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EFFECT OF PLANT POPULATION AND HARVESTING TIME ON GROWTH AND DRY MATTER PRODUCTION OF POTATO (*SOLANUM TUBEROSUM* L.)

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ABSTRACT: A field study was conducted involving potato varieties Al-111 and Al-624 with four population densities (88,888, 66,666, 44,444 and 33,333 plants/ha) and three harvesting times (70, 90 and 110 days after planting) to determine their influence on growth and dry matter production at Rarie, Alemaya University during the main season of 2000. High plant population significantly increased plant height but reduced number of branches, number of leaves, and haulm fresh and dry weights on per plant basis. Highly significant increase in tuber dry matter yield was recorded with increased plant population and delayed harvesting. A plant population of about 88,888 plants/ha and harvesting at 90^{th} day after planting (DAP) promoted production of maximum dry matter yield per unit area, irrespective of varieties studied.

Key words/phrases: Assimilate partitioning; Bulking rate and duration; Leaf area index and tuber dry matter production.

INTRODUCTION

Agronomic practices like population density and harvesting time appear to have a significant effect on yield and tuber dry matter production of potatoes; and factors which influenced the overall dry matter content stored in tubers also affect tuber yield (Beukema and Zaag, 1990). Allen and Scott (1980) reported increase in yield in increased plant population. This could be due to increased percent ground cover where more light was intercepted, consequently influencing photosynthesis. It is, therefore, very likely that substantial increases in rate of leaf cover and thereby tuber yield could be achieved by dramatically increasing stem density, either by increasing the size of the seed or the number planted.

On the other hand Beukema and Zaag (1990) reported that a high plant density stimulated early tuber growth (and also an early maturing crop). This was attributed to the ground being covered with foliage earlier (early season, more light intercepted and used for assimilation), fewer lateral branches being formed, and hence early start of tuber growth.

Early or late harvesting of the crop may be required because of various

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reasons, e.g., market price, prevailing and expected field conditions, the opportunity cost of land and the need for additional food for family (Beukema and Zaag, 1990), especially under conditions of subsistence farming. Harvesting time could influence both yield as well as quality by affecting the optimum bulking period (Beukema and Zaag, 1990).

Generally there appears to be little consistency among research reports on the study of influence of population density and/or harvesting time on growth and dry matter production of potatoes. Therefore, this paper presents data on the effect of varying population densities and harvesting times on growth and tuber dry matter production of potato varieties, Al-111 and Al-624 under semi-arid highland conditions of Eastern Ethiopia.

MATERIALS AND METHODS

The experiment was laid out in a split plot design to fit into randomized complete blocks with three replications. The two varieties were assigned to the main plot, while the twelve combination treatments representing planting densities (4) and harvesting time (3) to the sub plots were assigned. Whole seed tubers of medium size, ranging from 40-70 g of the respective varieties viz., Al-111 (V_1) and Al-624 (V_2) which had been stored for six months under diffuse light storage and had developed green, firm and strong sprouts were used for planting. A row spacing of 75 cm was uniformly adopted for all treatments while the intra-row spacings of 40 cm (P_1), 30 cm (P_2), 20 cm (P_3) and 15 cm (P_4), were adopted with a planting depth of 10 cm on a gross plot size of 8.1m^2 (4 rows with 5.4m length) and net plot size ranging from 6.30 m^2 to 7.43 m^2. The crop was harvested thrice at intervals of 20 days starting from 70th day after planting (DAP) (H_1), 90 DAP (H_2) and 110 DAP (H_3). Standard cultural practices applicable to the region were followed during the course of experimentation.

The mean number of stems, total number of leaves and leaf area index (LAI), as outlined by Firman and Allen (1989) [$\mathbf{log_{10}}$ (leaf area in cm^2) = 2.06 x $\mathbf{log_{10}}$ (leaf length in cm) – **0.458**] were recorded on per plant basis. Height and total number of branches of representative five stems were recorded at full growth stage. The fresh and dry (after oven drying at 100^0 C for 48 hours) weights of haulms of five randomly selected plants at first and second harvests were recorded and expressed as grams per plant. Tuber dry matter production was recorded and expressed on per plant and hectare basis.

RESULTS AND DISCUSSION

Growth Parameters

Plant height and stem number

Al-624 was taller than Al-111, attributable to genotypic character. Plant populations significantly affected plant height (Table 1). This could affect the standability of the crop and in turn affect the ability of the crop to intercept and utilize light (Ifenkwe and Allen, 1978). Inter-plant competition for light at high population densities might have contributed to increase in plant height at higher populations, which is in conformity with the observations of Ifenkwe and Allen (1978). This, however, was contrary to observations of Lynch and Rowberry (1977) who did not record any changes in plant height due to differences in plant population under Ontario (Canada) conditions.

Stem number per plant was not affected by varieties and plant population ($P<0.05$), probably because number of stems per seed tuber was determined early during sprouting. Similar results were obtained by Lynch and Rowberry (1977), Ifenkwe and Allen (1978) and Entz and Lacroix (1984).

Total number of branches

Al-624 was found to have significantly higher number of branches per stem than Al-111. Also the number of branches per stem decreased as population density increased (Table 1). These observations implied that branching could be a form of compensatory growth behavior or response. The increase in branch number at lower population densities obtained in the present study could be attributed to reduced inter-plant competition for growth factors like water, light and nutrients. This result is consistent with the observations of Lynch and Rowberry (1977), Ifenkwe and Allen (1978) and Entz and Lacroix (1984). This may be significant from the point of view of optimizing leaf area for satisfactory yields (Lynch and Rowberry, 1977). In contrast, Bremner and El Saeed (1963) observed no difference in axiliary branching due to plant population.

Total number of leaves and leaf area index

Leaf number per hill was significantly affected by plant population ($P<0.01$) but not by variety ($P<0.05$). The study also found an inverse relationship between population density and branch and leaf numbers (Table 1). The reduction in number of branches with concomitant reduction in number of leaves under high plant population could be due to competition for essential nutrients, particularly Nitrogen, whose shortage is reported to be associated with failure of latent meristems to develop (Bremner and El Saeed, 1963; Ifenkwe and Allen, 1978).

Table 1 Effect of variety and plant population on some vegetative growth parameters in potato varieties Al-111 (V_1) and Al-624 (V_2).

Parameter	Plant Population (P)	Variety V1	Variety V2	Mean
Plant height (cm)	P1	51.3	61.9	56.60c
	P2	53.8	64.7	59.22bc
	P3	57.1	66.6	61.83b
	P4	60.2	73.1	66.63a
	Mean	55.59	66.55	
Branch number per stem	P1	4.7	7.0	5.85a
	P2	4.4	6.0	5.12ab
	P3	3.6	5.6	4.57bc
	P4	2.7	4.9	3.79c
	Mean	3.83	5.87	
Leaf number per hill	P1	77.2	123.2	100.2a
	P2	57.1	105.9	81.53ab
	P3	56.5	87.7	72.12b
	P4	50.2	70.7	60.43b
	Mean	66.25	96.9	
Leaf area index	P1	1.91	2.68	2.29b
	P2	2.64	2.92	2.77b
	P3	3.66	4.12	3.89ab
	P4	4.60	4.90	4.57a
	Mean	3.20	3.65	
	Plant height P	Branch number P	Leaf number P	Leaf area index P
LSD 0.01	4.341	0.847	21.39	1.718

Means within column of respective parameters superscripted by the same letter are non-significant at 1% level.

Leaf area index (LAI) significantly increased with population density (Table 1). This result conformed with those of Bremner and EL Saeed (1963), Bremner and Taha (1966) and Ifenkwe and Allen (1978).

Haulm fresh and dry weights

Haulm fresh weights were recorded only at the first two harvesting dates as the third date corresponded to haulm senescence. A highly significant interaction was observed between variety and harvesting time (Fig. 1). The decrease in haulm fresh weight at the second harvest could be attributed to moisture loss and partitioning of assimilates to tubers with progress of maturity. Salter *et al.* (1980) recorded a similar observation in carrot.

Al-624 recorded significantly ($P<0.01$) higher (302.2 g/plant) haulm fresh weight than Al-111 (210.8 g/plant). Fresh haulm weight decreased significantly ($P<0.01$) with increasing population density (Table 2). Inter and intra-stem competitions may be responsible for the recorded differences.

This is in agreement with the observations of Moorby (1967) and Thompson and Taylor (1974) that the total haulm weight is a function of the number of branches and stems. This is further corroborated by the observation on number of branches in the present study where Al-624 recording higher number of branches (Table 1) also had higher haulm fresh weight.

Significant ($P<0.05$) interaction among variety and harvesting time was observed with trends similar to haulm fresh weight (Fig. 2). Al-624 recorded significantly ($P<0.05$) higher haulm dry weight than Al-111. This may be an effect of genotype (Beukema and Zaag, 1990). Highly significant influence ($P<0.01$) of plant population on dry weight of haulms was also observed with increases in dry weight associated with decrease in plant population (Table 2). The trend was similar to that of haulm fresh weight. Differences in net assimilation rate may be mainly responsible for the observed differences (Bremner and El Saeed, 1963; Ifenkwe and Allen, 1978). Harvesting time also significantly affected haulm dry weight. The fact that higher haulm dry weight (Table 2) was recorded at early harvest (H_1) than late harvest (H_2) perhaps indicated the effects of preferential assimilates partitioning to storage organs as the crop approached maturity stage (Bremner and Taha, 1966).

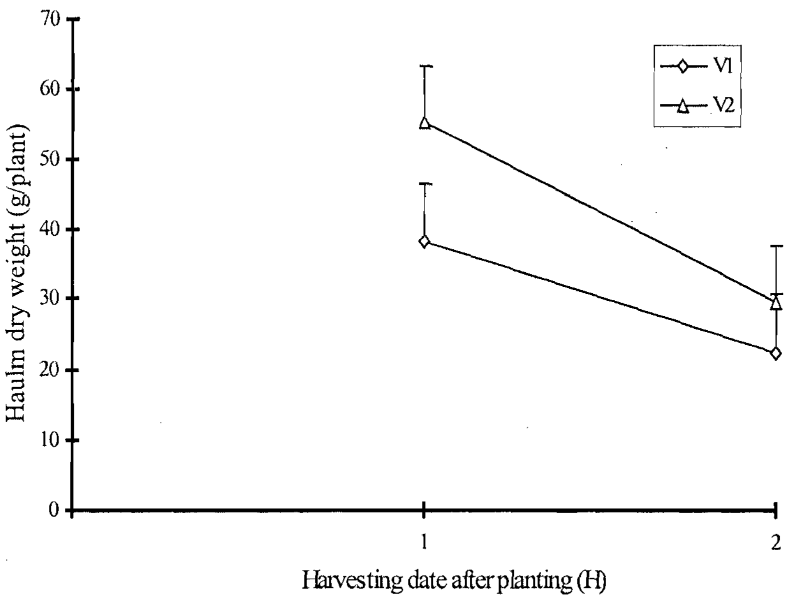

Fig. 1. Effect of variety and harvesting time on haulm fresh weight (g/plant). Vertical bars represent LSD at 1% level.

Table 2 Effect of plant population and harvesting time on haulm fresh weight (g/plant).

Harvesting	Plant Population (P)				
Date (H)	P_1	P_2	P_3	P_4	Mean
H_1	346.3(50.9)	410.2(55.2)	253.0(39.6)	294.9(40.8)	426.1(46.6)
H_2	224.3(32.65)	217.0(29.2)	177.3(23.9)	128.7(17.9)	186.8(25.9)
Mean	$285.3^{a}(41.8^{a})$	$313.6^{a}(42.2^{a})$	$215.1^{b}(31.7^{b})$	$211.8^{b}(29.3^{b})$	
	P				
LSD (0.01)	58.92(8.23)				

Means within row superscripted by the same letter are non-significant at 1% level.
Figures in parenthesis indicate corresponding dry weight.

Tuber Dry Matter Production

Highly significant interaction between variety and plant population with respect to tuber dry matter accumulation on per plant basis was recorded (Fig. 2). Highly significant interaction between variety and harvesting time was also recorded (Fig. 3). Similarly interaction between plant population and harvesting time was highly significant with first (70 DAP) and second (90 DAP) harvests indicating similar tuber dry matter content at all plant populations. However, the difference among plant populations became significant at third (110 DAP) harvest corroborating the observations of Bremner and Taha (1966) who attributed it to preferential assimilate transfer to the tubers at maturity and also to the concept that crop growth was dominated solely by tuber development at post-tuber phase (Moorby and Milthorpe, 1975; Lynch and Rowberry, 1977).

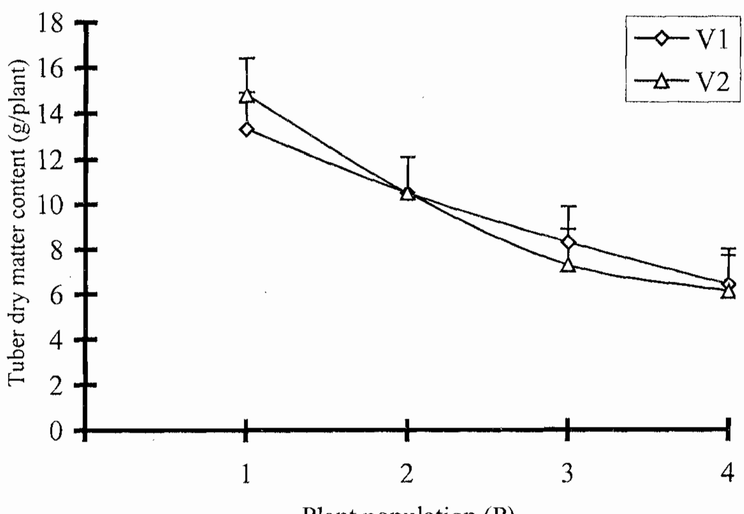

Fig. 2. Effect of variety and plant population on tuber dry matter content (g/plant). Vertical bars represent LSD at 1% level.

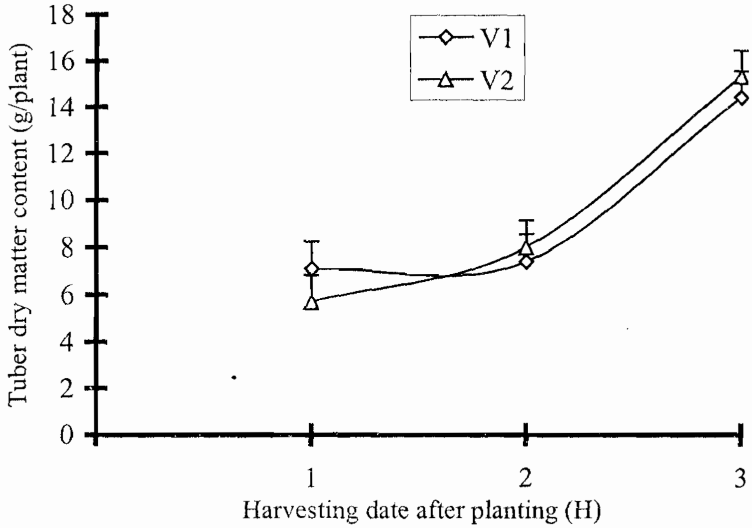

Fig. 3. Effect of variety and harvesting time on tuber dry matter content (g/plant). Vertical bars represent LSD at 1% level

Varieties did not differ significantly with regard to tuber dry matter content (Fig. 4). A significant increase in tuber dry matter content was, however, observed with the decrease in population density. This could be due to increased branch and leaf number possibly contributing to higher photosynthetic rates in plant canopies at low plant population arising from reduced competition. The higher LAI recorded at higher population (Table 1) possibly indicates preferential partitioning of assimilates for vegetative growth (Lynch and Rowberry, 1977). Harvesting time also significantly affected the dry matter content of tuber with increase in dry matter yield over time. Increase in the net assimilate rate towards the end of the season resulting from high proportion of assimilate transfer to the tuber rather than to the production of new leaves and branches (Bremner and Taha, 1966; Ifenkwe and Allen, 1978) may explain this phenomenon.

Significant ($P<0.01$) interactions between variety and harvesting time, and plant population and harvesting time were observed while considering tuber dry matter yield on per hectare basis (Table 3 and Fig. 4).

Although varietal difference was not observed in dry matter yield per unit area, plant population made influence ($P<0.01$). Similar observations were made by Ifenkwe and Allen (1978) and Bremner and Taha (1966). Harvesting time significantly influenced dry matter yield per unit area with increase over time mainly related to bulking duration (Moorby, 1967 and Beukema and Zaag, 1990).

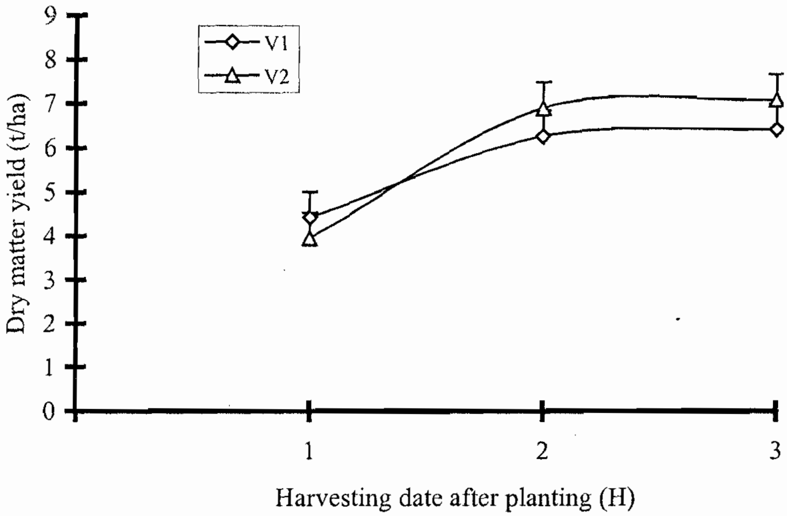

Fig. 4. Effect of variety and harvesting time on tuber dry matter yield (t/ha). Vertical bars represent LSD at 1% level.

Table 3 Effect of plant population and harvesting time on tuber dry matter production on per plant (g/plant) and per hectare basis.

Harvesting	Plant Population (P)				
Date (H)	P_1	P_2	P_3	P_4	Mean
H_1	9.4(3.4)	7.4(4.2)	4.7(4.3)	4.0(4.9)	$6.41^c(4.18^b)$
H_2	10.1(6.0)	8.4(6.5)	7.0(6.6)	5.0(7.1)	$7.66^b(6.58^a)$
H_3	22.6(6.9)	15.6(6.6)	11.7(6.3)	9.6d(7.1)	$14.89^a(6.75^a)$
Mean	$14.06^a(5.44^b)$	$10.49^b(5.79^b)$	$7.83^c(5.73^b)$	$6.23^d(6.38^a)$	
		P		H	
$LSD_{0.01}$		0.930(0.477)		0.805(0.413)	

Means separation within row and column superscripted by the same letter are non-significant at 1% level.
Figures in parenthesis indicate values on per hectare basis.

CONCLUSION

These data suggest that plant population influenced different growth parameters in both the varieties. Increase in dry matter yield at higher population, however, appeared to be associated with rate and duration of bulking with increased intra-hill competition among developing tubers for the critical factors.

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