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Effect of row spacing and time of earthing-up on vegetative and reproductive attributes of potato in Arbab village of Qarabagh District, Ghazni, Afghanistan

M. O. DARWIASH*, H. HAMAYOUN AND S. GHAFARI

Horticulture Department, Agriculture Faculty, Ghazni University, Afghanistan

**omerdarwiash153@yahoo.com*

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ABSTRACT

Field experiment was conducted to examine the consequence of intra-row spacing and time of earthing-up on vegetative and yield attributes of potato *var.* (Kufri Chandramukhi). Four intra-row spacing: 10, 20, 30 and 40 cm and four times of earthing-up: At 15, 30, 45 days after plant rise and no earthing were combined in a 4×4 factorial randomized complete block design. Intra row spacing significantly affected all the vegetative parameters, days to 50% flowering and maturity, plant-height and spread, stem diameter and leaf area, yield parameters tuber number, and tuber yield. Highest marketable tuber yield of 23.54 t ha^{-1} was produced at 40 cm intra-row spacing. The effect of time of earthing-up was found significant on all vegetative parameters like days to 50% flowering and maturity, plant height, spread, stem diameter, leaf area, stem number yield parameters, tuber number, total and marketable tuber yield. Earthing up at 15 days after plant emergence showed superior performance in most vegetative and yield parameters. Therefore, 40 cm intra-row spacing and earthing-up at 15 days after plant emergence is recommended for higher marketable yield of potato.

Key words: Intra-row spacing, Kufri Chandramukhi, time of earthing-up, yield

INTRODUCTION

The Agriculture system in Afghanistan has been completely destroyed by civil conflict for nearly 20 years. The productivity and quality of both Agricultural and Horticultural crops have reduced due to non-availability of good quality planting material. Potato is one of the important crops of Afghanistan. The agro-climatic conditions of Afghanistan are ideal and is suitable for good quality potato production. Potato is cultivated in nearly 14,000 hectares with an average yield of 16.8 t ha^{-1}.

Potato is grown during spring season in irrigated lands. Kufri Chandramukhi and Kufri Lauvkar are popular varieties in Afghanistan. Both varieties are short duration; white skinned, and has high dry matter and good keeping quality. Beside these, red skinned varieties Desiree and Cardinal are also grown in selected pockets. There are no formal seed production and supply systems existing in the country.

MATERIALS AND METHODS

The experiment was conducted at Qarabagh District, Ghazni Afghanistan during 2020 located Arbab village 60 m. near to Ghazni city, The temperature of experimental site varies between is 15°C to 22°C, rainfall variation of 100-300 mm. The soil of the experimental site was sandy loam soil texture.

Potato variety Kufri Chandramukhi was grown in the experiment. Four different rows spacing such as 10, 20, 30, and 40 cm and four different time of earthing-up such as earthing-up after 15 days, 30 days, and 45 days after emergence

of potato plant and no earthing-up to as a control treatment were laid out factorial RCBD with tree replications.

For this experiment a plot size of 10 m^2 (2.5 m length x 4 m width) was used. Well sprouted tubers of uniform size of Kufri Chandramukhi variety was grown. Phosphorus was applied in the form of DAP during planting time at the rate of 200 kg ha^{-1} and nitrogen was applied in a split, first banded at planting and then side dressed after full emergence with a total dose of 165 kg ha^{-1}. Earthing up was done uniformly by heaping the soil around the plant up to 20 cm height.

To evaluate the effect of row spacing and earthing-up on potato growth and yield, data were collected for vegetative parameters such as days to flowering (Shiri-e-Janagrad et al., 2009), days to maturity, plant height (Zelalem et al., 2009), plant spread, number of main stems (Zelalem et al., 2009), stem diameter, leaf area (Sintayehu, 2011) and yield parameters such as number of tubers per plant, marketable tuber and unmarketable tuber yield and total tuber yield (Zelalem et al., 2009) Data were collected from five randomly selected plants of the two middle rows except the yield data which was taken on plot basis.

Data were subjected to analysis with FRBD (SAS Institute Inc., 2002), by calculating ANOVA table treatment mean was compared by using LSD at 5% significance level (Montgomery, 2005).

RESULTS AND DISCUSSION

Effect of row spacing and earthing-up on growth parameters

The effect of both row spacing and time of earthing-up were found highly significant ($p<0.001$) on all growth parameters studied including days to 50% flowering and maturity.

Competition of plants for resources in the closer intra-row spacing that led the plants to stress and ultimately resulting early flowering instead of prolonged vegetative growth. This is in agreement with the work of Law-Ogbomo and Egharevba (2009) who reported that, days to 50% flowering was prolonged for plants grown with wider intra-row spacing (lower planting density). For earthing-up, the earliest days to 50% flowering (59.16 days) was observed at no earthing-up (control) treatment and this was not significantly different from potato plant earthed up at 45 days after complete plant emergence. However, flowering was prolonged when potatoes were earthed up at 15 days after complete plant emergence (Table 1). Days to 50% flowering was delayed by about 3 days at 15 days earthing-up after the complete plant emergence as compared to the control. This could be due to the fact that absence of earthing-up created stress in the plant due to lack of aeration and mechanical barrier of soil colloids during its active vegetative stage that affected the plant vegetative growth and brought early flowering. This result is in conformity with Qadir (1997) and Qadir et al. (1999), who confirmed that earthing-up at 15 days after complete plant emergence resulted in better potato plant performance in terms of the parameters considered.

Days to 50% maturity

The earliest days to 50% maturity (106.91 clays) was observed at the closer intra-row spacing of 10 cm but it was extended (113.33 days) at the wider intra-row spacing of 40 cm (Table 1). Days to maturity was delayed by 6 days in the wider intra-row spacing as compared to the closest intra-row spacing of 10 cm. This could be due to the presence of intense inter plant competition at the closer 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-row spacing (increasing planting density) had reduced days to maturity. For earthing-up, the earliest days to 50% maturity (108.75 days) was occurred at the control (no earthing-up) treatment but it was extended (112.33 days) at earthing-up of 15 days after complete plant emergence (Table 1). Days to 50% maturity was delayed by 3 days at 15 days earthing-up after the complete plant emergence as compared to the no earthing-up treatment. This might be due the reason that earthing-up at 15 days after complete plant emergence, matching with

Table 1. Growth parameters, days to flowering and maturity as affected by row spacing and time of earthing-up

Treatments	Days to 50% flowering	Days to flowering	Plant height (cm)	Plant spread (cm)	Mean stem No.	Check the readings	Leaf area (cm^2)
10	38.66	106.91[d]	66.19[a]	39.28	4.2		17.6
20	39.42	108.58	65.47[a]	42.59[b]	4.22[a]		21.86
30	60.83	112.16[b]	62.35[b]	47.37[a]	4.21[a]	6.18	27.10
40	61.66	113.3+	62.16[b]	49.68[a]	4.25		28.79
Time of earthing-up (Days)							
No earthing-up	39.16	108.73	62.03[c]	42.63[b]	4.08[b]		21.87
15	62.08	112.3	67.48	49.01[a]	4.67[a]		
30	60.08	110.30[b]	64.41[b]	44.19[b]	4.12[b]	3.14	23.90
45	39.25	109.58[b]	62.23	43.10[b]	4.04[b]	4.83	22.83[b]
L.S.D. % (0.05)	0.86	0.81	1.14	2.42	0.26		1. 132
C.V%	1.72	0.88	2.15	6.49	7.30	4.81	3.16

the active vegetative stage of the plant, created favorable soil environment and enhanced further vegetative growth that extended days to maturity. This result is in agreement with the finding of Qadir (1997) who confirmed that earthing-up at 15 days after complete plant emergence resulted in better plant performance.

Plant height

The highest plant height (66.1 cm) was obtained at the closer intra-row spacing of 10 cm and this is not significantly different from the plant height obtained at 20 cm intra-row spacing. On the other hand, the shortest plant height (62 cm) was observed at 30 and 40 cm intra-row spacing (Table 1), This might be due to the presence of higher competition for sunlight among plants grown at the closer intra-row spacing. This is in agreement with the finding of Zaag et al. (1989) who indicated that plant height was initially similar in all treatments but after 72 days the closely spaced plants became taller. Dennis et al. (1994) also reported that as intra-row spacing increased plant height decreased linearly. Similarly, Ifenkwe and Allen (1978), Law-Ogbomo and Egharevba (2009), Rajaclurai (1994) and Zebarth et al. (2006) concluded that closer intra-row spacing (higher plant density) resulted in the highest plant height. In case of earthing-up the highest plant height (67 cm) was obtained at 15 days earthing-up after complete plant emergence, whereas the shortest plant height (62 cm) was observed at the control (no earthing-up) treatment which is at par with 45 days earthing-up after complete plant emergence (Table 1), This might be due to the reason that early soil cultivation (earthing-up) facilitated the nutrient absorption through enhanced microbial processes and increased soil aeration. This result is in conformity with the finding of Qadir et al. (1999) and Qadir (1997) who confirmed that plant height was significantly higher in plants earthed up at two weeks after the complete plant emergence.

Plant spread

The widest plant spread (49.68 cm) was obtained at the wider intra-row spacing of 40 cm but the narrowest plant spread (39.28 cm) was recorded at the closer intra-row spacing of 10 cm (Table 1). This could be due to the positive effect of wider intra-row spacing, where there is minimum competition for resources between plants compared to the closer intra-row spacing, in that the photosynthetic efficiency of plants increased and the plants utilize the sufficiently available

resources. This result is in conformity with the finding of Ahmed et al. (2000) who reported that closer intra-row spacing resulted in poor vegetative growth such as plant spread compared to the wider intra-row spacing. Entz and LaCroix (1984) also stated that branching increased in the wider intra-row spacing. In similar manner, Zaag et al. (1989) reported that branching was similar in all treatments up to 30 clays but later the wider intra-row spacing gave the highest plant spread and is similar to the experimental finding of Zebarth et al. (2006) which indicated that closer intra-row spicing resulted in reduced number of branches resulting in the narrowest plant spread. Significantly the widest plant spread (49.01 cm) was observed at 15 days earthing-up after complete plant emergence but the narrowest plant spread (42.63 cm) was obtained at the control (no earthing-up) treatment which is similar to the effect of earthing-up at 30 and 45 days after complete plant emergence (Table 1). This could be due to the reason that earthing-up at 15 days after complete plant emergence, early in the growing season of the potato plant coincided with the proper time of soil workability and optimum soil moister level. This made the soil porous and aerated and the plants received the advantage of proper growth and development than the plants on the control and lately managed plots. Similar opinion was reported by Qadir (1997) and Qadir et al. (1999) in which plant spread was significantly higher when plants were earthed up 15 days after the complete plant emergence.

Main stem number

Significantly the highest main stem number 14.67) was recorded at 15 days earthing-up after complete plant emergence but the lowest main stem number (4.04) was obtained at 45 days earthing-up after complete plant emergence which was at par with no earthing-up (control treatment) and earthing-up at 30 days after complete plant emergence (Table 1). This might be due to the fact that earthing-up, a cultural practice, given to the plant during its active vegetative stage, enhanced the vegetative development of a greater number of stems. The result of this current investigation is in agreement with the work of Qadir (1997) who found that number of stems per plant (4.44) was significantly higher when plants were earthed up two weeks after complete plant emergence. Similarly, Qadir et al. (1999) also concluded that the number of stems per plant was significantly higher for plants earthed up at two weeks after complete plant emergence.

Stem diameter

The largest stem diameter (6.44 cm) was observed at the wider intra-row spacing of 40 cm whereas the smallest stem diameter (3.17 cm) was found at the narrowest intra-row spacing of 10 cm (Table 1). Wider intra-row spacing resulted in less competition among plants, availability of resources and light interception were increased resulted in large quantity of photo assimilate production as well as assimilation and thus increased plant vegetative growth ultimately increasing stem diameter. In line with the current finding, Dennis et al. (1994) also confirmed that increased intra-row spacing resulted in increased stem diameter. The largest stem diameter (5.48 cm) was obtained at 15 days earthing-up whereas the smallest stem diameter (4.64 cm) was obtained at no earthing-up (Table 1). In no earthing-up, there could be lower soil aeration and soil colloids also restricted plant roots vegetative but earthing-up controlled the weeds and enabled the plants to absorb more nutrients and increased their stem diameter. Gebremedhin et al. (2008) also indicated that one time earthing-up compared to no earthing-up increased yield components of potato. Qadir et al. (1999) and Qadir (1997) also stated that higher stem diameter was recorded at earthing-up of two weeks after plant emergence.

Leaf area

The largest leaf area (28.79 cm^2) was obtained at the wider intra-row spacing of 40 cm while the smallest leaf area (17.67 cm^2) was recorded at the closer intra-row spacing of 10 cm (Table 1). At the wider intra-row spacing due the presence of minimum competition, plants absorbed the sufficiently available resources, enough light and increased their photosynthetic efficiency that further increased the vegetative growth and ultimately resulted in increased leaf area. Oliveira (2000) also confirmed that leaf area decreased in

the closer intra-row spacing compared to the wider intra-row spacing that resulted in lager leaf area. In similar manner (Thambule and Ossom, 2010) stated that the largest mean leaf area was obtained in the wider intra-row spacing. Largest leaf area (26.81 cm^2) was observed at 15 days earthing-up after complete plant emergence while the smallest leaf area (21.87 cm^2) was recorded at no earthing-up, the control treatment (Table 1). Earthing up at 15 days after plant emergence coincided with the active vegetative stage of the plant improved the soil porosity and aeration, better root vegetative and penetration for nutrient absorption increased plant vegetative and development that ultimately increased leaf area. Qadir (1997) also concluded that better yield and yield components of potato including leaf area was recorded at earthing-up two weeks after complete plant emergence.

Table 2. Tuber number, total, marketable and unmarketable yield as affected by intra raw spacing and earthing-up

Treatments	Tuber no per hill	Total tuber yield ($t\ ha^{-1}$)	Marketable tuber yield ($t\ ha^{-1}$)
10	6.70^{d}	34.43^{a}	18.27
20	8.43	31.49^{b}	21.00^{ab}
30	10.55^{b}	30.00^{b}	10.55^{b}
40	10.9	26.09	21.19^{b}
Time of earthing-up (Days)			
No earthing-up	8.33	26.49	$17.\ CB^{C}$
15	10.30^{a}	36.44^{a}	27.48
30	9.46^{b}	31.61^{b}	22.38
45	8.51^{C}	27.48	17.82
LSD (0.05)	0.36	2.76	2.27
CV	4.82	10.85	12.86

Parameters studied included tuber number, total tuber yield and marketable tuber yield except unmarketable tuber yield which is only significantly affected by intra-row spacing (Table 2).

Tuber number

Significantly the highest number of tubers per plant (10) was recorded at the wider intra-row spacing of 40 cm whereas the lowest number of tubers per plant (7) was obtained at the closer intra-row spacing of 10 cm (Table 2). In the wider Intra 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-row spacing. Zamil et al., (2010) also indicated that the wider intra-row spacing gave the highest number of tubers per hill. In similar experiment, Zaag et al. (1989), Thornton et al. (2007), and Gulluoglu and Axioglu (2009) also reported that number of tubers per plant increased at the wider intra-row spacing. In case of earthing-up, the highest tuber number (10.30) was recorded at 15 days earthing-up after complete plant emergence whereas the lowest tuber number (8.33) was obtained at no earthing-up, control treatment which is at par with earthing-up at 45 days after complete plant emergence (Table 2). Earthing up at 15 days after complete plant emergence, during the active vegetative period of the plant created favorable soil conditions for a greater number of tubers initiation and development that increased tuber number. Similarly, Qadir (1997) and Qadir et al. (1999) also reported that number of tubers per plant was significantly higher at 15 days up after complete plant emergence. Tafi et al. (2010) also concluded that earthing-up of

potatoes at 10 cm plant height increased the length of underground stems that ultimately increased tuber number per plant.

Total tuber yield

The highest tuber yield per hectare (34.43 t ha^{-1}) was obtained at the closer intra-row spacing of 10 cm whereas the lowest (26.09 t ha^{-1}) was obtained at the wider intra-row spacing of 40 cm (Table 2). This is due to the compensation effect of closer intra-row spacing plants per hectare than the wider intra-row spacing which resulted in higher yield of tubers per plant. In a similar studies 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 insufficient number of plants grown per hectare compared to plants grown at closer intra-row spacing per hectare. Mahmood (2005) also confirmed that closer intra-row spacing gave the highest yield per hectare than the wider intra-row spacing. Different scientists, Nelson (1976), Rajadurai (1994), Ahmed et al. (2000), Midmore (2003), Rahemi et al. (2005), Gulluoglu and Arioglu (2009), Zamil et al. (2010), Mahmoodabad et al. (2011), at different times investigated the effect of intra-row spacing on potato yield and ultimately confirmed that potato tuber yield per hectare was decreased in the wider intra-row spacing but increased in the closer intra-row spacing due to more tubers being harvested in the closer intra-row spacing. The highest tuber yield (36.44 t ha^{-1}) was recorded at 15 days earthing-up after complete plant emergence whereas the lowest tuber yield (26.49 t ha^{-1}) was recorded at the control (no earthing-up) treatment which is at par with tuber yield recorded at 45 days earthing-up after complete plant emergence (27.48) (Table 2). Earthing up at 15 days after plant emergence conceded with the active growth stage of the plant improved the soil conditions for efficient nutrient absorption resulted in increased plant vegetative growth and development that ultimately resulted in the highest tuber yield per hectare. Qadir (1997) and Qadir et al. (1999) also reported the highest potato tuber yield per hectare at 15 days earthing-up after complete plant emergence.

Marketable tuber yield

The highest (23.54 t ha^{-1}) marketable tuber yield was obtained at the wider intra-row spacing of 30 cm whereas the lowest (18.27 t ha^{-1}) was obtained at the closer intra-row spacing of 10 cm (Table 2). At the wider intra-row spacing due the presence of minimum competition, plants absorbed available resources sufficiently 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 in line with the finding 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. Similarly, Zaag et al. (1989) also reported that marketable tuber yield increased in the wider intra-row spacing. The highest marketable tuber yield (27.48 t ha^{1}) was obtained at the 15 days earthing-up whereas the lowest (17.03 t ha^{-1}) was obtained at the closer intra-row spacing of 10 cm which is at par with 45 days earthing-up (17.82) (Table 2). This could be due to earthing-up at 15 days after complete plant emergence, during the active vegetative period of the plant improved the soil conditions for proper root growth and nutrient absorption that facilitate the above ground part for better vegetative development ultimately resulted in better marketable tuber yield. The current result is in line with the work of Qadir (1997) and Qadir et al. (1999) who confirmed that earthing-up at 15 days after complete plant emergence resulted in better potato plant performance and yield.

Unmarketable tuber yield

The highest unmarketable tuber yield (16.16 t ha^{1}) was obtained at the closer intra-row spacing of 10 cm. However, the lowest unmarketable tuber yield (4.89 t ha^{1}) was obtained at the wider intra-row spacing of 40 cm (Table 2). This could be due to the existence of higher computation between plants in closer intra-row spaced plants that results in a larger number of under sized tubers that leads to the less quality product. Similarly, Zaag et al. (1989) reported that marketable tuber yield increased in the wider intra-row spacing. In this

experiment unmarketable tuber yield was assessed by identifying under sized, cussed, deformed and green potato tubers and the most important reason for unmarked ability is under sized potato tuber.

CONCLUSION

The study showed that both intra-row spacing and time of earthing-up significantly affected days to 50% flowering, maturity, plant height, plant spread, stem diameter, leaf area, tuber number, total tuber yield and marketable tuber yield. It can be concluded from this study that for the majority of the vegetative parameters, 40 cm intra-row spacing and earthing-up after 15 clays of complete plant emergence are preferable. Similarly, the highest total tuber yield (34.43 t ha^{-1}) and unmarketable tuber yield (16.16 t ha^{-1}) was produced at the closest intra-row spacing of 10 cm. But from the total tuber yield produced in closest intra-row spacing of 10 cm 46.93% was unmarketable and hence, significantly the highest marketable tuber yield (23.54 t ha^{-1}) was obtained at the wider intra-row spacing of 30 cm. Similarly, the highest total tuber yield (36.44 t ha^{-1}) and marketable tuber yield (27. 48 t ha^{-1}) was produced at the time of earthing-up of 15 days after complete plant emergence. This study verified that vegetative and yield of potato is influenced by intra-row spacing and time earthing-up and accordingly 30 cm intra-row spacing in combination with earthing-up at 15 days after complete plant emergence can be used for optimum vegetative and the highest marketable tuber yield of Kufri Chandramukhi potato variety in the sandy loam soil of the study area.

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