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Effects of Intra-Row Spacing on Vegetative Growth Performance of Potato *(Solanumtuberosum L)* at Wolkite University, Ethiopia

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Abstract: An experiment was conducted on the effects of the intra-row spacing on the yield and yield components of potato cultivars in Wolkite University College of agriculture and natural resource. The treatments include three intra-row spacing (20 cm, 30 cm and 40, 50 cm). The treatments were arranged in the randomized complete block design (RCBD) replicated three times. Data was collected on number of leaves per plant, number of stem, leaf length, above ground fresh weight. Analysis of variance for all considered parameters (Leaf length, Number of Branches per plant, Number of Stem per plant, Number of leaf per plant, Plant height, above ground fresh weight). Among the studied characters leaf length, number of leaf per plant and above ground fresh weight were statistically different ($p<0.05$). However number of branches per plant, number of stem per plant and plant height were not statistically different. Cultivar *Gudenie* at 50 cm was shown significantly higher leaf length, number of leaf per plant and above ground fresh weight. Generally there was no significant effect number of branches per plant, number of stem per plant and plant height of the cultivar. Finally, it is better to study the effects of the spacing between plants with cultivars on yield to recommend the spacing in the study area. In addition to that since the best results were shown with 50 cm between plants, it is better to study more wider spacing along with economic analysis and objective stated. This is a short term strategy; therefore, the study should be repeated over year. In order to address the significance of all the studied characters and to recommend the appropriate intra-row spacing for the studied area.

Keywords: Intra-Row Spacing, Gudenie Variety, Potato

1. Introduction

Potato (*Solanumtuberosum L*) is an annual, herbaceous, dicotyledonous plant belonging to the nightshade family, *Solanaceae*. The origin of potato is in South America [13]. It was introduced to Ethiopia in 1858 by the German Botanist, Schemper [15]. The total production was estimated to be more than 5.2 million quintals in year 2007 [12]. Since then, potato has become an important garden crop in many parts of the country especially in the high lands parts.

In terms of volume of production potato is the fourth most important food in the world following rice, corn and wheat [12, 7]. It is a stable food crop in some countries and in others; it is used as vegetable [11]. In the year 2007 the total volume of world potato production was more than 325.3 million tons that was harvested from the total area of 19.33 million hectare. In the same year in Africa potato, production was 16.71 million tons from 1.54 million hectare [12, 7]. In the world potato is grown in more than 125 countries [7].

It is the second only to maize in terms of the number of producer countries. Potato was introduced to Ethiopia in 1858 by the German Botanist [15]. Since then, potato becomes an important garden crop in many parts of the country. About 70% of the available agricultural land is suitable for potato production which is located at an altitude of 1500 to 3000 m.a.s.l with an annual rainfall between 600 and 1200 mm [9]. The total area under potato production had reached 73,095 hectare and the production was

estimated to be more than 5.2 million quintals in the year 2007 [20]. Despite these facts, the national average yield of potato is 7.2 t ha^{-1} which is lower than the world's average 16.8 t ha^{-1}.

This is attributed to factors such as poor agronomic practices, lack of sustainable supply of improved planting material, high cost of seed tubers, disease and pest problem and in adequate storage [2]. According to [5], the absence of optimal intra-row spacing practices could significantly reduce total tuber yield up to 50%. Therefore, optimization of intra-row spacing is the one of most important agronomic practices of potato production as it affects the seed cost, plant development and potato tuber yield [10]. Any intra-row spacing variation could influence biomass accumulation and subsequently tuber number [16].

Potato ranks fourth important crop in the world. But due to inappropriate management system of production, the yield is below the potential of the crop as well as the farmer or producer can gain. Factors such as poor agronomic practices, lack of sustainable supply improved planting material, high cost of seed tubers; disease and pest problem and inadequate storage [2] are common problems of potato production. In lack of optimum plant spacing and lack of improved variety may be the factors for low productivity of potato. Farmers in the study area are using different spacing below or above the national recommendation depending on the purpose of planting either for consumption or for seed tuber due to lack of recommended inter and intra row spacing. Hence, it is important to maintain appropriate plant population per unit area to have high yield, marketable size and good quality of seed tuber. Even though different research was done in different part of the country on potato plant density but not under wolkite condition. Therefore, the present study was undertaken with the following objective.

To determine the optimal intra-row spacing for growth performance and yield of potato.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Wolkite University, College of Agriculture experimental site. Wolkite University, which is situated at Gurage zone of South Nation Nationality of people geographically located 158 km away from the capital city of Ethiopia, situated between 37^0 40'Elatitude and 8^0 20'Nlongitudeand between elevation of 1,001 to 3,662 m.a.s.l in Gurage administrative zone. The Guragae zone has different agro climatic zones as dega, Woinadega and Kolla and receives an average annual rainfall of 1100 mm with average minimum and maximum temperatures of 12°C and 30°C respectively. The dominant soil type of the area is vertisol 80%, red soil 15% and brown soil 5%.

2.2. Experimental Treatment and Design

Potato tuber was used for the experiment since the varieties are potential for central highland including in wolkite. This potato variety namely Gudenie with four levels of intra row spacing 20 cm, 30 cm, 40 cm, and 50 cm per row was laid out in arrangement. Treatments were arranged using randomized complete block design (RCBD) with three replications.

2.3. Experimental Procedures

For the experiment a plot size of 8.25 m^2 (2.75 m length and 3 m width) with the total area of 145 m^2 was used. A distance of 0.3 m was maintained between the plots and 0.5 m distance was maintained between blocks. 0.6 m row spacing was uniformly to be used. Well sprouted uniform tuber seeds of potato varieties are planted at uniform depth. Nitrogen and phosphorus was applied in the form of DAP during planting time at the rate of 195 kg ha^{-1} and nitrogen was also applied in split, first band of planting and then side dressed after full emergence at a rate of 165 kg ha^{-1} [4].

More than three times earthing- up between 5 days interval after planting was applied. Cultural practices such as weeding, cultivation and ridging was carried our as per the recommendation of the horticulture division of the site selection field proposal Center. To control diseases and pests regular flow up was done and unfortunately there was no recorded diseases and insect problem.

2.4. Data Collection and Sampling

Number of stems per plant (count): Only the main stems i.e. those originating from the mother tubers was counted. Numbers of stems per plant was record as the average stem count of three hills per plot.

Plant height (cm): Plant height was obtained by measuring from the base of the plant to the apical bud. The measurement was taken at the 13^{th} week after planting.

Number of leaves per plant: The compound leaves from the base to the tip of the plants were counted at 13^{th} week weeks after planting.

Leaf Length (cm): The compound leaves from the base to the tip of the plant was measured at 13^{th} week weeks after planting.

Above ground fresh weight (g): Six plants were obtained above the ground from each plot by destruction and measured the fresh biomass with sensitive balance immediately after destruction.

2.5. Data Analysis

Data was subjected to analysis of variance of the GLM procedure for RCBD scheme in Randomized Complete Block Design (RCBD) by Statistical software version 9.1 [17]. Means was compared using LSD value at 5% Significance Level [14].

3. Results

Table 1. *Means of different characters for the treatments.*

Treatment	Leaf length	Number of Branch per plant	Number of leaf per plant	Number of stem per plant	Plant height	Fresh Weight
1	8.98[b]	34.45[a]	75.98[a]	7.33[ba]	46.74[a]	82.65[a]
2	10.22[a]	25.59[a]	71.18[a]	8.09[a]	46.98[a]	83.46[a]
3	9.5[ba]	22.06[a]	49.79[b]	5.34[b]	43.9[a]	58.53[b]
4	10.28[a]	31.98[a]	67.85[a]	6.24[ba]	44.11[a]	81.97[a]
Grand Mean	9.75	28.52	66.2	6.75	45.43	76.65
CV%	4.94	54.07	12.19	18.67	6.06	12.42

Means followed by different letters differ significantly at $p<0.05$

4. Discussion

4.1. Leaf Length

The analysis of variance showed that Leaf length was significantly different ($P \leq 0.05$) affected by intra row spacing. The mean performance of the treatments indicated that the maximum leaf length (10.28) were recorded from the 50 cm (Table 1) than 20, 30, 40 cm. This indicated that the increment of spacing had an advantageous for leaf length. But no significant different was recorded among 30 cm, 40 cm and 50 cm. Which means that treatment one is significantly different with other treatments. The significance difference observed on treatment one as compared to each other's. According to the experiment the best one is 50 cm

4.2. The Number of Branches Per Plants

The analysis of variance showed that the number of branches was not-significantly different ($p>0.05$) affected by spacing (Appendix Table 2). However the mean performance of the treatments indicated that the spacing increases the number of branches were also increased (34.45) intra row spacing shown at 20 cm count in numbers because of different factor such as direct sun light absorption, more nutrient up take, active photosynthesis activity enhanced, well condition of the crop and also other factor occurs. but in lower spacing number of branch is decreased (22.06) due to lack of suitable growth factor show in (table 2). At (40 cm) the recommended one the research shown that not significantly different among 20 cm, 30 cm and 50 cm and also significantly different with in 20 cm with 40 cm. This implies that use any of the spacing for planting did not affect on number of branch in significant way. The observed gradual decline in number of branches were recorded due to density increased was in line with earlier report of [1] on potato plant.

4.3. Number of Leaf Per Plant

The analysis of variance showed that Number of leaf was significantly different ($P \leq 0.05$). The mean performance of the treatments indicated that the wider spacing (40 cm) had small number of leaf per plant as compared to the narrow spacing (20 and 30 cm). But at 50 cm the number of leaves per plant more from treatment three less stayed similar with that of the narrow spacing (treatment one and two). Moreover treatment one was significantly different from treatment three but not significantly different with treatment two and four. This result in line with (Mehla *et al*., 2000), described the same trend was observed in the intra row spacing treatments. But, the interaction was not statistically significant on the number of leaves per plant both 15 days after emergence and 30 days after emergence. This can be attributed to the less competition for available nutrients, water and light by the plants in the early growth and development stages.

4.4. Number of Stem Per Plants

The analysis of variance showed that the number of stem was non significantly different ($p>0.05$) (Appendix Table 4). The effect of intra row spacing of potato within the four treatments was showed that when the spacing was increased there was reduced number of stem per plants. The reason is at 40 cm the potato growth is increased more wider vegetative no more number of stem because competitions is easier for water nutrient and other essential substances for potato growth but the stem is very broad and thick. In the case of lower intra row spacing the number of stem per plant is increased (8.09) due to the above factor sever competition at (20 cm). According to the above information the research shown at (30 cm) was recommended and acceptable. The results showed that the closer spacing (20) had more number of stems per m^2 compared to low number of stems for plants at (30 cm) spacing (Table 1). The present study supported Number of main stem or branch per plant were not influenced by plant spacing as reported by different workers [3].

4.5. Plant Height

Results of the analysis of variance indicated that intra-row spacing were shown non-significantly ($p>0.05$) effect on plant height of potato plant. But the mean performances numerically the study was able to show a difference among the treatments in such a way that the maximum plant height (46.98) was shown in plants with intra-row spacing of 20 cm than 40 cm, 50 cm in (Table 1). Plants having 40 cm intra-row spacing was shown slightly lower plant height (43.9) with compared to that of 20 cm, 30 cm (46.98) and 50 cm (44.11). The higher plant height in closer intra-row spacing due to the response of higher competition for sunlight among plants.

The result of the experiment was controversial with the

findings of [19] who reported that the widest spacing enhances growth and height of the plant which was significantly different from narrow spacing. This current finding is also controversial by a study made by [8], They reported that significant effect of spacing on plant height, as a result of availability of wider inter row spacing for growth factor.

4.6. Above Ground Fresh Weight

The analysis of variance indicated that above ground fresh weight was significantly ($P \leq 0.05$) affected by spacing. The mean performance of the treatments indicated that there was increased in above ground fresh weight with increasing spacing between plants. Treatment one was significantly different with treatment three but not significantly different with two and four. Because of the stem, branch, leaf length, is wider the total above fresh weight increased but the spacing decreased the above factor such as stem, branch leaf length and leaf width is thin and narrow so small fresh weight. From the present research information at (20 cm) is recommended rather than other intra row spacing. Similarly, [20] concluded that closer intra row spacing (higher plant density) resulted in the highest plant height. However, Number of main stem or branch per plant were not influenced by plant spacing as reported by different workers [3] but stem number increased as a result of either by planting smaller tuber size or more tuber number per unit area pre plant [18]. It is a function of seed pieces type as their production was not affected by plant density nor excess application of fertilizers but, can significantly be affected by altering the planting date [6].

5. Conclusion

Potato is an annual, herbaceous, dicotyledonous plant belongs to night shade family, solanaceae. Any intra –row spacing variation could influence biomass accumulation and subsequently tuber numbers. Even if potato ranks fourth important crop many factors such as poor agronomic practice, lack of improved planting material, high cost of tubers, the production and productivity of the crop. Hence, application of appropriate agronomic practices is important to achieve the potential yield of the crop. There for, an experiment was done on the effects of intra-row spacing on growth performance of potato in 2015 in central highlands of Ethiopia, Wolkite demonstration and research farm.

To do that one varieties of potato namely, Gudenie varieties was tested with four intra-row spacing Viz. 20, 30, 40 and 50 cm. the treatments were arranged in RCBD design replicated three times and results were analyzed.

Analysis of variance for all considered parameters (Leaf length, Number of Branches per plant, Number of Stem per plant, Number of leaf per plant, Plant height, above ground fresh weight). Among the studied characters leaf length, number of leaf per plant and above ground fresh weight were statistically different ($p<0.05$). However number of branches per plant, number of stem per plant and plant height were not statistically different. This could be due to short growing period provided for the crop to observe the differences between intra-row spacing.

Generally the experiment with 50 cm inra-row spacing was shown better performance in the existing parameter as compared to other treatment. Therefore, since best result was shown with wider spacing it better to work with more spacing wider beyond this spacing along with its economic analysis and objective stated. Since the recommended using 50 cm intra-row spacing until another investigation was done. This is a short term strategy; therefore, the study should be repeated over year. In order to address the significance of all the studied characters and to recommend the appropriate intra-row spacing for the studied area.

Appendix

Table A1. *Analysis of Variance for Leaf length.*

Source	Df	SS	MS	F computed	F tab
Block	2	5.75	2.88		
Treatment	3	3.47	1.16	4.99*	4.76
Error	6	1.39	0.23		
Total	11	10.62			

Table A2. *Analysis of Variance for Number of Branches per plant.*

Source	Df	SS	MS	F computed	F tab
Block	2	475.34	237.67		
Treatment	3	292.38	97.46	0.41^{ns}	4.76
Error	6	1426.57	237.76		
Total	11	2194.28			

Table A3. *Analysis of Variance for Number of Stem per plant.*

Source	Df	SS	MS	F computed	F tab
Block	2	0.56	0.28		
Treatment	3	13.18	4.39	2.77^{ns}	4.76
Error	6	9.5	1.59		
Total	11	23.27			

Table A4. *Analysis of Variance for Number of leaf per plant.*

Source	Df	SS	MS	F computed	F tab
Block	2	193.13	96.57		
Treatment	3	1176.82	392.27	6.02*	4.76
Error	6	391.03	65.17		
Total	11	1760.98			

Table A5. *Analysis of Variance for Plant height.*

Source	Df	SS	MS	F computed	F tab
Block	2	27.57	13.78		
Treatment	3	24.55	8.18	1.08^{ns}	4.76
Error	6	45.54	7.59		
Total	11	97.66			

Table A6. *Analysis of Variance for above ground fresh weight.*

Source	Df	SS	MS	F computed	F tab
Block	2	912.46	456.23		
Treatment	3	1317.16	439.05	4.84*	4.76
Error	6	544.13	90.69		
Total	11	2773.76			

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