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The study of plant density and planting methods on some growth characteristics, seed and oil yield of medicinal pumpkin (*Cucurbita pepo* var. *styriaca*, cv. '*Kaki*)

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Abstract: The effect of plant densities (2, 2.5, 3 plant/m^2) and two methods of planting (transplanting and direct seeding) were investigated on some growth characteristics, seed and oil yield of medicinal pumpkin (*Cucurbita pepo* var. *styriaca*, cv. '*Kaki*). The experiment was carried out in a factorial trial based on complete randomized block design, with three replicates during spring and summer 2013. When the weather condition became suitable and seedlings were at true four leaves stage, both seeds and seedlings were planted at the same time in the farm. The results showed 2 plant/m^2 density had significant effect on plant lenght, leaf number, node number and sub branch number. Planting method also affected significantly on plant growth, so that the highest node number was achieved by using transplanting method. Plant density and planting method had significant effect on the oil content, so that the highest oil content was achieved by transplanting method with 2 plant/m^2 density. Also the most seed and oil yield obtained from transplanting method. Thus transplanting method had higher yields and its may be as a more reliable production method.

Keywords: Medicinal Pumpkin, Plant Density, Transplanting, Direct Seeding, Seed Yield

1. Introduction

Cucurbita pepo var. *styriaca*, cv. '*Kaki* is one of the valuable medicinal plants in the pharmaceutical industry in most developed countries, which from 2000 years before Christ was cultivated in Peru, and South America is certainly the country of origin [1]. This plant is just a few years that have been studied from different perspectives with the aim of extracting and processing of the active ingredients are grown in Iran. The purpose of this reviews to obtain the methods to increase crop yield and plant active ingredients. Therefore, adjusting the distance between plants and changes in plant density per unit area is a powerful tool for controlling the competition between plant species [2]. An experiment was conducted to study plant density and phosphate on *cucurbita pepo* var *styriaca*, the highest seed dry weight per plant from 10000 plant/ha plant density, with an average 91.2 gr and the lowest from 16,000 plant/ha plant density with an average 56 gr [3]. In Other research the most seed and fruit yield was achieved from cultivated plants with distance of 250 cm between rows and 50 cm row spacing [4]. In other research the highest seed yield (650 kg per hectare) was achieved from 300 cm spacing between lines and 55 cm on the lines of planting [5]. Density has several effects on crop yield at medicinal plants, because the aim of appropriate spacing between plants is to provide an appropriate combination of environmental factors (water, climate, light and soil) for maximum performance with optimum quality. [6] the effect of plant density on the oil percentage of *Nigella sativa* examined and reported that by increasing plant density, oil yield increased, although the amount of extracted oil in plant at lower plant density was higher. Transplant production has replaced direct seeding for many vegetable crops. One of the primary advantages offered by transplanting is earlier fruit production, allowing growers to capture better market conditions. Inaddition, the high cost of hybrid seed makes it desirable to use each seed as efficiently as possible. Transplanting also gives the crops a competitive advantage against weeds. [7] studied the effect of direct sowing, sowing pre-germinated seeds, and transplantations of seedlings of oil pumpkins on growth, yield and production costs in three

years of field experiments. Plants that developed from transplanted seedlings were luxuriant and produced more and larger fruits than those grown from direct sowing. The seed yield obtained from transplants was significantly higher (3.35 kg 20 m^{-2}) than that obtained from direct sowing (2.06 kg 20 m^{-2}) and pre-germinated seeds (2.54 kg 20 m^{-2}). The break-even price per kg seed yield from direct sowing (0.98 EUR kg^{-1} seed yield) was lower than the costs from transplanted seedlings (1.20 EUR kg^{-1}) where the profit ha^{-1} was higher. [8] evaluated the effect of planting methods (seed sowing and transplanting) on yield and yield components such as number of branches (sub-branches) per plant, fruits per plant, growth, fruit size, weight of fresh fruit, weight of seeds per fruit, number of seeds per fruit and seed yield of medicinal pumpkin. Results showed that the planting methods had significant effect on the number of ripen fruits per plant, fruits diameter, weight of seeds per fruit, weight of 1000 seeds and seed yield and had no significant effect on the other traits.

2. Materials and Methods

To study the effect of plant density and planting method on some growth characteristics, seed and oil yield of medicinal pumpkin (*Cucurbita pepo* var. *styriaca*, cv. '*Kaki*) experiment was carried out in a factorial trial based on complete randomized block design, with three replicates in Department of Agriculture of Ferdowsi University of Mashhad, during spring and summer 2013. The factors include planting methods (seed sowing and transplanting) and plant density (2, 2.5, 3 plant/m^2). Stack width was 200 cm and bilateral planting pattern by three replications. Surface irrigation was practiced every day until the seeds sprouted and then whenever it was needed and weeding was handy. From two to four weeks before transplanting, should prepare seedlings in small pots. When the weather condition became suitable and seedlings were at the four leaves stage, both seeds and seedlings were planted at the same time in the farm. Sampling was performed at three stages of flowering, fruiting and ripening. Plant length, number of leaf, number of node and number of sub branch were measured. At ripening stage, seed yield, oil yield and oil percentage, number of seed, weight of 1000 seeds, weight of fruit, number of fruit per plant in each treatment was assessed. Seed oil by using soxhlet and hexane solvent were measured. The oil content of the seeds was determined by treating the weighted powder seeds with hexane and refluxed for 4 h in a soxhlet extractor. The solvent was removed by rotary evaporator. Statistical analysis of the data based on a factorial experiment in a randomized complete block design and the Least Significant Difference (LSD) test was used to separate the means at $p<0.05$ by the software JMP 8.

3. Results and Discussion

3.1. Vegetative Traits

Table 1. *Results of variance analysis of planting method and planting spaces on studied traits at flowering stage*

SOV	df	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length
R	2	0.38	1.72	0.05	17.54
P	1	46.72^{ns}	26.88^{**}	2.72^{**}	0.68^{ns}
D	2	147.38^{**}	26.72^{**}	0.88^{*}	1210.29^{**}
P*D	2	5.38^{ns}	1.72^{ns}	0.22^{ns}	10.68^{ns}
Error	10	9.65	0.52	0.18	4.54

R: Replication, P: Planting method, D: Density, P*D: Interaction between P and D, ns: Not significant, *: Significant in 5% probability level, **: Significant in 1% probability level

Table 2. *The effect of planting methods on the studied traits*

Planting method	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length (cm)
Transplanting	17.33a	11.77a	2.33a	48.22a
Direct seeding	14.11a	9.33b	1.55b	48.61a

Table 3. *The effect of plant density on the studied traits*

Plant density	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length (cm)
2 plant/m2	21a	12.83a	2.16a	64.16a
2.5 plant/m2	15b	10.16b	2.16a	44.50b
3 plant/m2	11.16b	8.66c	1.50b	36.58c

The plant length was significantly influenced by plant density, so that the 50 cm distances (2 plant/m^2 density) with a mean plant length of 64.16 cm was significantly higher than 30 and 40 cm distances. This result is consistent with the result of [3]. Increasing plant density resulted in increasing space, water and food for the plants and enhances the growth of plants, thus increase the length of the plant. Planting method and plant density had a significant effect on the number of node per main stem (table 1), The highest number of node (11.77 node/main stem) obtained from transplanting method and the lowest number (9.33 node/main stem) obtained from direct seeding. Between plant density treatments, the higher number of node per main stem (12.83 node/main stem) obtained from 50 cm distances (2 plant/m^2 density) and the least number (8.66 node/main stem) obtained from 30 cm distances (3 plant/m^2 density). This

result is consistent with the result of [3]. Increasing plant density resulted in increasing space, water and food for the plants and enhanced the nodes of plants. Plant density had a significant effect on the number of leaf per plant (table 1), the highest number of leaf (21 leaf/plant) obtained from 50 cm distances (2 plant/m^2 density) and 30 and 40 cm distances (3, 2.5 plant/m^2 densities) had no significant difference (table 1), it is because of more number node in this distance. This result is in agreement with several investigators [3, 9, 10]. Planting method and plant density had a significant effect on the sub branches per plant at flowering stage. The results showed that the number of sub branch per plant was affected from planting method and the higher number (2.33 branch/plant) obtained from transplanting method and the least number (1.55 branch/plant) obtained from direct planting (seed sowing). Between plant density treatments, the higher number of sub branch per plant (2.16 branch/plant) obtained from 50 cm and 40 cm distances (2, 2.5 plant/m^2 density) and the least number (1.50 branch/plant) obtained from 30 cm distances (3 plant/m^2 density). This result is consistent with the results of [3, 9, 10, 11] in their study. Increasing plant density resulted in increasing space, water and food for the plants and enhanced the sub branch of plants.

The plant density had a significant effect on the plant length at fruiting stage, so that the highest plant length (191.66 cm) obtained from the 2 plant/m^2 density (table 4), it is because of more number node in this distance. Decreasing plant density resulted in increasing the vegetative growth of the plants and reducing the reproductive growth which leading to decreased competition between plants and increase the vegetative growth of the plants and thus increase the length. This result is consistent with the result of [3]. The number of node per main stem was affected by planting method and plant density. The highest number of node per main stem with an average of 37 node obtained from the 2 plant/m^2 density and 2.5, 3 plant/m^2 densities with an average of 35.66 node and 30.83 node per main stem were placed another group. Increasing plant density resulted in increasing space, water and food for the plants and enhanced the nodes of plants. This result is consistent with the result of [3]. The highest number of node (36.22 node/main stem) obtained from transplanting method and the lowest number (32.77 node/main stem) obtained from direct seeding. Plant density had a significant effect on the number of leaf per plant, so that comparison of plant densities showed that the 2 plant/m^2 density with a mean leaf per plant of 59.16 was significantly higher than 2.5, 3 plant/m^2 densities. With decreasing plant density, because of increasing space for expansion of the plants and food and other environmental factors resulted in increasing the length of the plant, the number of nodes and the number of sub branches and thus increase the number of leaves. This result is consistent with the results of [3, 9, 10] in their study. The sub branch was significantly influenced by plant density, so that the 2 plant/m^2 density with a mean sub branch of 9.66 branch per plant was significantly higher than 2.5, 3 plant/m^2 densities and the 2.5, 3 plant/m^2 densities had no significant difference (table 4). This difference in the number of sub branch of plants, is because of an increase in water and food and distances between plants. This result is consistent with the results of [3, 9, 10, 11] in their study.

Table 4. *Results of variance analysis of planting method and planting spaces on studied traits at fruiting stage*

SOV	df	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length
R	2	20.22	15.16	7.16	612.50
P	1	20.05^{ns}	53.38^{**}	0.50^{ns}	1012.50^{ns}
D	2	714.05^{**}	63.16^{**}	30.16^{**}	7454.16^{*}
P * D	2	15.38^{ns}	1.05^{ns}	0.16^{ns}	304.16^{ns}
Error	10	45.35	4.23	2.50	1405.83

R: Replication, P: Planting method, D: Density, P*D: Interaction between P and D, ns: Not significant, *: Significant in 5% probability level, **: Significant in 1% probability level

Table 5. *The effect of planting methods on the studied traits*

Planting method	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length (cm)
Transplanting	48.11^{a}	36.22^{a}	7^{a}	160^{a}
Direct seeding	46^{a}	32.77^{b}	7.33^{a}	145^{a}

Table 6. *The effect of plant density on the studied traits*

Plant density	Number of Leaf per plant	Number of Node per main stem	Sub branch Per plant	Plant length (cm)
2 plant/m^2	59.16^{a}	37^{a}	9.66^{a}	191.66^{a}
2.5 plant/m^2	44^{b}	35.66^{a}	6.50^{b}	142.50^{b}
3 plant/m^2	38^{b}	30.83^{b}	5.33^{b}	123.33^{b}

3.2. Seed Yield

The results indicated that the planting method and plant density had a significant effect on the seed yield (table 7). The seed yield in transplanting method (719.15 kg/ha) was significantly higher than direct planting (527.68 kg/ha) (table 7). It is because of enough time for growth and ripening most of the fruits in transplanting method and increasing the weight of 1000 seeds. Increasing crop growth rate of seedlings during vegetative growth, early reproductive stage

and also more absorption of light in the whole growing season, resulted in increasing seed yield. This result is consistent with the result of [8]. Considering significant effect of the number of fruit in increasing the seed yield of *Cucurbita pepo* var. *styriaca* and improving the number of fruit in case of planting bilaterally [12], if planting bilateral, increasing in the seed yield seems reasonable. Between plant densities, the highest seed yield (880.72 kg/ha) obtained from plant density of 3 plant/m^2 and the lowest seed yield (415.89 kg/ha) obtained from plant density of 2 plant/m^2 (table 7). These results corresponded with the results of [13, 14].

[15] 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 a lower seed production per fruit and per plant, and small fruits with lower weight.

3.3. Number of Fruits Per Plant

The results showed that the number of fruits was affected from plant density and the higher number (2.07 fruit/plant) obtained from 2 plant/m^2 density and the least number (0.99 fruit/plant) obtained from 3 plant/m^2 (table 7). These results corresponded with the results of [13] on Cucumber; [14] on Cucumber; [16] on Cucumber; [17] on Cucumber; [18] on Cucumber; [19] on Cucumber; [20] on Muskmelon. Increasing density reduces the production of biomass and reduce the production of fruits per plant. Probably the increasing competition for place, light and nutrients reduced fruit set, influencing the number of fruits per plant.

3.4. Weight of Fruit

The results showed that the planting method and plant density had a significant effect on the weight of fruit. The weight of fruit in transplanting method was 1.56 kg and it was 1.30 kg in direct planting (table 7). Between plant densities, the highest weight of fruit (1.76 kg) obtained from plant density of 2 plant/m^2 and plant densities of 2.5, 3 plant/m^2 had no significant different (table 7). This results is consistent with the results of [13] on Cucumber; [14] on Cucumber; [20] on Muskmelon; [21] on Cucumber; [22] on Squash. There was a general tendency of decrease in seed number per fruit and in the mean seed weight by increasing plant density. With decreasing plant density, because of increasing space for expansion of the plants and food and other environmental factors resulted in increasing the weight of fruit. Also increasing the weight of fruit at transplanting method because of preparing enough time to maturing and ripening the fruits by transplanting method that resulted in increasing fruit size.

3.5. Weight of 1000 Seeds

The results showed that the planting method and plant density had a significant effect on the weight of 1000 seeds. The weight of 1000 seeds in transplanting method was 140.05 gr and it was 101.71 gr in direct planting (table 7). This result is consistent with the result of [10]. Between plant densities, the highest weight of 1000 seeds (143.48 gr) obtained from plant density of 2 plant/m^2 and plant densities of 2.5, 3 plant/m^2 had no significant different (table 7). This result is consistent with the result of [12]. Effects of interaction between treatments on the weight of 1000 seeds were significant, so that the highest weight of 1000 seeds (179.01 gr) obtained from transplanting with a density 2 plant/m^2 and the lowest obtained from direct planting with a density 2.5 plant/m^2 (96.59 gr) (table 7). 2 plant/m^2 density via increasing the photosynthesis area and increase the power source and enhance the relationship between source and destination resulting in increasing weight of 1000 seeds.

3.6. Number of Seeds

The results showed that the number of seeds per fruit was affected from planting method and the higher number (268.44 seed/fruit) obtained from transplanting method and the least number (220.33 seed/fruit) obtained from direct planting. It is because of preparing enough time to maturing and ripening the fruits by transplanting method that resulted in increasing fruit size and formation of more seeds per fruit. This result is consistent with the result of [8].

3.7. Oil Content

The effect of plant density on the oil percent was significant, Between plant densities, the highest oil percent (46.48%) obtained from plant density of 2 plant/m^2 and plant densities of 2.5, 3 plant/m^2 had no significant different, so that increase in row distance from 30 cm to 50 cm, became causing an increase of oil percent from 41.45 percent to 46.48 percent (table 7). More row spacing, resulting in an increase of 5% oil compared with lower row spacing. The oil percent was influenced from interaction between treatments and the most oil percent obtained from transplanting with 2 plant/m^2 density (51.70%) (table 3).

3.8. Oil Yield

Table 7. *Results of variance analysis of planting method and planting spaces on studied traits at ripening stage*

SOV	df	Number of fruit	Weight of fruit	Oil percent	Seed yield	Oil yield	Number of seeds per fruit	Weight of 1000 seeds
R	2	0.003	0.05	18.04	2493.9	413.99	1407.05	400.85
P	1	0.0006^{ns}	0.29^{**}	3.67^{ns}	164982.0^{**}	26821.79^{**}	10416.05^{*}	6614.80^{**}
D	2	2.02^{**}	0.53^{**}	46.56^{*}	335248.8^{**}	34388.45^{**}	1040.05^{ns}	2344.59^{**}
P * D	2	0.0005^{ns}	0.008^{ns}	102.18^{*}	6932.6^{ns}	730.61^{ns}	555.72^{ns}	1340.43^{**}
Error	10	0.002	0.02	8.03	3034	353.2	1492.26	151.67

R: Replication, P: Planting method, D: Density, P*D: Interaction between P and D, ns: Not significant, *: Significant in 5% probability level, **: Significant in 1% probability level

Table 8. *The effect of planting methods on the studied traits*

Planting method	Oil percent	Seed yield (kg/ha)	Oil yield (kg/ha)	Number of seeds per fruit	Weight of 1000 seeds
Transplanting	43.72[a]	719.15[a]	287.97[a]	268.44[a]	140.05[a]
Direct seeding	42.82[a]	527.68[b]	210.77[b]	220.33[b]	101.71[b]

Table 9. *The effect of plant density on the studied traits*

Plant density	Oil percent	Seed yield (kg/ha)	Oil yield (kg/ha)	Number of seeds per fruit	Weight of 1000 seeds
2 plant/m^2	46.48[a]	415.89[c]	190.71[c]	255.83[a]	143.48[a]
2.5 plant/m^2	41.88[b]	573.64[b]	222.57[b]	247.33[a]	112.36[b]
3 plant/m^2	41.45[b]	880.72[a]	334.83[a]	230.00[a]	106.81[b]

The results showed that the oil yield was affected from planting method and plant density. The higher oil yield (287.97 kg/ha) obtained from transplanting method and the least oil yield (210.77 kg/ha) obtained from direct planting (seed sowing). The results of research on (*Sesamum indicum* L.) also showed that there is a positive correlation between seed yield and oil yield [23]. Between plant densities, the highest oil yield (334.83 kg/ha) obtained from plant density of 3 plant/m^2 and the lowest oil yield (190.71 kg/ha) obtained from plant density of 2 plant/m^2 (table 9). *Cucurbita pepo* var *styriaca* is a creeper and indeterminate plant [24], its oil is of the great importance in term of medicinal consumption. Thus, using of the appropriate density can be improve the vegetative growth and followed by the economic performance of the medicinal plant. The oil yield is affected of the seed yield and the seed yield is affected by the number of fruit and intra row space and planting pattern is affected of the number of fruit. Considering a positive correlation between the number of fruit and seed yield and oil yield of *Cucurbita pepo* var *styriaca*, So seems can enjoying a proper agronomic management Such as adjustment of intra row space and appropriate planting, because of decreasing in vegetative growth result in increasing the seed yield and oil yield.

4. Conclusion

Cucurbita pepo var *styriaca* is a creeper and indeterminate plant, its oil is of the great importance in term of medicinal consumption. Thus, using of the appropriate density can be improve the vegetative growth and followed by the economic performance of the medicinal plant. The oil yield is affected of the seed yield and the seed yield is affected by the number of fruit and intra row space and planting pattern is affected of the number of fruit. Considering a positive correlation between the number of fruit and seed yield and oil yield of *Cucurbita pepo* var *styriaca*, So seems can enjoying a proper agronomic management Such as adjustment of intra row space and appropriate planting, because of decreasing in vegetative growth result in increasing the seed yield and oil yield. Pumpkins are generally established via direct seeding however they can be sown as transplants. The results of present investigation detected that transplanting method and plant density resulting in increasing the seed and oil yield. So that, the highest seed and oil yield obtained from transplanting method. It is because of preparing enough time to maturing and ripening the fruits by transplanting method that resulted in increasing fruit size and formation of more seeds per fruit. It seems that plant density of 3 plant/m^2 is most appropriate for several agricultural characteristics of pumpkin seed, specially seed and oil yield.

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