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INVESTIGATING THE EFFECT OF PLANTING DATE ON PHOTOSYNTHETIC PROPERTIES OF DIFFERENT GENOTYPES OF QUINOA (*CHENOPODIUM QUINOA* WILLD.)

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Abstract
In order to investigate the effect of planting date and different genotypes of quinoa on Photosynthetic properties of quinoa, a factorial experiment in the form of a randomized complete block design with three replications was performed in the year of 2018 and 2019 in Kavar City-Fars-Iran. The treatments included 5 quinoa genotypes (Q29, Q26, Red Carina, Titicaca, and Giza1) that were sowed on 10, 20 and 30 March (as spring) and 10, 20 and 30 August (as summer planting dates).The results showed that the share of current photosynthesis in summer planting dates in each genotype was higher than spring. The 29Q genotype seems to have a higher share of current photosynthesis with greater utilization capacity than environmental conditions, according to Q29 and Titicaca were the most sensitive and tolerant genotypes among the studied genotypes against changes in the planting season, respectively. The results showed of planting date and genotype has significant effect on grain yield, and Photosynthetic properties.

Keywords; Quinoa, Current of photosynthesis, Share of current Photosynthesis, Current of Photosynthesis efficiency.

Introduction

Quinoa is a dicotyledonous plant with a scientific name *Chenopodium quinoa* Willd. It belongs to family Amaranthaceae and subfamily Chenopodiaceae, native to the Andes of the Americas (Bhargava and Srivastava, 2013). This plant is very tolerant of a wide range of Not live stresses such as cold, salinity and drought and is also well able to grow in marginal soils (Jacobsena *et al*., 2003). Quinoa seeds date back 5,000 years and were considered sacred in Inca rural civilization as the "mother seed"(Holy grain) (González, *et al*.,2015). Compared to many cereals, quinoa grains are more nutritious. Approximately, quinoa seeds contain 10-18% of protein, 4.5-8.5% of crude fat, 54.6% of carbohydrates, 64.2.5%, 2.4-3.5% of ash and 2.4-1.9%. The percentage of fiber is raw (Vidueiros *et al*., 2015). Young quinoa leaves are used as a fresh or cooked vegetable in a food compound such as Ash, (some kind of soup), but the main product is grains. Quinoa is used in the United States to make flour, soups, breakfast cereals, salads, and alcohol. Quinoa flour is well used as a flexible starch in combination with wheat flour to make bread, biscuits or food products (Tavoosi and Sepahvand, 2015.) Also, the proteins in this plant are suitable for improving the balance of amino acids in human food and livestock (Jacobsena *et al.*, 2003). Proper planting date is the first step in the crop production system that leads to an appropriate increase in production for new crops in each region (Rauf *et al.*, 2010). The eight introduced genotypes of quinoa were studied in Colorado, USA, with a yield of 1,120,000 kg per hectare, and the Cahuil genotype had the highest yield compared to the rest, despite the low plant height (129 cm). Genotype C0407 The genotype was very early (100-day cultivation) and had the highest protein content with 16.5-18% and with optimal performance (Johnson and McCamant, 1988) to determine the best date for quinoa implantation in the waters and climate of the Mediterranean. In Italy, two genotypes, KVLQ520Y and Regalona Baer, were studied in rainfed conditions. The Regalona Baer genotype was more productive in April cultivation and was more tolerant of high and low water stresses (Pulvento *et al.* 2010). In India, the highest yields were obtained on November 3 and at a distance of 20 cm (Bhargava *et al.*, 2007). Climate change of Iran towards hot and dry and gradual salinization of the country's agricultural lands on the one hand and high tolerance of quinoa plant against drought, salinity and frost (Pulvento *et al*., 2010), on the other hand, show that quinoa could be a suitable plant to achieve sustainable agriculture, proper nutrition and industrial production. FAO's recommendation for quinoa cultivation is even in poor and barren lands. Researchers have reported the ability of quinoa to grow and develop in areas with annual rainfall of 200-400 mm (Valencia-Chamorro, 2015). Planting time in any region depends on the climatic conditions of the region, especially the temperature, humidity and the length of the day. The time of planting of crops on the basis of ambient temperature with the desired temperature of each of the phenologic stages of growth and also the non-coincidence of sensitive growth stages with environmental stresses is determined. Planting time should be chosen in such a way that there is enough time for each of the stages to grow. Each component of performance is stabilized at a particular stage of growth, and sufficient time to perform the steps increases the yield of the seed (Siadat *et al*., 2013). Quinoa is a plant which cultivates in very harsh environmental conditions and can withstand severe stress, cold and heat (Bois *et al*., 2006). Quinoa needs about 25 Centigrade in the day and 12 hours of light in the early stages of growth, but requires short-term (about 8 hours) and low temperatures for reproductive and maturation stages. (Sepahvand and Sheikh, 2011). In order to determine the best date of Quinoa cultivation in the climate conditions of the Mediterranean Sea of Southern Italy, two cultivars of Quinoa (KVLQ520Y and Reggalon Baier) were evaluated in the cultivation dates of the 4th of April (March 4), which with Higher performance, are more tolerant of high and low water temperatures (Pulvento, *et al*., 2010) According to the results of a test in India, the highest grain yield was obtained on the planting date of November 30 (December 10) (Bhargava *et al*., 2006). In one experiments in Iran, two cultivars of quinoa (Sajama and Santamaria) were cultivated in May and March in Karaj. The results showed that planting in August produced a more suitable crop, but in May, despite good vegetative growth and flowering and Cluster production, no crop was produced and the reason for this was the flowering of plants with hot and long days and lack of seed production. (Sepahvand *et al*., 2010). In an experiments in the southern coast of Iran (Minab), quinoa was cultivated in the first and fifteenth dates of October, November, December and December 1. The results showed that at the time of beginning growth and even in the seed production stages, plants were severely attacked by pests and birds. The attack of the birds on the bushes of the late two dates (the 25th and 30th of December) was less than the other dates of the cultivation, but the occurrence of rainfall during Time of emergence of seedlings, cased destroying plants due to the death of the seedlings. Germination and vegetative growth of plants, cultivation in the first of October to November 6_{th} was appropriate, but as the weather cooled, the vegetative growth rate slowed down rapidly and the plants entered the breeding stage at a shorter height (Shahmansouri, 2015). In the study of quinoa adaptation in four different stations in Iran, a significant difference in yield was reported in different parts of Iran. In this study, the average grain yield in Ahvaz, Karaj and Iranshahr stations was 1162, 1081 and 823 kg / ha (Sepahvand, 2010). Comparing the three quinoa specimens, Sajama, SantaMaria, and Sajama Iranshahr, the SantaMaria genotype produced the highest yield. (11256 kg / ha), (Sepahvand and Perkasi 2014). In a study conducted by Sepahvand *et al*. (2011) in Karaj, the SantaMaria genotype had the highest yield at 2490 kg / ha. Tausi and Sepahvand and Sheikh (2014) examined three quinoa genotypes called Sajama, SantaMaria and Sajama Iranshahr in Ahvaz region and four planting dates of 10 and 25 October and 10 and 25 November, the highest yield date of 10 October (4.2 tons). Per hectare in this area (Miri, 2016).

Photosynthesis is a function of absorbed light that depends on the structural properties of the canopy as well as the photosynthetic properties (efficiency of using absorbed light) by plant species. More light absorption depends on the canopy structure, ie leaf area index and vertical distribution in the canopy, growth rate and leaf surface durability, leaf angle, and morphological characteristics such as plant height and lateral arrangement (Murchie and Reynolds,2013) Prerequisites for achieving high performance are the provision of favorable conditions for the use of existing radiation for the optimal production of photosynthetic materials (Murchie and Reynolds, 2013) Increases product performance (Reta-Sanches & Fowler, 2002)

This study was conducted to determine the proper planting date of quinoa in Mozaffari village in Kavar (city of Fars province- Iran). In that experiment, the yield response and Photosynthetic properties of different genotypes of quinoa were examined in relation to the different planting dates in spring and summer cultivation.

Mterials and Methods

In order to study and determine the most suitable genotype and planting date of Quinoa, a factorial experiment with three replications in Kavar city with latitude 29 ˚ 19' in North and longitude 52 ˚and 78ˊ in East and altitude 1589 meters above sea level 1589 meters with 424 mm, average rainfall of twenty-three years, was implemented in the year of 2018 and 2019. Experimental treatments included 5 quinoa genotypes (Q29, Q26, Red Carina, Titicaca, and Giza1) on the six dates on 10, 20 and 30 March (as spring) and 10, 20 and 30 August (as summer planting dates). Sowing was done manually at a distance of 30 cm in rows, and in the distance in rows was 5 cm. Irrigation interval was once every 10 days until the leaves changed color. To determine the yield of the grain and its components, two rows of marginal plants along the length and each half and a half meters from the top and bottom of each plot were removed and the number of residual bushes was cut from Bottom After harvesting and separating the seeds from the aerial parts, the seeds were dried at75 degrees Celsius for 48 hours in a dry oven and then weighed, and the grain yield per unit area was calculated as 14% based on moisture. The following relationships were used to measure Photosynthetic properties (Papakosta and Gagianas 1991)

$$\text{Current of photosynthesis } (gr/m^2) = \text{yield } (gr/m^2) - \text{Dry matter remobilization rate} (gr/m^2) \quad (1)$$

$$\text{Current of Photosynthesis efficiency } (gr/gr) = \frac{\text{Current of photosynthesis } (gr/m^2)}{\text{Shoot dry weight at the beginning of pollination } (gr/m^2)} \quad (2)$$

Share of current Photosynthesis (%) = 100- Remobilization efficiency

All statistical calculations of analysis of variance, correlation and data regression were performed using SAS statistical software and tables and graphs were drawn by Excel software. Bartlett test was used before the combined analysis to ensure uniformity of variance of experimental error. Combined analysis was performed assuming the year was random and the experimental treatments for the desired traits were constant. The means obtained after analysis of variance were compared by Duncan's multiple range test.

Table 1- Results of physical and chemical analysis of experimental farm soil before testing

	CLAY	SILT	SAND	Cu	Mn	Zn	Fe	K	P	N	OC	pH	Ec
year	%			PPM						%			$dS.m^{-1}$
2018	23.3	45.1	31.6	1.52	19.85	1.53	7.4	420	13.4	0.03	0.48	7.3	10.6
2019	25.1	39.7	35.2	1.7	17.2	1.2	8.1	371	12	0.03	0.52	7.38	9.8

Results and discussion

The results of physical and chemical analysis of the studied farm soil in the experimental years are shown in Table 1. Based on the obtained results, the studied farm soil had high salinity, alkaline acidity, low organic carbon, moderate to good phosphorus and potassium, and low consumption elements of iron, zinc, manganese and suitable copper and loam soil texture. Due to the high tolerance of quinoa to soil salinity, there was no need to wash the soil to reduce salinity. Also, based on these results, potassium and phosphorus fertilizers and foliar application of low-consumption elements were not used due to the appropriate level of these elements.

Table 2 - Summary of analysis of variance number of yield, Current of photosynthesis (C.P.), Share of current Photosynthesis (S.C.P.) and Current of Photosynthesis efficiency (C.P.E.) in different genotypes and planting dates

		Mean of Square		
S.O.V.	**df**	**C.P**	**C.P.E**	**S.C.P.**
Year (Y)	1	402.57 ns	0.001 ns	81.54 ns
Year× replication	4	16909.38 ns	0.19 ns	2445.22 ns
Genotype(G)	4	99822.4**	0.45**	9489.91**
Y× G	4	1677.8 ns	0.01 ns	283.97 ns
Sowing date(SD)	5	3656.21**	0.02**	279.32**
Y× SD	5	11890.63.2 ns	0.06 ns	301.51 ns
G× SD	20	3016.82**	0.02**	404.36**
Y× G× SD	20	13280.21 ns	0.01 ns	1480.88 ns
Error	116	1090.58	0.01	180.32
CV (%)		9.7	8.13	8.14

*, **: Significant at the 5% and 1% probability levels, respectively   ns: non-significan

Examination of the calculated traits related to current photosynthesis in the plant by experimental treatments during two years and two planting seasons showed no significant effect of the year and its interaction with genotype and planting date and their triple interaction. The results of analysis of variance of amount, efficiency and share of current photosynthesis showed a significant effect ($p \leq 0.01$) of genotype on these traits in both spring and summer crops and also a comparison of their two seasons.

The results also showed that the share of current photosynthesis in spring planting and the amount of current photosynthesis in summer planting were not significantly affected by planting date in this study.

The effect of planting date on other traits related to the amount of current photosynthesis in summer and spring crops and also comparing their two seasons was significant ($p \leq 0.01$). Based on the results obtained from analysis of variance, the interaction effect of planting date and genotype in all traits related to photosynthesis in both spring and summer crops and also comparing their two seasons was significant ($p \leq 0.01$).

Current photosynthesis rate

The study of the interaction of genotypes and planting date showed that the highest amount of current photosynthesis was obtained from Q29 genotype on the 10th of March planting date with an average of 257 grams per square meter. Other spring sowing dates as well as sowing of the same genotype on the ***20$_{th}$ of August*** had the highest rate of current photosynthesis (Table 3).

Current photosynthesis is a process in which photosynthetic material from the green organs of the plant from the pollination stage to the final ripening of the grain moves to the seed and has the largest share in grain filling and growth (Soltani, 2009). Carbon for grain filling depends on the effective absorption of light by the green surface of the plant after the pollination stage. This resource is also generally limited by the natural aging of the leaves and the occurrence of various stresses, while at the same time the demand for photosynthetic materials to fill the seeds and the demand for respiration to maintain the living biomass of the plant increases. Therefore, one of the most important sources of carbon for grain filling is stem reserves (Ehdaie *et al*., 2008).

Due to the fact that Q26 genotype in this experiment had the lowest amount of biomass among the studied genotypes, the lack of current photosynthesis can be justified. Also, increasing the temperature by changing the planting date reduces the current photosynthesis in quinoa planted at the end of the season. Spring planting and planting in summer (Table 3).

Studies have shown that most of the current photosynthesis in rice is related to the delayed planting date of this plant due to the optimal environmental conditions and low temperature and thus reduced respiration of plant organs. (Gilani *et al*.2018), The results are consistent with the report of Kobata and Uemuki (2004) on the main cause of termination of increase in dry matter of rice, wheat and barley grains, their growth restriction due to high temperature and also the potential to increase grain dry matter yield due to reduced metabolic activity in The temperature drops too low and the stock of assimilates for the grain provides only part of the need, leading to a low grain weight.

Table 3- The interaction effect of genotypes and planting dates on yield, Current of photosynthesis (C.P.), Share of current Photosynthesis (S.C.P.) and Current of Photosynthesis efficiency (C.P.E.).

Genotype	Sowing date	C.P.(gr/m2)		C.P.E.(gr/gr)		S.C.P. (%)	
Q29	***10_{th}March***	210.03	ab	43.45	a-d	54.22	a-g
	20_{th} March	257.05	a	56.35	a	74	a
	30_{th} March	236.44	ab	49.45	abc	76.34	a
	10_{th} August	197.06	b	52.18	ab	68.48	abc
	20_{th} August	206.48	ab	52.61	ab	71.98	ab
	30_{th} August	196.39	b	49.2	abc	62.73	a-e
Q26	***10_{th}March***	136.77	cd	31.55	c-g	32.87	fgh
	20_{th} March	79.33	d	16.32	fg	21.26	h
	30_{th} March	72.48	d	15.24	g	21.7	h
	100_{th} August	71.38	d	20.61	fg	22.99	h
	20_{th} August	80.17	d	22.42	fg	26.18	h
	30_{th} August	77.59	d	22.11	fg	23.21	h
RedCarina	***10_{th}March***	187.3	bc	42.33	a-e	65.9	a-d
	20_{th} March	117.12	d	23.79	efg	44.17	c-h
	30_{th} March	128.65	cd	27.13	d-g	54.61	a-g
	100_{th} August	131.14	cd	35.13	b-f	62.21	a-e
	20_{th} August	112.94	d	28.67	defg	53.71	a-g
	30_{th} August	98.3	d	24.73	d-g	39.77	d-h
Titicaca	***10_{th}March***	82.95	d	18.15	fg	34.8	fgh
	20_{th} March	130.27	cd	29.51	d-g	58.88	a-f
	30_{th} March	110.04	d	25.74	d-g	57.21	a-g
	100_{th} August	103.08	d	32.38	c-g	55.83	a-g
	20_{th} August	109.82	d	33.73	c-g	61.65	a-e
	30_{th} August	111.02	d	32.74	c-g	53.74	a-g
Giza1	***10_{th}March***	92.37	d	21.47	fg	31.05	gh
	20_{th} March	120.25	d	28.54	d-g	43.63	c-h
	30_{th} March	74.45	d	16.79	fg	36.21	e-h
	10_{th} August	93.14	d	30.1	d-g	42.61	c-h
	20_{th} August	98.06	d	31.58	c-g	44.77	c-h
	30_{th} August	101.7	d	31.73	c-g	46.54	b-h

Averages with at least one common letter in each column do not have statistically significant differences (Duncan 5%).

Current photosynthetic efficiency

In the study of the averages of two seasons, the interaction effects of planting date and genotype, all spring and summer planting dates in Q29 genotype were in the highest statistical group without significant differences with each other. A statistical group was placed (Table 3). Genotypes with longer growth periods have higher photosynthetic efficiency due to increased leaf chlorophyll content and late onset of signs of aging, resulting in more dry matter. The results obtained in the present experiment with the results reported by Reguera *et al*. (2018) and Rauf *et al*. 2007 corresponds to wheat.

Contribution of current photosynthesis

The highest share of current photosynthesis in the study of two seasons of planting dates belonged to the planting dates of 10th and 1st of August. These planting dates were statistically significant with a mean of 51.66 and 50.42%, respectively. The share of current photosynthesis in the planting dates of March 1 and August 20 were statistically significant with an average of 43.77 and 45.2%, respectively, in the last statistical group (Table 3).

Examination of the mean of two bi-seasons of genotypes showed that the share of current photosynthesis in RedCarina, Q29 and Titicaca genotypes with an average of 68, 53.4 and 53.7% was statistically significant in one group. The lowest share of current photosynthesis with an average of 24.7% was related to Q26 genotype. Two-season interaction of planting dates and genotype showed that Q29 genotype had the highest percentage of photosynthetic share in all planting dates, RedCarina on March 11 and 10 and August and Titicaca on March 10 and all summer planting dates (Table 3).

The share of current photosynthesis in summer planting dates in each genotype was higher than spring. With summer planting, more biomass was produced in the plant at the pollination stage and the share of vegetative stocks increased and the share of current photosynthesis decreased accordingly. Genotype Q29 with higher utilization capacity than environmental conditions have a higher share of current photosynthesis. Drought stress and heat at the end of the season increase (Modhej *et al*., 2011).

Two-year combined analysis of variance showed that the effect of year and its interaction with other factors on performance was not significant. As a result, the obtained averages were compared based on the average of two years after combined analysis. The results of analysis of variance showed that quinoa seed yield was affected by planting dates. The results also showed a significant effect of genotype on quinoa grain yield. The interaction effect of planting date and genotype on grain yield was significant (Table 1).

The study of the interaction between sowing date and genotype showed the highest grain yield from the sowing dates of March 1st and 10th in all genotypes. Genotype Q26 had the highest grain yield on the first sowing date of March (4079.7 kg / ha) Grain yield decreased on March 11 and all sowing dates in August compared to these two sowing dates in all genotypes. Seed yield in each genotype was placed in a statistical group on the dates of August and March 20. The lowest grain yield was obtained from planting Titicaca genotype in the twentieth male planting date. Seed yield increased in all genotypes compared to other summer genotypes on the 30th of August planting date (Table 3).

Table 4- Two-year average grain yield of studied genotypes at quinoa planting dates (kg / ha)

Sowing date	Genotypes									
	Q29		***Q26***		***RedCarina***		***Titicaca***		***Giza1***	
10thMarch	3848.0	ab	4079.7	a	2406.7	h	2968.5	fg	2968.5	fg
20th March	3497.5	cd	3692.2	bc	226.6	hi	2780.5	g	2780.5	g
30th March	3127.0	efg	3360.3	cde	1900.0	ijk	2066.4	hijk	2159.3	hij
100th August	2840.4	g	3077.6	efg	2128.0	hijk	1816.4	jk	2159.3	hij
20th August	2836.7	g	3045.2	efg	2125.8	hijk	1745.5	k	2140.4	hijk
30th August	3066.4	efg	3296.4	def	2411.1	h	2061.7	hijk	2224.5	hi

Averages with at least one common letter, do not have statistically significant differences (Duncan 5%).

Maximum grain yield in quinoa varies depending on the variety and environmental conditions, and environmental factors can affect yield by directly affecting the physiological processes of grain development and formation (Table 4) (Ali *et al*., 2020). Seed per square meter is possible (Hinojosa *et al*., 2018). High temperature in quinoa in the reproductive stage reduces fertility and can significantly reduce grain yield (Hinojosa *et al*., 2018). Thermal stress during grain filling mainly leads to the production of small and deformed grains and reduces the number of fully filled grains and their weight (Lesjak & Calderini, 2017). Improper planting date disturbs the balance of yield components in the plant, because the components Yields in crops are not independent of each other, and increasing a component by a certain amount often results in a decrease in one of the other components, in other words, in a proper yield, all components must be well balanced relative to each other.

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