BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

EFFECT OF SPLIT SUPPLEMENT FOLIAR PHOSPHOROUS APPLICATION ON GROWTH AND YIELD OF POTATO *(Solanum tuberosum)*.

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF (CROP SCIENCE)
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BINDURA UNIVERSITY OF SCIENCE EDUCATION

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RESEARCH PROJECT

DECLARATION

I, Anesu Handireketi, do hereby declare that this research project is a result of my original research work undertaken by myself except where clearly and specifically acknowledged. It is being submitted for the partial fulfilment of the Bachelor of Agricultural Science Honors Degree (Crop Science). It has not been submitted before for any degree or examination at any other University.

Name: Anesu Handireketi

Signature________________________________

_ Date: 19/12/22

I have supervised the research project for the above mentioned and I am convinced that the research project:

a) Can be submitted

Project Supervisors: i) ________________________________

Signature____________________

Date: 19/12/22

ii) ______________________________Signature______________________

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

Quality controller_____________________________Signature_____________________________

Date:

Official stamp/Date received in the Department of Crop Science office.

DEDICATION

This project is dedicated to my family.

ACKNOWLEDGEMENTS

Great thanks to my project supervisor Dr T.J. Chikuvire for the guidance and some push he gave me when I was doing my research. I deeply appreciate and acknowledge the manager of Landos farm Mr S. Kubare for allowing me to do my field work at his farm. I also appreciate his assistance on implementing the field work. Many thanks to Prof R. Mandumbu for his assistance and mentorship when I was doing my data analysis.

ABSTRACT

Supplement foliar phosphorus is needed in potato production to maximize the final yields. Whilst supplement foliar phosphorus is important in potato production, it is not quite clear on how it can be applied. The field experiment was carried out to investigate the effectiveness of split application of supplement foliar phosphorus on growth and yield of potato. All treatments were supplied with potato blend (8:24:20) as a basal fertilizer. For split application, supplement foliar phosphorus was applied soon after full emergence using a rate of 5l/hectare, and this was repeated 4 more times at an interval of 7 days using the same rate. For single application, supplement foliar phosphorus was applied once soon after full emergence using a rate of 25l/hectare. No supplement foliar phosphorus was applied in a control treatment. These 3 treatments were replicated 3 times in a randomized complete block design. Data collected on growth and yield parameters were subjected to analysis of variance (ANOVA) using GENSTAT 2016 edition and an LSD ($p=0.05$) was used to differentiate between statistically different means. Split application of supplement foliar phosphorus showed highest significant $p<0.05$ results on growth parameters (leaf area, leaf number, plant height and days to flowering). It also shows highest significant $p<0.05$ results on yield parameters (tuber number and tuber weight). The findings suggests that split application is the best when applying supplement foliar P. with the same amount of foliar fertilizer, a farmer can increase potato yields by using split application method than single application.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA: Analysis of Variance

FAO: Food and Agriculture Organization.

P: Phosphorus

Fe: Iron

K: Potassium

LSD: Least Significance Difference

N: Nitrogen

RCBD: Randomized complete block design

CHAPTER 1

1. Introduction

1.1 Background

Irish potato (*Solanum tuberosum L*) originated from South America in the Andes, and it moved to Ireland (Akoto *et al*., 2020). It is commonly known as Irish Potato since it was mainly grown in Ireland in 1800s during the time when the country experienced the great Irish famine which resulted in one of the worst agricultural disasters in history (Akoto *et al*., 2020). Potato is among the four most important crops in the world and it comes after wheat, maize and rice with an annual production of 314.1 million tons on 18 million hectares of land (Misgina, 2016). It is the most valuable non grain food product and has got a greater importance in the world's economy (Kahsay, 2019). Potato is a good source of nutrients such as carbohydrates and vitamins. It has a low concentrations of cholesterol, fats and sodium and have antioxidant properties which make them good for human consumption (Akoto *et al*., 2020). Potato also brings income and creates employment in developing countries such as Zimbabwe. Domestically, it is consumed as French fries, mashed potatoes and can also be used to feed livestock. It can be used in the industry for production of starch, ethanol and manufacturing of soap.

Potato being native to the Andean Region, is well adapted to cool and temperate climates (Kadian *et al*., 2012). Potato fits well in a multiple cropping pattern due to its short duration, flexibility of planting and harvesting nature along with its high commercial value. So far Zimbabwe has an average potato yield of 20 tonnes per hectare (Sakadzo *et al*., 2020).Optimal nutrient management is critical to obtain a high tuber yield and good quality of potato. Low use of fertilizers and serious imbalances in the Nitrogen: Phosphorus: Potassium (N:P: K) application ratio is partially responsible for low yields. In order to maximize nutrient use efficiency and mitigate environmental impacts, a farmer must use optimum fertilizer recommendations in potato production. Potato is most sensitive to nutrient stresses owing to its shallow and sparse root system. There are many nutrients needed by the potato crop, of which P is one of key ones.

Phosphorus is regarded as an essential element for all living organisms, (Tirado & Allsopp, 2010). Potato demands larger quantities of phosphorous than other crops. The nutrient is responsible for plant growth, tuber formation, bulking and tuber starch synthesis (Aarakit *et al*., 2010). When phosphorus concentration in soil increases, its loss due to surface runoff also increases (Aarakit *et al*., 2010). Mainly, Phosphorus fertilizers are soil applied but foliar application is also recommended as a supplement. Ekelöf *et al*. (2012) and Rosen & Bierman (2008) state that application of foliar phosphorus increases yield, but rate of soil applied phosphorus should remain unchanged as per recommended levels. The response of potato yield and tuber set to foliar P application differs since the P solution gets into the leaves through leaf cuticles which are sometimes permeable and some of the solution may enter the leaf through the stomata (Ekelöf *et al*., 2012). Some potato leaves have thick cuticles which delay entrance of foliar phosphorus.

Few authors have researched the effects of foliar Phosphorus application and split application in Zimbabwe, so there is need for some further research on foliar Phosphorus fertilizer application approach.

1.2 Problem Statement

The demand of potato is increasing in domestic and international markets and therefore, there is need to produce more potato through use of additional foliar phosphorus. Use of foliar phosphorus has a high potential of increasing yields in potato production. Due to delaying process of foliar phosphorus entrance to the leaf, it can be washed away from the leaves through irrigation or rainfall. Morning dew can also affect absorption of foliar phosphorus negatively. Morning dew can wash away the foliar phosphorus that is already on the leaf surface, and this can be a recurrent process which reduces foliar phosphorus efficiency. Studies on foliar phosphorus application on potatoes were conducted outside Zimbabwe and the effects may not correlate with those from local soils and climatic conditions. Little is documented concerning frequency of use of foliar phosphorus as additional P to potato production in Zimbabwe. There is need to determine if split application of foliar P, as a supplement to production of potato, increases the final yield as compared to single foliar application.

1.3 Justification

Improvement of potato yields leads to more revenue generation. This is important because it creates employment and also improves food security and livelihoods of farmers. Since nutrient management is one of the key pillars of yield improvement of potatoes, application of foliar P is essential. Dividing total foliar phosphorus application into two or more treatments can potentially enhance nutrient efficiency, promote optimum yields and mitigate the loss of nutrients. though split application of foliar fertilizers is laborious. The study is necessary to provide important information on yield and advice farmers as to whether they can split foliar P fertilizers or not.

1.4 Main Objective

To determine the effect of P foliar fertilizer application approach on potato performance.

1.5 Specific objectives

a) To determine the effect of P foliar fertilizer application approach on growth performance of potato (plant height, number of leaves, leaf area and days to 50 % flowering).
b) To determine the effect of P foliar fertilizer yield of potato with split and single application of foliar phosphorus (tuber number and tuber weight).

1.6 Hypotheses

a) H_0: there is no statistically significant difference between P foliar fertilizer application approaches on growth of potato (*Solanum tuberosum).*
b) H_0: there is no statistically significant difference between P foliar fertilizer application approaches on yields of potato (*Solanum tuberosum*)

CHAPTER 2

2. Literature Review

2.1 Background

About 8000 years ago in South America, potatoes were domesticated and in the sixteenth century, Spanish conquerors brought them to Europe and the United Kingdom (Tapiwa, 2019). China is currently the world's biggest producer with an annual production of 33.921 million tones, followed by Russia, Ukraine, Poland, and India (FAO, 2008).

2.2 Brief History of Irish Potato Production in Zimbabwe

The crop was introduced to Zimbabwe by the British settlers in the 1900s; common cultivars include BP1, Amethyst, Mont Claire, Opal, Emerald, and Jacaranda (Mpemba, 2016). After maize and wheat, the crop is now Zimbabwe's third-largest source of carbohydrates (The herald, 2011; Sakadzo *et al*., 2020). The Zimbabwean government praised the industry when it issued a policy designating the crop as a national strategic food security crop in 2012, after appreciating the value of Irish potato production (Svubure *et al.*, 2017). Potatoes may be cultivated all year round in Zimbabwe due to the country's favorable climate. For short season types, this is typically three times, which has attracted farmers. However, small holder farmers are discouraged from producing the crop three times a year due to market demand fluctuations and crop rotation to control pests and diseases (Fusire, 2001). Currently, 3500 hectares of land are used for potato farming each year, yielding an average of 20 tonnes per hectare (FAOSTAT, 2013; Sakadzo *et al*., 2020).

2.3 Uses of phosphorus in Potato

According to several investigations, the primary element influencing biomass formation under variable P supplies is light absorption by crops (Lynch *et al*., 1991; Colomb *et al*., 1995; Plenet *et al*., 2000). Low P levels cause plants to grow with fewer total leaves, which negatively affects light absorption and, in turn, plant development (Lynch *et al*., 1991; Plenet *et al*., 2000). The smaller individual leaves and/or fewer leaves overall may be the cause of the reduced total leaf area (Lynch *et al.*, 1991). P-deficient plants have fewer leaves because the shoot meristems are less active and initiate fewer leaves (Chiera *et al*., 2002). On the other hand, the smaller individual leaves may reflect a reduction in the rate of cell division or the expansion of epidermal cells, which in turn affects the pace of leaf expansion (Assuero *et al.*, 2004; Radin and Eidenbock, 1984). Lynch *et al*. (1991) and Colomb *et al*. (2000) found that non-P treated plants had considerably fewer terminal leaves than P treated plants, which ultimately reduced the total leaf area of the plant. There is evidence that phosphorus-deficient plants reduce the rate of photosynthesis (Brooks 1986). The Net Assimilation Rate (NAR) and, consequently, the rate of plant development is both impacted by the decline in photosynthetic rate per unit leaf area. However, several studies still indicated that a P shortage had no effect on the photosynthetic rate per unit leaf area (Dieter and Helios, 1990). The varying reactions may be caused by the severity of P deficit and the plant's or genotype's ability to handle low internal P (Kondracka and Rychter, 1997). As a result, genotypes vary greatly in their capacity to withstand P stress and the degree to which P deficit affects their physiological and morphological growth parameters (Fujita *et al*., 2004; Yong-fu, 2006). P affects potato development and yield in a variety of ways, including by accelerating the growth rate of all plant components for many weeks following emergence. Final tuber yields are a function of tuber set, tuber growth rate, and the length of tuber growth (Dyson and Watson 1971). The synthesis of tuber starch has also been linked to phosphorus (Stark and Love 2003). Tuber numbers per plant are typically boosted by adding P to P sensitive soils (Rosen and Bierman 2008). While some researchers (Nelson and Hawkins 1947; Benepal 1967; Freeman *et al*. 1998) claim that adding P enhanced the proportion of large tubers harvested, others found that the rise in the number of small tubers was counterbalanced by a decrease in the number of large tubers (JenkinsandAli2000; Rosen *et al*. 2006–2008; RosenandBierman2008). P is a nutrient for plants that affects cellular energy transfer, photosynthesis, and respiration and is a part of phospholipids, phosphorylated sugars, and nucleic acid nucleotides (Marschner, 1996; Plaxton and Carswell, 1999).   Although other studies observed yield responses, they found no effect of foliar P on the overall number of tubers (Mohr & Tomasiewicz, 2012). Surprisingly, the stem number appears to be unaffected by P additions (Jenkins and Ali2000). P is crucial for early-season potato growth and has also been connected to accelerating crop maturity (Stark and Love 2003).

2.4 Constraints to Potato Production in Zimbabwe

Deficiency of some nutrients is caused by continuous cultivation on the same piece of land without ideal nutrient restoration. In highlands of Kenya, K has been known to be adequate, but it seems to be partially depleted because of high uptake by potato which is a K demanding crop (Wekesa *et al* 2014). This resulted in need for correction of soil nutrients since Rosen (2015) states that imbalances in nutrient supply causes unavailability of some micronutrients for potato uptake.

P is, regrettably, one of the least readily available nutrients in most soil, particularly in tropical environments where low P availability is a significant barrier to agricultural development (Kochian *et al*., 2004). Because potatoes require a lot of P for ideal growth and yield, they suffer significant yield losses when grown on P-deficient soils (Alvarez-Sanchez *et al*., 1999; Dechassa *et al*., 2003). Under P deficient conditions, a reduction in plant biomass output or growth rate may be attributed to either a limited amount of absorbed photosynthetically active radiation (PAR) or a less effective conversion of the intercepted light (Colomb *et al.*, 1995). (Plenet *et al*., 2000). The potato value chain faces multiple challenges, including a lack of high-quality seeds, low yields, inadequate irrigation systems, poor disease management, perishability, inadequate storage facilities, poor post-harvest handling management, a shortage of processing facilities, inadequate skill and technology for processing, insufficient funding, and a lack of dishes and recipes. The potato business, according to FAO (2008), is dealing with a number of issues, such as a lack of diversity in potato types, which makes it harder to manage issues including drought, diseases, pests, climate change, and declining yields in marginal regions. Prior to the land reform program, white people who owned commercial farms controlled the majority of the potato sector in Zimbabwe. Lack of understanding regarding the timing of earthing up, cultivation techniques, and production costs are significant variables affecting potato output in Zimbabwe, (Masvodza, 2015); Sakadzo *et al.*, 2020).

2.5 Field application of Fertilizer

P fertilizer can be applied to potato crops in a variety of ways, including banding, fertigation, and broadcasting, soaking seed tubers, and spraying liquid fertilizers on the leaves. The last two approaches, however, are more for supplemental needs because only modest amounts can be used in this manner. One of the main issues with using phosphate fertilizer is that the soil fixes the applied phosphate, yet fertilizer P absorption is not very effective. When soluble phosphate is sprayed to the soil, it immediately loses its solubility upon contact with the soil, significantly reducing its availability to the planted crop (Jenkins and Ali, 2000; Ali *et al*., 2004). Since the majority of the applied P is fixed by the soil and not mobile, the best practice is to apply P fertilizer close to the active root zone (banding). Placing the fertilizer lessens soil contact, preventing fixation. As a result, the P uptake usage efficiency will rise. Since big capacity machines can be employed, broadcasting is the least effective but most popular application method. This lowers the cost of the application. Prior to planting, the fertilizer is applied, and when the ridges form, it is incorporated into them. Grewal and Trehan (1993) cite numerous sources that claim that soaking seed tubers in phosphorus solutions before planting them boosts tuber output and phosphorus uptake. Depending on the soil's availability, soaking seed tubers was a good way to partially or even completely satisfy the crop's P needs.

In central Sweden, Hahlin (1992) researched the ideal P fertilizer application rate for potatoes. Application rates of 0, 45, and 90 kg P/ha were tested. When the application rate was increased from 45 to 90 kg P/hectare, the yield increased from 29005 to 30000 kg/hectare. The author concluded that the recommendations for potatoes by then were appropriate and that the ideal application rate was likely higher than 90 kg P/ha. However, some commercial farmers apply more than recommended fertilizer application rates to enhance the potato yield.

2.6 Foliar fertilizer in potato production

One of the most crucial techniques for digesting plant nutrients further and preserving the plant's nutritional balance is foliar fertilization (Dkhil *et al.*, 2011). The potato crop can also get foliar applications of phosphorus, which are thought to boost both the production and the quantity of tubers. The plant's nutritional status and the concentration supplied to the leaf determine the pace at which leaves absorb mineral nutrients. The evaporation coefficient is frequently higher throughout the day, which makes it less conducive for foliar uptake and causes the sprays to dry on the leaf surface more quickly. Foliar-applied P fertilizers are suggested as an additional treatment to maintain a sufficient P status in the potato crop. However, the outcomes of scientific studies on these treatments vary, and only a small number of trials have truly demonstrated any appreciable results. The weather before and after the treatment, the amount of P in the soil and plant, and the application method all appear to have a significant impact on how the foliar-applied P responds (Rosen & Bierman, 2008). Chemical fertilizer is applied to increase crop yields, however doing so carelessly resulted in significant environmental and human health damage (Kande and Adediran, 2004). The essential period for the plant's requirement for nutrients is when potato tubers are composed.

Application of fertilizer has significant influence on potato quality and production (Westermann, 2005). Since foliar fertilization involves applying small amounts of nutrients directly to the leaves, its benefits should be investigated. These include reduced fertilizer consumption, convenience of administration, good fertilizer quality, and fertilizers that are easily soluble in water (Buck *et al*., 2008). The output of potatoes may benefit significantly from foliar fertilization.

Application of foliar phosphorus increased plant height, marketable tuber yield, and marketable tuber quantity considerably (Zelalem et al 2009). Higher tuber production was the effect of the foliar P application (Ekelöf, 2007). In most soils, phosphorus ranks second to nitrogen as the most significant macronutrient limiting plant development.

CHAPTER 3

3. Methodology

3.1 Study Site

The research was carried out during the winter season of the year 2022 at Landos Farm which is located in Banket (17°20'39" S and 30°21'49" E). Banket (originally known as Banket Junction) is a town in the province of Mashonaland West, Zimbabwe. It is located about 95 km north-west of Harare on the main Harare-Chinhoyi Road. The place is in the agro-ecological region IIb of Zimbabwe which experiences an annual rainfall of 800-1000mm and an average temperature of 18^0C in winter (Bradley et al, 2020; Republic of Zimbabwe, 2016). Nyamapfene (1991) classified the soils in order III of the Zimbabwean soil classification, belonging to the group 6 kaolitic soils derived from coarse sand grains from granite and these soils are in the class of clay loam soils. Soils are deep and well drained with a pH of 5.2 and are ideal for potato production.

3.2 Experimental design

The experiment was laid out as a single factor (1x3) in a Randomized Complete Block Design replicated 3 times. The experiment had 3 treatments namely split application, single application, and the control treatment. Slope was used as a blocking factor.

3.3 Procedure

Land preparation was done using a tractor towing a disc plough. A plough depth of 30cm was maintained. Plots which measured 5 rows by 5m each where made, leaving a distance of 30cm between the plots. The net plot was measuring 3 rows by 4m. Planting was done using the inter row spacing of 90cm whereas the in row was 30cm. The targeted plant population rate was 37 000 plants per hectare.

3.4 Management

3.5.1 Fertilizer management

Broadcasting of fertilizer was done soon after plot making. Potato Blend (8:24:20) was broadcast equally as a basal fertilizer in all treatments at the rate of 1000kg per hectare as the recommended rate for optimum plant growth. Planting of potato was done soon after broadcasting of the (8:24:20) Potato Blend. Planting was done using a spacing of 20cm in row and 90cm inter-row.

A foliar phosphorus spray (Power P^+ with 21% P) was sprayed to enhance the growth and yield of potato using a knapsack sprayer. The foliar spray was diluted with water using a ratio of 1: 50, foliar P and water respectively. The total amount of foliar phosphorus applied to each net plot was 25l/hectare. In the treatment that represents split application foliar phosphorus was applied 5 times. First foliar application was done seven days after full germination at a rate of 5l/hectare, and this was repeated 4 more times at an interval of 7 days using a rate of 5l/hectare. In the treatment that represents single application, foliar phosphorus was applied once seven days after germination after full germination at a rate of 25l per hectare. No foliar phosphorus was applied in the control treatment.

Calcium nitrate with a formulation of 15N: 26Ca was applied at a rate of 100kg/hectare in the fourth week. Straight after planting boron, copper sulphate, zinc sulphate was applied using a fertigator. Boron was applied at a rate of 2kg/hectare, both copper sulphate and zinc sulphate were applied at a rate of 300g/hectare. Urea with a formulation of 46 N was applied at a rate of 100kg/hectare in the third week.

3.5.2 Ridging

The potato shoots where ridged when they were about 10 cm tall and this was done by mounding around with soil to their full height. Ridging of potatoes increase the length of the underground stem that will bear tubers. This mounding was repeated twice at two to three-week intervals to ensure the best crop, with the added advantage of smothering weeds.

The soil between plant rows was loosened and then drawn into a ridge along the length of the potato rows. A shallow groove was left along the row at the top of the ridge to channel any water down to the developing tubers. Ridging also protects tubers from greening, potato tuber moth and late blight infestation. It was done and completed by the time when the crop was25 cm tall.

3.5.3 Diseases management

The two major diseases that needed to be controlled were early blight and late blight. These diseases were controlled by copper hydroxide (Cop Flo 50 SC) using a rate of 1litre per hectare and always Mancozeb (Dithane M45) using a rate of 2kg per hectare plus AquaRight @50ml/hectare. Spraying commenced soon after the plants emerged on a 14-day cycle. This interval was decreased to once every 10 days from 30 days after emergence and reduce it further to once every 7 days from 1st flowering.

3.5.4 Pest management

Potato Tuber Moth was the main pest that has to be controlled and this was to be done by a routine application of Flubendamide (Belt) using a rate of 100ml/hectare and Acetamprid at a rate of 200g/hectare. There was also need for scouting of Tuta (Tomato Leaf Miner) and apply Indox or Ampligo and Abamectin at a rate of 300ml/ha and 250ml/hectare respectively.

3.5.5 Weed management.

Weeds can cause significant yield loss. They compete with crop for water, nutrients, light and growing space. They also habour pests and pathogens. Commonly used herbicides include Topogard (tebutryne), Dual (metolachlor), Sencor (metribuzin) and EPTC. As for weed management Dual and Metribuzin was used as pre-emergence herbicides then (Rimex 25w Dg) and ETPC was used as a post emergence herbicide for broad leaved weeds.

3.5.6 Irrigation

No stress period was required after full germination is complete. The plants received 44 mm every 3rd - 5th day the first 6 weeks, and every 2nd – 3rd day the last 5 weeks using a pivot.

3.6 Data collection

The data for all objectives was collected from 5 plants in each net plot using a random sampling method except the final yield which was measured using all plants from the net plot per treatment. The selected plants were numbered using tags for future measurement. Average number of days taken to 50% flowering was counted soon after full germination of the potato. Number of leaves was counted from second week after full germination, and this was repeated at an interval of 2 weeks up to week 6. The leaf area index was calculated in the week 2 after full germination up to week 6. The leaf area index was calculated using a graph paper. The data for growth parameters was collected up to week 6 because that's the period when potato begins tuber forming and there was not further growth since the potato will be concentrating on tuber formation. The final yield was measured soon after harvesting using the average weight of the tubers using digital scales. The number of tubers was counted from tagged plants only.

3.7 Data analysis

The data was subjected to the analysis of variance (ANOVA) to determine the effectiveness of split application of supplementary foliar P growth and yield performance of potato using GenStat.

(Version 16). The tests were done at 0.05 probability level. Means of significant treatment difference were separated using the least significant difference (LSD) procedure.

CHAPTER 4

4. Results

4.1 Effects of different methods of supplement foliar phosphorus application on days taken to flowering by potato.

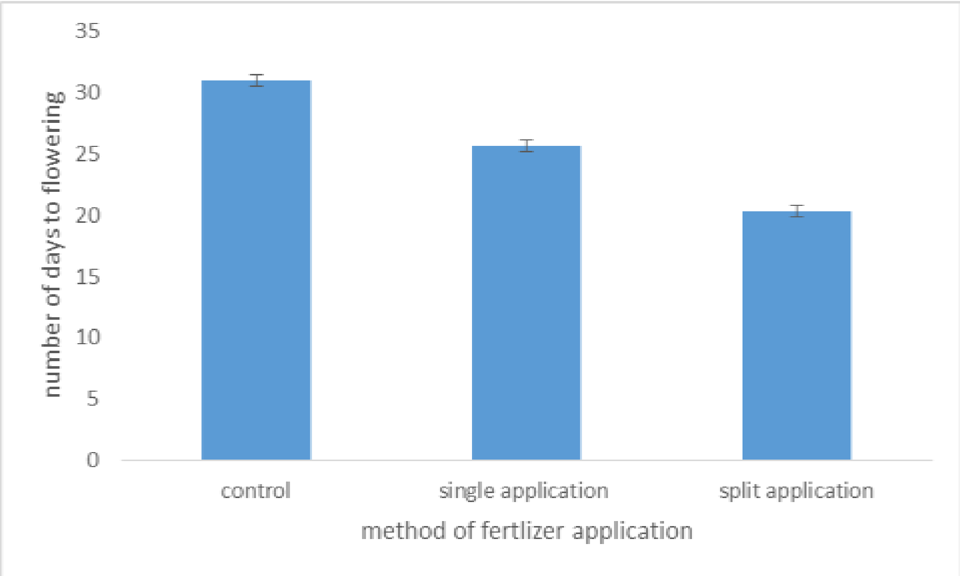

Figure 4.1 showing average number of days taken to 50% flowering.

Vertical error bars show the LSD at $p < 0.05$.

There was a significant difference on the number of days taken to flowering ($p<0.05$) by potato which received supplement foliar phosphorus in different frequencies. The potatoes that did not receive any supplement foliar phosphorus were the last to reach 50% flowering. The potatoes that were applied supplement foliar phosphorus as the split application has got the least number of days to flowering. The plants that receive one treatment of foliar P application were the second to reach the flowering stage.

4.2 Effects supplementary foliar phosphorus fertilizer on leaf number of Irish potato

Table 4.1 showing leaf number.

Treatments	*Week 2*	*Week 4*	*Week 6*
Control	5.33a	10.67a	16.33a
Single application	13.00b	19.33b	26.33b
Split application	9.00c	20.33b	36.00c
P value	<.001	<.001	<.001
LSD	0.756	1.999	2.389
Grand mean	9.11	16.78	26.22

Means followed by different letters in the same column differ significantly at $p< 0.05$.

In week 2 there was a significant difference on the number of leaves of potatoes ($p<0.05$) which were applied single application of foliar phosphorus and those which were applied split application of supplement foliar phosphorus. The highest number of leaves were observed in the plants that received single application of foliar phosphorus followed by those that received split applications of foliar phosphorus. The least number of leaves was obtained by plants that did not receive any supplement foliar phosphorus.

In week 4 there was no significant ($p<0.05$) difference on the leaf number of potato that received split and those that received single application of supplementary foliar P. The least number of leaves were obtained by potato plants that did not receive any supplement foliar phosphorus. In week 6 the highest number of leaves was observed in plants that received split application of supplement foliar P.

4.3 Effects of supplementary foliar phosphorus on leaf area of potato

Table 4.2 showing leaf area.

Treatments	*Week 2*	*Week 4*	*Week 6*
Control	20.33a	70.8a	101.1a

Single application	40.73b	81.03b	115.97b
Split application	31.67c	86.2c	130.46c
P value	<.001	<.001	<.001
LSD	1.748	1.972	2.292
Grand mean	30.91	79.35	115.84

Means followed by different letters in the same column differs significantly.

In week 2 there was a significant (p<0.05) differences in the leaf area of potato plants that received single and split application of supplement foliar phosphorus. The least leaf area was from the potato plants that did not receive any supplement foliar phosphorus. The potato that received a single application of supplement had the largest leaf area as compared to those that received a split applications of supplement foliar phosphorus.

In week 4 Potato plants that received split application of supplement foliar phosphorus, obtained the largest leaf area. The potato that received single application of supplement foliar phosphorus were the second highest in the leaf area size. This trend was similar to that observed in week 6.

4.4 Effects of supplement foliar phosphorus application methods on plant height of Potato
Table 4.3 showing plant heights.

Treatments	*Week 2*	*Week 4*	*Week 6*
Control	14.34a	25.36a	40.13a
Single application	20.0b	31.26b	51.03b
Split application	16.77c	37.16c	67.25c
P value	<.001	<.001	<001
LSD	0.783	2.627	1.251
Grand mean	17.04	31.26	52.80

Means followed by different letters in the same column differs significantly.

In week 2 there was a significant (p<0.05) difference in plant heights of potatoes that were applied single and split application of supplement foliar phosphorus. The potato that did not receive any supplement foliar phosphorus had the smallest plant height. The plant that received a single application of supplement foliar phosphorus were the highest in plant height followed by those that received split applications of supplement foliar phosphorus.

In week 4 the highest plant height was shown by the potato plants that receive the split application of supplement foliar phosphorus. In week six the same trend was of results was observed in week 6.

4.5 Effects of supplement foliar phosphorus application methods on the tuber number of potato

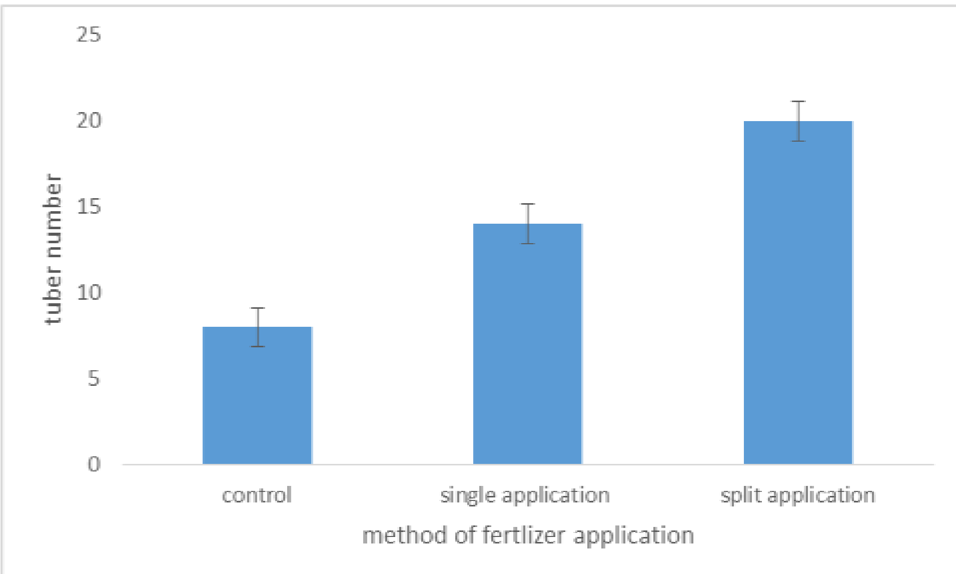

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Figure 4.2 effect of supplement foliar P application method on tuber numbers.

Vertical error bars show the LSD at p< 0.05.

There was a significant ($p<0.01$) difference in tuber number of potatoes that were applied single and split application of supplement foliar phosphorus. The largest number of tubers were obtained by plants that received a split application of supplement foliar phosphorus. The potato plant that did not receive any supplement foliar phosphorus had the least number of tubers.

4.6 Effects of supplement foliar phosphorus application methods on fresh tuber weight of potato

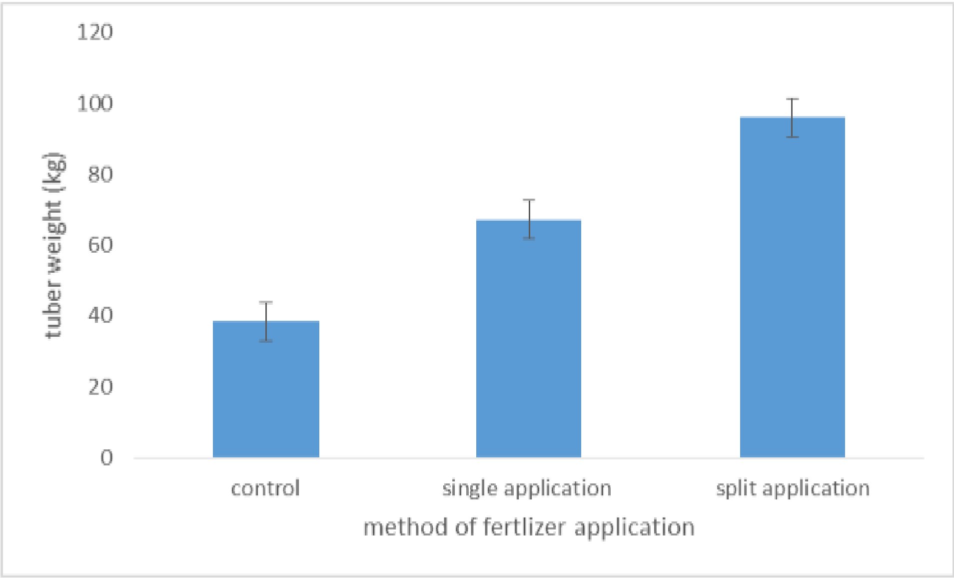

Figure 4.3 showing the tuber *weight.*

Vertical error bars show the LSD at $p < 0.05$.

There was a significant ($p<0.01$) difference in the tuber weight of potatoes that were applied supplement foliar phosphorus using different application methods. The least weight was obtained by potato plants that did not receive any supplement foliar phosphorus. The potato plants that were applied split application of supplement foliar phosphorus have got the highest tuber weight.

CHAPTER 5

5 Discussion

The potato plants that received basal phosphorus at 1000kg/hectare and not any supplement foliar phosphorus produced a few numbers of leaves, and they also had the shortest stem heights as compared to those plants that received a supplement foliar phosphorus probably due to unavailability of supplement foliar P which is a requirement to boost leaf initiation and shoot meristems activity (Chiera *et al*., 2002). The lowest leaf area results in a negative effect on light interception and hence poor growth (Plenet *et al*., 2000). Light is a most requirement of photosynthesis, so reduced interception of light results in low rate of photosynthesis hence low growth performance. Less leaf number and reduced single leaf size is linked up to reduced leaf area (Lynch *et al*., 1991). Sometimes the decreased single plant leaf can be caused by low cell division rate or decreased epidermal cell expansion (Assuero *et al*., 2004), which will reduce leaf expansion rate. The lowest growth in non-foliar P treated plants was also because potato requires supplement foliar P for enhancement of optimum growth (Dechassa *et al*., 2003). Colomb *et al*. (2000) determined significantly higher leaf number in foliar phosphorus treated plants than in non-foliar phosphorus treated plants, the higher leaf number resulted in increased plant leaf area. A single application of foliar P resulted in a highest plant height in week 2 due to availability of relatively more P than for a split application The higher application rate of foliar P results in higher absorption of foliar phosphorus hence higher growth performance than those that received low rate during the first week. That is why the crops that received single application of foliar phosphorus was the highest in leaf number, leaf area, stem height and stem diameter during week 2. Thus, phosphorus is essential for the general health and vigor of all plants. Some specific growth factors that have been associated with phosphorus are stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, improvements in crop quality, and supports development throughout entire life cycle of the plants (Mosaic, 2016).

Split application of supplement foliar phosphorus shows results after week 2. That is when potato plants that received split application of supplement foliar phosphorus started having the highest performance on growth. This was because by the time when potato was supplied with second application of foliar P, the crop canopy was huge enough to intercept most of the foliar spray hence maximized phosphorus use efficiency. The plants that received split application of foliar phosphorus, some of the applications were done after the crop had established a good crop canopy which intercepts most of the foliar spray.

The plants that did not receive any supplement foliar phosphorus were the last to reach the flowering stage. The results were related to those that were observed by Rosen and Bierman, (2008) they observed best crop performance in potato that received a supplementary P. Sebnie (2019) observed the effects of foliar phosphorus on the formation of reproductive parts of potato. The potato that received split applications of phosphorus were the first to reach the flowering stage. This was because foliar phosphorus was applied every week and these increased chances of foliar phosphorus absorption by the potato plant hence efficient use of phosphorus.

At zero application of supplement foliar phosphorus, lowest yields were attained. This was because foliar phosphorus fertilizers are required as a supplementary treatment to boost the final yields of the potato crop (Rosen & Bierman, 2008).

Highest tuber number and tuber weight were obtained by plants that received split application of supplement foliar phosphorus. This was because split foliar phosphorus application enhances the final yield of potato as compared to single application, since potato crop takes up phosphorus at every point of its growing season. However, the quantity needed per day differs depending on the growth stage. Phosphorus uptake by potato plant is at peak during tuber formation and development stage (Covarrubias-Ramírez *et al*., 2005). Split application of foliar phosphorus also produces highest tuber number because foliar P will have a good crop cover and increased exposure to the plant during tuber initiation (Allison *et al*., 2001). The highest tuber number and tuber weight was also a result of highest growth rate from the plants that received split application of foliar phosphorus.

CHAPTER 6

6.1 Conclusion

The current research shows that split application of supplement foliar phosphorus significantly increases most of the growth parameters of potato, which is leaf area, number of leaves, days to 50 % flowering and plant height. Split application of supplement foliar phosphorus started showing results after week 3 of first supplement foliar P application. Several applications of supplement foliar phosphorus during its growth period also have a good effect on the yield of potato. Supplement foliar phosphorus improved growth and yield of potato.

6.2 Recommendations

From this study, a farmer can increase the final yield of the potato by using split application of supplement foliar phosphorus. This is because, with the same amount of foliar phosphorus a farmer can produce higher yields when using split application method than using single application method. There is still need to repeat this research using different application rates of foliar phosphorus.

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APPENDICES

Appendix 1: Table 1 Showing random assignment of the treatments in blocks.
Field layout

Block 1	Plot 1 (Treatment 3)	Plot 2 (Treatment 1)	Plot 3 (Treatment 2)
Block 2	Plot 4 (Treatment 1)	Plot 5 (Treatment 3)	Plot 6 (Treatment 2)
Block 3	Plot 7 (Treatment 3)	Plot 8 (Treatment 2)	Plot 9 (Treatment 1)

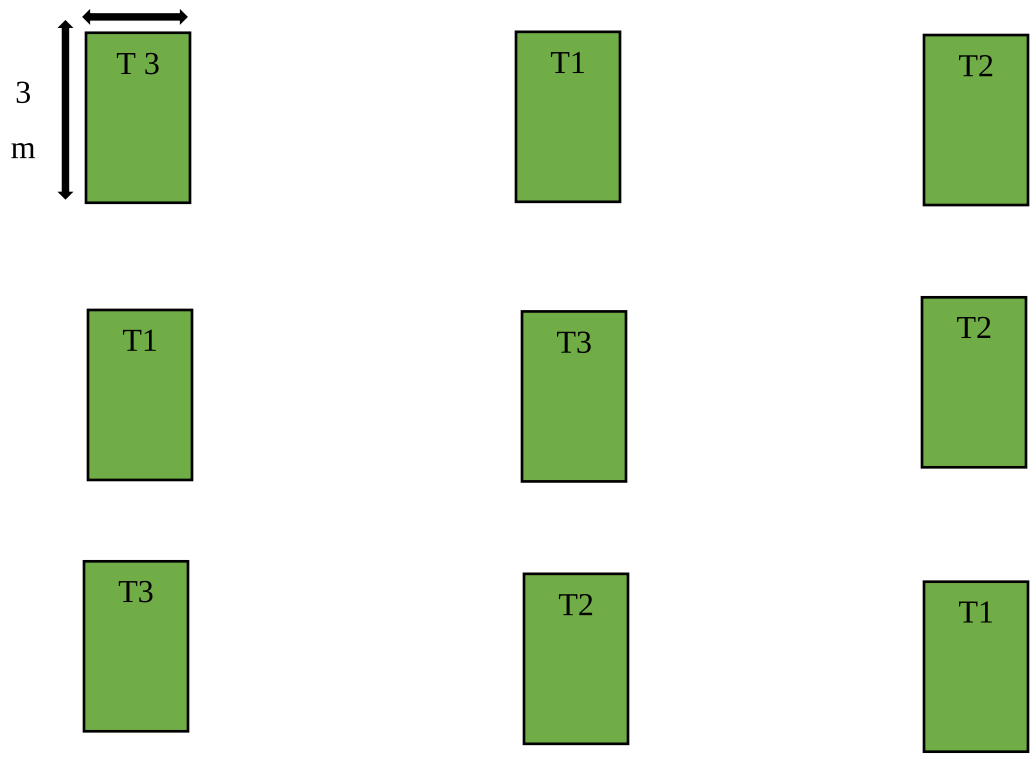
Where:

Plot size was (5m x 5rolls) x0.3m

Treatment 1: control

Treatment 2: split application of foliar phosphorus

Treatment 3: single application of foliar phosphorus0



Appendix 2: Analysis of Variance

2.1 Variate: Days to 50% flowering

Variate: days_to_flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	10.6667	5.3333	32.00	
replication.*Units* stratum					
treatment	2	170.6667	85.3333	512.00	<.001

Residual	4	0.6667	0.1667
Total	8	182.0000	

Tables of means

Variate: days_to_flowering

Grand mean 25.67

treatment	control	single application	split application
	31.00	25.67	20.33

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.236

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	0.925

Stratum standard errors and coefficients of variation

Variate: days_to_flowering

Stratum	d.f.	s.e.	cv%
replication	2	1.333	5.2
replication.*Units*	4	0.408	1.6

2.2 Variate: Leaf number week 2

Variate: wk2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	4.2222	2.1111	19.00	
replication.*Units* stratum					
treatment	2	88.2222	44.1111	397.00	<.001
Residual	4	0.4444	0.1111		
Total	8	92.8889			

Tables of means

Variate: wk2

Grand mean 9.11

treatment	control	single application	split application
	5.33	13.00	9.00

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.192

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	0.272

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	0.756

2.3 Variate: Leaf number week 4

Variate: wk4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.8889	0.4444	0.57	
replication.*Units* stratum					
treatment	2	169.5556	84.7778	109.00	<.001
Residual	4	3.1111	0.7778		
Total	8	173.5556			

Tables of means

Variate: wk4

Grand mean 16.78

treatment	control	single application	split application
	10.67	19.33	20.33

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.509

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	0.720

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	1.999

2.4 Variate: Leaf number week 6

Variate: wk6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	2.889	1.444	1.30	
replication.*Units* stratum					
treatment	2	580.222	290.111	261.10	<.001
Residual	4	4.444	1.111		
Total	8	587.556			

Tables of means

Variate: wk6

Grand mean 26.22

treatment	control	single application	split application
	16.33	26.33	36.00

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.609

Standard errors of differences of means

Table	treatment
rep.	3

d.f.	4
s.e.d.	0.861

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	2.389

2.5 Variate: Leaf area week 2

Variate: wk_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.7622	0.3811	0.64	
replication.*Units* stratum					
treatments	2	626.8089	313.4044	527.22	<.001
Residual	4	2.3778	0.5944		
Total	8	629.9489			

Tables of means

Variate: wk_2

Grand mean 30.91

treatments	control	single application	split application
	20.33	40.73	31.67

Standard errors of means

Table	treatments
rep.	3
d.f.	4
e.s.e.	0.445

Standard errors of differences of means

Table	treatments
rep.	3
d.f.	4
s.e.d.	0.630

Least significant differences of means (5% level)

Table	treatments
rep.	3
d.f.	4
l.s.d.	1.748

2.6 Variate: Leaf area week 4

Variate: wk4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.1147	0.0573	0.08	
replication.*Units* stratum					
treatments	2	368.7127	184.3563	243.53	<.001
Residual	4	3.0280	0.7570		
Total	8	371.8554			

Tables of means

Variate: wk4

Grand mean 79.35

treatments	control	single application	split application
	70.80	81.03	86.20

Standard errors of means

Table	treatments
rep.	3
d.f.	4
e.s.e.	0.502

Standard errors of differences of means

Table	treatments
rep.	3
d.f.	4
s.e.d.	0.710

Least significant differences of means (5% level)

Table	treatments
rep.	3
d.f.	4
l.s.d.	1.972

2.7 Variate: Leaf area week 6

Variate: wk6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.809	0.404	0.40	
replication.*Units* stratum					
treatments	2	1293.082	646.541	632.33	<.001
Residual	4	4.090	1.022		
Total	8	1297.980			

Tables of means

Variate: wk6

Grand mean 115.84

treatments	control	single application	split application
	101.10	115.97	130.46

Standard errors of means

Table	treatments
rep.	3
d.f.	4
e.s.e.	0.584

Standard errors of differences of means

Table	treatments
rep.	3
d.f.	4
s.e.d.	0.826

Least significant differences of means (5% level)

Table	treatments
rep.	3
d.f.	4
l.s.d.	2.292

2.8 Variate: Plant height week 2

Variate: wk2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.2817	0.1408	1.18	
replication.*Units* stratum					
treatment	2	48.3089	24.1544	202.61	<.001
Residual	4	0.4769	0.1192		
Total	8	49.0674			

Tables of means

Variate: wk2

Grand mean 17.04

treatment	control	single application	split application
	14.34	20.00	16.77

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	0.282

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	0.783

2.9 Variate: Plant height week 4

Variate: wk4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.709	0.354	0.26	
replication.*Units* stratum					
treatment	2	208.742	104.371	77.72	<.001
Residual	4	5.371	1.343		
Total	8	214.822			

Tables of means

Variate: wk4

Grand mean 31.26

treatment	control	single application	split application
	25.36	31.26	37.16

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	0.946

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	2.627

2.10 Variate: Plant height week 6

Variate: wk6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	0.7577	0.3788	1.24	
replication.*Units* stratum					
treatment	2	1117.6818	558.8409	1834.60	<.001
Residual	4	1.2184	0.3046		
Total	8	1119.6579			

Tables of means

Variate: wk6

Grand mean 52.80

treatment	control	single application	split application
	40.13	51.03	67.25

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.319

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	0.451

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	1.251

2.11 Variate Tuber number

Variate: tuber_number

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	2.000	1.000	1.00	
replication.*Units* stratum					
treatment	2	216.000	108.000	108.00	<.001
Residual	4	4.000	1.000		
Total	8	222.000			

Tables of means

Variate: tuber_number

Grand mean 14.00

treatment	control	single application	split application
	8.00	14.00	20.00

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	0.577

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	2.267

2.12 Variate Tuber weight

Variate: tw

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	2	46.08	23.04	1.00	
replication.*Units* stratum					
treatment	2	4976.64	2488.32	108.00	<.001
Residual	4	92.16	23.04		
Total	8	5114.88			

Tables of means

Variate: tw

Grand mean 67.2

treatment	control	single application	split application
	38.4	67.2	96.0

Standard errors of means

Table	treatment
rep.	3
d.f.	4
e.s.e.	2.77

Standard errors of differences of means

Table	treatment
rep.	3
d.f.	4
s.e.d.	3.92

Least significant differences of means (5% level)

Table	treatment
rep.	3
d.f.	4
l.s.d.	10.88