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Review

Review on effect of population density and tuber size on yield components and yield of potato (*Solanum tuberosum* L.)

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Population density and seed tuber is an important agronomic management practices in the production of potato (Solanum tuberosum L.). However, potato farmers in Ethiopia often use random population density and tuber sizes, which contribute to the low yield of the crop. Thus the objective of this study is to review effect of population density and tuber size on yield components and yield of potato. The result of this review shows that the highest plant height and main stems number was found in wider spacing and in medium to large tuber size. In the same way, the number of tuber per plant, average tuber weight and marketable yield increased when potatoes are planted in medium intra row spacing (60 x 30) and using medium (35 to 45 cm) to large (45 to 55 cm) tuber size. However, total tuber number/ha and unmarketable yield increased in closer spacing and medium (35 to 45 cm) tuber size. Thus according to the review to increase total yield and marketable yield, it is better to use medium plant spacing (60 x 30 cm) and medium-sized tubers (35 to 45 mm).

Key words: Population density, potato growth, potato yield, tuber size.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most widely grown tuber crops in the world and contributes immensely to human nutrition and food security (Miguel, 1985; Steven, 1999; Karim et al., 2010). It is the most important vegetable crop, constituting the fourth most important food crop in the world (Mattoo, 2006; Douches, 2013). Potato is one of mankind's most valuable food crops and mainstay in the diets of people in many parts of the world (Struik and Wiersema, 1999). Potato is one of the economically most important tuber crops in Ethiopia that play key roles as a source of food and cash income for small farmer holders; and it is endowed with suitable climatic and endemic conditions for potato production. However, the national average yield is very

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low (8.2 t ha^{-1}) compared to the world's average production (17.67 t^{ha-1}) (FAO, 2010). The major production problems that account for such low yield are unavailability and high cost of tuber seeds, lack of well adapted cultivars, poor agronomic practices, diseases, insect pests, inadequate storage, transportation and marketing facilities (Tekalign, 2005).

Tuber size and population density is one of the most important constraints limiting potato production in Ethiopia. Larger seed and closer spacing up to a certain limit increase the yield of tubers per unit area. The yield increases with a decrease in spacing (Banarjee et al., 1988). However, the optimal planting density differs depending on the environmental conditions, cultivars and soil fertility. On the other hand, planting large seed tubers is advantageous under certain circumstances such as unfavorable soil and weather conditions .As plant density increases, there is a marked decrease in plant size and yield per plant. This effect is due to increased inter-plant competition for water, light and nutrients. Therefore the objective of this review is to assess the effect of potato tubers size and population density on yield component and yield of potato.

EFFECT OF PLANT POPULATION AND TUBER SIZE ON PLANT HEIGHT

Plants grown at wider plant spacing of 75 x 30 cm had the highest plant height (77.48 cm) higher than the heights of plants grown at the spacing of 60 x 20 cm, 50 x 30 cm, and 50 x 20 cm by about 8.33, 8.4 and 15.47%, respectively (Zebenay, 2015). According to Bikila et al. (2014) the tallest plant height was observed when the inter row spacing and intra row spacing increase from 60x20 to 80x40 respectively. This may be due to better availability of nutrients, water and sun light since plants in wider spacing have less competition and grow more shoot; however, densely populated plants show intensive competition which leads to decrease in plant height. Wider intra row spacing resulted in reduction in plant height and in closer inter row spacing the highest plant height was observed. This is due to the presence of higher competition for sunlight among plants grown at closer intra row spacing (Tesfaye et al*.,* 2013). Similar results obtain by Ashwani et al*. (*2013) showed that planting at wider intra row spacing resulted in reduction in plant height. In general, the plant height of the potato crop increases when plants are planted in closer intra row spacing due to competition for sunlight. In other words, when plants are planted in wider intra row spacing the same result may be obtained due to the plant getting enough mineral, water and sunlight.

Regarding the tuber size, the maximum plant height (75.39 cm) was obtained from large seed tuber sizes (>56 mm) whereas shorter plant height was obtained from small seed tuber size .Large seed tuber sizes (>56 mm) produced the tallest plants which was higher than medium (35 to 45 mm) and small (25 to 34 mm) seed tuber sizes by about 4.9 and 8.9%, respectively. The variation in plant height might be due to the higher food reserves in tubers with larger size than small and medium seed tuber sizes (25 to 34 and 35 to 45 mm) which enhanced vegetative growth of the plant including the height of the plant (Zebenay, 2015).

EFFECT OF PLANT POPULATION AND TUBER SIZE ON MAIN STEM NUMBER

Planting densities of 4.17, 4.44, and 5.56 resulted in significantly highest number of main stems than the planting densities of 6.67 and 8.00 plant m^{-2} (Alemayehu et al., 2015,). In other findings, numbers of main stems were not influenced by plant population (Beukema and Van, 1990). However, stem number increased as a result of either by planting smaller tuber size or more tuber number per unit area per plant (Sturz et al., 2003). Young seed has a few sprouts that emerge slowly and hence produces a few main stems (Pavek and Thornton, 2009). The presence of internal inhibition limits sprouting at both the distal and dorsal ends of young seed tubers. Large size seed tubers produce more stems than small ones.

Number of stems produced by seed tubers planted at 60x30cm spacing was significantly higher at a spacing of 60x20 cm (Rajadurai, 1994). The seed tuber size had significant ($P< 0.01$) influence on number of main stem per hill. Plants grown from large seed tuber size produced higher number of main stems per hill than other seed tuber sizes. The highest number of main stems per hill (5.69) was recorded from large seed tuber size which significantly exceeded that of 46 to 55, 35 to 45 and 25 to 34 mm seed tuber sizes by about 40.84, 57.62 and 82.37%, respectively. Plants grown from large seed tuber size (>56 mm) produced highest number of stems per hill. The seed tuber size affects the growth of the crop due to large tubers having more number of buds. Higher number of bud per tuber produces more number of main stems (Zebenay, 2015).

EFFECT OF PLANT POPULATION AND TUBER SIZE ON TUBER NUMBER PER PLANT

The highest number of tuber per plant (10.93) was recorded at the wider intra row spacing 40 cm whereas the lowest number of tuber per plant (6.7) was obtained at closer spacing 10 cm (Table 1). This is because in wider intra row spacing there is minimum competition among plants for space and resource and better exposure for light; this results in increased number of tuber per plant (Tesfaye et al*.,* 2013). Number of tuber

Table 1. Means for tuber number, total yield, marketable yield and unmarketable yield as affected by intra row spacing.

Treatment	Tuber number (count hill^{-1})	Total tuber yield (t ha^{-1})	Marketable tuber yield (t ha^{-1})	Unmarketable tuber yield (t ha^{-1})
Intra row spacing (cm)				
10	6.70	34.43	18.27	16.16
20	8.43	31.49	21.71	9.74
30	10.56	30	23.54	6.46
40	10.93	26.09	21.19	4.89

Source: Tesfaye et al. (2012).

per plant increases with increasing seed tuber size and planting space. Large size seed tuber produces significantly more number of tubers over small. Tuber number per plot increases with increasing seed tuber size. However, the difference in tuber numbers between small and medium size seed tubers was not significant (Rajadurai, 1994).

Plants grown from large seed tuber size produced high total tuber number per hill whereas small seed tuber size produced low total tuber numbers per hill. Large seed tuber size (>56 mm) significantly exceeded in producing total number of tubers than that of 46-55, 35- 45 and 25-34 mm by about 12.47, 20.55 and 26.30%, respectively. Total tuber number per hill produced from 46-55 mm seed tuber size is not statistically and significantly different with 35-45 mm seed tuber size. Plants grown at closer plant spacing of 50 x 20 cm produced highest total tuber number per hill higher than plants spaced at 60 x 20 and 75 x 30 cm by about 11.27 and 12.18 %, respectively. However, total tuber number per hill produced at 50 x 20 cm plant spacing has no statistically significant difference with 60 x 30 cm and 50 x 30 cm plant spacing. The production of total number of tubers per hill increased as plants grown at narrow plant spacing and decreased at wider plant spacing. This might be due to the higher number of plants produced at closer plant spacing than plants at wider spacing which led to the production of highest number of total tubers per hill (Zebenay, 2015). Tuber numbers were significantly affected by plant population density, with the highest density plants having a lower number of tubers per plant (Michael et al., 2011).

EFFECT OF PLANT POPULATION AND TUBER SIZE ON AVERAGE TUBER WEIGHT (G)

Maximum average tuber weight (119.61 g) was recorded for plants grown from medium seed tuber size (35 to 45 mm) and planted at wider plant spacing (75 x 30 cm); the lowest average tuber weight (55.91 g) was obtained at closer plant spacing (50 x 20 cm) and large seed tuber size (>56 mm). Plants grown from medium seed tuber size (35 to 45 mm) across all plant spacing had maximum average tuber weight than other seed tuber sizes. Plants at wider spacing grown from medium seed tuber sizes gave maximum tuber weight than plants grown at other plant spacing and from seed tuber sizes. When plant density increased the weight of tubers decreased in all seed tuber sizes except in plants grown at plant spacing of 50 x 20 cm and from small seed tuber size (25 to 34 mm). The production of tubers with higher weight when medium seed tuber size (35 to 45 mm) was used as planting material with wider space (75 x 30 cm) might be due to the production of optimum number of stems with lesser competition for resource between plants compared to small and large seed tuber sizes planted at closer plant spacing (Zebenay, 2015).

EFFECT OF PLANT POPULATION AND TUBER SIZE ON TOTAL TUBER YIELD /HA

Increasing the planting density from 4.44 to 8.00 plants m^{-2} significantly increased total tuber number/ha. The highest tuber yield per hectare was obtained at closer spacing of 10 cm whereas the lowest was obtained at wider intra row spacing of 40 cm. The wider intra row spacing yield per hectare was reduced due to the insufficient number of plant grown per hectare compared to plant grown at closer intra row spacing per hectare. The maximum yield was obtained at closer plant spacing than wider plant spacing. This might be attributed to efficient use of available soil nutrients and other growth factors in plants grown at closer plant spacing than wider plant spacing. The increased yield at higher densities might be due to the ground being covered with green leaves earlier (earlier in the season, light is intercepted and used for assimilation), fewer lateral branches being formed and tuber growth starting earlier (Zebenay, 2015).

As shown in Table 2, narrow spacing increases the hectare yield and decreases the yield per plant. The highest yield was obtained with large size seed tuber (45-55 cm) planted in narrow spacing (60 x 20cm). However, the combination of large size seed tuber and narrow spacing produce many small side size tubers of low

Table 2. Effect of seed tuber size and planting space on tuber yield /ha.

Tuber size	Planting space		
	60x20 cm	60x30 cm	60x50 cm
15-30 mm	24.43	20.89	17.20
30-45 mm	24.22	24.89	20.88
45-55	28.45	24.37	21.23

Source: Rajadurai (1994).

market value (Rajadurai, 1994).

The highest yield was obtained from 65 cm inter row spacing; whereas the lowest yield was recorded at 80 cm inter row spacing. Regarding the intra row spacing the higher total yield per hectare was obtained from 20 cm intra row spacing. As intra row spacing increased from 20-35 cm, total tuber yield decreased from 37.54 to 29.38 t/ha. Intra -row spacing of 35 cm showed lower total tuber yield. It was clearly evident from the result that the yield of seed tuber per hectare increased with decreasing plant spacing. The increased yield was attributed to more tubers produced at the higher plant population per hectare although average tuber size decreased because of increasing inter plant competition at closely spaced plants leading to more unmarketable tuber yield. At closer spacing, there is high number of plant per unit area which brings about an increased ground cover that enables more light interception, consequently influencing photosynthesis (Harnet et al., 2014). Yield performance (kg/ha) was greatest at the medium density level (90 by 30 cm), followed by plants established at 90 by 45 cm. Reducing the intra-row spacing from 45 to 30 cm significantly ($p<0.05$) increased plant population and subsequently increased the yield (kg/ha) performance. Tuber yield was significantly ($p< 0.05$) affected by plant density as plants planted at 90 by 30 cm exhibited highest yield performance compared to those planted at 90 by 15 cm and 90 by 45 cm (Michael et al., 2012).
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EFFECT OF PLANT POPULATION AND TUBER SIZE ON MARKETABLE TUBER YIELD /HA

Effect of row spacing and seed type on yield found that those plants grown from large seed pieces produced higher marketable yield at the widest spacing (Robert et al., 2015). The highest marketable tuber yield was obtained in response to planting the tubers at the spacing of 60 x 30 cm whereas the lowest marketable tuber yield was recorded at the spacing of 50 x 30 cm plant spacing. Plant spacing of 60 x 30 cm produced higher marketable yield than 50 x 30 cm and 75 x 30 cm plant spacing by about 12.04 and 9.53%, respectively. Similarly, marketable tuber yield produced at 60 x 20 cm and 50 x20 cm exceeded that of 50 x 30 cm plant spacing by about 8.65 and 8.72%, respectively. Plant spacing of 60 x 30 cm, 60 x 20 cm and 50 x 20 cm produced marketable tuber yield per hectare without significant difference (Zebenay, 2015).

The highest marketable yield was obtained at the wider intra row spacing of 30 cm whereas the lowest was obtained at closer spacing of 10 cm. At wider intra row spacing due to presence of minimum competition, plants absorbed the sufficient available resource and intercepted more light. This increased their photosynthesis efficiency for higher photo assimilation production and ultimately resulted in increased more marketable tuber yield (Tesfaye et al., 2013). According to Alemayew et al. (2015) increasing the planting density from 4.44 to 6.67 plants m^{-2} significantly increased total and marketable tuber yield by 5.21 and 4.67 t/ha.

EFFECT OF PLANT POPULATION AND TUBER SIZE ON UNMARKETABLE TUBER YIELD /HA

The highest unmarketable yield was obtained at the closer intra row spacing of 10 cm whereas the lowest was obtained at closer spacing of 40 cm (Table 1). This is due to presence of higher competition between plants in closer intra row space (Tesfaye et al., 2013). The highest unmarketable tuber yield was obtained at closer plant spacing (50 x 20 cm) whereas the lowest unmarketable tuber yield was recorded at wider plant spacing (75 x 30 cm). the closer spacing of 60 x 20 cm and 50 x 30 cm would need more seed tubers than the spacing of 60 x 30 cm, the latter spacing (60 x 30 cm) would be more profitable. The highest unmarketable tuber yield was produced at the highest planting density of 8.00 plants m^{-2}, and exceeded the unmarketable tuber yield obtained at the lowest planting density of 4.17 plants m^{-2} by 0.863 t/ha (Alemayew et al., 2015). Generally, plants grown at closer spacing produced high unmarketable tuber yield than plants grown at wider plant spacing. Increasing plant density also increased the yield of unmarketable tuber yield. Closer plant spacing increased competition of plants for growth factors due to high number plant per unit area than wider plant spacing which led to producing high number of under size tubers which was high unmarketable tuber yield (Zebenay, 2015).

CONCLUSION

This review revealed that plant spacing of 60 x 30 cm and medium (35 to 45 mm) to large (45 to 55mm) seed tuber sizes resulted in the production of higher marketable tuber yields and higher tuber yield/ha. Even if using medium (35 to 45 mm) to large (45-55 mm) seed tuber sizes resulted in higher production, considering the income of the user, using medium seed tuber sizes (35 to 45 mm) with plant spacing of 60 x 30 cm is appropriate.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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