Asian Journal of Plant Sciences 6 (7): 1072-1079, 2007
ISSN 1682-3974

Effects of Irrigation Regimes and Row Arrangement on Yield, Yield Components and Seed Quality of Pumpkin (*Cucurbita pepo* L.)

[1]A. Ghanbari, [2]F. Nadjafi and [1]J. Shabahang
[1]Department of Agronomy, College of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran
[2]Department of Agriculture, Medicinal Plants and Drugs Research Institute,
Shahid Beheshti University, Tehran, Iran

Abstract: A research was conducted during growing season of 2005 to study the effects of irrigation regimes and row arrangement on yield, yield components and seed quality, oil percentage, germination index, germination percentage and seedling growth parameters and vigority of pumpkin (*Cucurbita pepo* L.). Three irrigation intervals of 7, 14 and 21 days and different plant spacing of 100×20, 100×40, 200×20 and 200×40 cm were used. Results indicated that the highest seed yield of pumpkin was observed in irrigation interval of 7 days, but it was not a significant difference between 7 and 14 days irrigation intervals. Irrigation intervals have a significant effect on number of seeds per fruit and the highest amount was observed in irrigation intervals of 7 days. Increasing irrigation interval up to 21 days decreased significantly the number of seeds per fruit and consequently seed yield per unit area. The highest seed oil yield was observed in irrigation interval of 7 days. Irrigation intervals had not significant effects on germination index and germination percentage of pumpkin but significantly affect lengths and wet weights of primary root and hypocotyls and vigority in pumpkin seeds. Results showed that the highest seed yield of pumpkin was obtained in 100 cm row distances in compare to 200 cm. Row distance had not a significant effect on number of seeds per fruit, but the highest fruits number was observed in lower row distances. Germination index and germination percentage were not affected by row distances but the highest root and hypocotyl lengths and wet weights and also seed vigority were observed in higher distances. Between row distances did not have a significant effect on evaluated parameters. The most favorable interaction treatment for seed yield and seed oil yield of pumpkin was irrigation interval of 7 days and plant spacing of 100×40 cm (25000 plants ha^{-1}).

Key words: Pumpkin, irrigation regimes, seed yield, seed quality, plant spacing

INTRODUCTION

Field water management practices are the most influential factors affecting crop yield particularly in irrigated agriculture in arid and semi arid regions (Al-Omran *et al*., 2005). It is necessary to get maximum yield in agriculture by using available water in order to get maximum profit from per unit area because existing agricultural land and irrigation water are rapidly diminishing due to rapid industrialization and urban development (Ertek *et al*., 2004). Optimizing irrigation management due to water scarcity together with appropriate crops for cultivation is highly in demand in these regions. The cost of irrigation pumping and inadequate irrigation scheme capacity as well as limited water sources is among the reasons that force many farmers in the region to reduce irrigation applications. The potential of water stress tolerance and the economical value of medicinal and aromatic plants, make them suitable alternative crops in dryland agroecosystems (Koocheki and Nadjafi, 2003).

Plant density is one of the main factors determining seed yield. Recent studies showed that relatively high plant densities were required to obtain the highest seed yield and quality in watermelon (Edelstein and Nerson, 2002) and muskmelon (Kanwar *et al*., 2000). These results are in line with several vegetable crops like onion (Kanwar *et al*., 2000) and cabbage (Singh *et al*., 2000) in which high seed yields were achieved at high plant densities. Andriolo (1999) showed that an ideal population density was necessary for an optimized Leaf Area Index (LAI), so that the maximum useful radiation for photosynthesis would be intercepted. On high density plantings, an optimized LAI can be reached very early, before plants start the reproductive phase. Thus, planting density influences plant growth, changing the emission of

Corresponding Author: Dr. Farsad Nadjafi, Department of Agriculture, Medicinal Plants and Drugs Research Institute, Shahid Beheshti University, Evin, Tehran, Iran Tel/Fax: +98-21-22431783

flowers and fruits and interfering on the biomass distribution between vegetative parts and fruits. Obtaining optimum plant population in seed production is one of the ways to guarantee high yield (Cardaso and Verdial, 2003). The increase of plant density is one of the most effectual techniques in sustainable agriculture: it is claimed to have a positive effect on crop yield by decreasing weed growth and ensuring a more complete covering of soil (Francis *et al.*, 1990). Nevertheless in semi arid environments, characterized by a limited water supply, the increase of plant density and the related increase of intraspesific competition could set a limit to the yield potential of the plant individuals. In these environments, the choice of the optimum distance between rows is therefore particularly important (Carruba *et al.*, 2002).

Seed quality for reproduction is influenced by a number of internal and environmental factors during seed development (Araujo *et al.*, 1982; Pedrosa *et al.*, 1987; Welbaum and Bradford, 1991) and is measured by germination percentage and rate (Bravo and Venegas, 1984), by longevity which is greatly influenced by storage temperature and moisture content (Doijode, 2000) and by the performance of their offspring (Davis *et al.*, 1987; El-Keblawy and Lovett Doust, 1998). Soil water supply is an important environment factor controlling germination and seedling establishment (Kramer and Kozlowski, 1979). Seed germination and early seedling growth are considered the most critical phases for establishment of any species and thus it is often emphasized that the tolerance of seeds to various stresses during germination should be determined (Uniyal and Nautiya, 1998).

Common pumpkin (*Cucurbita pepo* convar. *pepo* var. styriaca) is an annual plant belonging to cucurbitaceae family. Pumpkin has been used as a vegetable and medicine since ancient times, but has been cultivated as a medicinal plant only in recent decades. Nowadays it is cultivated all over the world for different kinds of usage. The fatty oil of seeds is also used as a local specialty, e.g., in Austria and Germany as salad dressing additive (Sigmund and Murkovic, 2004; Wagner, 2000). Pumpkin seeds are used in bakeries for special breads and also as snacks (Kuhlmann *et al.*, 1999). The seeds of pumpkin contains fatty oil, β-sitosterol and E-vitamin and is used as a raw material for certain pharmaceutical products including Peponen® and Gronfing® capsules which are mainly used to cure the prostatic hypertrophy and urinary tract irritation (Horvath and Bedo, 1988; Hillebrand *et al.*, 1996; Idouraine *et al.*, 1996). It is not fully clear which constituent is responsible for curing prostatic hypertrophy. A combination of several ingredients and particular content of sterols are generally considered to contribute to the pharmacological activity (Kuhlmann *et al.*, 1999). The production of pumpkin seeds is on the increase and production techniques require further research (Bavec, 2000).

Iran is a country with arid and semi-arid climate conditions, so with insufficient water resources there, elaborating alternative crops and/or different irrigation water management is urgent for farming lands. Employing water stress tolerant species with high economical income might provide an opportunity to optimize the applied irrigation water with more benefits for farmers. So the objective of this research was to study the effects of different irrigation regimes and row arrangement on yield, yield components and seed quality of pumpkin as a cash crop (*Cucurbita pepo* L.).

MATERIALS AND METHODS

A study was conducted in the growing season of 2005, at the experiment station of college of Agriculture, Ferdowsi University of Mashhad (Latitude: 36°, 15/N, longitude: 59°, 28′E and elevation, 928 m) to investigate the effects of irrigation regimes and row arrangement on yield, yield components and seed quality of pumpkin (*Cucurbita pepo* L.). The soil of the field was silty loam with pH: 7.8, contains total N (690 ppm), total P (2.5 ppm) and total K (0.28 ppm) with EC of 10 mmohs cm^{-1}. A split plot experiment base on a Randomized Complete Block Design with three replications was used. Irrigation intervals including of 7, 14 and 21 days were arranged in main-plots and different plant spacing (100×20, 100×40, 200×20 and 200×40 cm) were arranged in subplots. Each experimental plot was designed by 6 m long and consisted of 5 planting rows. Main plots (180 m^2) were irrigated up to field capacity with 2 cm of water (3600 L) in irrigation times. Furrows in each plot were irrigated by a hose (4 cm diameter) with a counter on it. In order to prevent the lateral spread of water, plots were surrounded by dikes with a distance of 2 m between plots. Weeds were controlled by hand when needed. All plots were fertilized uniformly by cow manure, 30 ton ha^{-1}, in autumn, before of cultivation. Seeds were sown directly in holes (three seeds in each hole) with 2 cm depth in the mentioned planting distances at 16 May. Before starting irrigation regimes, an irrigation interval of 7 days was used until the plantlets became 2 expanded leaves. At this time the correct density is achieved by depletion of extras plantlets. Manual harvesting was carried out at 18 October when 75% of fruits became yellowish-orange in color and seeds were dark green and well rounded. Sampling area was 8 m^2. Quantity parameters including of Seed Yield, Number of seeds per fruit, Number of fruits per square meter, mean weight of each fruit and 1000 seeds weight were measured. Seed quality parameters including oil percentage, germination percentage, germination index, seedling growth and seed vigor index, also were evaluated. For this subject, 25 seeds of each experimental plot were sampled and were put in 12 cm Petri dishes with Whatman No 1. filter paper moistened with 7 mL water. The dishes were incubated in a germinator under 25°C in the dark and the number of germinated seeds was recorded daily for a week to determine the germination percentage and germination index. Germination Index (GI) was calculated as McKenzie *et al.* (1980) formula:

$$GI = \sum_{n=0}^{t-1} X_n \, (t-n)/t$$

Where:

X_n = Germination percentage on the nth count,
n = The nth day of counting germination -1,
t = Total days of counting germination.

For seed growth measurements 10 seedling from each treatment were taken randomly after one week. The Hypocotyl and primary root lengths of individual seedlings were recorded. After recording the fresh weight of Hypocotyl and primary root of each seedling, these were kept in the oven at 80°C for 48 h to determine their dry weight (Evans, 1972). At the end of the experiment seedling vigor index was calculated as (Dhindwal *et al.*, 1991) formula:

VI = (average shoot length (cm) + average root length (cm) × germination percentage

The oil content of the seeds was determined by treating the weighted powder seeds with hexane and refluxed for 16 h in a Soxhlet extractor. The solvent was removed by rotary evaporator. The oil sample was then placed in a vacuum oven kept at 60°C for 30 min and then accurately weighted and the percentage yield calculated (Younis *et al.*, 2000).

The data were exposed to the statistical analysis of variance by one-way ANOVA using Statistical Analysis System (2001) (SAS) and means were compared by Duncan's multiple range test at 5% probability level.

RESULTS AND DISCUSSION

Results indicated that the highest seed yield of pumpkin was observed in irrigation interval of 7 days, but it was not a significant difference ($p = 0.05$), between 7 and 14 days irrigation intervals. Irrigation intervals have a significant effect on number of seeds per fruit and the highest amount was observed in irrigation intervals of 7 days (Table 1). Increasing irrigation interval up to 21 days decreased significantly the number of seeds per fruit and consequently seed yield per unit area (Table 1). Nadjafi and Rezvani Moghaddam (2002), reported that irrigation interval of 7 days have a significant higher seed yield in compare with 14, 21 and 28 days irrigation intervals, in *Plantago ovata*. They showed that irrigation intervals of 28 days significantly decreased the number of seeds per spike and number of spikes per plant.

Irrigation intervals had not significant effects on number of fruits per unit area, mean weight of fruit and 1000 seeds weight, but the highest amounts of these parameters was observed in irrigation interval of 7 days (Table 1). Al-Omran *et al.* (2005) reported that at high irrigation levels (non-stressed), fruit yield of *Cucurbita pepo* were high and decreased significantly at low irrigation levels (stressed). Research (Ertek *et al.*, 2004), showed that in irrigation interval of 5 days fruit yield of *Cucrbita pepo* is higher than 10 days irrigation interval. He claimed that increasing frequency of irrigation, increased fruit number and consequently fruit yield. He also reported that there was a significant correlation between fruit weight and irrigation frequency. Xia (1994) reported that mean seed weight was a relatively stable yield component in water stress treatments in different development stages of fababean (*Vicia faba* L.). Chapolivier and Merrien (1996) claimed that water stress treatments did not affect one thousand seeds weight in *Brassica napus*. Seed oil percentage did not affected by irrigation intervals, but the highest oil percentage was observed in irrigation interval of 7 days (Table 1). While Champolivier and Merrien (1996) reported that water stress declined oil concentration of *Brassica napus*. The highest seed oil yield was observed in irrigation interval of 7 days (Table 1). It seems that higher significant oil yield in lower irrigation intervals is in result of higher seed

Table 1: Effects of irrigation regimes on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Irrigation intervals (Day)	SY ($g\ m^{-2}$)	No. S/F	No. $F\ m^{-2}$	MWF (g)	1000 SW (g)	O (%)	OY ($g\ m^{-2}$)	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
7	97.0^{a}	384.6^{a}	1.4^{ns}	3707.8^{ns}	166.6^{ns}	38.8^{ns}	37.9^{a}	86.7^{ns}	94.6^{ns}	9.9^{a}	8.8^{a}	3.6^{ns}	5.5^{a}	5.2^{ns}	11.0^{a}	18.4^{a}
14	84.1^{a}	372.1^{a}	1.4^{ns}	3357.4^{ns}	161.4^{ns}	35.1^{ns}	30.0^{ab}	83.2^{ns}	93.0^{ns}	7.8^{b}	6.7^{b}	3.6^{ns}	4.3^{b}	5.1^{ns}	8.7^{b}	13.7^{b}
21	61.8^{b}	343.5^{b}	1.0^{ns}	3150.9^{ns}	160.8^{ns}	35.9^{ns}	22.4^{b}	89.2^{ns}	93.0^{ns}	7.9^{b}	6.4^{b}	3.6^{ns}	4.4^{b}	5.3^{ns}	8.2^{b}	13.6^{b}

SY: Seed Yield, No.S/F: No. of seeds per fruit, No. F/m^2: No. of fruits per m^2, MWF: Mean weight of each fruit, 1000 SW: 1000 seeds weight, O (%): Oil percentage, OY: Oil Yield, GI: Germination Index, G (%): Germination percentage, LR: Primary root length, LH: Hypocotyl length, DWR: Primary root dry weight (10 seeds), WWR: Primary root wet weight (10 seeds), DWH: Hypocotyl dry weight (10 seeds), WWH: Hypocotyl wet weight (10 seeds) VI: Seed Vigour Index Means within columns having different letter(s) are significantly different according to LSR at $p = 0.05$, ns: Non significant yield. Nadjafi (2006) also reported that higher essential oil yield of *Nepeta binaludensis* in irrigation intervals of 7 and 14 days compare to 21 days is consequent of higher herbage yield and essential oil percentage was not affected by irrigation intervals. Irrigation intervals had not significant effects on germination index and germination percentage of pumpkin but significantly affect lengths and wet weights of primary root and Hypocotyl and vigority in pumpkin seeds (Table 1). It seems that embryos of seeds which are collected from lower irrigation interval have a higher ability to uptake water and therefore higher vigority. Uniyal and Nautiyal (1998) reported that water stress had adverse effect on early seedling growth of *Ougeinia dalbergioides* Benth, as the root and shoot length decreased in the seed germinated under stress. They reported that increase in water stress level from -0.2 MPa to -1.0 MPa decreased significantly root length, shoot length and seed vigor index. They mentioned that water uptake in the seeds decreased with increasing level of water stress.

The highest seed yield of pumpkin was obtained in 100 cm row distances in compare to 200 cm. Row distance had not a significant effect on number of seeds per fruit, but the highest fruits number was observed in lower row distances (Table 2). Lower row distances had smaller fruits in compare to higher distances but the difference was not significant (Table 2). Also, 1000 seeds weight did not affect significantly by row distances (Table 2). So it seems that in lower row distances, fruit size, number of seeds per fruit and seeds weight declined but this decline was not considerable and increase in number of fruits compensate it and increase the seed yield per unit area. Research (Nerson, 2005) showed that increasing plant density from 0.5 to 8 plants m^{-2} in *Cucrbita pepo* increased the fruits number per unit area whereas the mean fruit weight decreased. These effects resulted in an increase of fruit yield per unit area at high plant densities. He reported that the highest seed yield per unit area was obtained at 4 plants m^{-2}. There was a general tendency of decrease in seed number per fruit and in the mean seed weight when increasing plant density. He mentioned that the fruit number per unit area is probably the main factor that dictates the seed yield limit. Squash plants have vigorous vegetative growth and there is probably strong competition between the plants at high population densities. Maximum seed yield will be achieved under practices that will promote the best compromise between a maximum fruit number with a minimum decrease in seed yield per fruit. To obtain higher seed production in *Cucurbita pepo*, Loy (1988) considers the increase of plant density and fruit number per plant a prior factor. In higher plant densities (35000 plants ha^{-1}) seed weight and fruit number per plant were lower, however seed yield per hectare was higher when compared to low densities (8000 plants ha^{-1}). This study concluded that 14000 plants ha^{-1} would be an adequate population with a plant spacing of 1.2×0.6 m. This planting density provided 44.4 g of seeds per plant. Using 14000 plant ha^{-1} resulted in 2.1 fruits $plant^{-1}$ and highest seed weight per fruit (21.0 g). Loy (1988) mentioned that a low seed yield per plant is due to small weight or quantity of fruits in high density planting. High plant population causes competition for place, light and nutrients resulting in lower seed production per fruit and per plant and small fruits with lower weight. Ho (1992), mentioned that the production of growing substances in the presence of seeds stimulates the fruit growth, confirming the idea that higher seeds amount per fruit results in bigger fruits.

Row distances had not significant effect on oil percentage but the highest oil yield was observed in lower row distances (Table 2). Wahba and Ezz El-Din (2002), mentioned that dense planting (25 cm between hills) produced the tallest plants and the highest yield of seeds and volatile yield of *Chrysanthemum coronarium* L. compared with wider planting distance (e.g., 50 or 75 cm between hills).

Germination index and germination percentage were not affected by row distances but the highest root and hypocotyl lengths and wet weights and also seed vigority were observed in higher distances (Table 2). Arista and Talaveras, 1996 reported that in lower plant densities of *Abies pinsapo*, seedling vigor and root and shoot lengths were higher in compare with higher densities. Edelstein *et al.* (1985) reported that different population densities of Spaghetti vegetable squash did not affect the seed size or germination percentage. There was no germination difference between different plant spacing in squash (Lima, 2003).

Within row distances did not affect any of evaluated parameters in pumpkin (Table 3). It seems that in *Cucurbita pepop* between row distances have more enormous effect on yield and yield components than

Table 2: Effects of row distances on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Row distance (cm)	SY ($g\ m^{-2}$)	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY ($g\ m^{-2}$)	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
100	93.5^{a}	359.6^{ns}	1.5^{a}	3345.4^{ns}	159.1^{ns}	37.1^{ns}	35.8^{a}	88.2^{ns}	92.6^{ns}	7.7^{ns}	6.6^{ns}	3.6^{ns}	4.6^{b}	5.2^{ns}	8.9^{b}	13.7^{ns}
200	68.4^{b}	373.8^{ns}	1.0^{b}	3465.3^{ns}	166.7^{ns}	36.2^{ns}	24.4^{b}	83.2^{ns}	94.4^{ns}	9.4^{ns}	7.9^{ns}	3.6^{ns}	4.9^{a}	5.3^{ns}	9.7^{a}	16.6^{ns}

*Means within columns having different letter(s) are significantly different according to LSR at $p = 0.05$, ns: non significant within row distances. This can be the result of the runner character of this species, which the most competition for light and space will be in within rows in compare with between rows.

Data in Table 4 indicate that the most favorable interaction treatment for seed yield and seed oil yield was narrow distance (100 cm) with irrigation interval of 7 days. Number of seeds per fruit, fruit weight and 1000 seeds weight was not affected significantly by interaction effect of irrigation regime and row distances but the effect of this interaction on number of fruits per unit area was significant (Table 4). The highest number of fruits per unit area was observed in narrow distance (100 cm) with irrigation interval of 7 and 14 days, but in irrigation interval of 21 days the highest seed yield and seed oil yield observed in higher plant density (Table 4). These results indicated that if water was not a limited factor, increasing in plant density and decreasing row distances, increased seed yield and seed oil yield in pumpkin. Nadjafi and Rezvani Moghddam (2002) reported that the highest seed yield of *Plantago ovata* was observed in higher irrigation frequency (irrigation interval of 7 days) and higher plant density (144 plants m^{-2}). Interaction effect of irrigation regime and row distance did not affect oil percentage, germination index, germination percentage and growth parameters of seedlings in pumpkin, but the highest growth parameters of seedlings was observed in irrigation in 7 days irrigation interval and 200 cm plant density, which have the lowest completion (Table 4).

Interaction effect of irrigation regime and within row plant distance on seed yield and seed oil yield of pumpkin was significant (Table 5). The highest seed yield and seed oil yield was observed in irrigation interval of 7 days and plant distances of 40 cm (Table 5). The effect of this interaction was not significant on yield components but the highest seeds number per fruit, number of fruits per unit area and fruit weight was observed in this treatment. Also oil percentage was affected significantly by this interaction and the highest oil percentage was observed in 7 days irrigation interval and 40 cm plant distance (Table 4). Germination index, germination percentage, seedling growth parameters and seed vigority of pumpkin was not affected significantly by this interaction (Table 5).

Effect of interaction of within and between row distances on seed yield, yield components and seed oil yield of pumpkin was not significant, only plant spacing of 100×20 cm had a lower fruit weight, but the highest seed yield (100.4 g m^{-2}) and seed oil yield (38.6 g m^{-2}) was observed in plant spacing of 100×40 cm (Table 6). Germination index and germination percentage was not significantly affected by row arrangement but seedling growth parameters were affected significantly by plant spacing (Table 6). The highest primary root and

Table 3: Effects of planting distances on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Plant distance (cm)	SY (g m^{-2})	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY (g m^{-2})	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
20	77.3^{ns}	364.0^{ns}	1.3^{ns}	3205.6^{ns}	161.6^{ns}	35.3^{ns}	27.9^{ns}	86.8^{ns}	94.0^{ns}	8.1^{ns}	6.9^{ns}	3.6^{ns}	4.6^{ns}	5.3^{ns}	9.1^{ns}	14.4^{ns}
40	84.6^{ns}	369.4^{ns}	1.3^{ns}	3605.4^{ns}	164.2^{ns}	38.0^{ns}	32.4^{ns}	85.9^{ns}	93.1^{ns}	9.0^{ns}	7.7^{ns}	3.6^{ns}	4.8^{ns}	5.2^{ns}	9.5^{ns}	15.9^{ns}

ns: non significant

Table 4: Interaction effects of irrigation regimes and row distance on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Irrigation intervals (Day)	Row distance (cm)	SY (g m^{-2})	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY (g m^{-2})	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
7	100	129.9^{a}	395.9^{ns}	1.9^{a}	3536.8^{ns}	164.3^{ns}	39.1^{ns}	51.5^{a}	84.6^{ns}	94.0^{ns}	8.9^{ns}	7.6^{ns}	3.6^{ns}	5.0^{b}	5.3^{ns}	10.0^{ns}	15.8^{ns}
	200	64.1^{c}	373.3^{ns}	1.0^{b}	3878.8^{ns}	168.8^{ns}	38.5^{ns}	24.3^{bc}	88.8^{ns}	95.3^{ns}	10.9^{ns}	10.0^{ns}	3.6^{ns}	5.9^{a}	5.4^{ns}	12.0^{ns}	20.2^{ns}
14	100	98.3^{b}	354.5^{ns}	1.7^{a}	3219.6^{ns}	158.4^{ns}	37.0^{ns}	37.4^{b}	87.8^{ns}	93.3^{ns}	6.7^{ns}	6.5^{ns}	3.6^{ns}	4.4^{d}	5.0^{ns}	8.7^{ns}	12.6^{ns}
	200	69.8^{bc}	389.5^{ns}	1.0^{b}	3495.1^{ns}	164.3^{ns}	33.3^{ns}	22.6^{c}	78.6^{ns}	92.6^{ns}	8.9^{ns}	6.9^{ns}	3.6^{ns}	4.1^{e}	5.3^{ns}	8.7^{ns}	14.8^{ns}
21	100	52.2^{c}	328.4^{ns}	0.9^{b}	3280.0^{ns}	154.5^{ns}	35.2^{ns}	18.5^{c}	92.1^{ns}	90.6^{ns}	7.4^{ns}	5.9^{ns}	3.6^{ns}	4.2^{e}	5.3^{ns}	7.9^{ns}	12.5^{ns}
	200	71.4^{bc}	358.5^{ns}	1.1^{b}	3021.9^{ns}	167.0^{ns}	36.7^{ns}	26.3^{bc}	86.2^{ns}	95.3^{ns}	8.4^{ns}	6.9^{ns}	3.6^{ns}	4.6^{c}	5.3^{ns}	8.4^{ns}	14.7^{ns}

* Means within columns having different letter(s) are significantly different according to LSR at p = 0.05, ns: non significant

Table 5: Interaction effects of irrigation regimes and planting distance on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Irrigation intervals (Day)	Plant distance (cm)	SY (g m^{-2})	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY (g m^{-2})	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
7	20	81.2^{bc}	378.7^{ns}	1.3^{ns}	3571.1^{ns}	166.2^{ns}	36.1^{bc}	29.3^{bc}	88.8^{ns}	95.3^{ns}	9.3^{ns}	8.5^{ns}	3.6^{ns}	5.3^{ns}	5.3^{ns}	10.9^{ns}	17.3^{ns}
	40	112.8^{a}	390.5^{ns}	1.6^{ns}	3844.4^{ns}	166.9^{ns}	41.5^{a}	46.5^{a}	84.6^{ns}	94^{ns}	10.5^{ns}	9.0^{ns}	3.6^{ns}	5.6^{ns}	5.3^{ns}	11.2^{ns}	18.8^{ns}
14	20	87.5^{b}	357.1^{ns}	1.5^{ns}	3132.1^{ns}	165.7^{ns}	36.0^{b}	32.6^{b}	81.0^{ns}	92^{ns}	6.7^{ns}	5.5^{ns}	4.0^{ns}	5.2^{ns}	8.2^{ns}	3.6^{ns}	11.7^{ns}
	40	80.7^{bc}	386.9^{ns}	1.3^{ns}	3582.7^{ns}	157.1^{ns}	34.3^{bc}	27.5^{bc}	85.4^{ns}	94^{ns}	8.9^{ns}	7.8^{ns}	3.6^{ns}	4.5^{ns}	5.0^{ns}	9.3^{ns}	15.7^{ns}
21	20	63.3^{bc}	356.2^{ns}	1.0^{ns}	2913.6^{ns}	153.0^{ns}	33.7^{c}	21.7^{c}	90.8^{ns}	94^{ns}	8.3^{ns}	6.6^{ns}	3.6^{ns}	4.5^{ns}	5.3^{ns}	8.3^{ns}	14.2^{ns}
	40	60.3^{c}	330.7^{ns}	1.0^{ns}	3388.2^{ns}	168.6^{ns}	34.3^{ab}	23.2^{c}	87.6^{ns}	91^{ns}	7.5^{ns}	6.2^{ns}	3.6^{ns}	4.3^{ns}	5.3^{ns}	8.0^{ns}	13.1^{ns}

* Means within columns having different letter(s) are significantly different according to LSR at p = 0.05, ns: non significant

Table 6: Interaction effects of row distances and planting distance on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Row distance (cm)	Plant distance (cm)	SY (g m^{-2})	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY (g m^{-2})	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
100	20	86.5^{ns}	346.3^{ns}	1.5^{ns}	3136.0^{b}	156.3^{ns}	37.1^{ns}	33.0^{ns}	90.4^{ns}	95.5^{ns}	9.1^{ab}	7.4^{ab}	3.6^{ns}	4.6^{b}	5.3^{ns}	9.3^{ns}	16.1^{ab}
	40	100.4^{ns}	373.0^{ns}	1.5^{ns}	3555.0^{a}	161.9^{ns}	37.1^{ns}	38.6^{ns}	85.9^{ns}	89.7^{ns}	6.2^{b}	5.9^{b}	3.6^{ns}	4.5^{b}	5.1^{ns}	8.4^{ns}	11.3^{b}
200	20	68.1^{ns}	381.7^{ns}	1.3^{ns}	3276.0^{a}	167.0^{ns}	33.5^{ns}	22.7^{ns}	83.2^{ns}	92.4^{ns}	7.2^{b}	6.4^{b}	3.6^{ns}	4.6^{b}	5.3^{ns}	8.9^{ns}	12.7^{b}
	40	68.1^{ns}	365.8^{ns}	1.1^{ns}	3655.0^{a}	166.4^{ns}	38.9^{ns}	26.1^{ns}	85.8^{ns}	96.4^{ns}	11.7^{a}	9.5^{a}	3.6^{ns}	5.1^{a}	5.3^{ns}	10.5^{ns}	20.5^{a}

Means within columns having different letter(s) are significantly different according to LSR at $p = 0.05$, ns: non significant

Table 7: Interaction effects of irrigation regimes, row distances and planting distance on yield, yield components and seed quality of Pumpkin (*Cucurbita pepo*)

Irrigation intervals (Day)	Row distance (cm)	Plant distance (cm)	SY (g m^{-2})	No. S/F	No. F m^{-2}	MWF (g)	1000 SW (g)	O (%)	OY (g m^{-2})	GI	G (%)	LR (cm)	LH (cm)	DWR (g)	WWR (g)	DWH (g)	WWH (g)	VI
7	100	20	89.7^{bc}	375.8^{ns}	1.5^{c}	3342.9^{ns}	153.4^{ns}	37.4^{abcd}	33.5^{c}	89.6^{bc}	93.7^{ns}	10.3^{ns}	8.9^{ns}	3.6^{ns}	5.3^{bc}	5.3^{ns}	11.0^{ns}	18.8^{ab}
		40	170.1^{a}	416.0^{ns}	2.3^{a}	3730.7^{ns}	175.2^{ns}	40.8^{ab}	69.4^{a}	79.7^{ns}	90.0^{ns}	7.5^{ns}	6.2^{ns}	3.6^{ns}	4.8^{bcd}	5.2^{ns}	9.1^{ns}	12.9^{ab}
	200	20	72.8^{cd}	381.6^{ns}	1.0^{fg}	3799.3^{ns}	179.0^{ns}	34.9^{cde}	25.1^{cd}	88.0^{ns}	93.3^{ns}	8.3^{ns}	8.2^{ns}	3.6^{ns}	5.4^{b}	5.3^{ns}	10.8^{ns}	15.6^{ab}
		40	55.4^{cd}	365.0^{ns}	0.9^{h}	3958.2^{ns}	158.6^{ns}	42.1^{a}	23.5^{cd}	89.6^{ns}	97.3^{ns}	13.6^{ns}	11.8^{ns}	3.6^{ns}	6.4^{a}	5.4^{ns}	13.2^{ns}	24.7^{a}
14	100	20	113.7^{b}	327.4^{ns}	2.1^{b}	2977.7^{ns}	165.5^{ns}	40.5^{abc}	46.3^{b}	89.3^{ns}	90.6^{ns}	6.2^{ns}	3.6^{ns}	4.1^{d}	5.3^{ns}	8.6^{ns}	7.0^{ns}	12.6^{ab}
		40	83.0^{bcd}	381.7^{ns}	1.4^{d}	3461.4^{ns}	151.4^{ns}	33.5^{e}	28.6^{cd}	86.4^{ns}	96.0^{ns}	6.4^{ns}	6.7^{ns}	3.6^{ns}	4.7^{bcd}	4.8^{ns}	8.9^{ns}	12.7^{ab}
	200	20	61.2^{cd}	386.9^{ns}	0.9^{gh}	3286.4^{ns}	165.9^{ns}	31.5^{e}	19.0^{d}	72.8^{ns}	93.3^{ns}	6.4^{ns}	4.8^{ns}	3.6^{ns}	3.9^{e}	5.2^{ns}	7.8^{ns}	10.9^{b}
		40	78.4^{cd}	392.2^{ns}	1.2^{e}	3703.9^{ns}	162.8^{ns}	35.1^{bcde}	26.3^{cd}	84.5^{ns}	92.0^{ns}	11.4^{ns}	8.9^{ns}	3.7^{ns}	4.3^{e}	5.3^{ns}	9.6^{ns}	18.8^{ab}
21	100	20	56.2^{cd}	335.6^{ns}	1.0^{f}	3086.6^{ns}	150.0^{ns}	33.4^{e}	19.2^{d}	92.5^{ns}	98.6^{ns}	10.0^{ns}	7.0^{ns}	3.6^{ns}	4.4^{e}	5.4^{ns}	8.5^{ns}	16.8^{ab}
		40	48.1^{d}	321.2^{ns}	0.8^{h}	3473.3^{ns}	159.1^{ns}	37.0^{abcde}	17.9^{d}	91.7^{ns}	82.6^{ns}	4.8^{ns}	4.8^{ns}	3.5^{ns}	5.3^{ns}	4.0^{e}	7.3^{ns}	8.2^{b}
	200	20	70.4^{cd}	376.8^{ns}	1.0^{f}	2740.7^{ns}	155.9^{ns}	34.0^{de}	24.1^{cd}	89.0^{ns}	90.6^{ns}	6.7^{ns}	6.1^{ns}	3.6^{ns}	4.6^{e}	5.2^{ns}	8.1^{ns}	11.6^{b}
		40	72.5^{cd}	340.2^{ns}	1.2^{e}	3303.1^{ns}	178.0^{ns}	39.4^{abcd}	28.5^{cd}	83.4^{ns}	100.0^{ns}	10.1^{ns}	7.7^{ns}	3.6^{ns}	4.7^{bcde}	5.3^{ns}	8.8^{ns}	17.9^{ab}

Means within columns having different letter(s) are significantly different according to LSR at $p = 0.05$, ns: non significant

hypocotyl lengths and wet weights and also seed vigority were observed in plant spacing of 200×40 cm. These results showed that lower plant densities and in result lower competition between plants for nutrients, space and light improved seed vigority in pumpkin seeds.

Data in Table 7 showed that the most favorable interaction treatment for seed yield (170.1 g m^{-2}) and seed oil yield (69.4 g m^{-2}) of pumpkin was irrigation interval of 7 days and plant spacing of 100×40 cm (25000 plants ha^{-1}). In this row arrangement and irrigation interval, number of fruits per unit area (2.1 F m^{-2}) was significantly higher than other treatments, but number of seeds per fruit, fruit size and 1000 seeds weight did not affected significantly by this interaction (Table 6). To obtain higher seed production in *Cucurbita pepo*, Loy (1988) considers the increase of plant density and fruit number per plant a prior factor. In higher plant densities (35000 plants ha^{-1}) seed weight and fruit number per plant were lower, however seed yield per hectare and fruits per unit area were higher when compared to low densities (8000 plants ha^{-1}). This author concluded that 14000 plants ha^{-1} would be an adequate population with a plant spacing of 1.2×0.6 m. This planting density provided 44.4 g of seeds per plant. Using 14000 plants ha^{-1} resulted in 2.1 fruits plant^{-1} and highest seed weight per fruit (21.0 g). In condition that water was a limitation factor (21 days irrigation interval), the highest seed yield and seed oil yield was observed in plant spacing of 200×40 cm (8000 plants ha^{-1}). So the results showed that the optimum plant density and row arrangement of pumpkin will be changed by limitation of another environmental factor such as water.

The highest seed oil percentage was observed in irrigation interval of 7 days and plant spacing of 100×40 cm. Germination index, germination percentage and seedlings growth parameters were not affected significantly by this interaction, but the highest seedlings growth parameters and seed vigority were showed in the lowest competition condition (the lowest plant density (8000 plants m^{-2}) and highest irrigation frequency) (Table 7).

CONCLUSIONS

Results of this study indicated that pumpkin can be irrigated by irrigation intervals of two weeks without any significant decrease in seed yield and seed oil yield. Also it produced considerable seed yield (68 g m^{-2}) in irrigation interval of 21 days. So because of high economical value of pumpkin seeds and water scarcity tolerance, this species can be introduced as a cash crop to dryland agroecosystems of the country.

REFERENCES

Andriolo, J.L., 1999. Fluxo de carbono da planta. In: Fisiologia das culturas protegidas. Santa Maria: Editora UFSM., pp: 13-46.

Araujo, E.F., E.C. Mantovani and R.F. Silva, 1982. Influencia da idade e armazenamento dos frutos na qualidade de sementes de abobora. Revista Brasileira de Sementes, Brasilia, 1: 77-87.

Arista, M. and S. Talavera, 1996. Density effect on the fruit-set, seed crop viability and seedling vigour of *Abies pinsapo*. Ann. Bot., 77: 187-192.

Al-Omran, A.M., A.S. Sheta, A.M. Flatah and A.R. Al-Harbi, 2005. Effect of drip irrigation on squash (*Cucurbita pepo*) yield and water-use efficiency in sandy calcareous soils amended with clay deposits. 73: 43-55.

Bavec, F., 2000. Navadna buea, oil pumpkins (*Cucurbita pepo* L. convar. *giromantiina* var. *oleifera* Pietsch., syn. convar. *Citrullina* (L.) Greb. var. *Styriaca* Greb.). In: Some of disregarded and/or new field crops (Slovene language). Univ. Maribor, Faculty of Agriculture.

Bravo, A. and X. Vengas, 1984. Germination of seeds of three squash (*Cucurbita maxima* Duch.) cultivars at suboptimal temperatures. Cien. Invest. Agric., 11: 135-140 (In Spanish).

Cardaso, A.I.I. and M.F. Verdial, 2003. Plant spacing and pollen quantity on yield and quality of squash seeds. Horticultura Brasileira, 3: 443-447.

Carruba, A. and I. Calabrese, 2002. Antioxidant compounds in some herbaceous aromatic plants. Acta Hortic., 47: 85-93.

Champolivier, L. and A. Merrien, 1996. Effects of water stress at different growth stages of *Brassica napus* L. var. *oleifera* on yield, yield components and seed quality. Eur. J. Agron., 5: 153-160.

Davis, L.E., A.G. Stephenson and J.A. Winsor, 1987. Pollen competition improves performance and reproductive output of the common zucchini squash under field conditions. J. Am. Soc. Hortic. Sci., 112: 712-716.

Dhindwal, A.S., B.P.S. Lather and J. Singh, 1991. Efficacy of seed treatment on germination, seedling emergence and vigour of cotton (*Gossypium hirsutum*) genotypes. Seed Res., 19: 59-61.

Doijode, S.D., 2000. Seed viability and biochemical changes during storage of winter squash (*Cucurbita maxima* Duch) seeds. Veg. Sci., 27: 168-171.

Edelstein, M., H. Nerson, H.S. Paris, Z. Karchi, Y. Burger and R. Zohar, 1985. Hybrid seed production in spaghetti squash (*Cucurbita pepo* L.) using ethephon and honeybees. Hassadeh, 12: 2416-2419.

Edelstein, M. and H. Nerson, 2002. Genotype and plant density affect watermelon grown for seed consumption. Hortscience, 37: 981-983.

El-Keblawy, A. and J. Lovett-Doust, 1998. Persistent, non-seed-size maternal effects on life-history traits in the progeny generation in squash, *Cucurbita pepo*. New Phytol., 140: 655-665.

Ertek, A, S. Sensoy, C. Kuecuekyumuk and I. Gedik, 2004. Irrigation frequency and amount affect yield components of summer squash (*Cucurbita pepo* L.). Agric. Water Manage., 67: 63-76.

Evans, G.C., 1972. The Quantitative Analysis of Plant Growth. Blackwell Science Publication, Oxford.

Francis, C.A., F.C. Butler and L.D. King, 1990. Sustainable Agriculture in Temperate Zones. John Wiley and Sons, Inc., New York, USA.

Hillebrand, A., M. Murkovic, J. Winkler and W. Pfannhauser, 1996. Ein hoher gehalt an vitamin E und ungesattingen fettsauren als neues zuchtziel des kurbiszuchters. Ernahrung, 20: 525-527.

Ho, L.C., 1992. Fruit Growth and Sink Strength. In: Fruit and Seed Production: Aspects of Development Environmental Physiology and Ecology. Marchall, C. and J. Grace (Eds.), Cambridge: University Press, pp: 101-124.

Horvath, S. and Z. Bedo, 1988. Another possibility in treatment of hyperlipidaemia with peponen of natural active substance. Mediflora (Special Issue), 89: 7-8.

Idouraine, A., E.A. Kohlhepp, C.W. Weber, W.A. Warid and J.J. Martinez-Tellez, 1996. Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo* L.). J. Agric. Food Chem., 44: 721-724.

Kanwar, J.S., B.S. Gill and S.S. Bal, 2000. Response of planting time and density to onion seed yield and quality. Seed Res., 28: 212-214.

Koocheki, A. and F. Nadjafi, 2003. The status of medicinal and aromatic plants in Iran and strategies for sustainable utilization. In: Abstract book of the 3rd World Congress on Medicinal and Aromatic Plants for Human Welfare, 3-7 February 2003, Chiang Mai, Thailand, pp: 283.

Kramer, P.J. and T.T. Kozlowski, 1979. Physiology of Woody Plants. Academic Press, New York, pp: 811.

Kuhlmann, H.K., U. Koetter and C. Theurer, 1999. Sterol contents in medicinal pumpkin (*Cucurbita pepo* convar. *citrullinia* var. *styriaca*). Acta Hortic., 492: 175-178.

Lima, M.S., I.I.A. Cardoso and M.F. Verdial, 2003. Plant spacing and pollen quantity on yield and quality of squash seeds. Horticultura Brasileira, 3: 443-447.

Loy, J.B., 1988. Improving seed yield in hull-less seeded strains of *Cucurbita pepo*. Cucurbit Genetics Cooperative, 11: 72-73.

McKenzie, K.S., J.N. Rutger and M.L. Peterson, 1980. Relation of seedling vigor to semidwarfism, early maturity and pubescence in closely related rice lines. Crop Sci., 20: 169-172.

Nadjafi, F. and P. Rezvani Moghaddam, 2002. Effects of irrigation regimes and plant densities on yield and agronomic characteristics of Isabgol (*Plantago ovata*). Agric. Sci. Technol., 2: 59-65 (In Farsi).

Nadjafi, F., 2006. Evaluation the ecological criteria of *Nepeta binaludensis* Jamzad for adaptation in low input agricultural systems. Ph.D Thesis of Agroecology, Ferdowsi University of Mashhad, Iran.

Nerson, H., 2005. Effects of fruit shape and plant density on seed yield and quality of squash. Scientia Horticulturae, 105: 293-304.

Pedrosa, J.F., G.M. Oliveria, F. Bezerra Neto and M.R. Monteiro, 1987. Influence of age and storage period of *Cucurbita maxima* × *Cucurbita moschata* fruits on seed yield and quality. Hortic. Brasil, 5: 15-17.

Sigmund, B. and M. Murkovic, 2004. Changes in chemical composition of pumpkin seeds during the roasting process for production of pumpkin seed oil (Part 2: Volatile Compounds). Food Chem., 84: 367-374.

Singh, R.C., V.R. Biswas, M.C. Arya, J.S. Mehta, K. Narenda and N. Kumar, 2000. Effect of plant population and dates of transplanting on seed yield of cabbage (*Brassica oleracea*). Indian J. Agric. Sci., 70: 405-406.

Uniyal, R.C. and A.R. Nautiyal, 1998. Seed germination and seedling extension growth in *Ougeinia dalbergioides* Benth. under water and salinity stress. New For., 16: 265-272.

Wagner, F.S., 2000. The health value of Styrian pumpkin-seed oil-science and fiction. Cucurbit Genet. Crop, 23: 122-123.

Wahba, H.E. and A.A. Ezz El-Din, 2002. Growth, yield and essential oil response of *Chrysanthemum coronarium* L. to plant spacing and foliar microelements. Egypt. J. Hortic., 29: 229-247.

Welbaum, G.E. and K.J. Bradford, 1991. Water relations of seed development and germination in muskmelon (*Cucumis melo* L.). VII. Influence of after-ripening and ageing on germination responses to temperature and water potential. J. Exp. Bot., 42: 1137-1145.

Xia, M.Z., 1994. Effect of soil drought during the generative development phase of faba bean (*Vicia faba*) on photosynthetic characters and biomass production. J. Agric. Sci. (Camb), 122: 67-72.

Younis, Y.M.H., S. Chirmay and S.S. Al-Shihry, 2000. African *Cucurbita pepo* L. Properties of seed and variability in fatty acid composition of seed oil. Phytochemistry, 54: 71-75.