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Growth, yield and quality responses to plant spacing in potato (*Solanum tuberosum*) varieties

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A field experiment was conducted from November to March during the 2012 / 2013 planting season at Africa University farm, Mutare, Zimbabwe to evaluate the effects of plant spacing and different potato varieties on growth, yield and quality of potato *(Solanum tuberosum L.).* The experiment was designed as a randomized complete block design with 4 × 3 factorial arrangements of treatments. The first factor was plant spacing (in-row spacing); 20, 25, 30 and 35 cm. The second factor was varieties: BP1, KY20 and Mnandi. Very close spacing produced a high number of small sized tubers leading to reduced marketable yield. The highest stem count was observed at high plant densities, the lowest at low plant densities. At low density plantings, leaf number per plant was high and at high density plantings the leaf number was reduced across all varieties. BP1 and KY20 exhibited the highest specific gravity and Mnandi had the least. Results of the study suggest that a wider spacing of 90 by 35 cm can be advantageous for all the three varieties since all the varieties compensated for the additional spacing to produce the highest marketable yield yet with less seed thus reducing production cost. Also from the study, an in-row spacing of 25 cm can be used by seed producers since the highest number of medium sized tubers was obtained and this size is normally used as seed.

Key words: Plant spacing, potato yield, potato quality, potato varieties.

INTRODUCTION

Many factors influence potato yield and quality and among these are cultivar, plant population, soil type, weather conditions, water management, fertilization, seed piece size, pests and diseases (Khalafalla, 2001). Planting density strongly affects yield and more tubers and yield per square meter are expected at higher planting densities (Karafyllidis et al., 1996). Bussan et al. (2007) and Creamer et al. (1999), argued that optimizing plant density was one of the most important practices in potato production management, as it affects seed cost, plant development, yield and the quality of the crop.

According to Love and Thompson-Johns (1999), plant spacing studies are among the earliest researches that were carried out in potato production. Even though a lot of research has been done on this topic, Masarirambi et al. (2012) stated that more information is still required on

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Table 1. Plant height in cm recorded at 30, 60 and 90 days after emergence.

Variety	Plant height (cm)								
	30 DAE			60 DAE			90 DAE		
	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
Spacing									
20	27.58	27.94	27.63	46.90^{a}	62.93^{c}	48.37^{a}	53.17^{a}	66.67^{b}	55.35^{ab}
25	25.55	29.26	27.48	47.80^{a}	65.82^{e}	48.47^{a}	55.62^{ab}	69.15^{bc}	56.15^{b}
30	25.38	25.64	28.10	65.90^{e}	65.77^{e}	55.09^{b}	69.60^{c}	70.33^{c}	70.80^{c}
35	26.90	26.93	27.77	66.67^{e}	66.90^{e}	66.65^{e}	76.82^{d}	69.50^{c}	69.87^{c}
Means	**25.30^{b}**	**26.95^{c}**	**22.74^{a}**						
Lsd Vrt		**1.35**			**1.34**			**1.38**	
Lsd SP		**1.56**			**1.55**			**1.60**	
Lsd Sp*Vrt		**2.702**			**2.685**			**2.774**	
P val SP		**NS**			*****			*****	
P val Vrt		*****			*****			*****	
P val SP*Vrt		**NS**			*****			*****	
CV%		**12.10**			**5.60**			**5.30**	

*****, Significance at P<0.05; NS, non-significance at P>0.05. The means not sharing a common letter in a column differ significantly at 0.05. Vrt, varieties; SP, spacing.

interrelationships of plant populations and tuber sizes in relation to growth and subsequent yield. Plant population studies in potato are thought to be never out dated because newly developed cultivars have unique tuber characteristics and evolving industries constantly come up with new tuber size requirements. Barry et al. (1990) and Güllüoglu and Arıoglu (2009) noted that the optimal planting density differed depending on environmental conditions and cultivars.

Although it is generally accepted that total yield increases with increasing plant density while the percentage of large tubers decreases, Creamer et al. (1999) argued that varieties differed in their ability to compensate for wider gaps as the plant population is reduced. The current study sought to find out how different plant spacing affects the growth, yield and quality of three potato varieties.

MATERIALS AND METHODS

The study was carried out at Africa University Farm (AU) in Mutare, Zimbabwe (18°53’70, 3”S: 32°36’27.9”E) at 1104 m above sea level. The planting material was obtained from the Seed Potato Association in Zimbabwe. Three early maturing varieties were used, namely BP1, Mnandi and KY20, and were planted at 20, 25, 30 and 35 cm in the row. The row to row spacing was 90 cm. All crop management and fertilizer applications were done as per standard practice. The experiment was a 3 × 4 factorial laid out as a RCBD of 4 blocks. The gross plot size was 3.6 m × 3.6 m and the harvest plot was 2 m × 2 m. Total yield, marketable tuber yield, plant height, stem count, tuber density, leaf counts, tuber size category, dry matter content and specific gravity of tubers were measured subjected to the Analysis of Variance (ANOVA) using Genstat Discovery 3 edition. Whenever the treatment was significant; Fisher`s least significance difference (LSD) test was used for mean separation at p=0.05.

RESULTS

Effect of spacing and variety on plant height at 30, 60 and 90 days after emergence (DAE)

At 30 DAE there was neither density effect nor variety by density interaction. However, varieties showed significant differences (p<0.05). Based on stem height, the varieties could be arranged as Mnandi < BP1 < KY20 (Table 1). These results show that variety KY20 was generally taller than the other varieties. The significant planting density differences (p<0.05) with regard to plant height observed at 60 and 90 DAP were dependent on variety. With regard to BP1, at 60 DAE, the in row spacing of 20 and 25 cm gave the same plant height while the spacing at 30 and 35 cm were the same.

Mnandi behaved similarly at low in row spacing but plant height increased progressively with increase in spacing above 25 cm while for KY20 the plant height was low ant 20 cm and the same for all spacings above 20 cm. The response by KY20 was maintained at 90 DAE. The plant height of BP1 increased progressively with increase in intra-row spacing while that of Mnandi increased progressively up to 30 cm and thereafter remained unchanged (Table 1).

Effect of plant spacing and variety on leaf count per plant at 30, 60 and 90 days after emergence

From 30 to 90 DAE the response of leaf counts to planting density was dependent on variety (Table 2). Generally, at 30 DAE all varieties showed similar growth habit in terms of leafiness at 30 and 35 cm intra-row

Table 2. Leaf counts per plant at 30, 60 and 90 days after emergence.

Variety	Leaf counts								
	30 DAE			60 DAE			90 DAE		
	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
Spacing									
20	113.17^{b}	112.83^{b}	92.42^{a}	224.83^{a}	248.68^{d}	225.00^{a}	318.08^{b}	319.00^{b}	308.17^{a}
25	128.17^{c}	138.17^{d}	117.67^{b}	234.50^{b}	262.42^{e}	243.33^{c}	338.83^{d}	339.80^{d}	326.85^{c}
30	165.75^{f}	162.42^{f}	147.08^{e}	287.08^{f}	283.58^{f}	261.08^{e}	356.33^{f}	357.75^{f}	346.92^{e}
35	164.33^{f}	165.17^{f}	146.17^{e}	287.58^{f}	287.17^{f}	263.25^{e}	377.83^{h}	377.50^{h}	361.00^{g}
Lsd Vrt		**2.64**			**2.35**			**1.36**	
Lsd SP		**3.00**			**2.71**			**1.57**	
Lsd SP* Vrt		**5.289**			**4.703**			**2.724**	
P val SP		*			*			*	
P val Vrt		*			*			*	
P val SP*Vrt *					*			*	
CV%		**4.80**			**2.20**			**1.00**	

*****, Significance at P<0.05; NS, non-significance at P>0.05. The means not sharing a common letter in a column differ significantly at 0.05. Vrt, varieties; SP, spacing.

spacing. Leafiness was lower at the lowest plant spacing for all varieties although Mnandi had the lowest leafiness at 20 and 25 cm. Mnandi also showed the lowest leafiness at 30 and 35 cm. At 90 DAE all varieties showed a progressive increase in leafiness with increase in intra-row spacing length. Once more Mnandi had the least leafiness (Table 2).

Effect of spacing and variety on tuber size distribution

Number of small sized tubers

Generally the proportion of small sized tubers increased with increase in plant density. At a spacing of 20 cm there were more small tubers for Mnandi than BP1 and KY20. At 25 cm BP1 had the most small tubers (Table 3). At the standard spacing (30 cm) the number of small tubers was the same for all varieties but the same as those for the higher density (20 cm in-row spacing) for KY20 and Mnandi. As the in-row spacing increased to 35 cm KY20 showed the least while there was no change for BP1 and Mnandi (Table 3).

Number of medium sized tubers

As shown in Table 3, there was a significant (p<0.05) interaction between variety and plant spacing on the number of medium sized tubers. BP1 was not affected by plant spacing with regard to medium tubers. Mnandi was affected by spacing but the optimal was at 25 cm while for KY20 the optimal was at 25 and 30 cm in row spacing.

Number of large sized tubers

The response of varieties with regards to large tubers varied according to plant spacing (Table 3). Reducing the plant population resulted in an increase in the proportion of the large sized tubers and this applied to all the three varieties. For BP1 and Mnandi increasing plant spacing to 35 cm did not increase the size of large tubers while for KY20 it did.

Number of oversized tubers

As shown in Table 3, plant spacing had a significant (p<0.05) effect on the number of oversized tubers while no varietal differences were apparent. Overall, the proportion of oversized tubers was high at the 35 cm only for BP1 and KY20.

Effect of spacing and variety on stem count

The number of stems per plant was influenced significantly (p<0.05) by both variety and plant spacing, For BP1 and Mnandi the stem count was least at 20 cm and unchanged from 25 to 35 cm. For KY20 it increased with increase in spacing but remained unchanged after 30 cm.

Spacing and variety effect on tuber density at harvesting

The tuber density decreased with increase in spacing for

Table 3. Tuber size categories (arcsine transformed data).

Variety	Tuber size category											
	Small			Medium			Large			Oversize		
	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
Spacing												
20	0.754^{d}	0.839^{de}	0.918^{e}	0.522^{a}	0.460^{a}	0.465^{a}	0.291^{ab}	0.267^{a}	0.282^{ab}	0.151^{c}	0.151^{a}	0.151^{a}
25	0.834^{de}	0.334^{bc}	0.361^{bc}	0.464^{a}	0.868^{b}	0.885^{b}	0.265^{a}	0.378^{b}	0.331^{ab}	0.151^{a}	0.151^{a}	0.151^{a}
30	0.308^{bc}	0.334^{bc}	0.399^{c}	0.487^{a}	0.803^{b}	0.448^{a}	0.717^{cd}	0.389^{b}	0.752^{d}	0.174^{a}	0.151^{a}	0.151^{a}
35	0.292^{b}	0.171^{a}	0.329^{bc}	0.417^{a}	0.434^{a}	0.531^{a}	0.635^{c}	0.769^{d}	0.709^{cd}	0.206^{b}	0.307^{c}	0.151^{a}
Lsd Vrt		0.0471		0.0519			0.0556		0.0135			
Lsd SP		0.0471		0.0599			0.0482		0.0156			
Lsd SP*Vrt		0.0815		0.1037			0.0964		0.0271			
P val SP		*		*			*		*			
P val Vrt		*		*			*		*			
P val SP*Vrt		*		*			*		*			
CV%		20.6		22.8			24.7		19.7			

*****, Significance at P<0.05; NS, non-significance at P>0.05. The means not sharing a common letter in a column differ significantly at 0.05. Vrt, varieties; SP, spacing. . † The means not sharing a common letter in a column differ significantly at 0.05. Small-25 mm to 37.5 mm in diameter; Medium- 37.5 mm to 50 mm in diameter; Large-50.00 mm to 56.25 mm in diameters and oversized-56.25 mm to 62.25 mm in diameter.

all varieties but more so for Mnandi than for the other two varieties (Table 4).

Effect of spacing and variety on total yield

Generally, the total yield rose with a decrease in plant population, reaching a peak at the standard spacing of 30 cm for BP1 and KY20 but at 35 cm for Mnandi (Table 4).

Effect of spacing and variety on marketable yield

Essentially marketable yield (medium + large + oversized tubers) increased with decrease in plant population showing an optimum at the standard population density (90 × 30 cm) (Table 4). The lowest density reduced yield for Mnandi but not for the other two varieties

Specific gravity

There was a significant interaction (p<0.05) between the variety and plant spacing on specific gravity. Generally there was a rise in specific gravity up until it reached a peak at the standard spacing of 30 cm and a further increase in in-row spacing led to a fall in specific gravity. BP1 showed a steady increase in specific gravity when in-row spacing was increased from 20 to 25 cm and when the in-row spacing was increased to 30 cm, the specific gravity was statistically the same as that obtained when an in-row spacing of 25 cm was used. Increasing the in-row spacing from 30 to 35 cm led to a sharp fall in the specific gravity. KY20 responded almost in the same way with BP1 on this parameter. When in-row spacing was increased from 20 cm to 25 there was a sharp increase in the specific gravity and it remained constant when a spacing of 30 cm was used. Increasing the in-row spacing to 35 cm resulted in a sharp fall in the specific gravity. Cultivar Mnandi did not show any increase in specific gravity when in-row spacing was increased from 20 to 25 cm. It showed a steady increase when the in-row spacing was increased to 30 cm but increasing the in-row further did not result in any changes as the specific gravity.

In general it can be seen that higher densities (20 and 25 cm) and lower densities (35 cm) resulted in a reduction in specific gravity.

As for the effect of variety on specific gravity the results showed a significant differences (P<0.05) with BP1 and KY20 exhibiting the highest values and Munandi having the least Table 5.

Dry matter

Dry matter was affected differently for the different varieties. For BP1 and KY20 the optimum was at 25 and 30 cm while for Mnandi it was at 30 and 35 cm (both unchanged).

DISCUSSION

Effect of spacing and variety on plant height

Generally, the three varieties responded differently to plant height when exposed to different plant spacing.

Table 4. Number of stem counts, tubers per plant, total yield (t/ha) and the marketable yield (t/ha).

Variety	Variety											
	Stem count			Tuber density			Total Yield (t/ha)			Marketable yield		
Spacing	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
20	2.91[a]	2.75[a]	2.66[a]	18.25[d]	16.67[c]	16.42[d]	16.35[b]	16.54[b]	15.00[a]	14.47[a]	14.74[ab]	14.83[ab]
25	6.50[d]	3.75[b]	6.66[d]	15.67[bc]	15.50[b]	13.80[c]	15.48[ab]	16.18[b]	14.48[a]	15.21[abc]	14.01[a]	14.35[a]
30	6.38[d]	5.00[c]	6.41[d]	12.67[a]	12.67[a]	10.17[b]	21.77[f]	21.89[f]	17.67[c]	16.98[d]	17.29[d]	16.44[c]
35	6.41[d]	5.08[c]	6.41[d]	12.67[a]	12.67[a]	9.50[a]	20.33[e]	19.44[e]	18.24[d]	16.47[cd]	17.51[d]	15.98[b]
Lsd Vrt		0.37			0.61			1.599			0.72	
Lsd SP		0.40			0.71			1.847			0.83	
Lsd SP*Vrt		0.6955			1.070			1.082			1.448	
P val SP		*			*			*			*	
P val Vrt		*			*			*			*	
P val SP*Vrt		*			*			*			*	
CV%		16.90			11.10			13.10			35.5	

*****, Significance at P<0.05; NS, non-significance at P>0.05. The means not sharing a common letter in a column differ significantly at 0.05. Vrt, varieties; SP, spacing. .

Table 5. Specific gravity and dry matter percentage.

Variety	**Specific gravity (g/m^2)**			**Dry matter (%)**		
	BP1	**KY20**	**Mnandi**	**BP1**	**KY20**	**Mnandi**
Spacing						
20	1.07350[a]	1.07050[a]	1.06550[a]	18.83900[bc]	18.20600[b]	17.15100[a]
25	1.07650[b]	1.08120[c]	1.06925[b]	19.47200[cd]	20.47400[e]	17.94200[ab]
30	1.08000[b]	1.07900[b]	1.07825[d]	20.21000[de]	19.99000[de]	19.84100[de]
35	1.07200[a]	1.07000[a]	1.07725[c]	18.52200[b]	18.1000[b]	19.63000[ce]
Lsd Vrt	**0.00252**			**0.53220**		
Lsd SP	**0.00218**			**0.46090**		
Lsd SP*Vrt	**2.702**			**0.9218**		
P val SP	*****			*****		
P val	*****			*****		
P val SP*Vrt	*****			*****		
CV%	**12.6**			**3.4**		

*****, Significance at P<0.05; NS, non-significance at P>0.05. The means not sharing a common letter in a column differ significantly at 0.05. Vrt, varieties; SP, spacing. .

KY20 was taller than the other two varieties which were the same. These differences are likely due to varietal differences that could be associated with their canopy structure or other growth habit like internode length, a parameter we did not measure in this study. Simongo et al. (2011) attributed differences in stem height to the differences that the cultivars had in canopy structure. The canopy structure has an effect on photosynthesis as it increases the rate at which incoming solar radiation is intercepted. This occurs when the canopy has features that increase photosynthesis like erect leaves. Overall, a canopy that favours a higher photosynthetic rate will have a higher growth rate and stem growth.

Effect of plant spacing and variety on leaf count per plant

The phenomenon that at low densities leafiness was high disagreed with Masarirambi et al. (2012) perhaps because we worked with different plant densities. We found a high number of leaves at low plant densities attributable, perhaps, to decreasing inter-plant competition for water, light and nutrients at highest plant density. The observed leafiness would be expected to have an impact on dry matter accumulation, with leafy varieties showing an advantage (Table 2) over the less leafy ones.

The leafiness at low densities might also be explained by the fact that all the varieties were responding to the availability of growth requirements at low plant densities thus favoring branching. This agrees with Vander Zaag et al. (1990) who also found a high number of leaves at low plant densities.

Effect of spacing and variety on tuber size distribution

Number of small sized tubers: In general, it can be seen that the higher densities resulted in smaller tubers across all varieties. This is in agreement with Getachew et al. (2013) who concluded that tuber bulking of individuals at close spacing were reduced and resulting in small tubers. Khalafalla (2001), Mutetwa, (2010) and Love and Thompson-Johns (1999) also found closer spacing to result in smaller tuber sizes. In a similar work, Rieman et al. (1953) reported that Russet Burbank (a variety) had a tendency of producing many but small tubers regardless of plant density. Therefore, different varieties have different capacities of producing different tuber sizes based on number of tubers that a particular variety can set.

Number of medium sized tubers

The different varieties responded differently to the different plant spacing. These differences might be due to the differences of the genetics of the three varieties. The differences might be influenced by the number of tubers that the variety inherently sets. In a similar experiment Rieman et al. (1953) reported that Russet Burbank had a tendency of producing many tubers but their size was small. So in this case the varieties that produce more of the medium sized tubers would have produced tubers in moderation such that food is almost equally distributed to all the plants in the same manner.

Number of large sized tubers

Reducing the plant population resulted in an increase in large sized tubers and this applied to all the three varieties. This may be because of few sinks available per unit area that resulted in less competition between the individuals at low plant densities. More resources where channeled to each individual tuber at low density plantings resulting in a high number of large sized tubers. In other studies (Güllüoglu and Arıoglu 2009; Love and Thompson-Johns 1999) larger numbers of large sized tubers occurred when a wider spacing was used because of availability of growth requirements for the growth of the tubers.

Number of oversized tubers

The varieties produced a small proportion of oversized tubers. However at 90 × 35 cm BP1 and KY20 had higher tubers in this category a difference that should be varietal. In general, oversized tubers are not common for some varieties. Perhaps an increase in plant spacing to 90 × 45 cm would have produced marked differences.

Effect of spacing and variety on stem count

The number of stems per plant was influenced significantly ($p<0.05$) by both variety and plant spacing, For BP1 and Mnandi the stem count was least at 20 cm and unchanged from 25 t0 35 cm. For KY20 it increased with increase in spacing but remained unchanged after 30 cm.

Generally the stem count was least at 20 cm and unchanged from 25 to 35. This could have been a result of high competition at the lowest spacing. This disagrees with the findings of Masarirambi et al. (2012) who found out that the number of stems increased with an increase in plant density. However, if one compares their data within our range (90 × 20 cm to 90 × 35 cm) one can observe that they did not observe any differences. Nielson et al. (1989) found a relationship between eye numbers and stem density and postulated that this was varietal. When they tested two varieties Russet Burbank and Nooksack cultivars they found out that Russet Burbank averaged twice as many eyes per seed tuber compared to Nooksack tubers of equal size. Thus more stems would be produced on russet Burbank compared to Nooksack.

Spacing and variety effect on tuber density

The phenomenon of having high number of tubers at high densities as found in our study can be explained by the fact that at low density plantings fewer sinks are produced per unit area and these increased as the planting density increased. This is in agreement with Patel et al. (2002) and Karafyllidis et al. (1996) who found that tuber numbers were more at higher plant densities than lower plant densities. However, this is in contrast with Masarirambi et al. (2012) and Güllüoglu and Arıoglu (2009) who concluded that the availability of space had an effect on number of tubers formed. They pointed out that the greater the space the higher the number of tubers because space availability has an imposing effect on number of tubers formed. At all plant spacings, the number of tubers differed among the different varieties with Mnandi having the least and KY20 and BP1 having the highest. According to Thompson and Taylor (1974) argues that the number and size of tubers is genetically controlled and the number may be 3 to 60 tubers per plant. When they carried out their studies on different varieties at different densities they found out that Pentland Marble variety had more tubers/m^2 compared to Maris Peer variety which had the least number at high densities. Wurr et al. (1993) also concluded that stem number was varietal.

Effect of spacing and variety on total yield in tonnes/hectare

Generally, the total yield rose with a decrease in plant population, reaching a peak at the standard spacing of 30 cm. The plant spacing of 35 cm, although it had a much greater advantage of accumulating more assimilates it could not compensate for yield at wider spacing resulting in it having a lower yield compared to that of an in-row spacing of 30 cm. This can be attributed to the extended amount of foliage that was produced resulting in the total yield obtained to be low as most of the assimilates supported the haulm growth at the expense of the tuber growth. This agrees with Getachew et al. (2013) who also observed a fall in total yield when the in-row was further increased to 40 cm.

At all the in-row spacings that were used, it can be said that total yields were higher for BP1 and KY20, with Mnandi having the least. This can be attributed to the genetic make-up of the different varieties as shown by the number of leaves that were produced by each of the varieties. When the leaf counts were taken at 90 DAP (Table 2), BP1 and KY20 had the highest leaf mean values and their yield at the end is almost similar, again suggesting the leaf number influenced yield.

Effect of spacing and variety on marketable yield

This phenomenon of having marketable yield rising with a decrease in plant population might be because of less inter-plant competition at low plant densities. Plants were able to efficiently use the available growth requirements and that had a direct effect on yield. Masarirambi et al. (2012) also noted that when there was an intensive competition such as the one experienced at high densities there was an earlier set in of inter plant competition for growth resources such as light, water and nutrients resulting in a decrease in relative growth rate. This contradicts Khalafalla (2001) that at relatively high plant densities the marketable yield was high.

KY20 had the highest marketable yield followed by BP1 and Mnandi respectively at 30 and 35 cm and for 20 and 25 cm the marketable yield was just the same. These differences could have been attributed to the difference in the genetic make–up of the varieties.

Specific gravity

Specific gravity was influenced both by variety and planting density. However, this important parameter is influenced by a many factors including variety, planting density, nutrition, planting time, seed quality, irrigation and many others. A fall in specific gravity at high densities across all varieties could be accounted for by the intense competition among the plants. Therefore, the amount of nutrients that was partitioned to each individual plant was less as compared to sparsely planted plants. In similar studies Getachew et al. (2013), Vander Zaag et al. (1990) and Burton (1948), agreed with our findings, concluding that there was a rise in specific gravity up until it reached a peak and then fell. They also found out that specific gravity increased with an increase in the plant spacing. Getachew et al. (2013) and Fonseka et al. (1996) showed a fall in the specific gravity at very sparse densities after reaching its peak, in this case at 35 cm. This was attributed to the minimum competition among the plants. Competition led to a continual growth of the vegetative parts thus leading to less assimilates being channelled to the tubers. Veeranna et al. (1997) reported that growth parameters and specific gravity were improved by wider plant spacing and this agrees with the findings of the study.

As for the effect of variety on specific gravity the results showed varying specific gravity across all the plant spacing used as shown in Table 5. This can be explained by the fact that different varieties have different specific gravities. Myhre (1959) in his studies on factors affecting specific gravity he concluded that different varieties have different specific gravity.

Dry matter percentage

The lower dry matter at the highest plant densities may have been caused by intra-competition among the plants. In similar studies Getachew et al. (2013), Vander Zaag et al. (1990) and Burton (1948), also found out that percentage dry matter increased with an increase in the plant spacing. Getachew et al. (2013) and Fonseka et al. (1996) pointed out that the fall in the percentage dry matter at very sparse densities after reaching its peak, in this case at 35 cm can be attributed to the minimum competition among the plants which then led to a continual growth of the vegetative parts thus leading to less assimilates being channeled to the tubers. Veeranna et al. (1997) (cited in Mutetwa, 2010) reported that growth parameters and dry matter accumulation were improved by wider plant spacing and this agrees with the findings of the study.

This explains why there was higher dry matter percentage as those varieties that had more leaf counts have the capacity to carry out more photosynthesis and were able to produce more assimilates which were then channeled to the sinks below ground. Wurr (1974) in similar studies found out, as we did, that tuber dry-matter percentage was varietal.

Conclusion

In this study we showed many important findings: In general, plant height increased progressively with increase in intra-row spacing depending on variety while leafiness was generally lower at the lowest plant spacing for all varieties although all varieties showed a progressive increase in leafiness with increase in intra-row spacing length. Generally the proportion of small sized tubers increased with increase in plant density but varieties differed in this response while there was no consistent trend with regard to medium tubers, with some varieties showing more medium tubers as plant density decreased. Reducing the plant population resulted in an increase in the proportion of the large sized tubers and this applied to all the three varieties and the proportion of oversized tubers was high at the 35 cm only for some varieties and not others. The number of stems per plant was influenced significantly by both variety and plant spacing while the tuber density decreased with increase in spacing for all varieties but more so for Mnandi than for the other two varieties. The total yield and marketable yield rose with a decrease in plant population, reaching a peak at the standard spacing of 30 cm. As for specific gravity there was a significant interaction between the variety and plant spacing. Generally there was a rise in specific gravity up until it reached a peak at the standard spacing of 30 cm and a further increase in in-row spacing led to a fall in specific gravity. Lastly dry matter was affected differently for the different varieties.

Conflict of Interest

The authors have not declared any conflict of interest.

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