



Effects of in-row spacing on growth and yield of Irish potato (*Solanum tuberosum* L.) varieties in Eastern Highlands of Zimbabwe

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Abstract

Irish potato (*Solanum tuberosum* L.) yields vary widely, usually showing a declining trend, due to differences in in-row spacing used, as well as poor varietal selection for specific locations. This study evaluated the growth and yield responses to different in-row spacings of different varieties of Irish potato grown in Eastern highlands of Zimbabwe. The treatments consisted of three varieties, namely BP1, Diamond and Garnet, and three in-row spacings, namely: 10 cm, 30 cm and 50 cm. Inter-row spacing was maintained at 90 cm for all treatments. Treatments were arranged in a Randomized Complete Block Design (RCBD); 3 × 3 factorial arrangement, replicated 3 times. Measurements taken were on plant height, number of potato tubers plant⁻¹, and weight of marketable potato tubers, and then averaged. All in-row spacings were significantly different at $P < 0.001$ with 10 cm producing the highest mean height (92.29 cm). Of the three varieties (Garnet, Diamond and BP1), BP1 produced the greatest height (76.12 cm). There was significant interaction ($P = 0.001$) between variety and in-row spacing on the mean number of tubers plant⁻¹. BP1 produced superior ($P < 0.001$) mean weight of tubers (15.14 t ha⁻¹) and potato tubers plant⁻¹ (21.47) in comparison to Garnet and Diamond at 10 cm in-row spacing. In conclusion, the study reported the optimum in-row spacing of 10 cm at which, BP1, among the other tested varieties, showed potential to attain the greatest growth and tuber yield when grown under ideal conditions.

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Introduction

The Irish potato (*Solanum tuberosum* L.) is one of the most widely grown tuber crops in the world and contributes immensely to human nutrition and food security (Karim *et al.*, 2010). According to quantity of production and consumption, potato is the most important crop (FAO, 2005), ranking first in volume produced, among all root and tuber crops grown (Shunka *et al.*, 2016). The potato crop yield can be up to 60 t ha⁻¹ in commercial farms and ranges between 15-24 t ha⁻¹ in smallholder farming (Zimbabwe Commercial Farmers' Union (ZCFU), 2012). It is an economically important crop due to high foreign currency income from exports (Masarirambi *et al.*, 2012).

A number of potato varieties such as Pimpernel, BP1, Montclare, Diamond, KY20 and Garnet are grown in highlands of Zimbabwe, which include Chimanimani and Nyanga Districts. An agronomic practice of appropriate in-row spacing is one of the determinants of desirable plant population densities of Irish potato (Haile and Boke, 2011). However, the choice of spacing is not related to the level of production only, but also to the Irish potato variety to be grown. An optimal plant density of a particular variety grown using its optimum spacing requirement manifests its performance by showing optimal growth through efficient utilisation of moisture, nutrients and light, and also high tuber highyield (Mahmood, 2005).

Nevertheless, the production of Irish potato in the highlands of Zimbabwe is restrained by poor ridging practices, poor variety selection, poor sprouting practices, inadequate education on farming techniques, pests and diseases, among others (Zivenga and Karavina, 2012). Because of the steep slopes in some places where Irish potato is grown, the most important constraint in highland Irish potato production is the inaccurate compromise on in-row spacing in accordance with varietal choice. Potato varieties characteristically vary in plant development and tuber yield in specific localities, depending on the in-row spacing used. Inappropriate in-row spacing for a particular variety reduces total biomass

accumulation and the ultimate tuber number (Santos and Gilreath, 2004; Sithole, 2007). According to Endale and Begremedhin (2001), a suitable in-row spacing for an adaptable variety in a locality increases tuber yield by 50%.

Depending on the level of production as well as farming implements being used, different in-row spacing are being used across the world, impacting differently on the growth rate and yield of Irish potato. In general, the commonly used in-row spacing for Irish potato in Zimbabwe is varied but ranges between 25 cm and 40 cm, while inter-row spacing is less varied.

Use of various in-row spacing by potato farmers, for any chosen potato variety, results in no known variety which produces the highest tuber yield. This is because of lack of researches in specific locations and technical skills on the production of the crop. There is a missing link between different potato cultivars, different farming regions as well as ideal in-row spacing in the production of Irish potato in specific regions (Zivenga and Karavina, 2012). Hence, these gaps result in decreased marketable Irish potato tubers which are preferred by consumers.

The optimum in-row spacing and the best variety in terms of the highest tuber yield produced remain unknown in Nyanga, as the varieties and the variables under consideration are strongly affected by environmental factors such as rainfall, soil type and agronomic practices. Therefore, this current research seeks to determine the potential effects of in-row spacing on growth and yield of the different Irish potato varieties grown in Nyanga District.

Materials and methods

Study area

The field research was conducted in Mambemba village, ward 22, Nyanga District. The district lies within the Eastern Highlands, 15 km South of Nyanga Township (Zalud *et al.*, 2011). The study area is located at 18 ° 31' S latitude and 32 ° 30' E and with an altitude of 1 510 m above sea level. Nyanga District

ward 22 is in natural region I which receives an average rainfall of between 700 mm and 1050 mm per annum.

The average temperature for Nyanga ranges from 12 °C during winter to 25 °C in summer. Temperatures can drop to 6 °C or less in winter. The soils of the site are well drained, dark red fersiallitic (SE.2) Zimbabwe classification (Zalud *et al.*, 2011). The area was fallowed the previous season. The soils of the experimental field were low in organic matter (2%) and slightly alkaline (pH 7.2).

Treatments and experimental design

The treatments consisted of three different varieties, namely BP1, Diamond and Garnet, and three in-row spacing namely: 10 cm, 30 cm and 50 cm. Inter-row spacing was maintained at 90 cm for all treatments. The treatments were arranged in a Randomized Complete Block Design (RCBD); 3 × 3 factorial arrangement, replicated 3 times.

Source of propagule and sprouting

Certified (disease-free seed tubers) were obtained from Nyanga Experimental Station, where the three varieties were authenticated. The researcher exposed the tubers to heat to initiate quick sprouting of the tubers.

Planting

The seed potatoes with an average sprout length of 10mm were used in the experiment. Basal dressing of 800 kg ha⁻¹ of compound S to encourage good leaf and stem formation (Mutubuki *et al.*, 2015) was applied using the drilling application method. The potato seeds tubers with an average sprout length of 10 mm were used in the experiment.

The seed tubers were placed at 10 cm, 30 cm and 50 cm apart as determined by the assigned treatment as well as the inter-row spacing of 90 cm. Ammonium nitrate (AN) (34.5%) was applied as top dressing, using the hill placement method at a rate of 172 kg ha⁻¹ and 150 kg ha⁻¹ as split application at vegetative growth and tuber initiation, and bulking stages

respectively. In addition, sulphate of potash (K₂SO₄) was applied in two splits i.e. half at planting and half at 55-60 days after planting (Sharma and Sud, 2001) at 260 kg K ha⁻¹.

Variables measured

Plant heights of 10 plants from each plot were measured from the base to the top of the selected Irish potato plants when each variety had reached its full blooming stage (64-69 days from planting) (Zelalem *et al.*, 2009) days depending on cultivar. Tuber harvesting was done when all above ground matter had turned yellow and fallen off (95-106 days after planting) (Mahamood, 2005), depending on cultivar. All the potatoes of each cultivar plot were harvested separately. All the potato tubers plant⁻¹ were counted and recorded to come up with the average quantity of the potato tubers. Potato tubers from all the plots were weighed and the averages recorded.

Height measurements

Plant heights of 10 plants from each plot were measured from the base to the top of the selected Irish potato plants when each variety had reached its full blooming stage (64-69 days from planting) (Zelalem *et al.*, 2009), depending on cultivar.

Weight of marketable potato tubers

Tuber harvesting was when all above ground matter had turned yellow and fallen off (95-106 days after planting) (Mahamood, 2005), depending on cultivar. All the potato tubers of each cultivar in each plot were harvested separately. Potato tubers from all the plots were weighed and the averages recorded.

Number of tubers per plant

All the potato tubers per plant for a cultivar and in-row spacing were counted and recorded to come up with the average quantity of the potato tubers.

Statistical analysis

Two-way Analysis of variance (ANOVA), in GenStat 14th Edition was used to analyse the data. Separation of treatment means was then employed using the

Bonferroni test at 5% level of significance.

Results

Effects of variety and in-row spacing on plant heights

There was significant effect of variety ($F_{2,16} = 21.78$; $P < 0.001$) and in-row spacing ($F_{2,16} = 176.37$; $P < 0.001$) on the heights of Irish potato plants. The interaction between variety and in-row spacing was statistically insignificant ($P = 0.61$) at 5% level of significance.

For the in-row spacing means, the Bonferroni tests for plant heights showed that all in-row spacing were significantly ($P < 0.001$) different ($P < 0.001$) at, with 10 cm producing the highest mean height (92.29 cm), followed by 50 cm which had a height of 63.14 cm and 30 cm producing the lowest mean heights of 57.24 cm. Diamond and BP1 varieties had significantly ($P < 0.001$) greater ($P < 0.001$) mean height than Garnet although the two (Diamond and BP1) were not significantly different from each other in terms of plant height (Table 1).

Table 1. Bonferroni tests for variety and in row spacing on mean plant height of Irish potato.

Treatment		Plant height (cm)
Variety	Garnet	63.48 ^a
	Diamond	73.06 ^b
	BP1	76.12 ^b
In-row Spacing	30cm	57.24 ^a
	50cm	63.14 ^b
	10cm	92.29 ^c

Effects of variety and in-row spacing on the weight of marketable tubers

Weight of marketable tubers was significantly affected ($F_{2,16} = 214.40$; $P < 0.001$) by in-row spacing. Variety effect was also significant ($F_{2,16} = 26.86$; $P < 0.001$). However, there was no in-row-variety interaction ($F_{4,16} = 0.67$; $P = 0.620$).

BP1 produced a significantly ($P < 0.001$) higher ($P < 0.001$) mean weight of tubers than Garnet and Diamond which were not significantly different ($P = 0.05$) (Table 2). All the in-row spacing had significantly ($P < 0.001$) different mean weights ($P < 0.001$). In-row spacing of 10 cm had the highest significant mean weight of 19.32 t ha⁻¹.

Table 2. Influence of variety and in-row spacing on weights of marketable tubers.

Treatment		Tuber weight (t ha ⁻¹)
Variety	Garnet	10.84 ^a
	Diamond	12.03 ^a
	BP1	15.14 ^b
In-row spacing	30cm	6.86 ^a
	50cm	11.83 ^b
	10cm	19.32 ^c

Effects of variety and In-row spacing on number of tubers plant⁻¹

Effect of in-row spacing and variety on number of tubers plant⁻¹ were significant ($F_{2,16} = 248.54$; $P < 0.001$) and ($F_{2,16} = 33.50$; $P < 0.001$) respectively. The interaction between variety and in-row spacing

was statistically significant ($P = 0.001$) at 5% level of significance.

BP1 10 cm had a superior mean number of tubers (21.47) as compared to all other groups (21.47) potato tubers per plant (Table 3). Diamond 30 cm, Garnet 30 cm, BP1 30 cm, Diamond 50 cm and Garnet 50 cm

had no significant differences in the mean number of tubers per plant⁻¹ of 3.83, 5.17, 5.83, 6.48 and 7.57 respectively. Garnet 50 cm with 7.57 potatoes plant⁻¹ was not significantly different from BP1 50 cm, which produced 11.19 potatoes plant⁻¹. Diamond 10 cm and Garnet 10 cm also produced high numbers of tubers plant⁻¹, but their plant tuber numbers were not significantly different.

Discussion

Effects of variety and in-row spacing on plant heights

According to the study, there was significant effect of both variety and in-row spacing on the heights of Irish potato. The Irish potato plant grown using 10 cm in-row spacing resulted in the highest Irish potato plants. This was because smaller in-row spacing

distance increased plant population density which promoted plant competition for sunlight and consequently resulted in tall potato plant stalks in comparison to compared to the other Irish potato plants with larger in-row spacing distances such as 30 cm and 50 cm. The results of the study done by Barry *et al.* (2000) concur with the results of this study since they state that smaller in-row distances increase plant population densities which increase plant competition for nutrients, water and space, apart from sunlight. However, high plant densities usually result in very tall plant stems which are weaker, more fragile and succulent, than usual. Brady (2004) also mentioned that the competition for sunlight in plants results in taller than usual plants as a result of phototropism.

Table 3. Bonferroni tests for variety, in row spacing and interaction effect on number of tubers plant⁻¹.

Treatment		Tubers plant ⁻¹
Variety	Garnet	8.75a
	Diamond	8.93a
	BP1	12.83b
In-row spacing	30 cm	4.94a
	50 cm	8.41b
	10cm	17.15c
Variety*In-row spacing	Diamond 30 cm	3.83a
	Garnet 30 cm	5.17a
	BP1 30 cm	5.83a
	Diamond 50 cm	6.48a
	Garnet 50 cm	7.57ab
	BP1 50 cm	11.19bc
	Diamond 10 cm	13.50cd
	Garnet 10 cm	16.47d
	BP1 10 cm	21.47e

The study also showed that the heights of Diamond and BP1 potato varieties were statistically the same but different from Garnet. According to Lynch and Rowberry (2007), though Diamond and BP1 are early maturity Irish potato varieties, they both develop healthier and taller stems than most of the short seasoned potato varieties. The average heights of Diamond and BP1, when grown using 25 cm to 40 cm, were between 65cm and 80 cm. However, the lowest

mean heights were recorded in the Garnet potato variety. These results were in contrast with Nelson (1997) who reported that Garnet could grow up to heights between 65 cm and 70cm, especially when grown using optimal spacing and attaining the recommended plant population densities. The differences between our results of the current research and those of Nelson(1997) about Garnet could be because of other factors such as soil

conditions, moisture availability, climatic conditions and altitude.

Effects of variety and in-row spacing on weight and number of marketable tubers

BP1 produced the highest number of tubers per plant at 10 cm in-row spacing. According to Rex (1990), Irish potato produces high marketable tuber yield when the particular variety has been grown under its optimal plant population densities. High numbers of tubers at high plant densities have been reported (O'Brien and Allen, 1992; Allen and Wurr, 1992; Wurr *et al.*, 1993; Karafyllidis *et al.*, 1996). The high numbers of tubers at high densities may be accounted for by the fact that at low density plantings, fewer sinks are produced per unit area⁻¹, and increase as the planting density increases (Mangani *et al.* 2015). Khalafalla (2001) attributed this to increased number of plants unit area⁻¹ and more tubers plant⁻¹. Similar results were reported by Nelson (1967).

There was significant effect of both variety and in-row spacing on the weights of Irish potato plants. The highest weight of the marketable tubers was produced by BP1. Also, the highest mean weight was obtained at an in-row spacing of 10 cm. The results agree with Strange and Blackmore (2013) whose findings indicate that BP1 is one of the most productive early maturing Irish potato varieties. However, the narrowest in-row potato plant spacing in the study by Love and Thompson-Johns (1999) was 8 cm, which had the highest total yield, as determined by tuber weight. The effects of density on average tuber size, which is a function of tuber weight found in this study, are not consistent with the results of Lynch and Rowberry (1977) who found average tuber size to decrease with increasing plant density. This contradiction could be because of the different varieties used, differences in varietal characteristics, environmental and agronomic practices. Results of Lynch and Rowberry (1977) were based on various in-row and between row plant spacing.

Conclusion

The study revealed effects of 10 cm, 30 cm and 50 cm

in-row spacing on growth and tuber yield of BP1, Diamond and Garnet Irish potato varieties. There was significant interaction between variety and in-row spacing on the mean number of tubers plant⁻¹. BP1 portrayed superior performance in growth (height) and number of tubers per plant⁻¹ in comparison to Garnet and Diamond at 10 cm in-row spacing. All in-row spacing's were significantly different, with 10 cm producing the highest mean height of the three in-row spacings. BP1 also produced the greatest mean weight of tubers and potato tubers per plant. Wider in-row spacing's produced less and less number of tubers plant⁻¹. This entails that high numbers of tubers are produced at high plant densities. The study recommends use of the growing of BP1 at an in-row spacing of 10 cm for optimum growth and marketable tuber yield in highlands.

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