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Effects of spacing on the yield and yield related parameters of potato (*Solanum Tuberosum I.*) At bale highland

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Abstract

Field experiment was conducted at Sinana, Goba and Upper Dinsho to determine effects of spacing on the yield and yield related parameters of potato varieties. The treatments of the experiment were three levels of spacing between plants (30 cm, 35 cm and 40 cm), three levels of spacing between rows (75 cm, 85 cm and 95 cm) and two varieties (Ararsa and Gudane). There were a total of 18 treatments. Each treatment replicates three times. The experiment was laid down with Randomized Complete Block Design (RCBD). Plant growth parameters such as plant height, number of stem per plant, number of hill per plot and yield related parameters such as number of tuber per hill, number of marketable tuber per plot, number of unmarketable tuber per plot, weight of marketable tuber per plot and weight of unmarketable tuber per plot was collected. Additionally, total tuber yield per plot was also recorded. All recorded data were inserted to GenStat computer software, and analyzed to determine the effects of treatments on selected parameters. Accordingly, potato growth parameters such as plant height, number of stem per hill are significantly ($p<0.05$) affected by variety and location. Plant height significantly affected by the interaction effects of spacing between plants with location and variety. All yield component parameters except number of tuber per hill significantly affected by spacing between plants and rows as well as their interaction with other factors. Consequently, the highest number of hill per plot (12.76), the highest number of marketable tuber per plot (71.3), the lowest weight of unmarketable tuber (760.2) was recorded in response to 30 cm spacing between plants. On the other hand, the maximum number of hill per plot (13.8), the highest number of marketable tuber per plot (70.63), the maximum mean weight of marketable tuber (8660), the highest number of unmarketable tuber per plot (40.5) and the maximum mean weight of unmarketable tuber per plot (1080 g) was recorded from plots established using 75 cm spacing between rows. The highest tuber yield was obtained in response to 30 cm spacing between plants and 75 cm spacing between rows. The result of analysis showed different ways of response of parameters to factors. Gudane variety gives the highest weight of marketable tuber per plot and the highest tuber yield in response to 40 cm x 75 cm spacing between plants and rows. However, Ararsa variety gives the maximum number of tuber per hill, maximum marketable tuber, the highest weight of marketable tuber, the lowest weight of unmarketable tuber and the highest tuber yield at 30 cm x 75 cm spacing between plants and rows. Therefore, Potato producing farmers are recommended to use 40 cm x 75 cm, 30 cm x 75 cm spacing between plants and rows for Gudane and Ararsa varieties, respectively.

Keywords: Spacing; Rows; Hill; Tuber per plot; Tuber yield

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Introduction

Potato (*Solanum tuberosum L.)* is the fourth largest crop next to Wheat, Rice and Maize [1]. It is an important source of food and employment in developing countries. Potato crop was first introduced to Ethiopia around 1858 by Schimper, a German botanist [2]. However, its adoption was limited until nineteenth century due to genetically very limited availability of potato

varieties and their susceptibility to diseases and pests [3]. The occurrence of a prolonged famine, which happened at the end of the nineteenth century, rapidly increases potato adoption in Ethiopia [4]. Therefore, it is being used as hunger alleviating crop because of early maturity than other crops. According to CSA data of 2010 E.C, 66,923.33 ha of land was covered by potato and 9,214,031.85 Quintals of potato were produced annually (CSA, 2016/2017).

Potato crop needs intra and inter row spacing. Enough spacing allowed maximum tillering growth of the plant and better quality tuber formation. For potato producing areas of Ethiopia 30 cm and 75 cm spacing are recommended between plants and between rows respectively [5,6] reported that tuber expansion is affected by spacing as the surrounding soil volume becomes insufficient to hold the expanding masses of tubers in addition to competitions from imposed by nearby planted crops. Other study at Ofla wereda, Northern Ethiopia conducted on inter and intra row spacing determined and recommended 20 cm spacing between plants and 65 cm spacing between rows for the highest tuber yield about 37.54 ton ha-1 [7]. Additionally, research done at Guji zone southern Ethiopia also recommended different spacing between plants and rows for potato production. The Author recommended 30 cm × 75 cm spacing between plants and rows to obtain a marketable tuber yield of about 42.57 t ha-1 at Guji zone southern Ethiopia [8]. These two different spacing recommendations may due to different morphological characteristics of potato varieties which lead to conduct research to determine other spacing for best production for other varieties.

Different varieties may need different inter and intra row spacing, since their morphological characteristics are different. This indicates that recommendation for one potato variety may not applicable for other varieties vary in morphological appearance. Therefore, this experiment was proposed with the following objectives:

- To determine the optimum spacing between plants for different varieties of potato production
- To determine the optimum spacing between rows for different varieties potato production

Material and Methods

Description of study area

This experiment was conducted at Goba, Upper Dinsho and Sinana district for three consecutive years. Goba is one of the highland district of Bale zones, Oromia Regional state 445 km far from Finfine (Addis Ababa) capital city of Ethiopia and 15 km from Robe the capital town of Bale zone at South East direction. It is located between 39^0 37' 30''-40^0 12' 00''E and 6°38' 0''-7° 4' 0'' N. About 45% of this District is rugged or mountainous; Mount Tullu Demtu is the highest point in this District, the Zone and the Oromia Region; other important peaks include Mount Batu. Rivers include the Togona and Shaya. A survey of the land in this District shows that 13% is arable or cultivable, 27.6% pasture, 54.6% forest, and the remaining 4.8% is considered as unusable [9]. Goba District has two types of rainfall regime. The long rainy season extends from March to April with high rain fall during June, July and August. The altitude of the District ranges from 1500 m.a.s.l-4377 m.a.s.l and the temperature varies from some times less than 0°C-23°C. The major soil types are Chromic and Pellic Vertisols in some parts, Chromic, Orthic and Vertic Luvisols around highlands and plateaus areas [9]. Dinsho district is part of the formerly known Sinana-Dinsho district. The altitude of this woreda ranges from 2000 m.a.s.l-3600 m.a.s.l. A survey of the land in this district showed that 33.1% is arable or cultivable where 29.8% was under Annual crops, 30.4% pasture, 30.2% forest or heavy vegetation and the remaining 2.3% is considered as swampy, mountainous or unusable. SARC is found at 463 km away from Finfine, 33 km and 50 km from the nearby towns, Robe and Goba, respectively. Its geographic location is 07°07' N latitude and 40° 10'E longitude. The elevation of the center is 2400 m.a.s.l. with topography of gentle slope to plain, which has beautiful scene for vision and is quite conducive for agricultural production system under rain-fed in the present climatic conditions.

Experimental design and treatments

The experiment was conducted using Randomized Complete Block design with three replications of each treatment. The treatments of the experiments were three levels of spacing between plants (30 cm, 35 cm and 40 cm) and three levels of spacing between rows (75 cm, 85 cm and 95 cm). Two varieties namely Gudane and Ararsa were used for this experiment. There were a total number of 18 treatments. The seed of potato used for this experiment were obtained from Sinana Agricultural Research center. Gudane was adapted variety whereas Ararsa was released from SARC. All other agronomic practices were done according to the recommendation for all treatments.

Methods of land preparation and planting

Land preparation was done with plough thoroughly by traditional land cultivation. The prepared land was leveled to be suitable for plant establishment. Planting was done using different spacing between plants and rows during the month of March in 2017 at Goba and Sinana districts of Bale zone. Medium sized tuber of potato was used. Additionally, scientifically recommended amount of both UREA and DAP fertilizer was used for establishment of experiment.

Collected data

Plant height: The measurement in meters from the bottom of the plant to the tip of potato plant.

Number of hill per plot: The amount of plant grown from the planted tubers

Number of stem per hill: The average number of stem grew up from one planted tuber

Number of tuber per hill: Is the average number of tubers obtained one single planted tuber

Number of marketable tuber per plot: Is the average number of marketable tubers and was recorded by counting tubers which was not green and very small based on visual inspection

Weight of marketable tuber per plot: Is the average weight of tubers counted as marketable tubers

Number of unmarketable tuber per plot: Is the average number of tubers which was exposed to sunlight changed their color to green and very small identified by visual inspection

Weight of unmarketable tuber per plot: The average weight of tubers which was counted as unmarketable tubers

Total yield per hectare: Is the sum of weight of marketable tuber and weight of unmarketable tuber. It was recorded by converting to weight per hectare

Data analysis and interpretation

All data were subjected GenStat 15th Edition computer software and analyzed to determine the significant effects of treatments on selected parameters. LSD was used for mean separation at 5% level of significance using DMRT. Then the result of analysis was interpreted accordingly.

Result and Discussion

Effects of spacing between plants and rows on potato growth parameters

Analysis of variance showed that the main effects of spacing between plants showed non-significant ($p<0.05$) effects on plant height of potato at Goba, Upper Dinsho and SARC research station. Similarly, the spacing between rows had no significant effects of plant height at Upper Dinsho and SARC research station (**Table 1**). This may due to the less competition among plants for nutrients, air and moisture. The result is in line with the finding reported by [10] as spacing between plants has no significant effects on plant height of potato. However, at Goba experimental site the spacing between rows significantly affected plant height of the crop. Accordingly, the longest plant was obtained from plots with 75 cm spacing between rows. In fact, the plants with lower space between rows compete more for sunlight and increases their height to get sun for synthesis processes [11] also reported as the closely spaced potato gives maximum plant height. On the other hand, number of stem per hill was significantly affected by spacing between plants at SARC research site. Accordingly, the maximum number of stem per hill (3.37) was obtained from plots with 35 cm spacing between plants. The minimum mean number of stem per hill (2.42) was recorded for plots established with 30 cm spacing between plants at particular site. However, number of stem per hill was not significantly affected by spacing between plants at Goba and Upper Dinsho research site. Number of stem per hill was also not significantly affected by spacing between rows at Goba and SARC research station but significantly affected by the spacing between rows at Upper Dinsho research site.

Table 1: The main effects of spacing between plants, and rows on the growth parameters of potato at Goba, Upper Dinsho and SARC on station.

Treatments	Means of selected growth parameters by Location					
SPBP	Plant height (cm)			Number of stem per hill		
	Goba	Upper Dinsho	SARC station	Goba	Upper Dinsho	SARC station
30	39.48a	45.96a	50.38a	4.10a	5.72a	2.42bc
35	38.44a	45.24a	47.53a	3.98a	5.18a	3.37a
40	38.67a	45.32a	50.46a	4.133a	5.16a	2.67b
Means	38.86	45.51	49.46	4.07	5.35	2.8
CV (%)	9.3	5	8.7	22.7	24.2	34.6
LSD (0.05)	NS	NS	NS	NS	NS	0.66*
SPBR	-	-	-	-	-	-
75	39.91a	45.04a	50.58a	4.07a	6.01a	2.50a
85	39.55a	46.32a	47.74a	3.96a	4.92ab	2.97a
95	37.13b	45.16a	50.04a	4.19a	5.12a	2.93a
Means	38.86	45.51	49.46	4.07	5.35	2.8
CV (%)	9.3	5	8.7	22.7	24.2	34.6
LSD (0.05)	2.44*	NS	NS	NS	0.88*	NS

CV: Coefficient of Variance, LSD: Least Significant Difference, NS: Non Significant, Means followed with the same letter are not significantly different; Means followed by different letters are significantly different

On the other hand, the combined analysis indicated that the interaction effects of spacing between plants and rows for both varieties have no significant effects on plant height and average number of stems per hill of the crop at all location. The result is supported by [8] where non-significant effects of the interaction effects of spacing between plants and rows on plant height were reported. However, there was highly significant ($p<0.01$) variation among the mean number of stem per hill due to location and variety. Accordingly, the maximum number of stem per hill (5.35) was obtained from experiment established at Upper Dinsho where the minimum mean number of stem (2.8) was obtained from Sinana On station. The variation may due to different environmental factors like soil fertility, moisture content of the soil, humidity and sun light. Variety Ararsa showed lowest number of stem per hill (3.49) than Gudane Variety (4.66). The difference may due to genetic variation among the varieties.

Table 2: Effects of Location on the mean number of stem per hill.

Location	Mean number of stem per hill
SARC On station	5.352a
Goba	4.07 b
Upper Dinsho	2.80c
CV (%)	31
LSD(0.05)	0.4813

CV:Coefficient of Variance, LSD:Least Significant Difference, means with the same letter are not significantly different.

Response of potato growth parameters to spacing between plants and rows were determined. There is no significant variation among the mean plant height for both varieties due to treatments (**Table 3**). However, there is variation among the mean of the parameters of the varieties. This may due to genetic variation among the varieties.

Table 3: Responses of plant growth parameters to spacing between plants and rows of two potato varieties.

Treatments	Means of selected growth parameters of Varieties			
Spacing between plants	Plant height (cm)		Number of stem per hill	
	Gudane	Ararsa	Gudane	Ararsa
30	48.13a	42.41b	4.69a	3.47b
35	46.56a	40.93a	4.72a	3.59b
40	48.11a	41.52b	4.56a	3.41b
Means	44.61		4.01	
CV (%)	8.1		31	
LSD (0.05)	NS		NS	
Spacing between rows				
75	48.15a	42.21b	4.91a	3.47b
85	47.99a	41.09b	4.39a	3.50b

Yield components of Potato as influenced by spacing between plants and rows

Analysis of variance done over location indicated that number of hill per plot was significantly ($p<0.05$) affected by spacing between plants and rows at SARC on station research site. Similar to this, at Goba experimental site number of hill per plot was significantly affected by spacing between rows. As a result, the maximum number of hill per plot (15.5, 16.78) was recorded in response to 30 cm spacing between plants and 75 cm spacing between rows respectively at SARC research station. The relative maximum number of hill per plot (12.94) was recorded for plots established using 75 cm spacing between rows at Goba. On the other hand, the mean minimum number of hill per plot (11.44, 9.39) were obtained from plots established with 40 cm spacing between plants, 85 cm spacing between rows at Sinana and 95 cm spacing between rows at Goba. At both location as spacing between plants and rows increased the mean number of hill per plot decreased. This may due to the exposure of the soil to moisture evaporation which causes moisture stress then reduction in number of hill per plot. At Upper Dinsho experimental site number of hill per plot was not significantly affected by spacing between plants and rows.

The main effects of spacing between plants and rows showed no significant effects on number of tuber per hill at all location. In spite of that, there were significant effects of spacing between plants on the mean number of marketable tuber per plot at upper Dinsho experimental site. Accordingly, the highest number of marketable tuber per plot (82.94) was recorded for plots established with 30 cm spacing between plants and the lowest number of marketable tuber per plot (54.11, 60.06) were obtained from plots established using 35 cm and 40 cm spacing between plants at specified location. However, number of marketable tuber per plot was not significantly ($p<0.05$) affected by spacing between plants at Sinana and Goba research site. The main effects of spacing between rows on number of marketable tuber per plot was significantly high ($p<0.01$) at Sinana and Goba research site. Consequently, the highest number of marketable tuber per plot was recorded for plots established using closest spacing while the lowest number marketable tuber per plot was obtained from plots with wider spacing between rows. Accordingly, the maximum number of marketable tuber per plot (96, 46.56) was recorded in response to 75 cm spacing between rows at Sinana and Goba respectively. The number of marketable tuber per plot recorded for the closest plots were 32% and 28% greater than that of the medium and wider spacing between rows. The variation among the mean number of marketable tuber per plot may due to difference in the fertility level of soil and other environmental factors among the locations.

Weight of marketable tuber per plot was significantly ($p<0.05$) affected by spacing between plants and rows at SARC experimental site. The result indicated that increasing the spacing between plants and rows decreases weight of marketable tuber per plot. In fact, increasing spacing between plants and rows than the optimum amount may expose the soil for moisture loss which indirect reduces the weight of marketable tuber of potato. Contrary, the mean weight of marketable tuber per plot at upper Dinsho didn't significantly affected by the spacing between plants and rows. The reason may availability of moisture and plant nutrients for growth and tuber development of potato which reduces the competition among plants.

Analysis of variance for the mean number of unmarketable tuber per plot was also done. At Goba and Upper Dinsho experimental site, number of unmarketable tuber per plot was significantly ($p<0.05$) affected by spacing between plants and rows. In similar manner spacing between rows significantly affected number of unmarketable tuber per plot at SARC research station. The result showed that, increasing the spacing between plants and rows decreases the mean number of unmarketable tuber per plot. It is phenomenon that at optimum spacing between plants and rows potato gives the maximum number of tubers including marketable and unmarketable which are under sized as well as exposed to sun light. Therefore, the mean number of unmarketable tuber per plot for optimum spacing between rows may result in higher number of unmarketable tuber per plot. The result is in line with the finding of Kinde Lamessa, who reported maximum number of marketable and unmarketable tuber at 20 cm × 50 cm spacing between plants and rows.

Weight of unmarketable tuber per plot was significantly affected by spacing between plants at Upper Dinsho but not at SARC and Goba experimental site. According to the result, increasing spacing between plants increases the weight of unmarketable tuber per plot (**Table 4**). In fact, at wider spacing between plants there will be exposure of soil for moisture loss and the weight of unmarketable tuber will be high due to the unfavorable environmental condition for tuber development. On the other hand, since the condition enhances the crop to produce high number of under sized tubers the weight of unmarketable tuber per plot will be increased.

In the same manner, spacing between rows had significantly

Table 4: Effects of spacing between plants and rows on the yield components of potato at SARC on station, Goba and Upper Dinsho.

Means of selected yield components parameters by location																	
SPBP	SARC On station						Goba						Upper Dinsho				
	NHPP	NTPH	NM-TPP	WMT-PP	NUM-TPP	WUM-TPP	NHPP	NTPH	NM-TPP	WM-TPP	NUM-TPP	WUM-TPP	NTPH	NM-TPP	WM-TPP	NU-MTPP	WU-MTPP
30	15.50a	7.56 a	90.61a	10.64a	41.50a	0.68a	11.39a	5.22a	40.28a	3.10a	16.28a	0.22a	11.93a	82.94a	8.78a	48.06a	1.38b
35	12.89b	8.23a	77.33a	8.78ab	41.72a	0.77a	10.72a	4.99a	34.67a	2.90a	13.83ab	0.17a	10.76a	54.11b	6.71a	31.67b	1.31b
40	11.44b	7.82a	75.33a	7.97b	35.67a	0.65a	9.89a	4.68a	35.94a	2.88a	11.33b	0.169a	11.08a	60.06b	12.29a	47.72a	2.46a
Mean	13.28	7.87	81.1	9.13	39.65	0.7	10.67	4.96	37	2.96	13.81	0.19	11.26	65.7	9.26	42.5	1.72
CV (%)	14.8	20.6	23.6	33	26	29.4	27.5	21.1	24.2	26.2	39.9	28.4	22.4	24.3	27.2	23.7	29.2
LSD(0.05)	1.33**	NS	NS	0.71*	NS	NS	NS	NS	NS	NS	3.36*	NS	NS	19.71*	NS	15.46*	0.81**
Spacing between the rows																	
75	16.78a	7.53a	96.00a	10.69a	51.22a	0.92a	12.94a	5.00a	46.56a	3.46a	17.17a	11.94a	11.60a	69.33a	11.84a	53.00a	
85	11.44b	8.22 a	72.56b	7.78b	36.50b	0.60b	9.67b	4.78a	33.17b	2.77b	11.89b	10.61a	11.72a	68.67a	8.27a	39.78ab	
95	11.61b	7.8a a	74.72b	8.92ab	31.17b	0.58b	9.39b	5.11a	31.17b	2.65b	12.39b	12.28a	10.44a	59.11a	7.68a	34.67b	
Mean	13.28	7.87	81.1	9.13	39.65	0.7	10.67	4.96	37	2.96	13.81	11.61	11.26	65.7	9.26	42.5	
CV (%)	14.8	20.6	23.6	33	26	29.4	27.5	21.1	24.2	26.2	29.9	27.5	22.4	24.3	27.2	23.7	
LSD(0.05)	1.33**	NS	12.96**	2.034*	9.65**	0.23*	1.99**	NS	6.06**	0.53**	3.36**	NS	NS	NS	NS	15.46*	

NHPP:Number of Hill Per Plot, NTPH:Number of Tuber Per Hill, NMTPP:Number of Marketable Tuber Per Plot, WMTPP:Weight of Marketable Tuber Per Plot (in kg), NUMTPP:Number of Unmarketable Tuber Per Plot, WUMTPP:Weight of Unmarketable Tuber Per Plot (in kg).

($p<0.05$) influenced the weight of unmarketable tuber per plot at SARC research station and Goba experimental site but not at Upper Dinsho. At both locations the highest weight of unmarketable tuber per plot was recorded for plots with closest spacing between rows. The wide spacing between rows than the optimum amount may prevent the crop not only to produce marketable tuber but also to produce unmarketable tuber by exposing the crop for moisture stress which in turn causes yield losses. The result contradicts with the finding of where the highest unmarketable tuber at 55 cm × 25 cm spacing between rows and plants was reported. The contradiction of the results may due the variety used and environmental factors among the two experimental sites. Different varieties may need different spacing for their growth and tuber development.

Analysis of variance indicated that except number of hill per plot and number of stem per plant all yield component parameters were significantly ($p<0.05$) affected by spacing between plants and rows. Average number of marketable tuber per plot decreases as spacing between plants and rows increases for both varieties. Both varieties gave the maximum number of marketable tuber per plots at 30 cm × 75 cm spacing between plants and rows. The number of marketable tubers obtained from plots with 30 cm × 75 cm spacing between plants and rows are 70.55% and 77.64% higher than the widest plots for Ararsa and Gudane variety, respectively. This indicates the importance of closest spacing in conserving moisture needed for tuber growth and development.

On the other hand, number of unmarketable tuber per plot was also significantly ($p<0.05$) influenced by spacing between plants and rows. Accordingly, as spacing between plants and rows increases from (30 cm-40 cm and 75 cm-95 cm); number of unmarketable tuber per plot increased for both varieties. As a result, the maximum number of unmarketable tuber per plot (32.78, 69.78) was recorded at 40 cm x 75 cm spacing for Ararsa variety and 30 cm x 75 cm spacing for Gudane variety. However, the minimum number of unmarketable tuber per plot (22 and 20.22) was recorded for plots with 40 cm x 95 cm spacing for Ararsa variety and 35 cm x 95 cm spacing for Gudane variety. Both varieties gave the maximum number of unmarketable tuber per plot at 95 cm spacing between rows. This showed as the widest spacing between rows influences number of unmarketable tuber per plot. This may due moisture loss of the soil which affects tuber initiation and development. On the other hand, increasing the spacing between rows than optimal may expose the soil to wind erosion, to lose moisture and nutrients. As a result, number of under sized and green tuber will be increased.

Analysis of variance showed that, weight of marketable tuber per plot was also significantly influenced by spacing between plants and rows. The response of both varieties to spacing between plants and rows is different. Accordingly; Ararsa variety give the maximum weight of marketable tuber per plot at 30 cm x 75 cm spacing between plants and rows whereas the maximum weight of marketable tuber per plot was recorded at 40 cm x 75 cm spacing between plants and rows for Gudane variety. For both varieties increasing spacing between rows decreases the weight of marketable tuber per plot. This may due to exposure of soil to moisture loss which contributed for marketable tuber weight reduction. Weight of unmarketable tuber per plot was also significantly affected by spacing between plants and rows. According to the result the mean weight of unmarketable tuber per plot increases as the spacing between plants and rows increases. In fact, if the spacing between rows increased than

Table 5: The interaction effects of spacing the yield components of potato varieties.

SPBP	SPBR	VAR	Means of selected yield components parameters					
			NHPP	NSPPP	NMTPP	NUMTPP	WMTPP	WUMTPP
30	75	A	14.78ab	8.33ab	60.33cde	28.44cd	8.29ab	0.51b
	-	G	16.11a	8.71ab	83.33ab	69.78a	8.39ab	1.25ab
	85	A	10.22ef	8.24ab	56.67cde	27.44cd	6.49abc	4.79b
	-	G	11.89cdef	8.58ab	74.56bc	33.11bcd	7.99abc	6.66b
	95	A	11.89bcdef	8.04ab	53.89cde	26.11cd	6.17bc	8.59b
	-	G	11.67cdef	7.51ab	72.78bcd	26.78cd	7.72abc	7.99b
35	75	A	12.78bcde	7.00b	46.44e	32.44bcd	6.74abc	7.40b
	-	G	14.33abc	8.867ab	83.67ab	46.44b	7.03abc	9.64b
	85	A	9.89ef	7.067b	44.33e	25.78cd	6.74abc	8.067b
	-	G	11.00def	9.42a	64.22bcde	39.33bc	6.07bc	7.17b
	95	A	11.56cdef	7.289ab	42.56e	25.33cd	6.28bc	7.15b
	-	G	10.89def	8.31ab	51.00de	24.22cd	5.87bc	5.59b
40	75	A	12.00bcdef	7.96ab	58.11cde	32.78bcd	7.4abc	1.866a
	-	G	13.33bcd	7.40ab	100.67a	20.22d	9.60a	1.15ab
	85	A	9.44f	7.067b	45.11e	26.44cd	6.51abc	1.13ab
	-	G	11.00def	9.067ab	65.67bcde	32.89bcd	6.10bc	0.543b
	95	A	10.11ef	7.60ab	42.56e	22.00cd	5.35bc	0.79b
	-	G	10.44def	8.07ab	56.67cde	36.00bcd	4.86c	1.07b
Mean			12	8	61	32	6.9	0.9
CV (%)			23	24	34	29	31	28
LSD			NS	NS	19.39*	14.52**	2.63*	0.71*

SPBP:Space between plants; SPBR:Space between rows; VAR:Variety; NHPP=Number of hill per plot; NSPP: Number of stem per plant; NMTPP:Number of marketable tuber per plot; NUMTPP:Number of unmarketable tuber per plot; WMTPP:Weight of marketable tuber per plot (kg); WUMTPP:Weight of unmarketable tuber per plot (kg); CV:Coefficient of variance; LSD:Least significant difference.

optimum spacing needed by the potato there will be exposure of land for wind which causes soil moisture and nutrient losses through evaporation. This directly influences the growth and development of potato and number of under sized and green tubers will be increased. However, both varieties had their own optimum spacing between plants at which they gave minimum weight of unmarketable tuber per plot. Accordingly, Ararsa variety gave the mean minimum weight of unmarketable tuber per plot at 30 cm x 75 cm spacing where, Gudane gives the minimum weight of unmarketable tuber per plot at 40 cm x 75 cm spacing between plants and rows. The variation among spacing between plants needed for these varieties may due to the variation in genetic morphological characteristics of the varieties.

Effects of Spacing between Plants and Rows on Tuber Yield of Potato (*Solanum Tuberosum L.*)

Analysis of variance indicated that tuber yield of potato is not significantly affected by spacing between plants at all locations. However, spacing between rows significantly affected tuber yield of the crop ($p<0.05$). Accordingly, increasing spacing between rows from 75 cm-95 cm decreases the tuber yield of potato 43.3 t ha-1 to 40.81 t ha-1. The tuber yield recorded for 85 cm par with the tuber yield recorded for 95 cm spacing between rows but significantly different from that of 75 cm spacing.

Table 6: Effects of Spacing on the yield of potato.

Spacing between pants	Mean tuber yield (t ha^{-1})
40	42.48a
30	41.92a
35	40.70a
Mean	41.7
CV (%)	11.7
LSD (0.05)	NS
75	43.3a
85	41b
95	40.81b
Mean	41.7
CV (%)	11.7
LSD (0.05)	2.22*
CV:Coefficient of variance, LSD:Least significant difference.	

Table 7: Effects of spacing on the tuber yield of different potato varieties at Bale.

Mean Tuber Yield (t ha^{-1})			
Spacing between plants	**Spacing between rows**	**Gudane**	**Ararsa**
30	75	43.17ab	42.72abc
	85	42.03abcd	40.50bcd
	95	42.37abcd	41.11bcd
35	75	41.68bcd	41.23bcd
	85	39.56d	41.29bcd
	95	40.48bcd	39.99cd
40	75	44.72a	42.59abcd
	85	40.81bcd	40.65bcd
	95	40.96bcd	41.08bcd
Mean	-	-	41.5
CV	-	-	6.6
LSD	-	-	2.57*
CV: Coefficient of variation, LSD: Least significant difference.			

The spacing between plants and rows responded to this parameter in different ways. This indicates that both varieties need different spacing between plants and rows for tuber production and development. Accordingly, Ararsa variety gives the maximum tuber yield (42.72 t ha^{-1}) at 30 cm x 75 cm spacing between plants and rows whereas Gudane variety gives the highest total tuber yield (44.72 t ha^{-1}) at 40 cm x 75 cm spacing between plants and rows. This may due to the variation in morphological characteristics of the varieties.

Conclusion and Recommendation

Field experiment conducted at Sinana on station, Goba and Upper Dinsho for three consecutive years showed that different spacing between plants and rows responded to growth, yield components parameters and total tuber yield in different way. This may due to the genetic variation of the varieties which contributes for different morphological characteristics of the crop. Therefore, it was determined that different spacing between plants and rows required for tuber production and development.

To conclude Ararsa variety gives the highest number of marketable tuber per plot, the highest weight of marketable tuber per plot, the minimum number of marketable tuber per plot, the minimum weight of unmarketable tuber per plot and the highest tuber yield at 30 cm x 75 cm spacing between plants and rows. On the other hand, the maximum number of marketable tuber per plot, the highest weight of marketable tuber per plot, the lowest number of unmarketable tuber per plot, the highest weight of marketable tuber per plot and the highest tuber yield was recorded for Gudane variety at 40 cm x 75 cm spacing between plants and rows. Therefore, 30 cm x 75 cm and 40 cm x 75 cm spacing was recommended for Ararsa and Gudane variety producers respectively at the highlands of Bale.

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