e
Amethyst	126e
BRI 1	100f
BP1	100f
Mean	125.00
Probability	0.001
LSD	4.115
Coefficient of Variation	1.9 %

4.3 Effect of variety on yield of potato

There was a significant difference ($P<0.05$) among varieties on yield of potatoes. BRI6 and BRI3 were the highest yielding producing 69.63 t/ha and 58.89 t/ha respectively and there was no statistical difference ($P<0.05$) between them (Figure 4.1). BRI7 and BP1 were the lowest yielding producing 9.89 t/ha and 13.22 t/ha respectively with no statistical difference ($P<0.05$) between them.

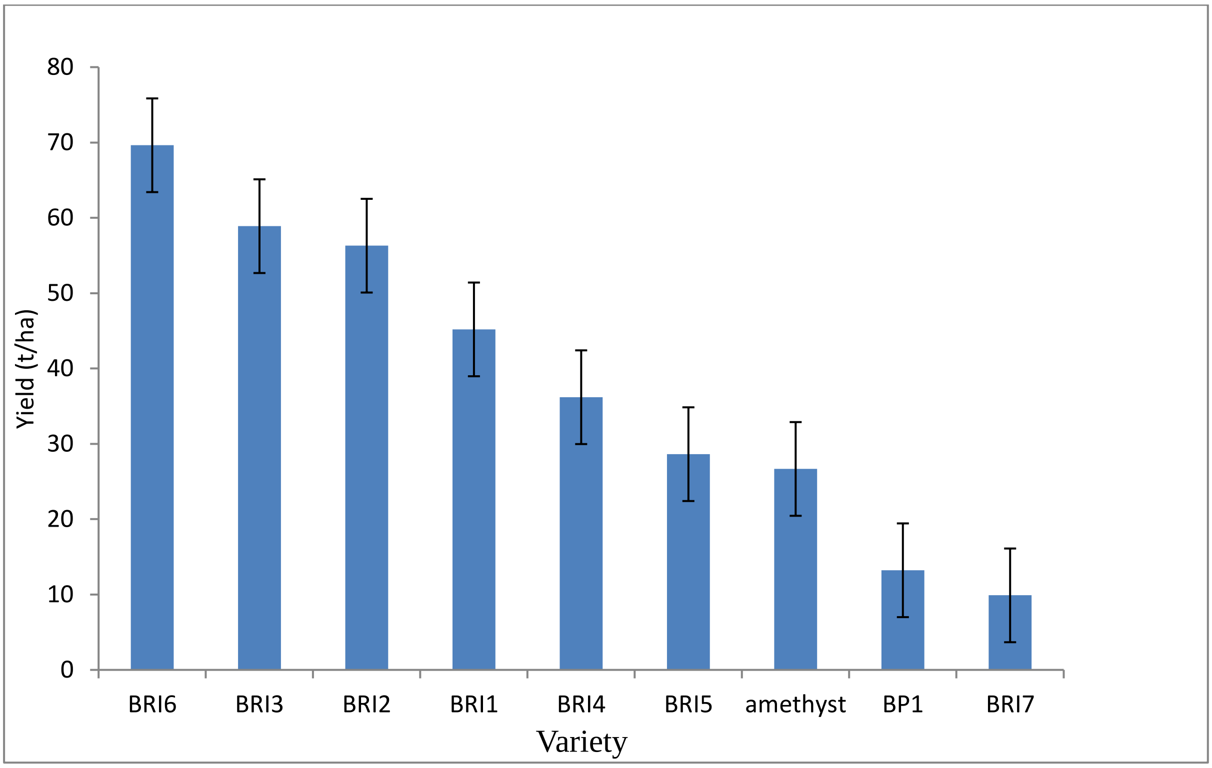

Figure 4.2 Tuber yields of the potato varieties.

CHAPTER 5

5.0 DISCUSSION

The local varieties Amethyst and BP1 were outperformed in terms of yield by some of the new varieties. All the new varieties produced a yield greater than amethyst and BP1except for BRI7 and there was no significant difference between amethyst, BRI4 and BRI5 . BP1 is a short season variety has an expected yield of 13.5 – 20 t/ha but it had a higher yield as compared to Amethyst which is a long season variety with an expected yield of 35 – 60 t/ha. The poor performance of Amethyst and BP1 could have been caused by the occurrence of Bacterial wilt disease in some of the plots in the experiment including 2 of the Amethyst plots (Appendix 3). There are no potato varieties that are resistant to bacterial wilt but the symptom expression differs among varieties (Anonymous, 2015). The high yield of BRI6 can be attributed to the tuber number as it had the highest number of tubers. It still had the highest yield even though most of its tubers were small in size. BRI3 and BRI had no significant yield differences and also a small difference in the number of tubers. The low yields of BRI7 and BP1 can be due to the number of tubers as the two had the lowest numbers (Appendix 4). The number of days to maturity can also be the cause of the highest yields obtained by the long season varieties. However the varieties that took the longest to reach physiological maturity did not have the highest yields. This may be due to the infection by bacterial wilt as it affects varieties differently. The difference may also be due to different fertiliser use efficiency of the varieties (Kays and Nottingham, 2007).

Amethyst and BRI7 took highest number of days to flowering while varieties BRI2, BRI6 and BRI1 the lowest. The time it takes for a variety to flower can be associated with the length of the season the plant requires to grow. Flowering in potatoes coincides with the tuberisation stage and this is known as the flowering transition (Almekinders and Struik, 1996). Early flowering results in early tuberisation. The differences in flowering dates among the varieties could be due to the different seasonal lengths required by each variety. The difference could also be caused by different day length especially during the late winter as Abelenda et al. (2011) state that flowering of some potato varieties is affected by day length.

BP1 and BRI1 are short season varieties while BRI2, BRI3 BRI4, BRI5, BRI6, BRI7 and Amethyst are long season. Short season varieties mature in less than 100 days while long season in more than 120 days (Anonymous, 2013). The length of the growing season required by a variety may be the cause of high yields. This is because the plant will have a longer time to photosynthesise and produce more dry matter. A prolonged growing season may also mean a longer tuber bulking stage of the plant’s development. However BRI7 had the longest growing period but had the lowest yield. This could be due to the production of mostly small sized tubers as it has the highest distribution of tubers in the Small and Charts grades. The total number of tubers produced can also explain the higher yields in BRI6 and BRI3 as they had the highest number of tubers produced (Appendix 4).

CHAPTER 6

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The results concluded that variety had an effect on the yield, number of days to 50 % flowering and number of days to 95 % maturity. The new varieties had a higher yield than locally released varieties Amethyst and BP1 with BRI6 having the highest yield. The varieties that took more than 120 days to reach 95 % maturity are long season varieties and these were BRI7, BRI5, BRI3, BRI4, BRI2, BRI6 and Amethyst. Varieties that matured in 100 days or less are short season varieties and these were BRI1 and BP1.

6.2 Recommendations

A multi-locational trial is required to determine the performance of the varieties in different farming regions of the country before one variety is selected for released. Evaluation for drought tolerance, diseases and pest resistance should be done to determine other characteristic of the new varieties. The varieties that do not get to be released should be kept and maintained as germplasm that can be used in future breeding programmes.

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APPENDICES

Appendix 1: ANOVA for effect of variety on the yield of potato varieties

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	41.365	20.683	4.89	
Block.*Units* stratum					
Treatment	8	753.916	94.240	22.27	<.001
Residual	16	67.721	4.233		
Total	26	863.003			

Coefficient of Variation: 19.9

Appendix 2: ANOVA for effect of variety on number of days to 50 % flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.963	0.481	0.25	
Block.*Units* stratum					
Treatment	8	672.519	84.065	43.34	<.001
Residual	16	31.037	1.940		
Total	26	704.519			

Coefficient of Variation: 6.2 %

Appendix 3: ANOVA for effect of variety on number of days to 95 % maturity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.889	1.444	0.26	
Block.*Units* stratum					
Treatment	8	5274.667	659.333	116.64	<.001
Residual	16	90.444	5.653		
Total	26	5368.000			

Coefficient of Variation: 1.9 %

Appendix 4: Number of tubers and their grades

Variety	Extra large	Large	Medium	Small	charts	Total
BRI1	13	40	78	53	31	215
BRI2	17	58	94	52	56	277
BRI3	19	59	83	55	54	270
BRI4	0	34	72	101	35	242
BRI5	17	20	53	38	29	157
BRI6	16	46	56	135	46	299
BRI7	4	3	11	21	16	55
BP1	4	15	18	12	4	53
Amethyst	8	30	65	42	39	184

Appendix 5: Notable Pests and Diseases

Block 1	Pest/Disease	Block 2	Pest/Disease	Block 3	Pest/Disease
BRI1	Bacterial wilt	BRI1		BRI1	
BRI2	Bacterial wilt	BRI2		BRI2	Bacterial wilt
BRI3		BRI3	Bacterial wilt	BRI3	Bacterial wilt
BRI4	Bacterial wilt	BRI4	Bacterial wilt	BRI4	
BRI5		BRI5		BRI5	
BRI6	Bacterial wilt	BRI6	Bacterial wilt	BRI6	Bacterial wilt
BRI7		BRI7	Tuber moth, Bacterial wilt	BRI7	
Amethyst		Amethyst	Tuber moth, Bacterial wilt	Amethyst	Bacterial wilt
BP1		BP1		BP1	