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Effect of Intra-row Spacing on Growth and Yield of Irish Potato (*Solanum tuberosum* L. cv. Mondial) Grown in a Sub-tropical Environment of Eswatini

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Abstract

Irish potato 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. In this study the growth and yield responses to different intra-row spacing on Irish potato cultivar Mondial was evaluated. The treatments consisted of four intra-rows spacing namely: 15 cm, 30 cm, 45 cm and 60 cm. Inter-row spacing was maintained at 90 cm for all treatments. Treatments were arranged in a Randomized Complete Block Design (RCBD) and replicated four times. Measurements were taken on plant height, number of potato tubers per plant, leaf length and width and fresh weight of potato tubers. In-row spacing were significantly different at $P < 0.05$ with 15 cm producing the highest mean height (26.90 cm) at 14 weeks after planting. The number of stems per plant were not significantly influenced ($P > 0.05$) by the intra- row spacing. The highest number of main stems (6) was

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recorded at 45 cm spacing and the lowest (5) at 15 cm spacing. The number of tubers per plant were not significantly different (P>0.05) in all the intra row spacing, and 15 cm intra row spacing had the highest number of tubers. There were significant (P<0.05) differences among the different intra row spacing for yield per plot. The highest yield (6.71 t/ha) was at the 60 cm spacing and the lowest (4.87 t/ha) was at the 15cm spacing in terms of size and marketability of the tubers. Based on the findings of the study it can be concluded that intra row spacing can be chosen according to the farmer's desired size of tuber: that is to say as the intra row spacing decreases there is also a decrease in the size of tuber produced and vice versa. These results have shown that Irish potato (cultivar Mondial) grown at the 60 cm x 90 cm intra row spacing gave the best yield results and economic yields.

Keywords: Intra-row spacing, Irish potato, cultivar Mondial, marketable yield, commercialization.

INTRODUCTION

The role of agriculture in hunger and poverty reduction remains the subject of debate, especially the part that produces food, is linked to poverty alleviation and human development (Cooke, 1999; Food and Agriculture Organisation (FAO), 2012). Given that expanding the cultivated area is not a possibility to meet future needs, in order to feed the growing population, it is therefore imperative to encourage the production of high yielding crops such as Irish potatoes (Cooke, 1999; Acquaah, 2005; FAO; 2008; World Bank, 2011). Irish potato (*Solanum tuberosum* L.) belongs to the family Solanaceae or the night shade family (Netherlands Consultative Potato Institute, 2007; Cashman, 2012; Bikila et al., 2014). Potato cultivars differ in time of maturity, resistance to pest and diseases, physiological disorders, appearance, storage, uses and marketing characteristics of the tubers. Each cultivar has a unique requirement for optimum performance (Mosley and Chase, 1993; Bikila et al., 2014; Cashman, 2012; Nxumalo et al., 2017). Yield potential

is genetically and varies widely among cultivars. The expected yield for potato is about 15-20 tonnes/ha (Netherlands Consultative Potato Institute, 2007; Edje and Ossom, 2009; Cashman, 2012). There is a missing link between different potato cultivars which have been recently introduced in most African countries on the ideal in-row spacing in the specific regions (Georgakis et al., 1997; Martin et al., 2006; Haverkortc et al., 2015). The use of various in-row spacing by potato farmers for any chosen potato cultivar results in varied tuber yields (Georgakis et al., 1997; Love and Thompson-Johns, 1999; Masarirambi et al., 2012; Zivenga and Karavina, 2012). Eswatini still imports most of its potatoes from the Republic of South Africa, which is an indication that more has to be done to maximise production. Due to demand in French-fries in the country, the cultivar Mondial was introduced to local farmers by the Malkerns Research Station. Local potato Mondial growers have not been able to produce the desired potato tuber size for the French-fry market, thus the market is not satisfied with the local farmers produce. The Malkerns Research Station does not have the recommendations on the spacing of the Mondial cultivar, but has recommendations for other cultivars like Fiona, Sifra, Avalanche, and BP1 (Nxumalo et al., 2017). Therefore this research seeks to find the best spacing for the potato cultivar Mondial to obtain optimum yield. According to Martin et al. (2006) and Endale and Gebremendlin (2001), the absence of optimal intra and inter-row spacing practices could lead to significantly reduced tuber yield in potatoes by up to 50%. Therefore, there is a need to optimise research on intra-row spacing as it is one of the most important agronomic practices of potato production that affects the seed cost, plant development and potato tuber yield (Gulluoglu and Arioglu, 2009; Asian Vegetable Research Development Center [AVRDC]; 2000; Guenthner, 2001). Irish potato is an important vegetable crop in Eswatini and the whole of southern Africa, and thus new cropping systems that could maximize its production are needed. The proposed growing of Irish potato under different intra-row spacing will help in determining its maximum growth and yield. This in turn will help in improving the country's economy by reducing

the amount of imports and benefit farmers in getting maximum returns. The choice of appropriate intra row spacing that gives optimum density (number plants) of Irish potato is crucial for its productivity, considering that plant density of crops affects above-ground access to sunlight, degree of soil surface cover, and below-ground tuberisation. The effect of intra-row spacing on Irish potato cultivar Mondial productivity has not been studied in-depth in the country more so because it has been recently introduced.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the Horticulture Department Farm, Faculty of Agriculture Luyengo Campus of the University of Eswatini. The farm is located at Luyengo in the Manzini region, in the Middle-veld agro ecological zone. Luyengo is located at latitude $26^{0}4'$S and longitude $31^{0}4'$E. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most of the rain falling between October and April. Drought hazard is about 40%. The average summer temperature is 27^{0}C and winter temperature is about 15^{0}C. The soil type is an oxisol (M-set) of the Malkerns series (Murdoch, 1970).

Planting materials

Certified seed tubers of Mondial potato variety used in the experiment were purchased at the National Agricultural Marketing Board (NAMBoard).

Experimental design

The experiment was a single factor experiment which consisted of four levels of intra row spacing i.e., level one (S1) 90 x 15 cm, level two (S2) 90 x 30 cm, level three (S3) 90 x 45 cm and level four (S4) 90 x 60 cm as shown in Table 1. The experiment was set up in a Randomized Complete Block Design (RCBD) and each treatment was replicated four times. Plot sizes were 6 m x 6 m and 1 m between rows.

Table 1: Treatment lay-out.

Block (replicates)	**Plant spacing**			
1	90 x 60 cm	90 x 15 cm	90 x 30 cm	90 x 45 cm
2	90 x 30 cm	90 x 60 cm	90 x 45 cm	90 x 15 cm
3	90 x 45 cm	90 x 30 cm	90 x 15 cm	90 x 60 cm
4	90 x 15 cm	90 x 45 cm	90 x 60 cm	90 x 30 cm

Data collection

To evaluate the effect of intra row spacing on potato growth and yield, data collected included: plant height, number of main stems, leaf area, chlorophyll content, number of leaves per plant, number of tubers per plant, fresh mass of tubers, dry matter content of tubers, total yield per plot and tuber firmness.

Plant height

Plant height of six plants randomly selected from each plot was taken by measuring the height from the base of the plant to the apical shoot using 30 cm ruler.

Number of shoots per hill

Numbers of main stems were counted from the six plants selected for data collection and recorded.

Leaf length and width

Leaf length and width were measured using a 30 cm ruler and were then used for calculating the leaf area.

Leaf area

Leaf area was calculated using the formula, Area (cm2) = 13.9633 + 1.662L (cm) + 5.2688W (cm) (Yeshilita and Taye, 2016), which is model for non-destructive estimation of leaf area for potato derived from the equation of leaf area: $LA = y0 + (a \times L) + (b \times W)$ (Sadik et al., 2011).

Chlorophyll content

Chlorophyll content was measured using a SPAD-502 chlorophyll meter (CCM-200, Opti-sciences, Chicago, Illinois, USA). Leaves from the top and middle part of the plants were selected and used to measure the chlorophyll content.

Number of leaves per plant

The number of leaves was counted from each of the six randomly selected potato plants used for data collection.

Number of tubers per plant

The number of tubers from the six sampled plants used for data collection was counted immediately after harvest in order to come up with the average number of tubers produced per plant in the different intra row spacings.

Tuber firmness

Five tubers were selected from each replicate and their firmness was measured using a penetrometer (Shalom Laboratory supplies c.c., 132 Commercial Road, Int. plaza, Durban, Republic of South Africa).

Yield per plot

Tubers from the intra rows were used to collect yield data and guard rows were not harvested for final data. The tubers were weighed using an electric balance to evaluate the yield per plot in tonnes per hectare (t/ha).

Fresh and dry masses of tubers

Five tubers were selected from each replicate and weighed for their fresh weight using a balance scale (Mettler Tolodo [scale 7-digit, 7-segment LCD display], Griefensee, Switzerland).The five tubers were then then oven dried until constant mass was achieved at 75^{0}C. They were then weighed to get the dry weight. Percent dry matter content for each sample was calculated based on the formula described by Bonierbale et al. (2006):

$$Dry\ matter\ content\ \% = \frac{Weight\ of\ sample\ after\ drying(g)}{Initial\ weight\ of\ sample\ (g)}\ x\ 100$$

Data analysis

Data collected were subjected to Analysis of Variance (ANOVA) using Gen Stat discovery edition 3 (Payne, 2009). Where significant differences were detected, mean separation was performed using the Duncan's New Multiple Range Test (DNMRT) at 5% probability level (Gomez and Gomez, 1984).

RESULTS

Vegetative growth

Plant height

There was a significant ($P<0.05$) difference on the effect of intra row spacing on plant height of potato cultivar Mondial at 11 weeks after planting [WAP] (Figure 1). The highest plant height (26.9 cm) was obtained at 15 cm intra row spacing and the lowest (22.3 cm) was obtained at 60 cm spacing. The second highest plant height (23.9 cm) was obtained from plants grown at 30 cm spacing (Figure 1).

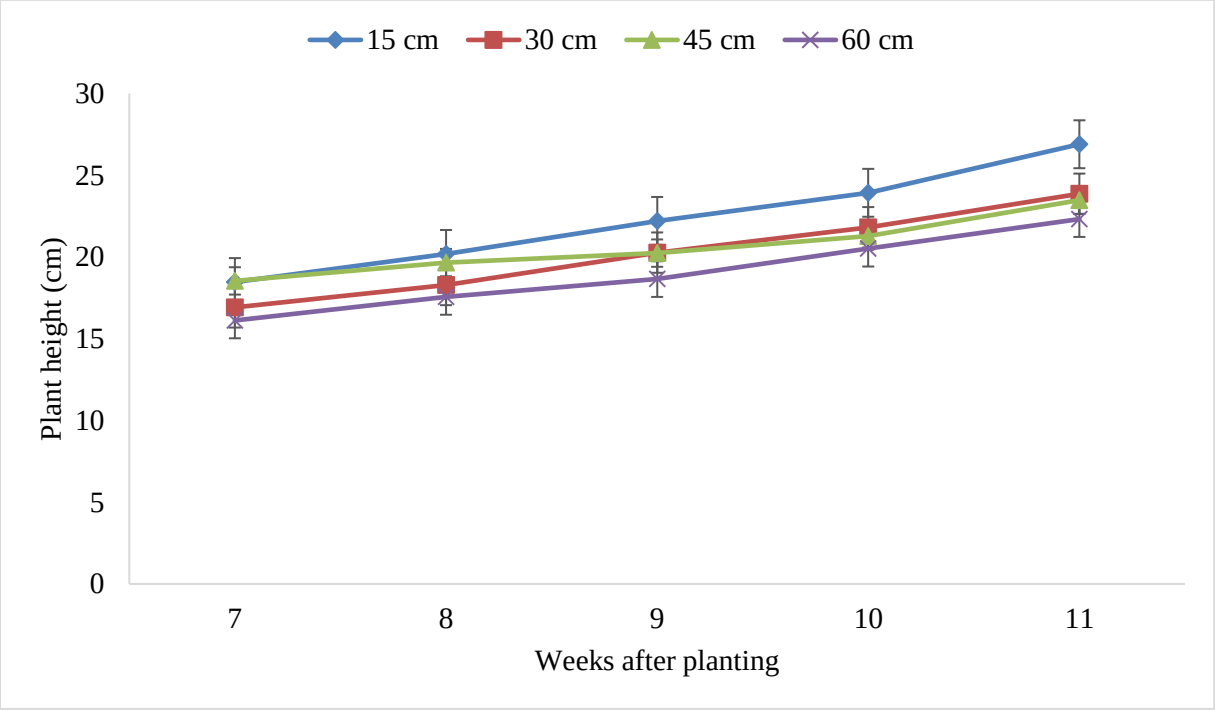

Figure 1: Effect of intra row spacing on plant height. Vertical bars represent standard error (SE) below and above the mean.

Number of shoots per plant

There were no significant (P>0.05) difference on the number of shoots per plant by the intra-row spacing (Figure 2). At 7 WAP the highest numbers of shoots (6.0) were obtained at the 45 cm spacing and the lowest (4.0 cm) at 15 cm spacing. The second highest number of shoots (5.1) was obtained at the 60 cm spacing (Figure 2).

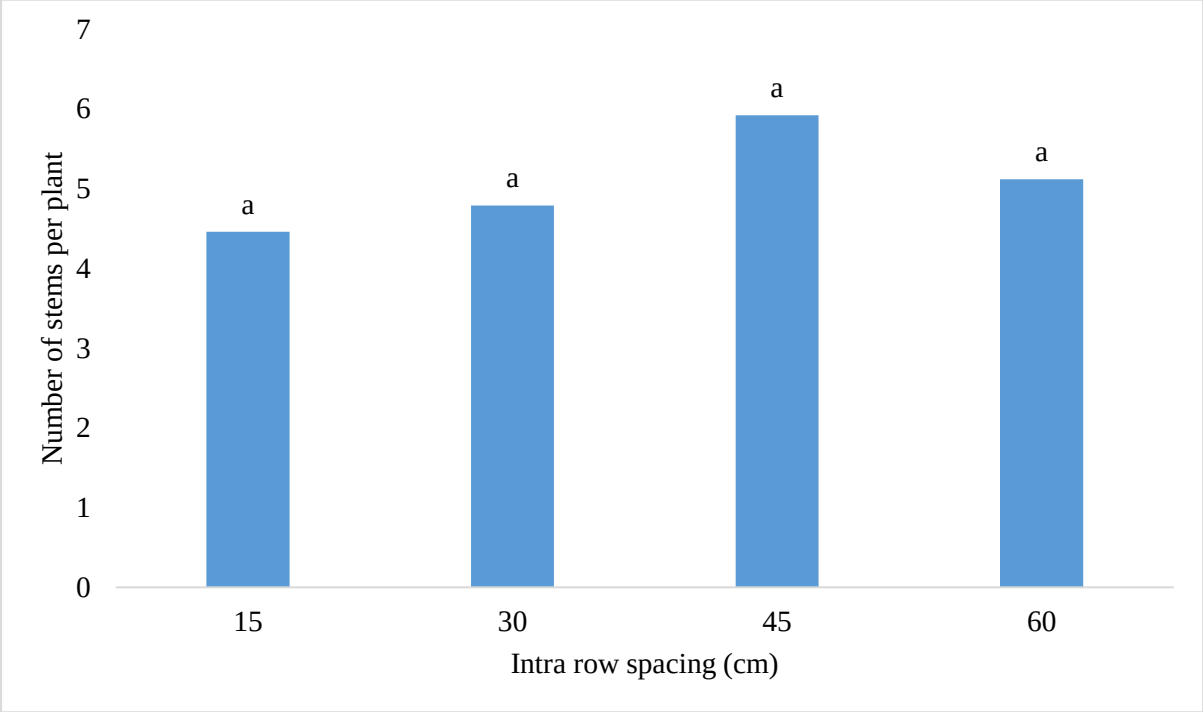

Figure 2: Effect of intra row spacing on number of stems per plant. Bars followed by the same letter are not significantly different from one another. Mean separation done using the Duncan's New Multiple Range Test (DNMRT) at P=0.05.

Chlorophyll content

There were no significant (P>0.05) differences for the chlorophyll content in the plant leaves for the entire intra row spacing (Figure 3). At 12 WAP, the highest chlorophyll content (34.8 µmolm²) was obtained at the 45 cm intra row spacing. The lowest chlorophyll content (26.6 µmolm²) was obtained at the 15 cm spacing. The second highest chlorophyll content (30.3µmolm²) was obtained at the 30 cm spacing. The chlorophyll content increased up to 12 WAP then started decreasing in all treatments (Figure 3).

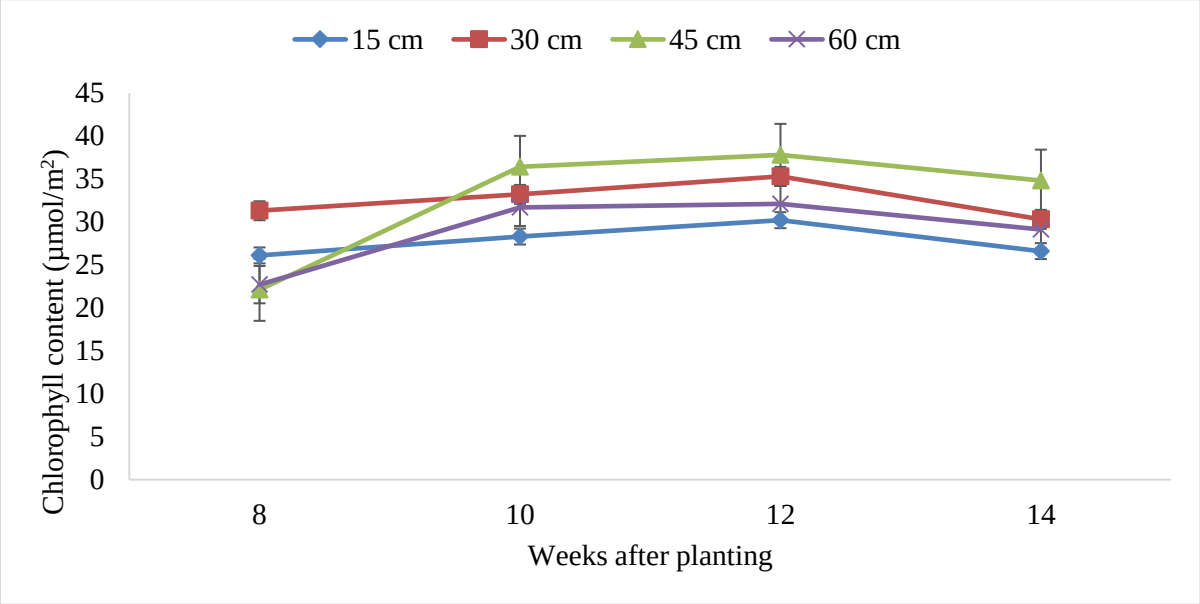

Figure 3: Effect of intra row spacing on the chlorophyll content of potato plant leaves. Vertical bars represent S.E. below and above the mean.

Number of leaves

Significant (P<0.05) differences were noted in all the different intra row spacing for the number of leaves per plant (Figure 4). At 10 WAP, the highest leaf count (54) was noted in the wider intra-row spacing of 60 cm and the lowest leaf count (45) was obtained in the 15 cm intra row spacing. The second highest number of leaves (51) was obtained in the 45 cm intra row spacing (Figure 4).

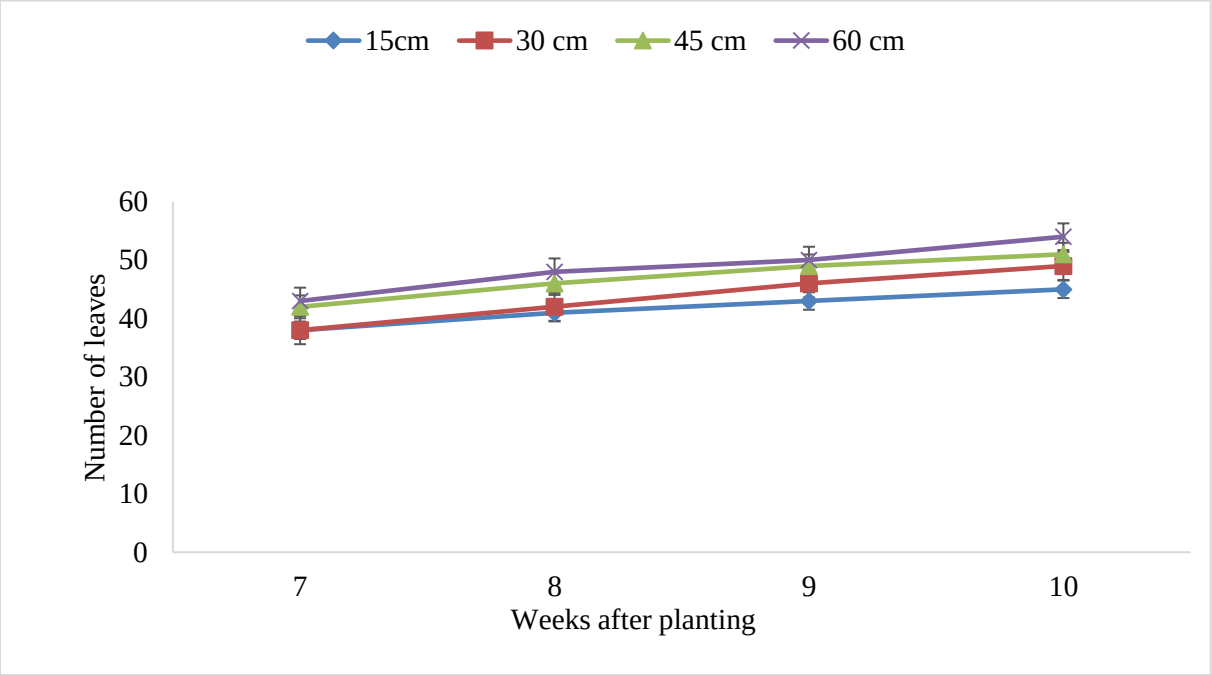

Figure 4: Effect of intra-row spacing on the number of leaves per plant. Vertical bars are SE below and above the mean.

Leaf area

There were no significant (P>0.05) differences on the effect of intra row spacing on leaf area at 9 WAP after planting (Figure 5). At 9 WAP the highest leaf area (441 $cm^{2)}$ was observed at the 60 cm intra row spacing. The lowest leaf area (426 cm^2) was obtained at 15 cm intra row spacing. The second highest leaf area (439) was obtained at the 45 cm spacing (Figure 5).

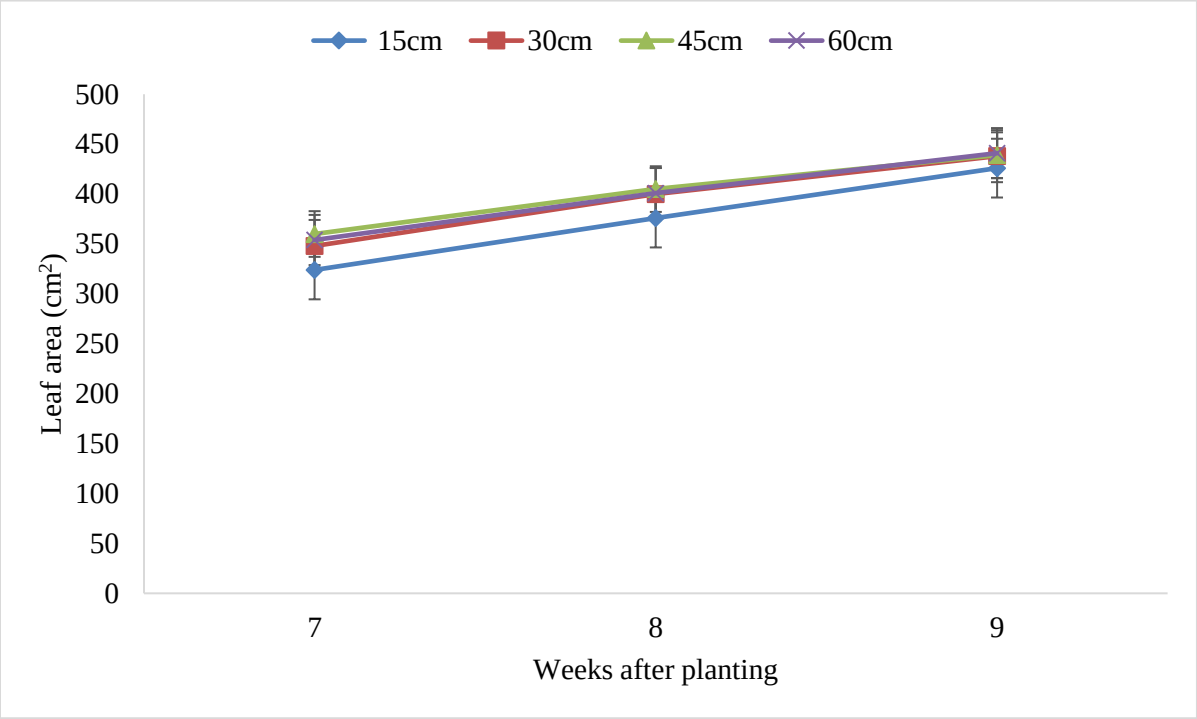

Figure 5: Effect of intra row spacing on the leaf area of potato plants. Vertical bars represent S.E. below and above the mean.

Yield parameters

Tuber firmness

There were no significant (P>0.05) difference in tuber firmness for the entire intra row spacing (Figure 6). The highest tuber firmness (6.82kg/f) was observed from potato plants at 45 cm spacing and the lowest (6.44kg/f) was at 60 cm spacing. The second highest tuber firmness (6.75kg/f) was observed at 15 cm spacing (Figure 6).

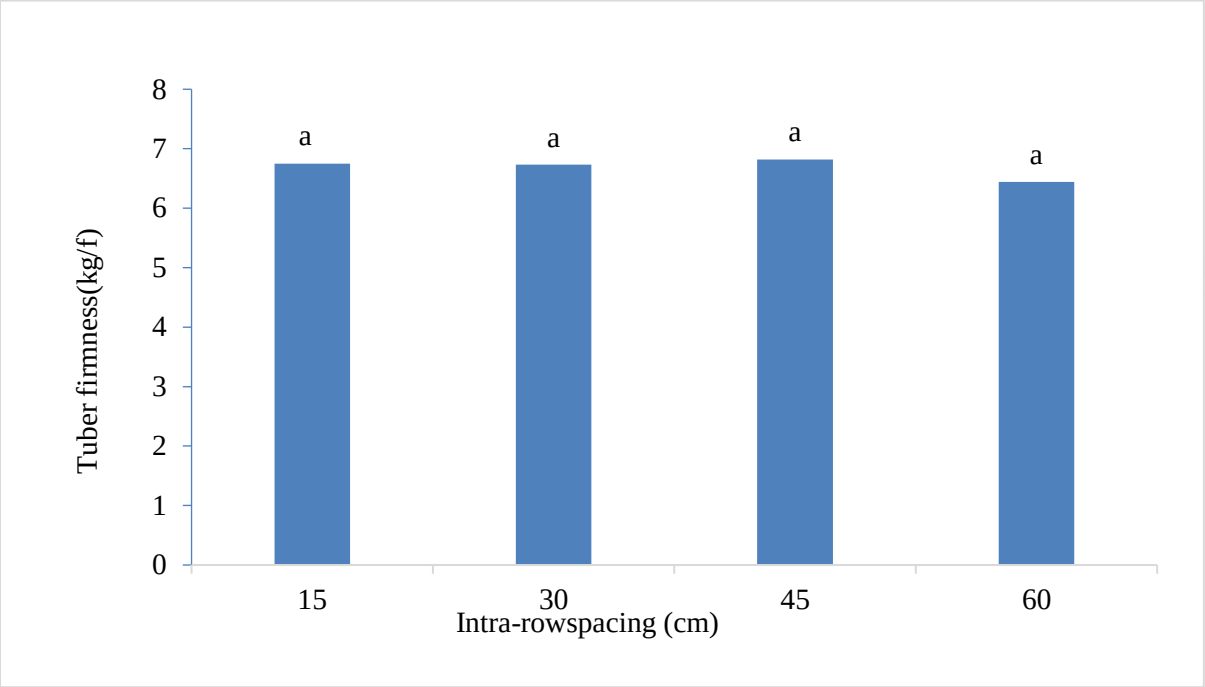

Figure 6: Effect of intra row spacing on tuber firmness. Bars followed by the same letter (s) are not significantly different from one another. Mean separation done using DNMRT at P=0.05.

Fresh and dry mass of tubers

There were significant (P<0.05) differences on the fresh and dry mass of tubers as a result of the influence of intra row spacing (Figure 7). The highest fresh mass of tubers (0.779 kg) was obtained at 60cm intra row spacing and the lowest (0.633 kg) 15 cm spacing. The second highest fresh mass of tubers (0.738 kg) was at 45 cm spacing. The highest dry matter content (0.174 kg) was obtained at the 60 cm intra row spacing and the lowest (0.14 kg) was at the 15 cm spacing. The second highest dry mass was obtained at the 45 cm intra row spacing (Figure 7).

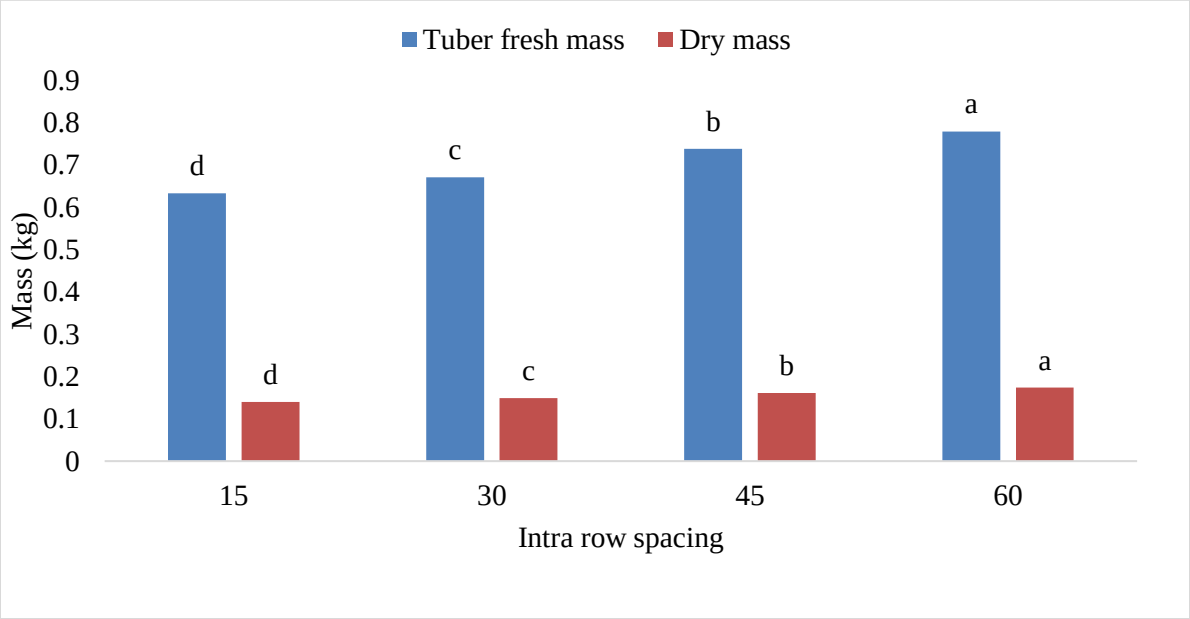

Figure 7: Effect of intra row spacing on fresh weight of tubers. Means followed by the same letter (s) are not significantly different from one another. Mean separation done by DNMRT at P=0.05.

Number of tubers per plant

There were no significant (P>0.05) differences in number of tubers per plant in the entire intra-row spacing (Figure 8). The highest number of tubers per plant (8) was obtained at the 15 cm intra row spacing and the lowest (7) was obtained at the 60 cm intra row spacing. The second highest number of tubers (8) was at the 45 cm intra row spacing (Figure 8).

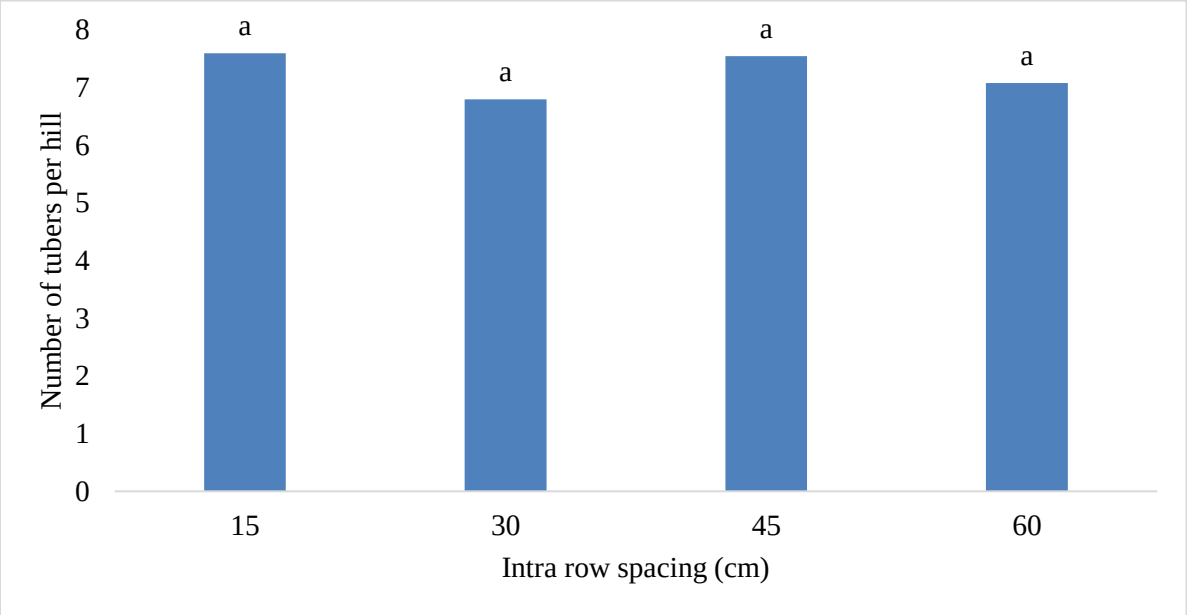

Figure 8: effect of intra row spacing on number of tubers per hill. Bars followed by the same letter (s) are not significantly different from one another. Mean separation done using DNMRT at P=0.05.

Yield per plot

There were significant (P<0.05) differences among the different intra row spacing for yield per plot (Figure 9). The highest yield (6.71t/ha) was obtained at the 60 cm spacing and the lowest (4.87 t/ha) was at the 15cm spacing respectively. The second highest yield (6.5 t/ha) was obtained at the 45 cm intra row spacing (Figure 9).

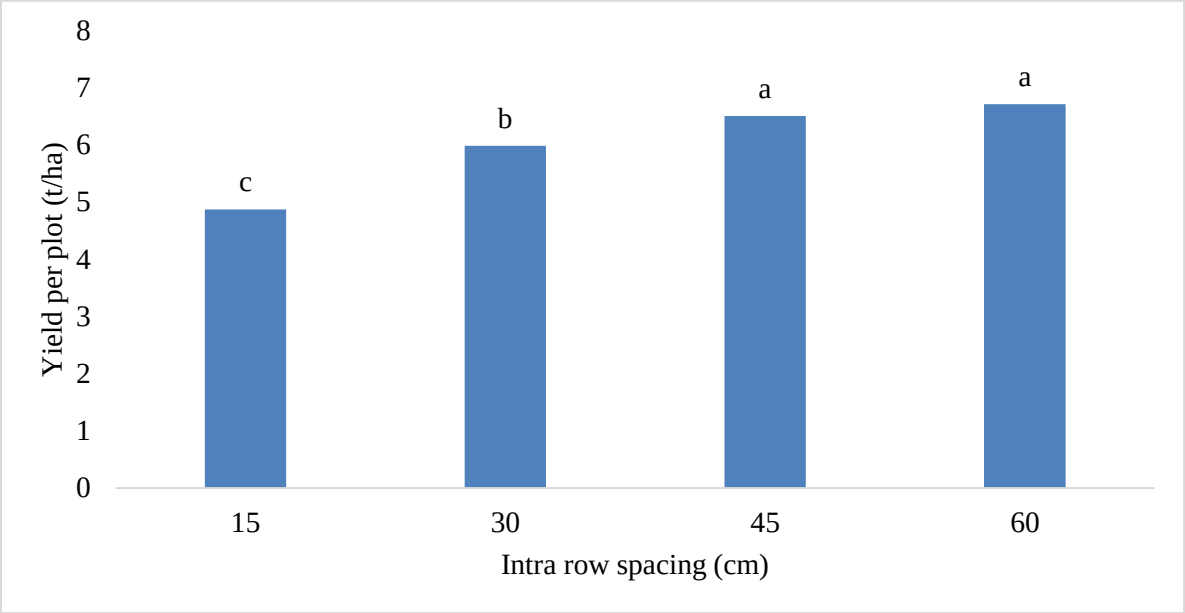

Figure 9: Effects of intra row spacing on the yield per plot. Means followed by the same letter are not significantly different from one another. Mean separation by DNMRT at P=0.05.

DISCUSSION

Irish potato plants grown at 15 cm intra-row spacing resulted in the tallest plants and the shortest plants were obtained at 60 cm spacing. This was probably because smaller in-row spacing distance increased plant population density which promoted plant competition for sunlight and consequently resulted in tall potato plant stalks compared to the other Irish potato plants with wider in-row spacing distances such as 45 cm and 60 cm (Mvumi et al., 2018). The results are in agreement with a study done by Barry et al. (1990), in which it was reported that smaller intra-row distance in potatoes increased plant population densities which increased plant competition for nutrients, water and space, apart from sunlight. Brady (2004) also reported that the competition for sunlight in plants such as potatoes resulted in taller than usual plants as a result of phototropism. The number of leaves was significantly influenced by the effect of intra-row spacing. The results of this study are in agreement with the findings by Mangani et al. (2015). These authors also found that there was high number of leaves at low plant density (wider intra-row spacing) of Irish potato. The authors attributed this to the decrease in inter plant related competition for water, nutrient and light which is present at higher planting density. The result is consistent with the findings of Yenagi et al. (2004) who reported that leaf area plant^{-1} in potato decreased with decreasing spacing in potato.

There were no significant differences among the intra row spacing for number of shoots per plant. This is in agreement with the findings by Vander Zaag et al. (1990) who reported that the number shoots per plant in potatoes were not influenced by plant spacing. Sturz et al. (2007) also found similar results. The authors reported that the stem number may be influenced by other factors such as physiological age of the seed tuber, pre-plant storage temperatures or green sprouting and variety. Abrha (2011) reported that planting distance determines the number of shoots (hill) per unit area and each stem behaves as separate potato plant since each has its own root and stem system.

There were no significant differences in all the intra row spacing for the number of tubers per plant. These results are in agreement with Lamessa and Zewdu (2016), who also found that the average number tubers per plant were not significantly affected by effect of spacing and fertilizer application. According to Yenegi et al. (2004), reduction in potato tuber number in densely populated area might be due to increased number of plants per unit area. This increase in number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in number tubers.

Intra-row spacing showed significant difference in tuber mass per plant, the highest tuber mass were produced at the 45 and 60 cm spacing and the lowest recorded at the 15 cm spacing. Similar results were reported by Tohin (2010) who found that tuber weight in potatoes decreased with decreasing plant spacing. The author also reported that the larger tubers in wider spacing were probably due to less competition among the plants for space, light, water and nutrients which facilitated faster growth and development of tubers thereby increasing tuber size in wider spacing as compared to closer spacing.

Number of tubers per plant was not significantly different from each other in all the intra-row spacing. Lamessa and Zewdu (2016) also found that the average number of tubers per plant was not significant due to the main effect of spacing and fertilizer application on Gudane Irish potato variety. Gulluoglu and Arioglu (2009) reported that the greater the spacing the higher the number of potato tubers formed per plant.

Significant differences were recorded due to effect of intra-row spacing on yield of Mondial potato tubers. Lamessa and Zewdu (2016) indicated that population density and fertilizer application were major factors that affect production and productivity of potato but still they found that statistically there were no significant differences due to spacing on yield which is contradicting with the findings of this study. The authors further reported that higher plant density due to narrow spacing compensate for the reductions in plant yield. However, Pardales et al. (1982) found that closely spaced plants gave the highest yield of taro (*Calocasia esculenta*).

This study showed that there was increased dry matter with decreasing plant population that is, dry matter content increased as the spacing became wider. Getachew et al. (2013) found that high plant population is associated with low dry matter content in potatoes. The authors reported that at low plant spacing, there was high competition for light and other important resources which eventually led to a few resources being channeled to each sink. Mangani et al. (2015) reported that the low dry matter content at the widest plant spacing was due the high photosynthetic rate thus relatively high vegetative growth at the expense of the tubers, thus the dry matter partitioning to the tubers was less.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The findings of the study revealed that there were no significant differences in number of shoots/plant, number of tubers per plant, yield per plot, chlorophyll content, and dry and wet root mass due to different intra-row spacing. Plant height was affected significantly by intra-row spacing on the fifth week of data collection, with the 15cm spacing producing the tallest plants. Average tuber weight per plant was highest at the 60 cm spacing and the dry matter content for tubers was also highest at the same spacing.

Recommendations

It is recommended that farmers wishing to grow Irish potato (Mondial variety) that they use the intra row spacing of 60 cm by 90 cm for best results and economic yields. Using the 15 cm intra row spacing produces higher yields in terms of quantity but fewer marketable tubers.

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