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The Effect of Planting Date, Depth and Density on Yield and Yield Components of Potato in Shahrood (Iran)

HAMID REZA ARAB[1], HOSSEIN AFSHARI[1*], MORTEZA SAM DALIRI[2], GHANBAR LAEI[1], SEYYED RASOUL TOUDAR[2]

1- Faculty of Agriculture, Damghan Branch, Islamic Azad University, Damghan, Iran
2- Faculty of Agriculture, Chalous Branch, Islamic Azad University, Chalus, Iran

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*Corresponding author: Email: afshari2000ir@yahoo.com

ABSTRACT

In order to study the effect of planting date, depth of sowing and planting density on yield and yield components of potato (*Solanum tuberosum* L.), an experiment was carried out in Shahrood (Iran) in 2009-2010. The first treatment was three planting date (11, 21 and 31 May 2010), the second treatment was planting density including 8 and16 plants per square meter and the third treatment was depth of sowing (10, 20 and 30 cm). For studying crop growth physiology, sampling was done every 15 days. Total dry weight along with leaf, stem and tuber weights were determined to demonstrate dry matter accumulation trend. Final yield and yield components were measured at the end of growth season. Other traits included plant height, number of tubers in square meter, number of tubers in plant, average tuber weight, and protein yield. Results showed that tuber yield was affected by experimental factors. Planting date, depth of sowing and planting density significantly affected tuber yield. Planting date, depth of sowing and planting density significantly affected all traits except protein percentage which was not significantly influenced by plant density factor. Planting date (11 May 2010) and plant density (8 plants/m^2) and depth of sowing (20 cm) treatment produced 31.800 ton/ha and was maximum yield in comparison to other treatments.

Keywords: Potato, Agria, Yield, Yield component, Plant density, Planting depth

INTRODUCTION

Due to exceeding increase of world's population and greater need for food, Farmers are greatly orientated to larger production of agricultural crops. Considering limitation of arable lands, subject of yield enhancement per unit area is more extensively discussed than before. Thus, all agricultural experts believe that use of cultivars, and selection of appropriate planting date and other factors will significantly improve yield amount per unit area. Various climatic factors influence crop increment but among all, thermal regime plays the most significant role. Based on thermal stability principle, a crop reaches certain stage of its increment process (disregarding needed time to reach that stage) when it absorbs a certain

amount of ambient energy. Accordingly, certain amount of energy is required for any of two consecutive growth stages. Taking into account the temperature fluctuations and day duration besides lack of precise estimation for crop's phenology stages, it is necessary to use growth degree-day to exactly determine the respective stages (padashi and Khajeh-pour, 2007). Based on these explanations in this research, planting date was studied as the main factor in a multivariate experiment.

On the other hand, plant number per unit area largely affects crop access to resources including solar radiation and nutrients. Thus, crop population adjustment is considered as one of the most important and effective factors in potato yield improvement (Watson and Dyson, 1971). Planting depth plays essential role in formation of stolons and aerial potato stems so that stolons number and ultimately, the yield itself will increase with planting tubers depth (up to approximately 20 cm; depends on cropping conditions) (Ezekiel, 1992).

Potato (*Solanum tuberosum* L.) is the fourth important agricultural crop after wheat, rice and corn around the world. It is located in second place of crop production in Iran. New potato cultivars have been imported to Iran due to its significance as one of the country's major agricultural crops and also great potential for producing this strategic product. The imported cultivars produce high yields but have special ecological requirements. Ideal or favorable yields can be achieved if these requirements be perfectly provided (Fazeli Sabzevar *et al.*, 2001).

Potato planting date can be determined based on its growth season duration in any region. The conclusions emanating from the findings of former studies are suggestive of the fact that planting date influences leaf area index trend as well as amount of absorbed radiation in crop population and is eventually an important factor for determining potato yield. Delayed planting dates cause yield reduction (Peter *et al*., 1988).

Imam and Niknejad (1994) reported that for short-duration potatoes in temperate regions where the objective is to maximize sellable tuber yield for harvests much earlier than shade aging, early planting has advantages as long as it does not suffer from shedding caused by frost action.

Krishnappa (1993) stated that delayed planting resulted in yield decline. In his opinion, yield difference in delayed planting dates is caused by reduction in number of tubers per plant and shrinkage of leaves.

Obrien *et al*. (1998) reported that increase in plant density reduced number of tubers per plant and number of stolons as well. Gholipour (1996) reported in a study that the number of generative tubers per plant and per unit area decreased as a result of the planting depth increasing; they attributed this phenomenon to reduction in number of stems. Considering that plant density; planting date and depth of sowing (planting depth) are significantly important in maximizing the tuber yield, this research was conducted in year 2010 to find suitable plant density, planting date and sowing depth of potato (Agria cultivar) in Shahrood region.

MATERIALS AND METHODS

The experiment was conducted in a research field located in north of Shahrood (54° 55` E, 35° 36` N and at an altitude of 1345 meters with average annual participation is167 mm and average annual temperatures 14.5 °C). According to soil analysis test, the field has a loamy gravel textured soil.

The study was done as a factorial experiment based on randomized complete blocks design with three replications. It included three planting dates (11, 21 and

31 May 2010), two plant densities (16 and 18 plants/m^2) and three planting depths (10, 20 and 30 cm).

The experimental land was fallow in the previous year. According to results of soil analysis test, 30 ton/ha of rotten animal compost were distributed in autumn. Subsequently, the land was deeply plowed. In late March when soil moisture reached its suitable level, the plot was immediately plowed again. Subsequently, 30 kg/ha of ammonium phosphate, 300 kg/ha of potassium sulfate and 200 kg/ha of urea fertilizers were applied. Finally, furrows with 65 cm inter row distances were made using furrower. Seed tubers of potato cultivar Agria were manually planted at following dates: 11, 21 and 31 May 2010 at three different depths of 10, 20 and 30 cm in two densities of 16 and 8 plants/m^2. Before planting, the tubers were infected using anti-fungi poisons and treated similarly in all plots during growing operation.

In order to evaluate dry matter accumulation and growth indices, samples were taken every 15 days based on a single plant considering the marginal effect. Then, leaf, stem and tuber of each crop were separately placed in fanned electrical oven to dry at 75 °C temperature for 48 hours. Because of not having access to leaf area-meter apparatus, 30 leaves of each sample were arbitrarily separated; their length and width were measured and they were subsequently dried; their surface areas were computed using the specific formula for potato leaf area (Young, 1981). The tubers were turned into rings and placed into oven so as to accelerate their drying process.

In order to calculate tuber protein content, tuber's nitrogen percentage was initially measured with Kjeldahl method (Salo-vaananen and Koivistoinen, 1996).

At the end of growth season and before harvesting, tubers of five randomly selected plants from each plot were counted. Final harvesting was done one square meter from middle of every plot considering marginal effects from 1 m2 in each plot. The obtained data were analyzed using SAS program and mean comparison was done using Duncan multiple range test at 5% probability level.

RESULTS AND DISCUSSION

According to variance analysis (Table 1) there were highly significant ($P<0.01$) differences between levels of experimental factors for all studied traits except protein content of plant density. Interaction of planting date and planting depth were significant ($P<0.05$) on yield, number of lower case per plant and number per unit area, but protein content, average of number weight and Stem length were not affected. Interaction effects of planting date density for number of tuber in plant was significant at the 1% probability level, but average tuber weight and stem length were significantly different at the level of 5%, and protein content, number of tuber in unit area and yield were not significantly different. Interaction effects of planting depth density for trait protein content was significantly different at the level of 5%, but traits average tuber weight, stem length, number of tuber in plant and yield were not significantly different. Interaction effects of planting depth density date for trait yield was significantly different at the level of 5%, but average tuber weight, protein content, stem length, number of tuber in plant, and yield were not significantly different (Table 1).

Table 1. Variance analysis of experimental treatments' effects on studied traits

S.O.V	df	Mean of squares					
		Average tuber weight	Number of tuber per unit area	Number of tuber per plant	Yield	Protein content	Stem length
Block	2	29.3*	48.11 ns	0.58 ns	0.55 ns	0.28 ns	0.29 ns
Planting Date	2	1269**	3296**	28.01**	649.89**	42.93**	944**
Planting Depth	2	198**	762**	5.71**	40.88**	4.80**	93**
Planting Density	1	4097**	5732**	35.3**	13.30**	0.32 ns	7.63**
Planting Date*Depth	4	10.01 ns	99.25*	0.81*	3.64*	0.03 ns	1.24 ns
Planting Density*Date	2	42.13*	8.90 ns	2.28**	0.047 ns	0.18 ns	2.62*
Planting Depth*Density	2	7.16 ns	75.38 ns	0.33 ns	2.27 ns	0.32 *	0.33 ns
Depth*Density*Date	4	14.11 ns	30.80 ns	0.27 ns	4.62 *	0.29 ns	3.18 ns
Error	34	11.4	46.02	0.24	1.24	0.129	0.98

ns,* and**: no significant, significant at 5% and 1% probability levels, respectively.

Planting date

Mean comparison of different planting dates revealed that May 11st and 21st produced the highest and lowest potato yields, respectively (Table 2). Generally, delay in planting date from May 11th to May 31st reduced the yield. According to Evins and Bruman (1964) results, delayed planting caused delayed tuber stimulation but tuber volume enhancement rate height be accelerated. As Rezaie and Soltani (2006) believed, higher temperature and greater nitrogen reservoirs during tuber formation can cause delay in tuber formation which reduces the yield. Increase in respiration reduces tuber yields at high temperatures. Therefore, exceeding temperature at the time of tuber formation results in reduction of carbohydrates accumulation which is vital for tuber formation and development.

The largest and smallest numbers of tubers per plant were obtained in May 11th and May 31st planting dates, respectively (Table 2). Number of tubers per plant reduced with delay in planting date. Krishna (1993) concluded that delayed planting caused reduction in yield. In his opinion, lower yields of more delayed planting dates were because of reduction in number of tubers per plant and shrinkage of leaves.

Comparison of different planting dates indicates that the highest and lowest values of plant height belonged to 11th and 31st May, respectively (Table 2). Plant height generally decreases with delay in planting date from 11th until 31st May. Karafilidis and Georgakis (2002) reported that planting date effect on length of potato stem. The planting dates 11th and 31st May exhibited the greatest and lowest tuber weights, respectively (Table 2). Igram and Mc-Claud (1984) reported that any environmental factor stimulating vegetative growth of aerial organs would reduces tuber growth as well as the percentage of tubers' dry matter.

Comparison of different planting dates revealed that 11th and 31st May featured the highest and lowest percentages of tuber protein contents, respectively. Prosba and Bialzik (1994) stated that delay in potato planting would reduce dry tuber weight, its

starch content, tuber protein and total protein.

Plant density

Mean comparison of different plant densities showed that 8 plants/m^2 assumed greater yield than other treatment (Table 3). Concerning number of tubers per unit area, 16 plants/m^2 produced better result in comparison with the other one. Goush *et al.* (2002) reported that increase in density and shading would reduce crop's dry matter as well as tuber yield and percentage of sellable tubers.

Eight plants/m^2 also yielded larger number of tubers per plant than 16 plants/m^2 treatment (Table 3). Ifinkov (1975) concluded that as the plant density increased the number of tubers produced each stem and also each plant decreased due to exceeded competition, while the number of produced tubers per unit area increased. Ubrine *et al.* (1998) reported that increase in plant density reduced number of tubers and stolons per plant and made taller plants than the other density (Table 3). Karafilidis and Georgaakis (2002) reported that planting date affected plant height. Allen and Wurr (1973) report that effect of density was significant on the height of main stem in potato crop and main stem became taller as density increased. The reason was further competition for more sunlight absorption.

Mean comparison of different plant densities shows that 16 plants/m2 density produced to lower tuber weight than 8 plants/m treatment (Table 3). Ifinkov and Allen (1978) studied plant density effect on tuber yield and reported that with increase in plant density, weight and size of each plant's tubers were decreased.

Planting depth

Mean comparison of different planting depths indicates that 20 cm depth possessed greater yield in comparison with two other depths (Table 4). Planting the tubers at the depth of 30 cm led to the least yield. Findings of this research revealed that larger number of stem at 20 cm depth compared to that of 30 cm depth would result in exceeding competition for environmental factors among crops. On the other hand, this situation improves crop capability of producing photosynthetic matters and increases every tuber's portion from the photosynthetic products.

Table 2. Mean comparisons of studied traits

Planting date	Yield (tons/ha)	Number of tubers per plant	Number of tubers per unit area	Height (cm)	Tuber weight (gr)	Protein (%)
11 May 2010	28.34 a	6.30 a	70.86 a	68.08 a	54.51 a	1.61 a
21 May 2010	22.80 b	4.90 b	55.73 b	61.55 b	46.75 b	0.99 b
31 May 2010	16.33 c	3.81 c	43.86 c	53.22 c	37.72 c	0.85 c

Mean followed by similar letters in each column are not significantly different.

Table 3.Mean comparisons of averages for planting density effect on tuber yield, number of tubers in plant, number of tuber in unit area, average tuber weight and stem length of potato in farm conditions

Planting density (plants/m²)	Tuber weight (gr)	Height (cm)	Number of tubers per unit area	Number of tubers per plant	Yield (ton/ha)
8	55.04 a	60.71 b	5.81 a	46.51 a	22.99 a
16	37.61 b	61.46 a	4.19 b	67.12 b	22.00 b

Mean followed by similar letters in each column are not significantly different.

Table 4. Mean comparisons of averages for planting depth effect on the yield, number of tubers in plant, number of tuber in unit area, average tuber weight and stem length of potato in farm conditions

Planting depth (cm)	Plant height	Average tuber weight (gr)	Number of tubers per plant	Number of tubers per unit area	Yield (ton/ha)
10	61.83a	47.70 a	5.17 a	58.20 a	23.19 a
20	6288 a	48.73 a	5.46 a	63.53 a	23.52 a
30	58.53 c	42.54 b	4.37 b	49.73 b	20.76 b

Mean followed by similar letters in each column are not significantly different.

With more stems at 20 cm planting depth, more tubers would be also present per unit area and ultimately, total tuber yield per hectare is larger for this depth than 30 cm treatment. For attribute of number of tubers per unit area, the greatest and lowest values were achieved for 20 cm and 30 cm planting depths, respectively (Table 4).

Number of tubers per unit area decreased with increase in planting depth from 20 to 30 cm. Mean comparison showed that 20 cm depth yielded larger number of tubers per plant compared to two other depths (Table 4). Gholipour (1996) reported that number of produced tubers per plant and unit area decreased as planting depth increased and mentioned the reduction of stem number as its reason. According to mean comparison table, the highest and lowest values of tuber yield were belonged to 20 cm and 30 cm planting depths, respectively (Table 4). Mean comparison of plant depth levels also showed that 20 cm planting depth led to taller plants compared to the other levels (Table 4). Abbasifar *et al.* (1995) reported that stem length was shortened as planting depth was increased.

Planting depth effect was significant on protein percentage which decreased as depth increased from 20 cm to 30 cm. The result of this research indicated that larger number of stems at 20 cm depth compared to 30 cm caused exceeded competition for light absorption in crops. On the other hand, it improved crop's capability for producing photosynthetic matters and increased portion of every tuber from photosynthetic products and ultimately, total tuber yield per hectare at this planting depth was greater than 30 cm treatment.

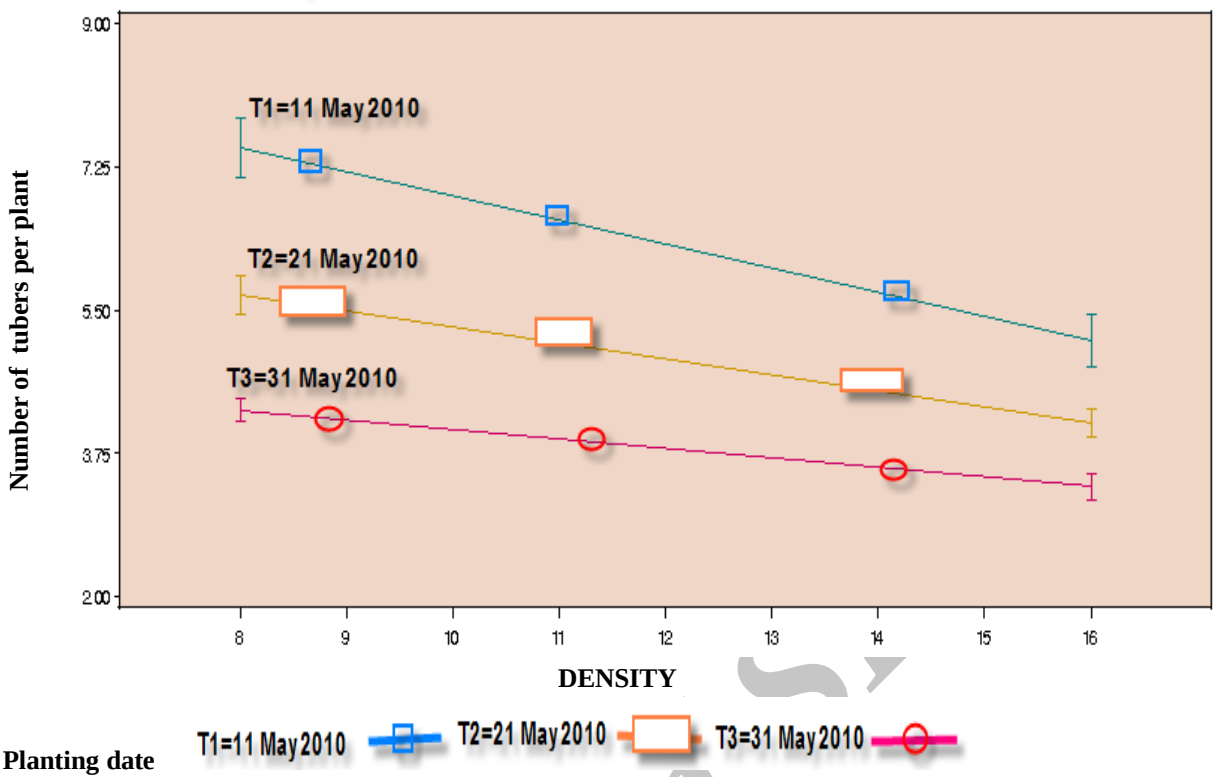

Figure 1. Variation trend of number of tubers per plant for different planting dates and densities

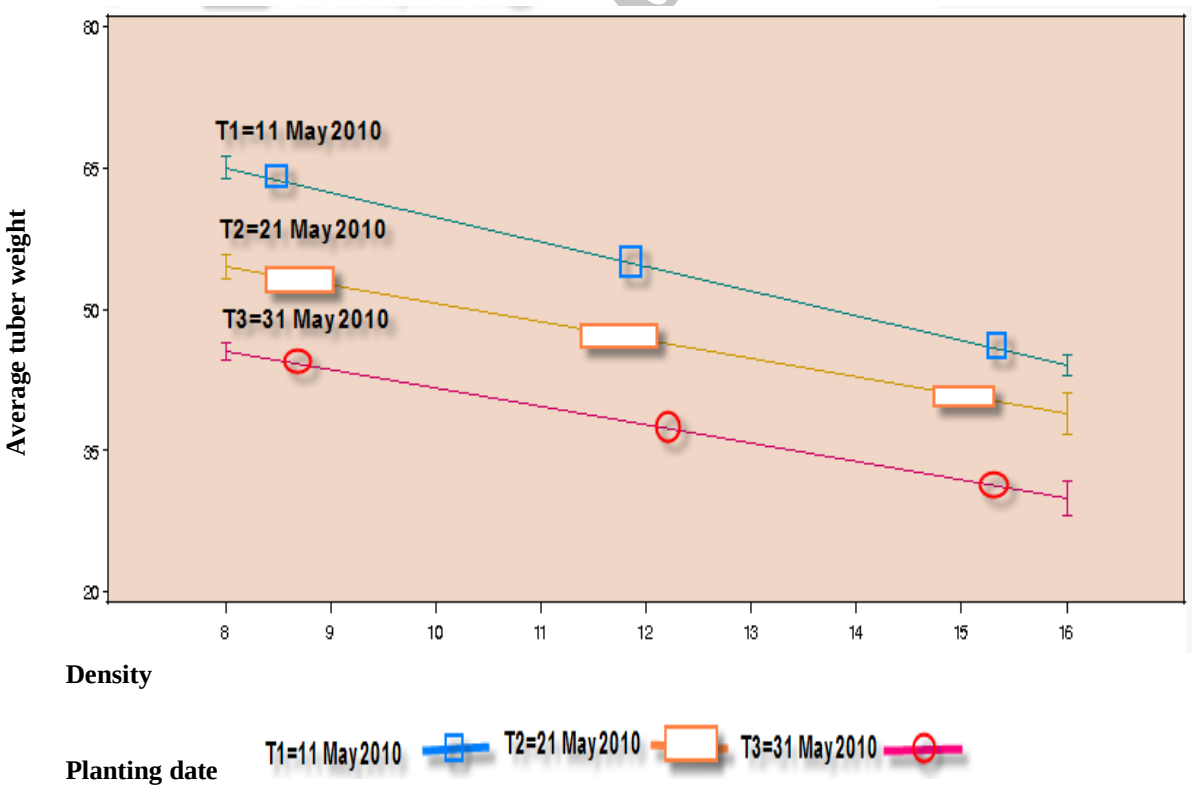

Figure 2. Variation trend of average tuber weight for different planting dates and densities

Table 5. Comparison of averages for interaction effects of planting depth and date on tuber yield

Planting depth (cm)	Planting date		
	11 May 2010	21 May 2010	31 May 2010
10	28.95 a	22.66 d	17.11 e
20	29.80 a	24.63 c	17.00 e
30	26.28 b	21.11 d	14.90 f

Mean followed by similar letters in each column are not significantly different.

Table 6. Mean comparison of triple interaction effects of planting date, depth and density on tuber yield

Depth	Density	Planting Date		
		11 May 2010	21 May2 010	31 May 2010
10	8	28.33 bc	23.23 hg	17.20 kj
	16	27.80 bcd	22.10 hi	17.03 kj
20	8	31.80 a	24.96 feg	17.83 j
	16	29.56 b	24.30 fg	16.16 kji
30	8	26.56 ced	21.63 hi	15.36 ki
	16	26.00 fed	20.60 i	14.43 i

Mean followed by similar letters in each column are not significantly different.

Interaction effect of plant density and date

The results show that the maximum number of tubers per unit area was observed in 8 plants/m density in May 11th (Diagram 1). Also, at May 31st planting date and 16 plants/m density produced the smallest number of tubers per unit area. Effects of plant density, planting date and their interaction effect were significant on tuber weight. The results show that the maximum and minimum tuber weight were obtained in 8 plants/m density in May11th and 16 plants/m^2 density in May 31st, respectively.

Interaction effect of planting depth and date

Interaction of planting date and planting depth influenced the yield, the number of tubers per plant, and the number of tubers per unit area, significantly. Studying interaction effect of planting date and planting depth implies that the best yield was obtained in may11th in planting depth of 20 cm (Table 5).

Interaction effect of planting depth, date and density

Riple interaction effect of planting date, depth and density was not significant on the tuber weight, the number of tuber per plant, number of tuber per unit area, protein content and stem length. The maximum values of potato yield were observed in 8 plants/m^2 density at 11th May and at planting depth of 20 cm. Generally, increase in planting depth reduced the yield (Table 6).

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