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Consequence of Inter and Intra-Row Spacing on Growth and Yield Components of Potato (SolaniumTubersom L.) under Irrigation at North Shewa Zone of Oromia Region, Ethiopia

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Abstract
Lack of production practices have been the major bottleneck of potato production and productivities in oromia, particularly at Fitche area. Since there have been no recommended inter and intra row spacing, farmers used to practice non-uniform plant spacing. Thus, a field experiment was conducted to investigate the influence of intra and inter row spacing on growth and yield parameters of potato, thereby to recommended the optimum intra and inter row spacing practices to farmers in the study area. The study was conducted between August 2015 and April 2016 at Fitchearea(Addis Ababa university Salalecampus, demonstration field).Four different intra and inter row spacing's (60*20, 60*25, 60*30,70*20,70*25,70*30,80*20,80*25 and 80*30) were evaluated using one variety of potato (Managasha) laid out in randomized complete block design replicated three times. Data on growth and yield parameters were recorded and subjected to analysis of variance (ANOVA). Results indicated that inter and intra row spacing of 80*30 was superior in growth parameters such as, days to 50% flowering,days to 70% maturity, stem diameter, main stem number, plant height. Mean tuber no. count hill^{-1}, Total tuber yield (t/ha), Marketable tuber yield(t/ha), were better at wider intra and inter row spacing (80*30).But Un marketable tuber yield(t/ha) was superior at closest inter and intra row spacing (60*20).The 80*30 intra and inter row spacing is recommended for the growers of potato plant.
Keywords:-Inter and intra row spacing, North shewa Zone, potato

1. INTRODUCTION

Potato (*Solanum tuberosum*L.) is an annual, herbaceous, dicotyledonous plant belonging to the nightshadefamily, *Solanaceae*. The origin of potato is in South America (Smith, 1968). It was introduced to Ethiopia in 1895 by Schimper (German botanist). The total area under potato production in the world was estimated 36,736 ha with total annual production of 385,258 metric tons (FAO, 2008). The national average yield was about 10.5 tons/ha, which is very low compared to the world average of 16.4 tons/ha. At present, about 40,000 to 50,000 (ha) of land was under potato cultivation(FAO, 2008).

Potato is one of the most important food crops in the world. In volume of world crop production, it ranks fourth following wheat, maize, and rice (FAO, 1995). The production of potato is expanding at a faster rate than other food crops in developing countries, including Ethiopia (FAO, 1995).

The nutritional value of the potato crop has been well appreciated and documented (Horton, 1987). Potato produces more energy and protein per cultivated area and per unit of time than most other major crops; and it is fat-free and contains substantial amount of vitamins especially vitamins B and C, and minerals (CIP, 1988).

The crop has also proved that it has great potential for adaptation to the diverse growing conditions of the tropics where the majority of the developing countries are located. Nearly 75% of the world population (3.5 Billion) inhabits the 95 potato producing countries of the developing world (CIP, 1988). Besides, potato is also suited to small farmers in developing countries for its labor requirement is less than that of cereals. Its shorter growing period makes it possible for the small farmer to use this crop in a system where more than one crop is possible on the same land per season (Mangistu, 1982).

In Ethiopia, many production problems accounted for the low yield of potato. Among them, lack of proper planting material, inappropriate agronomic practices, absence of proper pest and disease management practices and unavailability of proper transport, storage and marketing facilities are the prominent ones (BerekeTsehai, 1994). Low soil fertility is also one of the factors limiting the productivity of crops, including potato (Tamirie, 1982; Berga*et al.*, 1994). Similarly, Bekele (2001) suggested that the annual total production is very low due to the acute shortage of good quality seed-potatoes, poor production and yielding capacities and high susceptibility to late blights. Tamirie speculated that this might be caused as a result of the removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmland and lack of proper crop rotation program. Traditionally, farmers maintain or improve the fertility of farmland soils either by practicing fallowing, use of farmyard manure, intercropping and/or crop rotation. The use of some of these cultural practices as a means of maintaining or improving soil fertility is limited to a great extent due to small land holdings of farmers.

The quality of seed tubers produced for production purpose depends on seed tuber size and plant population density per unit of land. But plant population per unit of land varies depend on the intended use of the crop for tuber seed or ware (Berga*et al*, 1994).In addition, require different spacing's between plants and also between rows for producing good quality seed tubers.

However, farmers in Ethiopia are not using the recommendations due to lack of awareness or it may not fit to the conditions of that specific area. Hence, it is important to identify appropriate plant population per unit land area. However, farmers in Fiche area have no experience of applying the nationally recommended plant spacing rather they randomly practice undetermined plant spacing and there is no any study conducted before which assures whether the recommended plant spacing works effectively or not in fiche area. In view of these, the present study was initiated to find out optimum intra and inter row spacing of local potato cultivar for Fiche district and the study will be conducted with the following objective:

- To determine and suggest appropriateintra and inter - row spacing on the growth and yield of potatofor fiche district.

2.MATERIALS AND METHODS

2.1 Description of the Study Area

The experiment was conducted in 2015/2016 from August2015to April2016 under irrigated condition at Fiche area (Addis Ababa University, Selale campus demonstration field) which is found 112 km far from Addis Ababa. The experimental site lies an altitude of about 2750m above sea level and which located at latitude 9°48″0″ N and longitude 38°42″0″E. Fitche district is characterized by highland agro ecological zone which have average temperature of 16.5°c and average rainfall of 1150 mm per year. The soil type is clay with PH of 6.4 (Fitche metrological station, 2014/15).

2.2 Treatments and Experimental Design

A field experiments was conducted on two factorial combination of two different inter and intra row spacing level (60 ,70& 80 and 20, 25& 30cm respectively). The experiment was include a total of 9 treatment combinations (60×20, 60×25, 60*30, 70×20,70*25 , 70×30, 80*20,80*25and 80*30). The experiment was laid out in randomized Complete block design (RCBD) with three replications and there was a total of 27 plots. The size of each plot was 2m x 1.5m (3m^2) the distance between plots and blocks was 0.5 m and 1 m, respectively.

2.3 Experimental Procedure

Seed was obtained from Holeta Agricultural Research Center (HARC). Before sowing seeds, the experimental field was plowed and harrowed using ox drawn plowing. Large clods was broken down in order to make the land fine tilth, and then 27 (twenty seven) plots with size of 2m x1.5m was measured and laid out. Irrigation and drainage channels were designed for conveyance and drainage of excess water. The plots was leveled; furrows and ridges was made. Seed with piece of potato tuber contained two eyes was sowed on 15/02/2016 G.C.

A two day irrigation interval was maintained for the 1st four weeks and then extended to seven days interval until 15 days to harvest, when irrigation was stopped completely. Other recommended agronomic practices like, weeding, plant protection, etc., was kept uniform for all treatments. Harvesting of potato tubers was done when 70% plants show neck fall (EARO, 2004). After harvest potato was cured for four (4) days by windrowing on the ground.

3.4 Data collection

The growth and yield data were collected during the field experiment from 5 (five)previously tagged plants randomly from each plot except flowering date and days to maturity which were determined on plot basis. Accordingly, the following data were collected.

3.4.1 Growth parameters

Flowering date was record as the actual number of days from the date of planting to when 50% of plants was produced flower in each plot (EARO, 2008).Days to maturity was the actual number of days from the day of planting to the time when 70% of plants' foliage fall down (EARO, 2004) in the field experiment. Plant height was alsomeasured in centimeter from the soil surface to the tip of matured leaf in the plant at maturity. Refers to the mean number of leaves per plant produced by sampled plants and was calculated by dividing the total number of leaves counted from the sampled plants to the number of sampled plants to get mean leaf number per plant.Main stem(branch) number per plantwas calculated by dividing the total number of stems counted from the sampled plants to the number of sampled plants to get mean stem number per plant.

3.4.2 Yield and yield components

The average weight of matured tubers of sampled plantswere taken using a sensitive balance after harvesting and curing. The mean number of tuber was collected frompreviously tagged plants and was calculated by dividing the total number of tubers counted from the sampled plants to the number of sampled plants to get mean tuber number per plant.Total tuber yield was collected from tagged plants and marketable tuber yield was differentiated from unmarketable tuber yield depending on their size, colored, shape and other characters.

3.5 Data Analysis

The data collected were subjected to analysis of variance (ANOVA), analysis using SAS 2003 version 9.1.3 . andmean separation was done by using LSD at 5% probability level.

4. RESULTS AND DISCUSSION

4.1 Effect of intra and inter row spacing on growth parameters

The interaction of inter and intra row spacing were found highly significant at (p<0.05) on all the growth parameters studied including days to 50% flowering and maturity, plant height, stem diameter, leaf area and main stem number (Table1).

Table 1: Interaction effect of inter and intra row spacing on Days to flowering and maturity, plant height , Main stem and Leaf number per plant

Treatment	Days to 50% flowering	Days to 70% maturity	Plant height (cm)	Main stem no.	Leaf number per plant
60*20	60.66[d]	107.33f	51f	2.3e	152.33f
60*25	62.67[cd]	108.33f	54.33e	3.33bcd	191.67e
60*30	66.67[ab]	110.33d	3.57d	3d	241a
70*20	63.67[c]	109.33d	53c	2.41e	197.33de
70*25	64.33[c]	111.66c	58.66c	3.58cb	205e
70*30	68.66[ab]	112c	62.33ab	3.75b	242.67a
80*20	64[c]	112.33cb	58dc	3.16cd	209.33c
80*25	67[b]	113.33b	61b	3.66b	227.33b
80*30	69.33[a]	114.66a	63.33a	4.5a	245.66a
LSD (%)	1.87	0.58	1.40	8.35	2.49
CV (%)	2.11	1.13	1.41	0.47	9.17

The diverseletters pointout that differ significantly at p<0.05

4.1.1 Days to 50% flowering

The delayed days to 50% flowering (69.33) was observed in 80*30 cm interand intra row spacing. Whereas, earliest days to 50% flowering(60.66) was observed at the closer intra and inter row spacing of 60*20cm (Table 1). Days to 50% flowering was delayed by about 9 days in the wider interand intra row spacing (80*30cm) as compared to the closest intra and inter row spacing of 60*20cm.

In the closer intra and inter row spacing that lead the plants to stress and ultimately the plants flower early instead of prolonged vegetative growth.This may possibly be due to higher competition of plants for resources Thisend result is in conformity with the work of Eghareyba (2009)who reported that, days to 50% flowering was prolonged for plants grown with lower planting density (wider intra row spacing).

4.1.2 Days to 50% maturity

The extended days to 50% maturity (114.66 days) was observed at the wider inter and intra row spacing of 80*30cm but earliest days to 50% maturity (107.33 days) was observed at the closer interand inter row spacing of 60*20cm (Table 1). Days to 50% maturity was delayed by 7.33 days in the wider inter and intra row spacing (80*30) as compared to the closest inter and intra row spacing of 60*20cm. This could be due to the presence of intense inter plant competition at the closer inter and intra row spacing that leads to depletion of the available nutrient and as a result plants stressed and tend to mature earlier. The current finding is in agreement with the work of (Mengistu and Yamoah, 2010) who concluded that closer intra and inter row spacing (increasing planting density) had shortened days to maturity.

4.1.3 Plant height

The maximum plant height (63.33cm) was obtained at the wider inter and intra row spacing of 80*30cm. However, the shortest plant height (51cm) was recorded at the closer inter and intra row spacing of 60*20cm. This is significantly different from the plant height obtained at 80*30cm interand intra row spacing (Table 1). This might be due to the presence of higher competition for sunlight and space among plants grown at the closer inter and intra row spacing. This is in agreement with the finding ofZaag*et al.* (1989) who indicated that plant height has no significance in all treatments. As intra row spacing increased plant height decreased linearly (Dennis et al.,1994).Zeberth*et al.* (2006)concluded that closer inter and intra row spacing (higher plant density) resulted in the highest plant height.

4.1.4 Main stem number

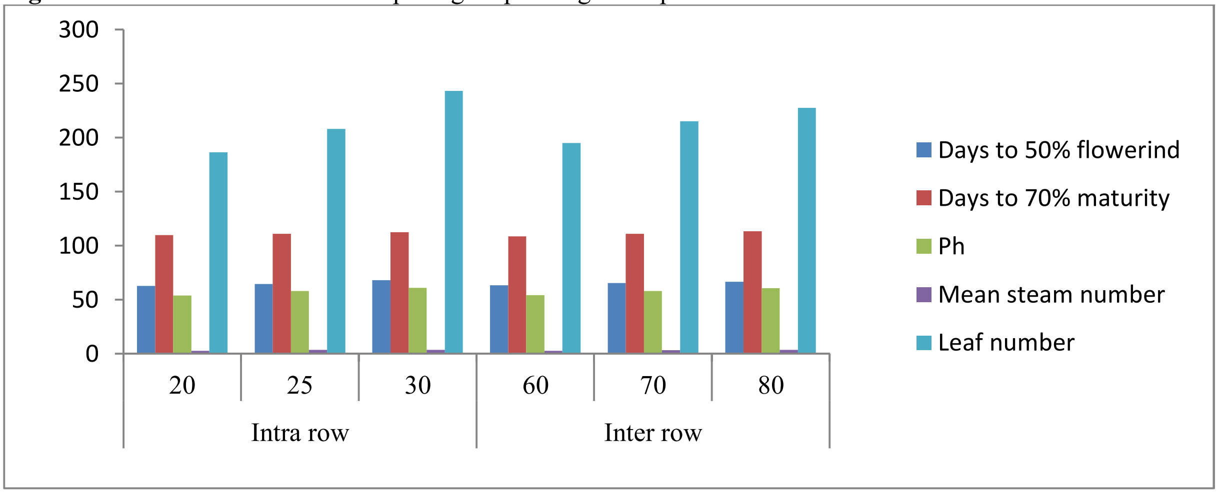
Appreciably the highest main stem number (4.5) was recorded at the wider inter and intra row spacing of 80*30cm but the lowest main stem number (2.3) was obtained at the closer inter and intra row spacing of 60*20cm. About 3 and 3.16 main stem number was recorded at the inter and intra row spacing of 60*30 and

80*20 cm, respectively (Table 1). This might be due to the fact that higher competition for sunlight, nutrient and space among plants grown at the closer intra and inter row spacing to the plant during its active growth stage, enhanced the growth and development of more number of stems. The result of this current investigation is in agreement with the work ofQadir (1997) who found that number of stems per plant (4.44) was significantly higher when plants were wide space.

4.15 Leaf number per plant

The largest leaf number per plant (245.66) was obtained at the wider inter and intra row spacing of 70*30 and 80*30cm while the smallest leaf number per plant (152.33) was recorded at the closer inter and intra row spacing of 60*20cm (Table 1). At the wider intra row spacing due to the presence of minimum competition, plants absorbed the sufficiently available resources and lighter and increased their photosynthetic efficiency that further increased the vegetative growth and ultimately resulted in increased leaf number per plant.Oliveira,(2000) also confirmed that leaf area decreased in the closer intra row spacing compared to the wider intra row spacing that resulted in longer leaf area.

Fig.1. Effect of Inter and Intra row spacing on potato growth parameters.



4.2 Effect of intra and inter row spacing up on yield parameters scope

The effect of inter and intra row spacing were found highly significant (p<0.05) onyield parameters studied including tuber number, total tuber yield and marketable tuber yield **(**Table2).

Table 2: Interaction effect of inter and intra row spacing on tuber number, total yield, marketable yield and unmarketable yield.

Treatment	Mean tuber no. count hill^{-1}	Total tuber yield (t/ha)	Marketable tuber yield(t/ha)	Un marketable tuber yield(t/ha)
60*20	8.56g	31dc	23.08e	14.18a
60*25	10.46f	36.66b	24.20ed	11.73b
60*30	12.6e	38.33ab	26.66c	9.67c
70*20	12.53de	26.66e	24.67d	11.5b
70*25	13.53bc	30d	26.66c	8.08cd
70*30	14.28b	37.33b	28b	6.63ed
80*20	13dc	27.66e	26.20c	6.83de
80*25	12.72dce	33c	28.33b	5.5fe
80*30	14.56a	40.33a	29.66a	4.33f
LSD (%)	3.92	3.89	2.83	10.73
CV (%)	0.84	2.25	1.29	1.62

Means followed by different letters differ significantly at p<0.05

4.3 Tuber number:

The highest number of tubers per plant (14.56) was recorded at the wider inter and intra row spacing of 80*30cm whereas the lowest number of tubers per plant (8.56) was obtained at the closer inter row intra row spacing of 60*20 cm (Table 2). In the wider intra and inter row spacing there could be minimum competition among plants for space and resources and also better plant exposure for high radiation interception that increased the photosynthetic efficiency of the plant and finally resulting in increased number of tubers per plant. Similar to the result of the current investigation Mahmood (2005) also reported that maximum numbers of tubers per plant was obtained in the wider intra and inter row spacing.

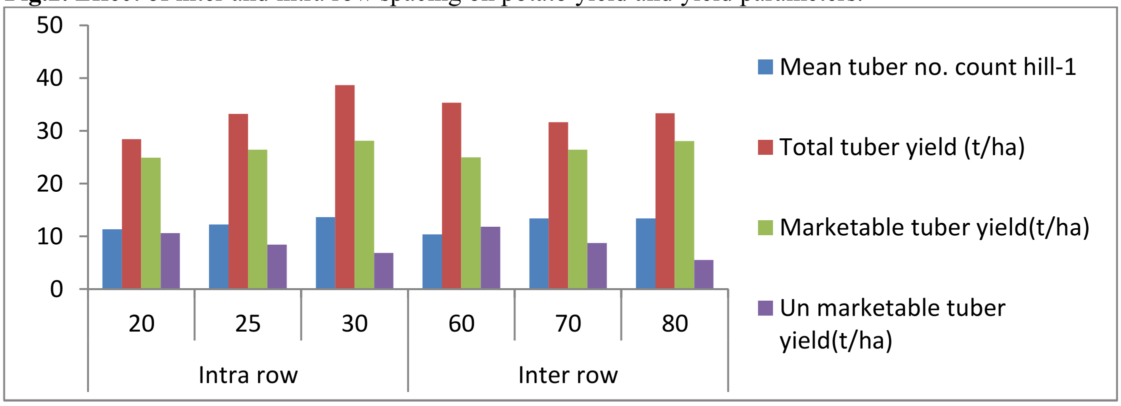
4.4 Total tuber yield

The highest tuber yield per hectare (40.33t ha^{-1}) was obtained at the wider inter and intra row spacing of 80*30 cm whereas the lowest (26.66t ha^{-1}) was obtained at the closer inter and intra row spacing of 70*20cm (Table 2). This is due to the compensation effect of closer inter and intra row spaced plants per hectare than the wider intra and inter row spacing which resulted in higher yield of tubers per plant. In a similar manner Burton (1989) also investigated the effect of intra row spacing on the yield of potato and finally concluded that in a wider intra row spacing yield per hectare was reduced due to the insufficient number of plants grown per hectare compared to plants grown at closer intra row spacing per hectare.

4.5 Marketable tuber yield

The highest marketable tuber yield (29.66t ha^{-1}) was obtained at the wider inter and intra row spacing of 80*20 cm whereas the lowest (23.08t ha^{-1}) was obtained at the closer inter and intera row spacing of 60*20 cm (Table 2). At the wider inter and intra row spacing scored highest tuber yield due to the presence of minimum competition, plants absorbed the sufficiently available resources and intercepted more light. This increased their photosynthetic efficiency for higher photo assimilate production and ultimately resulted in increased more marketable tuber yield. The result of the current investigation is similar with the result of (Dwelle and Love (1993) who concluded that in closer intra row spacing bulking rate of individual tubers decrease and this resulted in smaller tubers and lower marketable tuber yield.

Fig.2. Effect of inter and intra row spacing on potato yield and yield parameters.



4.6 Unmarketable tuber yield

The highest unmarketable tuber yield (14.18t ha^{-1}) was obtained at the closer inter and intra row spacing of 60*20 cm. However, the lowest unmarketable tuber yield (4.33t ha^{-1}) was obtained at the wider inter and inter row spacing of 80*30 cm (Table 2). This could be due to the existence of higher computation between plants in closer intra row spaced plants that results more number of under sized tubers that leads to the less quality product. Marketable tuber yield increased in the wider intra row spacing (Zaag*et al.*,1989). In this experiment, unmarketable tuber yield was assessed by identifying under sized, diseased, deformed and green potato tubers and the most important reason for unmarketability is under sized potato tuber.

5. CONCLUSION AND RECOMMENDATION

The present study confirmed that inter and intra row spacing significantly affected days to 50% flowering and maturity, plant height, tuber number, total tuber yield and marketable tuber yield. It can be concluded from this study that for the majority of the growth parameters 80*30cm inter and intra row spacing are preferable. Similarly, the highest total tuber yield (40.33t ha^{-1}) and lowestunmarketable tuber yield (4.33 t ha^{-1}) was produced at the wider inter and intra row spacing of 80*30cm. But from the total tuber yield produced in the closest intra row spacing of 60*20cm 14.18t % was unmarketable and hence, significantly the highest marketable tuber yield (29.66 t ha^{-1}) was obtained at the wider intra row spacing of 80*30 cm.The 80*30 intra and inter row spacing is recommended for the growers of potato plant because of it gives high plant height, tuber number, total tuber yield and marketable tuber yield while it gives low unmarketable yield.

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