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Full Length Research Paper

Effects of seed size and in-row spacing on growth and yield of early potato in a mediterranean-type environment in Turkey

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Optimizing plant density and seed size are the most important subjects of early potato production systems in mediterranean-type environments due to their effects on seed cost, plant development, yield and quality of the crop. The effects of different in-row spacing (20, 25, 30 and 35 cm) and seed size (small, medium and large) treatments on yield components and tuber yield of early potato were studied in Adana, where is situated in the east mediterranean region of Turkey, during 2006 and 2007 growing seasons. It was determined that closer spacing reduced tuber number per hill, average tuber weight, tuber yield per hill and percentages of large and medium size tubers. Total yields increased as increasing planting density up to 20 cm spacing. Planting larger seeds positively affected all growth and yield components in both years. Tuber yield per hectare was increased up to certain stem density and then started to decline at all seed sizes. However, the optimum stem density for the maximum tuber yield per hectare markedly differed depending on size of seed tubers. The optimum stem density increased with increasing seed size. Our findings indicated that size of seed tuber has further importance for growth of potato plant as well as competition aspect in early potato production in the mediterranean-type environments. Hence it was concluded that using larger tubers had an advantage for vigorous early growth and for obtain high tuber yield in early potato production in the mediterranean-type environments. Seed size should be considered during recommendation for planting density in potato production.

Key words: Seed size, in-row spacing, early potato, competition.

INTRODUCTION

Potato is grown during winter and spring months (from December - January to May - June) as early crop in the mediterranean basin. The length of growing period of potato is relatively short (60 - 90 days after emergence) in this cropping system. In addition, low temperatures after planting and early growth stages and high temperatures during the tuber bulking stage significantly constrain growth and yield of potato. Therefore, application of proper management practices to enhance vigorous early growth is very important to achieve higher tuber yield from potato under these types of environments (Caliskan et al., 2004; Foti ve ark., 1999).

The optimizing of plant density is one of the most important subjects of potato production management, because it affects to seed cost, plant development, yield and quality of the crop (Bussan et al., 2007). In practice, plant density in potato crop is manipulated through the number and size of the seed tubers planted (Allen and Wurr, 1992). Therefore, many studies have been conducted to establish the optimal combination of seed size and planting distance for a certain environment (Barry et al., 1990; Creamer et al., 1999; Entz and LaCroix, 1984; Kleinhenz and Bennett, 1992; Negi et al., 1995; Strange and Blackmore, 1990; Bussan et al., 2007). In general, total yields increased as increasing plant density while percentage of large tubers decreased. However, the optimal planting density differed depending on the environmental conditions and cultivars. As a general rule, the higher plant densities are recommended for early potato

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Table 1. Some important climatical data of Adana during experimental periods.

Months	Min. Temp. (°C)		Max. Temp. (°C)		Mean Temp. (°C)		Relative Humidity (%)		Rainfall (mm)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
January	3.1	1.9	13.8	15.4	8.1	8.0	56.7	53.8	39.3	34.0
February	5.0	5.7	15.4	16.4	9.9	10.7	69.7	69.9	133.7	116.8
March	7.7	7.4	18.7	19.5	13.0	13.4	75.1	67.4	62.8	105.4
April	11.0	9.3	22.8	22.3	16.9	15.9	70.8	61.3	15.8	54.7
May	13.8	17.1	28.1	29.8	20.8	22.9	65.6	66.8	29.7	31.0

production systems in the mediterranean type of environments since, out-season production of potato crop limits its growth and yield potential (Caliskan 1997; Mauromicale et al., 2003).

Planting of large seed tubers can be advantageous under certain circumstances such as soil and weather conditions at planting are unfavorable, if the growing season is short and if there is a risk (frost, hail or drought) during the first part of the growing season (Beukema and Zaag, 1990). Actually, early potato production system in the mediterranean basin covers all above mentioned risk factors. This study was aimed to evaluate the effects of seed size on growth and yield of early potato and to optimize plant density by means of arranging seed size and in-row spacing in early potato production in Turkey.

MATERIALS AND METHODS

Field experiments were conducted in a farmer field in Adana province (Southern Turkey, 39° 59' N, 35° 18' E, 23 m a.s.l.) in 2006 and 2007, using the cv. Marabel. The soil of the experimental field was loamy clay, low in organic matter (2%) and slightly alkaline (pH 7.2). Adana province has typical mediterranean climate conditions with hot-dry summers and mild-rainy winters. Some important climatical data of Adana province are given in Table 1.

A split plot design with 3 replications was used each year. 4 in-row spacing (20, 25, 30 and 35 cm) were assigned to the main plots and 3 seed size (small, medium and large) were assigned to the sub plots. Small, medium and large seeds corresponded 28 - 25 mm, 36 - 35 mm and 46 - 55 mm diameter, respectively. The average weights of individual seed tuber from small, medium and large seed lots were 45, 75 and 118 g in 2006 and 40, 73 and 115 g in 2007, respectively Each sub-plots consisted of four rows having 5 m length and spaced 70 cm apart. All the seeds were planted by hand on 16 January in 2006 and 25 January in 2007. Cultivation, hilling up and hand weeding were conducted as necessary. Three sprinkler irrigations were applied during growing period in both years. Middle 2 rows in each plot were harvested by hand for determination of yield and yield components in 17 May 2006 and in 20 May 2007.

Analysis of variance was performed independently for each year using MSTAT-C statistical program. F-test was used to determine significance of main effects and interactions for the variables measured. Relationships between stem density and yield traits were evaluated with regression analysis.

RESULTS

Seed size significantly affected the number of main stem per plant while the effect of in-row spacing on the number of main stem per plant was not significant in both years. Consistently, the larger seed tuber produced the more main stems per seed in both years (Table 2).

Although number of main stems per plant was not significantly affected by in-row spacing, number of main stems per unit area significantly decreased with wider in-row spacing (Table 2). Planting of different sized seed tubers at various in-row spacing resulted in significantly different number of main stems per m^2 in both years. Small seeds had the highest stem density of 19.4 and 17.9 stem m^{-2} at 20 cm in-row spacing in 2006 and 2007, respectively, while the large seeds had the similar stem density at the widest (35 cm) in-row spacing (Table 2).

In-row spacing and seed size significantly affected the number of tubers per plant in both years (Table 3). The number of tubers per plant increased with larger seed size and wider spacing. The number of tubers m^{-2} increased with stem density in case of using small seeds, whereas number of tubers increased up to around 25 - 26 stems m^{-2} (25 cm in-row spacing) and then started to decrease after that densities, in case of using large seeds (Figure 1). The maximum number of tubers m^{-2} with small seeds never reached to lowest value of the largest seed size in the experiment.

Mean tuber weight was significantly affected by both in-row spacing and seed size in both years (Table 2). The lowest mean tuber weight was obtained from the closest in-row spacing (20 cm) and mean tuber weight values tended to increase with widening in-row spacing. However, no additional benefit of wider in-row spacing than 30 cm on mean tuber weight was observed in both years. The heavier seeds produced not only more tubers but also heavier individual tubers.

Although in-row spacing × seed size interaction was not found as significant since response of seed size to different in-row spacing was similar, the regression curves related stem density per square meter and mean tuber weight demonstrated distinct differences among seed size effects (Figure 2). The heaviest tubers was around 60 - 65 g with even the most sparse stem density (10 - 11 stem m^{-2} with 35 cm in-row spacing) when small seeds used. The large seeds produced heavier individual tubers (around 75 g) whereas they had much more stem density (18 - 20 stems m^{-2}) with the same in-row spacing

Table 2. Effects of different in-row spacing and seed size on number of main stems and tubers of early potato.

	Number of stem plant^{-1}		Number of stem m^{-2}		Number of tuber plant^{-1}		Number of tuber m^{-2}	
	2006	2007	2006	2007	2006	2007	2006	2007
Intra-row spacing								
20 cm	3.5	3.3	24.8	23.3	8.6	8.1	61.4	57.6
25 cm	3.6	3.3	20.4	18.8	10.7	9.9	60.9	56.3
30 cm	3.5	3.2	16.7	15.2	11.4	10.5	54.4	49.8
35 cm	3.6	3.2	14.6	14.4	11.7	10.9	47.9	44.5
LSD (%5)	0.2	0.3	1.1	1.3	1.1	1.5	5.5	7.2
Seed size								
Small	2.8	2.5	14.9	13.6	8.6	8.1	46.0	43.3
Medium	3.5	3.2	18.9	17.6	10.3	9.6	54.3	51.1
Large	4.4	4.2	23.6	22.5	12.9	11.7	68.1	61.8
LSD(%5)	0.2	0.2	1.3	1.2	0.7	0.7	3.5	3.7
In-row spacing (A)	NS	NS	**	**	**	*	**	*
Seed size (B)	**	**	**	**	**	**	**	**
A x B	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.1	6.5	7.7	7.7	7.6	7.9	7.2	8.1

* p < 0.05, ** p < 0.01, NS: Not significant.

Table 3. Effects of different in-row spacing and seed size on mean tuber weight and tuber yield values of early potato.

	Mean tuber weight (g)		Tuber yield (g plant^{-1})		Tuber yield (t ha^{-1})	
	2006	2007	2006	2007	2006	2007
Intra-row spacing						
20 cm	57.9	57.8	499.8	466.6	35.7	33.3
25 cm	65.1	63.9	699.5	634.3	38.9	35.2
30 cm	67.8	69.8	781.6	687.0	37.2	35.0
35 cm	67.4	66.1	804.9	726.9	32.2	29.1
LSD (%5)	3.8	5.5	60.9	119.9	3.0	3.1
Seed size						
Small	59.6	59.7	515.0	448.8	27.0	25.4
Medium	64.2	64.7	662.1	623.8	34.2	32.4
Large	69.9	68.8	912.3	813.5	46.8	41.8
LSD(%5)	3.7	2.6	33.1	79.2	1.9	1.5
In-row spacing (A)	**	**	**	**	**	**
Seed size (B)	**	**	**	**	**	**
A x B	NS	NS	**	**	NS	*
CV (%)	6.7	4.7	5.5	5.2	6.0	5.1

* p < 0.05, ** p < 0.01, NS: Not significant.

spacing (35 cm).

Tuber yields (per plant and per hectare) of early potato were significantly affected by either the main effects of in-row spacing and seed size or in-row spacing × seed size interaction effect in both year (Table 3). Both tuber yields per plant and per hectare consistently increased with increasing seed size. However, the effects of in-row spacing on both yield traits were opposite. The wider planting distance in rows resulted in significantly higher tuber yields per plant, whereas the widest in-row spacing produced the lowest tuber yield per hectare in both years. The highest tuber yield per hectare was obtained 25 or 30 cm in-row spacing (Table 3).

The interaction of seed sizes and in-row spacing also significantly affected to both tuber yield per plant and per hectare. Response of different sized seed tubers to

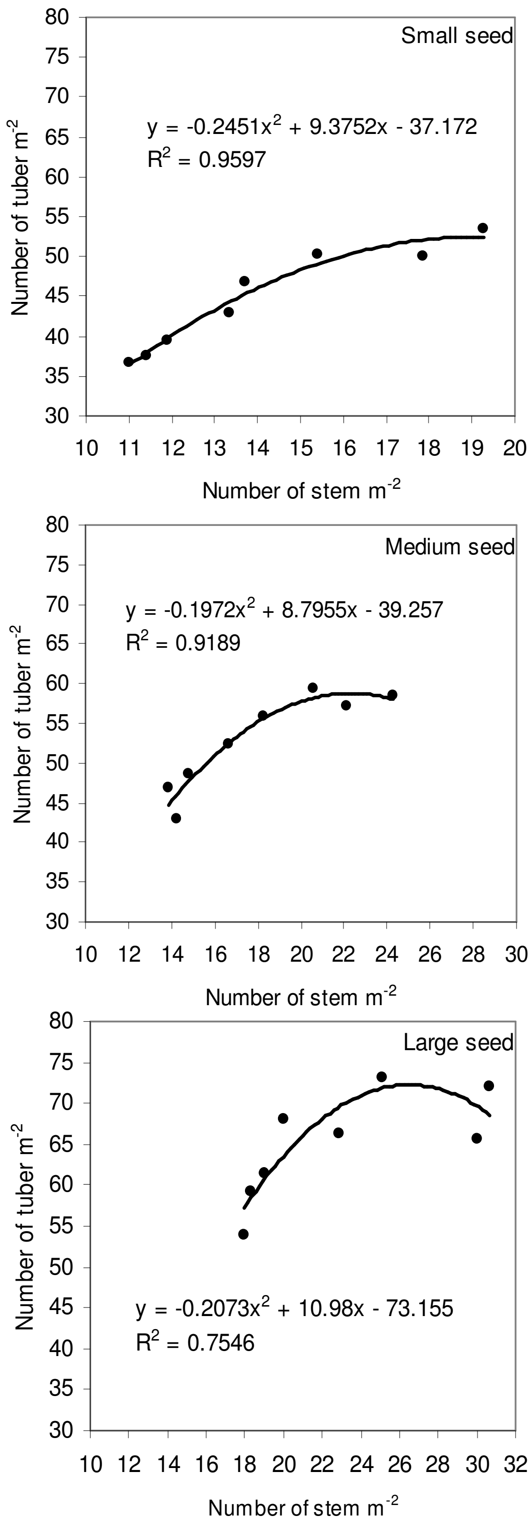

Figure 1. Relationship between stem density and number of tuber unit area with different seed size.

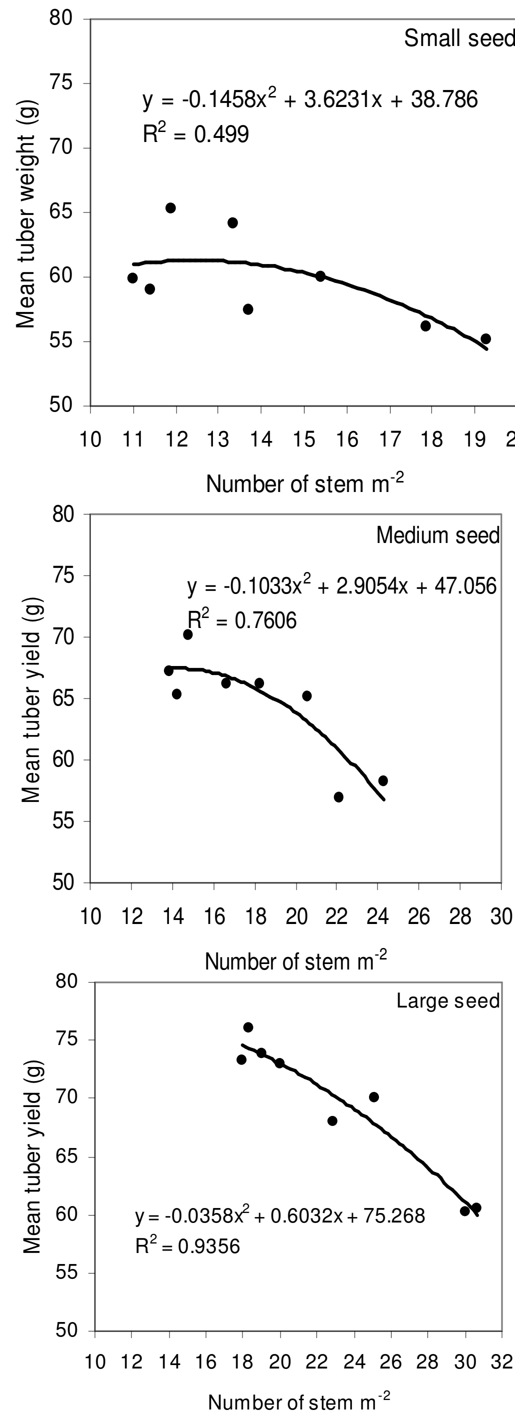

Figure 2. Relationship between stem density and mean tuber weight with different seed size.

different stem densities in respect to yield per plant was illustrated in Figure 3. Tuber yield per plant consistently decreased with increasing stem density for all seed size, but the slope of the decline was different among seed sizes. Although small seed tubers gave less stem density at all planting distance, they produced also lower values of tuber yield per plant. While the maximum tuber yield per plant was around 600 g with small seed tubers,

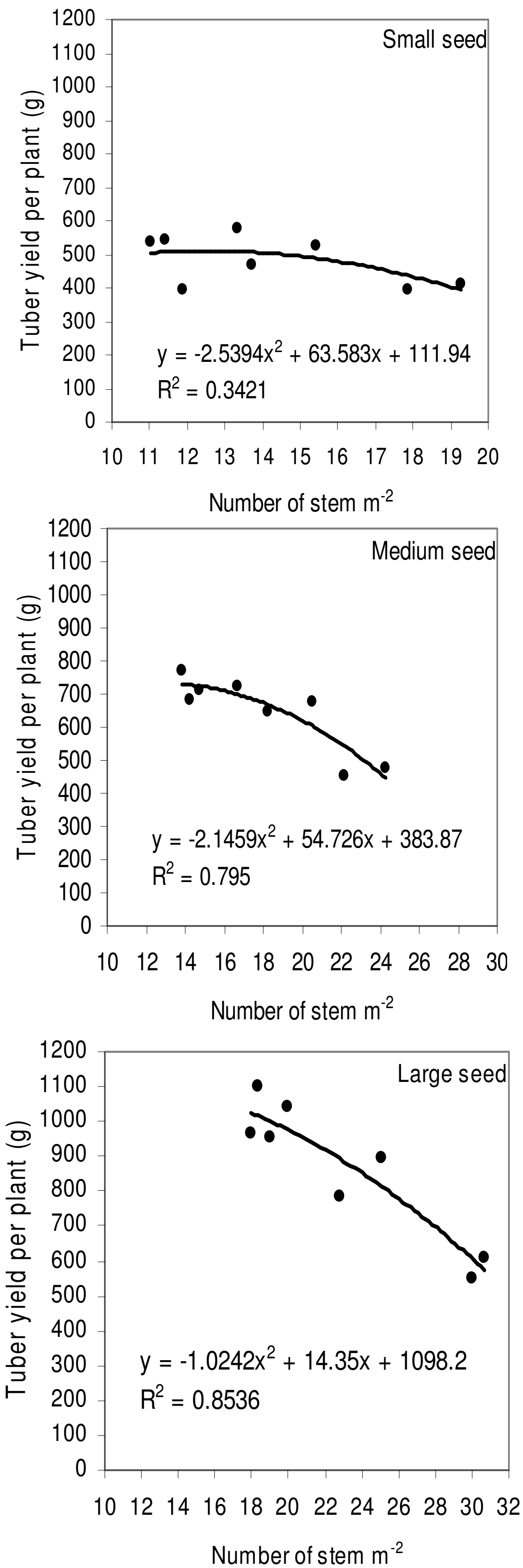

Figure 3. Relationship between stem density and tuber yield per plant with different seed size.

maximum tuber yields per plant with medium and large seed tubers were around 700 - 800 g and 1000 - 1100 g, respectively (Figure 3). Noteworthy point in that Figure 3 is the starting point of the competition in respect to stem density. Small seeds gave the lowest tuber yield per plant due to increasing competition at 18 - 20 stem m^2 density, whereas large tubers encountered the least competition and gave the highest tuber yield per plant at same stem density.

The relationship between stem density and tuber yield per hectare was illustrated in Figure 4. Tuber yield per hectare was increased up to certain stem density and then started to decline at all seed sizes. However, the optimum stem density for the maximum tuber yield per hectare markedly differed depending on size of seed tubers. The optimum stem density increased with increasing seed size.

Seed size significantly affected percentage of large, medium and small tubers in both years. Ratio of large tubers significantly affected by in-row spacing treatments but, the effect of in-row spacing on ratios of medium and small tuber was found as significant only in 2006. In-row spacing x seed size interaction did not affect size grading in both years (Table 4). The percentage of large tuber in total tuber yield was increased with increasing seed size and with widening in row spacing in both years.

DISCUSSION

It is well known that plant density is very important aspect of potato production since it significantly affects number of tubers per plant and per stem, mean tuber weight, tuber yield and size grading (Allen and Wurr, 1992). As a general rule, the higher plant densities are recommended for early potato in the mediterranean production system since out-season production of potato crop limits its growth and yield potential (Caliskan, 1997; Mauromicale et al., 2003).

Planting distance (row or in-row spacing) determines the number of plant (hill) per unit area. Several stems develop from individual seed tubers depending on size and physiological age of seed tubers. Each stem behaves as separate potato plant since each has own root and shoot system (Struik, 2007). Therefore, number of main stems per unit area (stem density) is generally considered as more realistic indicator of plant density than number of planted tubers in potato field (Bussan et al., 2007; Firman and Allen, 2007).

Both planting distance and size of seed tubers significantly affect stem density. In case of using standard size seed tubers, the main determinant of stem density is planting distance since each plant (hill) will have almost same number of stem. Hence, the competition between plants (hills) is prominent in the potato field. On the other hand, an intra-plant competition should be taken into consideration when different size seed tubers used. Many authors previously reported that the larger size of seed

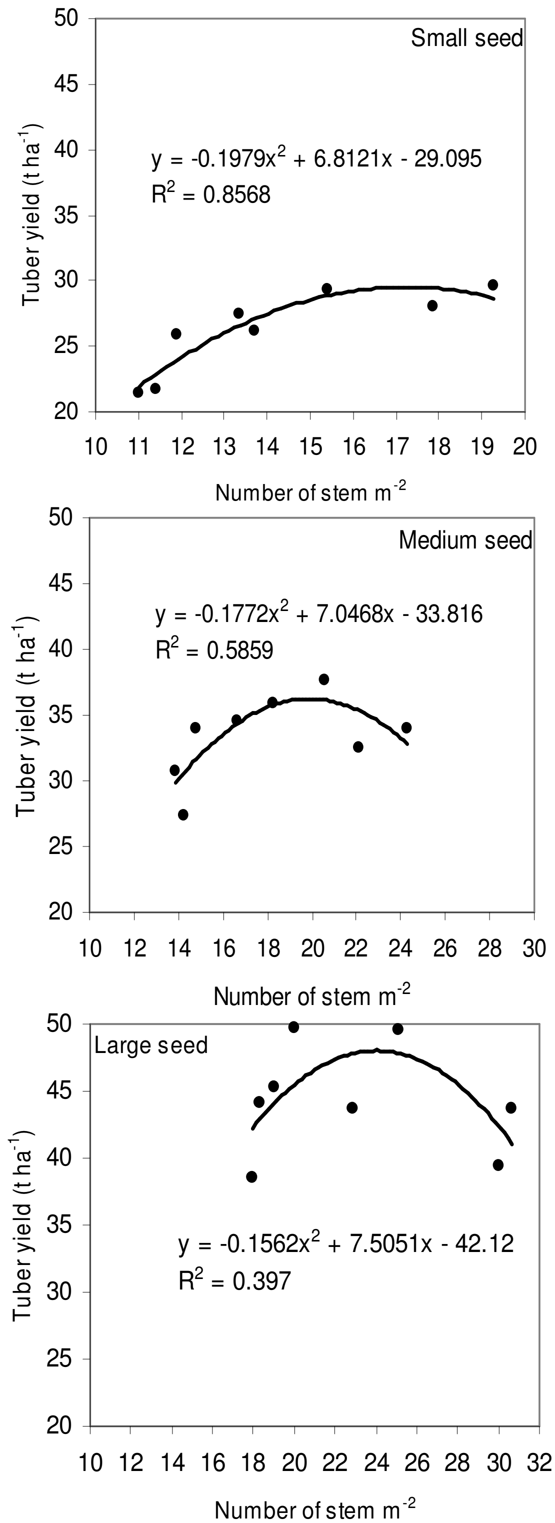

Figure 4. Relationship between stem density and tuber yield per hectare with different seed size

tuber produced more main stems due to increasing eye number per seed in larger tubers (Svensson, 1962; Iritani et al., 1972; Wurr, 1974; Entz and LaCroix, 1984).

Tuber production per plant are directly correlated with number of main stems per plant and significantly affected by inter-plant and intra-plant competition (Svensson, 1962; Moorby, 1967; Bussan et al., 2007). Our results revealed that major yield components such as number of tuber per plant, mean tuber weight and tuber yield per plant significantly decreased as planting distance get closer due to increasing inter-plants competition. However, yield and yield components significantly increased with increasing seed size. Tuber yield per hectare reduced after an optimum in-row spacing for each seed size due to reduction of hill number per hectare with widening of planting distance. However, the larger seed tubers responded better to widening of in-row spacing in respect to yield per hectare. The higher tuber yield per hill with the larger seed types was compensatory to reduction of hill number at wider in-row spacing in some extent. Many authors previously reported similar effects of seed size and in-row spacing on yield components and tuber yield under different production systems (Bremner and Taha, 1966; Entz and LaCroix, 1984; Strange and Blackmore, 1990; Vander Zaag et al., 1990; Bussan et al., 2007).

Our findings stated expressly special importance of seed size as well as competition aspect in early potato production in the mediterranean-type environments. The size of mother tubers (seed) affects not only number of stems per seed but also growth of stems. Bohl et al. (2001) reported that mother tubers fed the growing sprouts even after emergence until certain period. This is very important in early potato production under the mediterranean conditions since growing period is short and heat stress limits tuber growth during last period. The larger seed types showed more abundant haulm growth probably due to having earlier emergence and more main stems. It probably caused more carbohydrates supply to tubers and tuber yield increased. Caliskan (1997) also reported similar effects of seed size on growth and yield of early potato in a similar environment. Our findings clearly indicated that using larger tubers had an advantage for vigorous early growth and higher tuber yield in early potato production in the mediterranean-type environments. However, planting of large seed tubers at very close distance resulted in lower tuber yield due to increasing both inter- and intra-plant competition. Therefore, seed size should be considered during recommendation for planting density in potato production.

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