



Effect of Planting Method on Growth, Yield and Quality of Three Irish Potato (*Solanum tuberosum*) Varieties Grown in Zimbabwe

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The planting methods currently used by Irish potato farmers were optimized for old varieties more than three decades ago. No such work has since been done regardless of the newer varieties that have been introduced since then. Hence, an experiment was conducted to investigate the effect of two planting methods (planting in the furrow; ridging up to a height of 20 cm immediately after planting (IAP)) on three varieties of Irish potato (BP1, Mnandi and KY20) that are grown in Zimbabwe. The trial was done at Africa University Farm in Mutare, Zimbabwe. The experiment was a 2 x 3 factorial arrangement laid out in 4 replications using a randomized complete block design. The first factor was the two planting methods and the second factor was the three varieties. The unit plot size was 3.6 x 3.6 m² and the net harvestable plot was 2 m x 2 m discarding the border rows. The inter and intra-row spacings were 90 and 30 cm, respectively. The result showed that

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ridging delayed crop emergence as compared to furrow planting (43.4% vs. 35.7% 8 days after planting and 92.7% vs. 78.4% 12 days after planting (DAP) but did not significantly reduce crop yield, which, in fact, it increased. Ridge planting reduced the incidence of green tubers by close to 50%. Stem density per plant was influenced by variation in variety. Marketable tuber yield was improved by ridge planting. Specific gravity decreased with ridge planting but quality of potato did not deteriorate. This study showed that ridging IAP was beneficial for the varieties used but more work is needed to establish the ideal tuber seed piece size as the ability of tubers to emerge might be dependent on the size of the tuber seed piece planted.

Keywords: Potato; planting method; variety; growth components; yield.

1. INTRODUCTION

Planting method may be one of the important practices that may address the problem of low yields and poor quality in Irish potato. Yield responses of various classes of crops differed according to planting methods and ecological zones [1]. They argued that different planting methods such as planting of crops on ridges, mounds (heaps) and occasionally on the flat had been used as standard procedure in crop husbandry uncritically by farmers. The potatoes planted in furrows yielded better than those planted on hills [2].

The shallow planting hastened emergence [3,4]. But other researchers [5,6] reported that deeper planting should hasten emergence due to the availability of water underneath as compared to shallow planting. They also stated that nodes, stolons and tubers per stem were reduced by shallow planting. Further, shallow planted tubers enhanced marketable yield than deeper planted ones [7,8]. They attributed some of the differences in marketable yield to the number of green tubers that were many in shallow plantings.

It has been reported that water movement on the soil surface from the hill to the furrow may hinder the capture of water and nutrients by plants resulting in a negative impact on yield [2]. The differences on water harvesting capabilities between the furrow and hill planting methods are thought to have an impact on crop stress, tuber production and tuber quality. Irish potato farmers in Zimbabwe use planting methods unverified by scientific study especially when they adopt newer improved varieties. No work to optimize planting method has been done on such varieties. Hence, they achieve very low yields that are below 15 t/ha despite that the potential for Irish potato is higher than 60 t/ha. The objective of the present study was, therefore, to investigate the effect of

two planting methods on three potato varieties that are grown in Zimbabwe.

2. MATERIALS AND METHODS

2.1 Site Description and Experimental Design

The study was carried out at Africa University Farm (AU) in Mutare, Zimbabwe, (18°53'70, 3°S: 32°36'27.9"E). The site has an elevation of 1104 m asl and an annual rainfall of 800-1000 mm per year. The trial site's soils are red sandy clay loam. The three potato varieties BP1, Mnandi and KY20 were used in the study. All the three are superior quality and took 3-4 months to mature. These varieties are widely grown in Zimbabwe. The experiment was a 2 x 3 factorial RCBD with four blocks. The first factor was planting method at the two levels namely planting in the furrow (Furrow) and ridged up to a height of 20 cm soon after planting (Ridged IAP). The second factor was the three varieties BP1, KY20 and Mnandi. The unit plot size was 3.6 m x 3.6 m and the harvest plot was 2 m x 2 m. Each plot comprised of four lines with an inter-row spacing of 90 cm and an in-row spacing of 30 cm. Each line had 12 plants. The two middle rows in each plot were regarded as experimental rows whereas the two outer rows of plants were treated as border rows.

2.2 Crop Management Practices

A single soil sample was taken before planting from each block. The samples from the blocks were then mixed to give one composite sample for the entire experimental area. Soil analysis for pH, macro and micro nutrients gave the following: pH (CaCl₂) 5.01, N 45.37 (ppm), P 0.797 (ppm), Mg 4.40 (meq %), Cl 7.1 (meq %), Zn 3.53 (ppm) and Cu 0.65 (ppm). A basal application of a fertilizer blend (N 5%:P₂O₅ 18%:K₂O 27 %) was banded @ 1500 kg/ha. The

crops were side dressed with the nitrogenous fertilizer, ammonium nitrate @ 300 kg/ha at 3 weeks after emergence. Water was applied through sprinkler irrigation as a supplement to the rainfall received. Soil moisture levels were determined by the use of field tensiometers. The experimental units planted in the furrow were ridged twice. The first ridging was done when the crops had reached a height of about 20 cm and the second after three weeks of the first ridging. Those treatments which were ridged immediately after planting were ridged three times. The first ridging was done immediately after planting whereas the other ridging's were done when the crops had reached a height of around 20 cm and the second one was done three weeks after the first ridging.

2.3 Data Collection and Analysis

Data on different growth and yield contributing factors were recorded. Plant height, stem density per hill and number of leaves per plant were recorded from three randomly selecting plants at 30, 60 and 90 days after planting (DAP). The average number of tubers per plant was obtained from four randomly selected plants of each treatment. The harvested tubers were graded into four classes, 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 extra large (56.25 mm to 62.25 mm in diameter)[5]. Immediately after harvesting specific gravity and dry matter content of the tubers were measured using the formulae: Specific gravity = $\frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$ and dry matter (%) = $(24.182 \pm 0.035) + (211.04 \pm 3.33) (\text{Specific gravity} - 1.09)$ [6], respectively. Dry matter content was obtained using the formula which correlates specific gravity to dry matter by a correlation factor of 0.937. The recorded data were subjected to analysis of variance using Genstat Discovery 3 edition. Means were separated using Fisher's least significant differences (LSD) test at 5%.

3. RESULTS AND DISCUSSION

3.1 Plant Emergence

There were no significant differences ($p > 0.05$) on emergence at 8, 10, 12 and 14 days after planting across the varieties (Table 1). There was also no significant interaction ($p > 0.05$) between variety and planting method. However,

planting methods affected emergence ($P < 0.05$). The furrow planted tubers emerged earlier than the ridged tubers. Nevertheless, no differences were observed by 14 DAP. The observation that the potatoes planted in the furrow emerged earlier than those ridged immediately after planting suggested that emergence must have been influenced by the distance the emerging shoots had to travel before reaching the soil surface. This is consistency with the findings of several workers [2,7,8]. They concluded that shallow planting hastened emergence and deep planting delayed emergence. However, others [4,9] stated the contrary and suggested that moisture was the limiting factor for sprout emergence at shallow planting depths.

3.2 Plant Height

The two planting methods did not significantly ($p > 0.05$) affect plant height and no significant interaction ($p > 0.05$) was observed between variety and planting method (Table 2). However, varieties differed significantly ($P < 0.05$) in height. At 30 days after emergence, KY20 was taller than Mnandi and BP1, while the later two were similar. This trend was also evident at 60 and 90 days after emergence. Perhaps they differed in canopy structure leading to different heights during their growing period. Varietal differences in respect to canopy structure [10] which attributed to yield is reported elsewhere [11].

3.3 Stem Density at Harvest

Planting method and its interaction with variety did not significantly ($p > 0.05$) affect stem density and also in interaction between variety and method (Table 3). However, stem density significantly ($P < 0.05$) depended on variety (Table 3). Mnandi had the least number of stem counts compared to other twos. Perhaps, because the varieties used have similar tuber size. The planting method did not affect stem density. This is purely due to varietal difference. This agrees with the findings that the potato var. Russet Burbank responded to planting depth whilst the other, Umatilla, did not [12]. In the present investigation BP1 and KY20 produced more number of stems than Mnandi but this was not influenced by planting method. It is reported that an inter-relationship between eye numbers and stem density is varietal [13]. When they tested two varieties, Russet Burbank and Nooksack they recorded that Russet Burbank, averaged twice as many eyes per seed tuber than Nooksack tubers of equal size.

Table 1. Plant emergence at 8, 10, 12 and 14 days after planting in planting methods

Treatments	Emergence (%)							
	8 DAP		10 DAP		12 DAP		14 DAP	
	Furrow	Ridge IAP	Furrow	Ridge IAP	Furrow	Ridge IAP	Furrow	Ridge IAP
Variety								
BP1	42.50	34.40	63.38	52.23	92.78	80.00	94.27	94.00
KY20	42.70	35.40	64.58	51.45	92.10	76.95	93.20	93.00
Mnandi	45.10	37.20	64.30	50.12	93.25	78.25	94.60	94.02
Mean	43.40 ^b	35.70 ^a	64.08 ^b	51.27 ^a	92.7 ^b	78.40 ^a	94.02 ^a	93.31 ^a
Lsd vrt	5.49		1.81		1.74		1.21	
Lsd pm	4.48		1.48		1.42		0.99	
P vrt	ns		ns		ns		ns	
P pm	*		*		*		*	
P vrt*pm	ns		ns		ns		ns	
CV%	13		3		1.9		1.2	

Means not sharing a common letter in a column differ significantly at 5% probability level. pm = planting method; vrt = variety; IAP = immediately after planting; ns = not significant, DAP = days after planting

Table 2. Plant height (cm) of three potato varieties at 30, 60 and 90 DAP in two planting methods

Treatments	Plant height									
	Planting method (pm)	30 DAE			60 DAE			90 DAE		
		Furrow	Ridging IAP	Mean	Furrow	Ridging IAP	Mean	Furrow	Ridging IAP	Mean
Variety										
BP1	22.95	22.50	22.73 ^a	51.74	51.95	51.85 ^a	59.45	58.56	59.00 ^a	
KY20	26.38	27.57	26.98 ^b	59.83	58.98	59.40 ^b	64.28	63.38	63.85 ^b	
Mnandi	24.43	22.35	23.36 ^a	51.03	51.05	51.04 ^a	59.39	57.93	58.66 ^a	
Lsd vrt			0.58			0.90			1.59	
P vrt			*			*			*	
P pm			NS			NS			NS	
P vrt*pm			NS			NS			NS	
CV%			8.20			4.10			4.60	

Means not sharing a common letter in a column differ significantly at 5% probability level. pm = planting method; vrt = variety; IAP = immediately after planting; ns = not significant, DAP = days after planting

Table 3. Stem counts, number of tubers and greening tubers per plant of three potato varieties in two planting methods

Variety	Stem counts			Tuber number/plant			Greening tubers		
	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
Planting method									
Furrow	5.58	7.58	5.50	13.92 ^b	12.75 ^{ab}	12.33 ^a	7.17 ^c	8.17 ^{cd}	8.50 ^d
Ridging IAP	7.58	5.33	5.42	16.25 ^c	16.50 ^c	16.00 ^c	4.30 ^a	4.25 ^a	5.58 ^b
Mean	6.58 ^b			6.46 ^b			5.46 ^a		
Lsd vrt	0.58			0.90			0.85		
Lsd pm	0.47			0.73			0.69		
Lsd pm*vrt	2.29			1.277			1.207		
P vrt	NS			*			*		
P pm	*			*			*		
P vrt*pm	NS			*			*		
CV%	16.5			18.1			14.8		

The means not sharing a common letter in a column differ significantly at 5% probability level; pm = planting method; vrt = variety; IAP = immediately after planting; ns = not significant, DAP = days after planting

3.4 Number of Tubers per Plant

Table 3 shows significant ($p < 0.05$) interaction with regard to number of tubers per plant. Tuber planted in ridges gave more tubers per plant compared to furrow planting, suggesting that node and stolons per stem increased as planting depth increased as reported elsewhere [14]. Although we did not monitor temperature at each planting depth, we assumed that the furrow method had higher temperatures which were helpful for early growth of plants but led to nutrient deficiency due to shortage of soil moisture and thus, hampered tuber yield [7,15-17]. The number of tubers per plant is purely a varietal character which is genetically controlled, ranging from 3-60 [18,19].

3.5 Number of Green Tubers per Plant

The interaction of planting method and variety for number of green tubers per plant differed significantly ($P < 0.05$) (Table 3). In general, the number of green tubers was lower with regard to the ridged method of planting compared to furrow method. Essentially, Mnandi and BP1 produced more green tubers than KY20. The less greening associated with an increase in planting depth is supported by several workers [7,10,16].

3.6 Marketable and Total Yield

Marketable yield increased significantly ($p < 0.05$) with ridging IAP regardless of variety (Table 4). However, BP1 ridged IAP had statistically similar marketable yield with KY20 and Mnandi in the furrow. Under furrow, BP1 had the least marketable yield. The marketable yield was negatively correlated with tuber greening

($R = -0.6739$, $P < 0.001$). With regard to marketable yield, ridging IAP significantly ($P < 0.05$) improved yield for all the varieties presumably because it increased tuber density and lowered tuber greening. Other studies also showed that shallow planted tubers had less marketable yield when compared to deeper planted tubers [7,8]. The differences of variety in yield was significant ($P < 0.05$). The vars. BP1 and KY20 gave the highest total yield. It was not clear why this was so because the yield of potato is a complex phenomenon associated with many biotic and abiotic factors [20].

All the varieties showed an increase in the total yield as the planting method was changed from furrow to ridging. All the varieties when ridged immediately after planting yielded furrow plantings (Table 4). The total yield was positively correlated with tuber density ($R = 0.6194$, $P < 0.001$), plant height at 60 DAE ($R = 0.5451$, $P < 0.01$), and plant height at 90 DAE ($R = 0.52$, $P < 0.01$). Other studies also showed that the number of node and stolons increased with the increased depth of planting which affected tuber numbers [21]. In the present study we did not measure nodes and stolons per stem. The results of the present study are in agreement with the findings that depth of planting increased tuber yield [7] though some researchers did not agree with such findings (2,8). They concluded that there were no differences in yield due to alteration of planting depths.

3.7 Specific Gravity of Tubers

There was an interaction between variety and planting method. All the varieties except Mnandi showed reduced specific gravity as planting

Table 4. Yield (total and marketable) (t/ha) and specific gravity of three potato varieties in two planting methods

Variety	Marketable yield			Specific gravity			Total yield (t/ha)		
	BP1	KY20	Mnandi	BP1	KY20	Mnandi	BP1	KY20	Mnandi
Planting method									
Furrow	9.20 ^a	11.58 ^b	11.36 ^b	1.08475 ^b	1.08575 ^b	1.0850 ^b	15.28 ^b	15.35 ^b	13.04 ^a
Ridging IAP	11.60 ^b	13.02 ^c	13.00 ^c	1.07825 ^a	1.07800 ^a	1.08375 ^b	17.73 ^c	17.55 ^c	15.57 ^b
Lsd vrt	0.58			0.00142			1.02		
Lsd pm	0.47			0.00116			1.456		
Lsd pm*Vrt	0.829			0.002016			1.456		
P vrt	*			*			*		
P pm	*			*			*		
P vrt*pm	*			*			*		
CV%	16.5			13.2			8.7		

The means not sharing a common letter in a column differ significantly at 0.05 probability. pm = planting method; vrt = variety; IAP = immediately after planting; ns = not significant, DAP = days after planting

method changed from the furrow to ridging IAP (Table 4). Specific gravity is the single most important quality parameter for processing potatoes. In this study BP1 and KY20 had lower specific gravity when ridged IAP while Mnandi remained unchanged. However, this parameter is influenced by a myriad of factors including variety, planting time, seed quality, planting density nutrition, irrigation and many others [22,23]. The higher specific gravity under furrow planting may have been caused by less competition for growth requirements like nutrients and moisture since the furrow planting resulted in fewer number of tubers per plant. It is reported that different varieties had different specific gravity values [24] and also that competition among tubers reduced specific gravity [22,23]. However, the specific gravities reported in this trial are very suitable for processing.

4. CONCLUSIONS

The results of the study revealed that ridging delayed emergence but this delay did not negatively affect yield. In fact, marketable yield and total yield were increased significantly by deeper planting. Although specific gravity declined with deeper planting, in absolute terms the decrease did not lead to specific gravity lower than that ideal for such popular use as French fries. This study showed that ridging IAP was beneficial for the varieties used but more works related to tuber size and ridging IAP is need as the ability of tubers to emerge might dependent on the size of the seed piece.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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