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Effect of sowing date and planting method on yield and components yield of three varieties of quinoa (*Chenopodium quinoa* Willd)

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ABSTRACT

The most important parameter for the adaptability a crop to different climates is the planting date which has the greatest influence on the phonological characteristics of the plant. Therefore, this study was conducted to determine whether it is possible to plant different varieties of quinoa at different planting dates in hot and dry climates. The experiment was conducted as a split-plot experiment based on a randomized complete block design with four replications in two crop years, 2018-2019 and 2019-2020. The planting date was considered as the main plot at four levels (October 21, October 31, November 10 and November 20), the planting method (transplanting and seed sowing) as the sub-plot and the quinoa varieties (Gizal, Q26 and Titicaca) as the sub-sub-plot. The results showed that delays in planting date reduced leaf area index (LAI), plant height, grain yield components, grain yield and biological yield of quinoa. The highest values for these traits were recorded for the first sowing date of October 21, and early/late transplanting was inferior and superior to direct seed sowing, respectively. Among the varieties studied, Q26 variety was superior to the other two varieties in terms of growth, yield components and grain yield. The highest grain yield (3190 kg/ha) was recorded for Q26 under direct sowing on October 21 and the lowest (733 and 721 kg/ha) for Titicaca under direct sowing on November 20 and 30, respectively. Overall, early autumn sowing was suitable for growing different quinoa varieties in Khuzestan province due to longer growing period and avoiding the heat stress at the end of the growing period. Transplanting did not have much advantage over early seed sowing, but was better than delayed seed sowing.

Key words: Yield, Oil, Protein, Transplantation, Food security.

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd), which belongs to the Amaranthaceae, is an annual herbaceous pseudocereal with high nutritional value and digestibility (De Santis et al., 2016). Quinoa grains are a rich source of protein, iron, magnesium, phosphorus, fiber and vitamin B_2. The nutritional value of quinoa depends on amino acid compounds, calcium, phosphorus, high iron content and low sodium (Navruz-Varli and Sanlier, 2016; Fathi and Kardoni, 2020). The quantity and quality of the proteins of this cereal are higher more abundance than those of other cereals. Compared to wheat, quinoa has a balanced content of amino acids which are preferablefor human and animal nutrition (Sharma and Lakhawat, 2017). Quinoa is used for making flour, soup, breakfast cereals, food preparation and salad (Small, 2013).

In recent years, quinoa has become known as a potential crop to increase food security around the world due to its special characteristics and good growing ability under harsh climatic conditions (Choukr-Allah et al., 2016). Climate change (global warming and drying of soils), soil salinity, and high tolerance of quinoa to abiotic stresses show the importance of using quinoa as a suitable crop for sustainable agriculture (Ruiz et al., 2014).

Planting date is crucial to optimization of phenological stages to maximize plant growth and crop yield. Planting date is the first factor considered when growing a plant in a new region. The sowing date is determined on the basis of the variety and the weather in the region (Baum et al., 2020). Climatic conditions, especially temperature, humidity, and day length, determine the optimum time for sowing crops. To determine the optimum sowing date, it is ideal to match the ambient temperature with the optimum temperature for each phenological stage. In addition, the sensitive growth stages should not coincide with environmental stress (Moradi et al., 2013). Early sowing results in evapotranspirative water loss, but late sowing may result in lower grain yield (Humphreys and Gaydon, 2015).

A number of studies have been conducted on the sowing date of quinoa in arid and semiarid regions (Razzaghi et al., 2020). Saeidi et al., (2020) studied the effects of sowing date and nitrogen fertilization on this crop. They reported that maximum grain yield (8657 kg/ha) was harvested when the sowing date was between September 23 and October 12 and nitrogen fertilization was 320 kg/ha. Gharineh et al., (2019) observed that the highest and lowest number of panicles per plant and number of grains per panicle were recorded when the sowing date was November 11 and December16, respectively. Due to the positive impact on productivity and provision of more photosynthetic osmolytes for grain production, selection of the optimum sowing date leads to higher grain yield (Rajinder et al., 2017).

Unfavorable field conditions for seed sowing or a short growing season indicate the need for transplanting. Transplanting usually results in a short growing season for the plants (Holscher et al., 2020). However, the success of transplanting depends on the plant and environmental conditions. By increasing light use efficiency (LUE) compared to directly sowing seeds, transplanting increases yields (Tao et al., 2015). Shortening the growing period in the main field and early flowering by transplanting is an effective way to increase yield. In maize cultivation, there were notable yield differences between seed sowing and transplanting. However, transplanting led to earlier crop maturation compared to seed sowing, thereby reducing the risk of losses from natural factors like rain or storms (Badran, 2002).

Transplanting quinoa in Washington in April had negative results, but good results in May, resulting in higher yields than direct sowing (Ludvigson et al., 2019). Dao et al., (2020) in their study of different sowing methods for quinoa, reported that traditional planting produced higher yields than transplanting for some varieties (especially Titicaca and Puno). Transplanting increases the uniformity of the field and causes the plant to reach the desired leaf area index (LAI) in a shorter time. Transplanting may change plant growth patterns, leading to root damage and increased susceptibility to drought and nutrient stress, ultimately impacting plant growth and yield.

As a result of the significance of quinoa in various regions, this research was carried out to examine the impact of different sowing methods on several quinoa varieties to expand the options for cultivating this crop. The research aimed to contrast the conventional sowing method with a new, creative approach to determine which method would lead to increased yields and superior-quality quinoa. Furthermore, the study aimed to pinpoint any possible difficulties or advantages linked to each sowing method to offer guidance to farmers seeking to enhance their quinoa cultivation.

MATERIALS AND METHODS

Treatments and conditions

This experiment was carried out in crop years 2018-2019 and 2019-2020 in the Agricultural Research and Training Center and Natural Resources of Ahvaz, Khuzestan (31° 20'N and 48°40'E; 18 meters above sea level). The average rainfall in this area is 240 mm, making it an arid or semi-arid region. Table 1 shows the meteorological parameters. The experiment was conducted as a factorial split plot in a randomized complete block design with four replicates. The sowing date was considered as the main plot at four levels (October 21, October 31, November 10, and November 20), the sowing methods (transplanting and seed sowing) as the sub-plot, and the three quinoa varieties (Gizal, Q26, and Titicaca) as the sub-sub-plot (Bazile et al., 2016b; De Santis et al., 2016, 2018). The varieties of quinoa used in this study were provided by the Seed and Plant Improvement Institute (SPII) from Karaj of Iran, origin and other information showed in Table 2.

Tillage was carried out in early September and soil samples for physical and chemical analysis were collected from 0-30 cm depth (Table 3). According to the result of the soil test, NPK fertilizers in the form of urea, triple superphosphate and potassium sulfate were applied to the soil at the rate of 150, 100 and 100 kg/ha respectively on October 10.

Each plot consisted of six strips 5 m long and 3 m wide, 50 cm apart. For each square meter, 40 seeds were mixed with sand at a ratio of 1:3 and spread at a depth of 2-3 cm. The spacing between the main plots, sub-plots and each block was 1, 0.5 and 2 m, respectively. During transplanting, the seeds were sown in trays with humus and one month later the seedlings were transplanted into the plots. Direct seed sowing was carried out on the same day. During the growing season, the plants were irrigated regularly as required. Weeds, pests and diseases were controlled chemically and mechanically.

In this experiment, the following traits/indices were measured: LAI, plant height, number of branches per plant, yield components (number of panicles per plant, number of grains per panicle, and 1000-grain weight), grain yield, grain protein content, and grain oil content.

Plant height, number of branches, and LAI

Plant height and the number of branchesof 10 plants were measured and averaged.. To estimate LAI per unit area at each stage, leaf samples were taken 120 days after planting. The following equation was used to determine LAI (Javadi et al., 2006). In the following equation, LA represents leaf area and GA represents soil area (square meters).

$$LAI= (LA/GA) \qquad \text{Eq. 1}$$

Yield and yield components

To determine yield and yield components**,** 0.5 m of the beginning and 0.5 m of the end of lines 3, 4, and 5 were skipped at physiological maturity and then harvested over an area of 1 m^2. Harvesting was carried out manually on January 14 (Titicaca variety) and January 23 (Q26 and Gizal varieties). To measure the number of panicles per plant (Primary and secondary panicles), the total number of panicles per unit area was calculated by dividing this value by the number of plants: the number of panicles per plant. The primary panicle has a dense bundle of seed-bearing ped uncles at the top of the primary stem that grew vertically and was separated by short internodes. In contrast, secondary panicles grew obliquely, were more dispersed along the stem, and were separated by larger internodes. The number of grains per panicle was also measured on 10 panicles per plant (both type panicles) and the average of the values was calculated. To determine the 1000-grain weight, two 500-grain groups were counted, averaged, and multiplied by 2. Grain yield was calculated in kg/ha at a grain moisture content of 12%. For biological yield (grain yield+ total dry weight plant), samples were taken to the laboratory and placed in a ventilated oven at 75°C for drying for 48 hours.

Protein and oil content

At the time of physiological maturity, after sampling (0.5 g of milled grain), the nitrogen content of the grain was measured by the Kjeldahl method. Also, the percentage of protein was calculated according to the following equation (Voltas et al., 1997).

$$\text{Protein} = N\times 6.25 \qquad \text{Eq. 2}$$

To determine the percentage of seed oil (w/w), a Soxhlet apparatus was used for 3 hours at 50° C. and the solvent was ether. By weighing the oil obtained from 5 g of the powdered quinoa seeds, the percentage of oil was determined (Uquiche et al., 2008).

Harvest index

Harvest index (HI) was calculated according to the following formula:

$$HI (\%) = \text{Grain yield} / \text{Biological yield} \times 100$$

Statistical Analysis

Before performing the combined analysis, Bartlett's test was used to ensure the uniformity of the experimental variance of the error. Because the difference between the error variances was not significant, a combined analysis of variance (two-way ANOVA) was performed using SAS (9.4 ver.) statistical software, and least significant difference(LSD) tests at the 0.05 probability level were used to compare the means. Year and repetition were considered as random factors with planting date, planting method and variety as fixed factors.

RESULTS

Plant height and LAI

LAI was influenced by year, sowing date, variety and planting date × planting method, planting date × variety and planting method × variety (Table 4). Plant height was influenced by two-way, three-way, and four-way interactions: year × planting date × planting method × variety (Table 4). It was found that LAI was higher in 2018 than in 2019, and October 21 and 31 outperformed the other dates. Seed sowing and Q26 variety led to the highest LAI and plant height compared to transplanting and other varieties (Table 4).

It was found that at the first and second planting dates, with direct sowing of seeds performed better than transplanting and had a higher LAI. When sowing was delayed until mid-November, transplanting proved to be more successful than direct seed sowing in terms of LAI. The highest LAI (5.65) was related to the date of the first direct seed sowing. The lowest LAI was related to the November 10-20 planting date and direct seed sowing, being 39% lower than the first planting date and direct seed sowing (Figure 1, a). It was also found that for all three varieties, the highest LAI was related to the first seed sowing date (October 21). Variety Q26 had the highest LAI (5.8) (Figure 1, b). The interaction of planting method × variety also showed that direct seed sowing resulted in higher LAI in all three varieties, with the highest value found in the Q26 variety (5.62; Table 6).

The highest plant height was recorded in the first planting date in both years and for all three varieties, and the lowest plant height was observed from the last planting date or November 20. In both years, the highest height of quinoa (76.5 and 77 cm) was observed following direct seed sowing of variety Q26., Transplanting reduced plant height in varieties of Q26, Gizal and Titicaca by 6%, 3% and 15% in the first year and by 7%, 17% and 2% in the second year (Table 6). At the late planting date (November 10-20), transplanting performed better than direct seed sowing. The Q26 variety had the highest plant height at this planting date, and transplanting increased plant height for this variety (by 11% and 10% in 2019 and 2020, respectively) compared to direct seed sowing (Table 6).

Number or branches

The effect of planting date × planting method × variety on the number of quinoa branches was significant (Table 4). The number of branches was higher in 2018 than 2019, and earlier planting on October 21 resulted in a higher number of branches than late planting. In addition, direct seed sowing and the Q26 variety resulted in higher number of branches (Table 5). Delaying the planting date reduced the number of branches in all three varieties, but transplanting mitigated this negative effect.

The delay in planting until November 10 resulted in a 36% decrease in the number of branches in the Q26 variety and 33% and 32% in the Gizal and Titicaca varieties, respectively. Transplanting on this date also improved the number of branches compare to direct seed sowing. On this planting date, the change in the number of branches in Giza1, Q26, and Titicaca varieties was 14%, 8%, and 13%, respectively, compared to direct seed sowing. Variety Q26 planted on October 21 and direct seed sowing had the highest number of branches (33.6). Transplanting at this planting date and for this variety reduced the number of branches by 18%, while the effects of Transplanting on the Gizal and Titicaca varieties were estimated to be about 5% and 3%, respectively (Table 5).

Component grain yield

The results of the components of grain yield also showed that the effect of planting date on number of panicles per plant, number of grains per panicle and variety on 1000-grain weight was significant. The interactive effect of planting date × variety on number of panicles per plant and number of grains per panicle, and planting date × planting method × year and planting method × variety on 1000-grain weight was significant. The effect of year × variety was significant for all components (except for 1000-grain weight), but the effect of year × planting method and year × planting date influenced only 1000-grain weight (Table 4).

Delayed planting date reduced some grain yield components (number of panicles per plant and number of grains per panicle) of the quinoa varieties. The highest yield components were observed for the Q26 variety and an October 21 planting date, and the lowest yield components were observed for a November 10 planting date, which caused a 44%, 39%, and 46% reduction in the number of panicles per plant and a 27%, 30%, and 38% reduction in the number of grains per panicle for Giza1, Q26, and Titicaca varieties, respectively, compared to the October 21 planting date (Figure 2). It was also found that for all three varieties, seed sowing resulted in a higher number of panicles per plant than transplanting (Table 6).

The 1000-grain weight results also showed that in both years, the highest 1000-grain weight (in 2018 with an average of 3.27 g and in 2019 with an average of 3.19 g) was related to the second date of direct seed sowing (October 31). The lowest 1000-grain weight was obtained on the last date of transplantation (November 20) in both years with averages of 1.68 and 1.69 g in the first and second years, respectively (Table 7). It was also observed that the Q26 variety ranked first in terms of 1000-grain weight, the Gizal variety ranked second and the Titicaca variety ranked last (Table 4).

Grain and Biological Yield

The results related to grain yield and biological yield of quinoa also showed that grain yield was affected by the interaction of year × planting date, year × planting method, planting date × planting method, year × planting date × planting method, planting date × variety, and year × planting method × variety.,the biological yield was affected by the interaction of year × planting date × planting method × variety (Table 4).

In 2018, grain yield exceeded that of 2019. Direct seed sowing on October 21 consistently led to the highest grain yields in both years. Specifically, for direct seed sowing on October 21, quinoa yield in the first and second years was 3,148 and 2,873 kg/ha, respectively. This represents a 14% and 43% increase compared to transplanting at the same time, and a 67% and 68% increase compared to delayed planting (Table 7).

The interaction of planting method × variety × year also showed that in both years for all three varieties, seed sowing resulted in higher yield. In both years the highest grain yield was obtained by the Q26 variety: 1,818 and 2,073 kg/ha (Table 7).

Biological yield was higher in 2018 than in 2019. In 2018, the highest biological yield was recorded for direct seed sowing of the Q26 variety on November 10, with an average of 10,105 kg/ha. In 2019, for this variety, direct seed sowing on October 21 had the highest biological yield with an average of 11,211 kg/ha. Furthermore, the lowest biological yield in both years was obtained when Gizal variety was transplanting on November 20 (Table 5).

Harvest index

The results of quinoa HI showed, that it was affected by main effect years, variety, the interaction of year × planting date, year × planting method, planting date × planting method, year × planting date× variety, and planting date × planting method× variety (Table 4). In both years, October 21 planting and November 20 had maximum and minimum HI values respectively. Also, in both years and early planting, direct seed sowing had higher results than transplanting, with the highest HI recorded for this method. However, in delayed planting, transplanting can help mitigate the negative effects of the delay.

The interaction of planting date × planting method variety was evident, with the highest HI (around 41.8%) observed in the Q26 variety on October 21 using direct seed sowing. The lowest HI (about 12.3%) was also recorded for the Titicaca variety on November 20 using direct seed sowing (Table 5).

Protein and oil content

The protein and oil content of quinoa grains were influenced by the interactions between planting date, planting method, and variety (Table 4). Grain protein and oil contents were found to increase with a delay in planting date for all three varieties, and transplanting was more so than for direct seed sowing. The highest contents of protein (15.6%) and oil (6.49%) were observed in the varieties of Gizal and Titicaca, which differed by 7% and 21% from the first sowing and transplanting dates, respectively, but were not statistically different from each other. Moreover, the lowest values of grain protein and oil were observed in the second date of transplantation of Gizal variety (Table 5).

DISCUSSION

Quinoa yield, like many other crops, is influenced by the interaction of environmental and genetic factors (Bazile et al., 2016b, a). Our study found that a planting date later than early fall reduced grain and biological yield of quinoa, with the extent of change varying by variety. A 20-day delay from the optimal planting date (October 12) resulted in a 60% reduction in grain yield, a 40% reduction in biological yield and 54% harvest index. In the study by Gharineh et al. (2019) and Saeidi et al. (2020) on this crop, a lower grain yield was also found due to delay in planting.

Crop yield depends on the growth of plant parts, flowering, fertility of flowers, grain development, and accumulation of materials in the grain. (Guo et al., 2017). It was observed that the number of grains per panicle and 1000-grain weight were strongly affected by delayed planting (Table 5). Lower number and weight of grains due to delayed sowing has already been reported in several studies on this crop (Gharineh et al., 2019; Saeidi et al., 2020). But in our study decrease in the number of grain of 10 days delayed (October 31) was accompanied by an increase in grain weight, which indicates the resource limitation in this plant. Curti et al., (2018) Curti et al. (2018) found that protein and fat accumulation, as well as seed size, do not correlate with the distribution of nutrients among different seed tissues. They also highlighted the specific environmental and genetic effects on each of these components. There is a consistent positive correlation between the size of the embryo/seed and the lipid content in quinoa. Conversely, there is a negative correlation between the size of the embryo/seed and the protein content (Miranda et al., 2013; Graf et al., 2016). Delayed planting in quinoa causes the flowering and pollination period to coincide with end-of-season heat stress, resulting in a lower number of grains per panicle (Saeidi et al., 2020). Grain filling rate and period are the most important determinants of grain weight (Álvaro et al., 2008), and high temperatures during the grain filling period, have a negative effect on grain weight (Nurse et al., 2016).

Our study revealed that the grain weight increased compared to October 21st data, but there was a sharp decrease in grain weight by November 20th. (Table 5). In general, quinoa was sensitive to temperatures above 25 ° C and below 20 ° C during the grain filling period, so delayed planting during the grain filling coincides with an increase in temperature under Mediterranean climates. At high temperatures, pollen vigor and the number of flowers decrease, and most quinoa varieties do not produce grains at temperatures above 35 °C (Morrison and Stewart, 2002; Hirich et al., 2014). Quinoa is also sensitive to day length. At the pollination and grain filling stages, sensitivity to day length is greater than at other growth stages, which varies by genotype (del Pozo et al., 2023). Our results also showed that as the planting date delay increases, the growth degree days (GDD) obtained per month is lower, which may affect the production of this crop (Table 1). In other studies, it has been reported that there is an inverse relationship between grain weight the and number of grains (Benincasa et al., 2017), which is also due to the increased distribution of photosynthetic material per grain.. In addition, vegetative growth indices of quinoa, such as LAI, plant height, and number of branches, decreased significantly with delayed planting date due to changes in temperature, light, and rainfall, which affects the distribution of photosynthetic materials to the grain. Präger et al., (2019) also observed that delayed planting reduced the growth indices of quinoa. The reason for the faster and more appropriate growth increase at the mid-October planting date at than other planting dates was attributed to more favorable temperatures for leaf growth, a longer growing season, and better utilization of environmental potential (Hirich et al., 2014; Präger et al., 2019). Limitation of the remobilization contribution and remobilization efficiency are other factors that reduce yield and yield components in quinoa due to late planting. It has been reported that reserves accumulated before flowering play an important role in determining grain yield, but depends upons on environmental conditions and variety (Pal et al., 2012). Planting date, nutrition, and environmental stress are factors affecting the remobilization rate of photoassimilates from the stem and leaf to grain (Aynehband et al., 2011; Bijanzadeh et al., 2019). Moreover, shortening of the growing season due to delay in planting, reduces the amount of dry matter accumulation in the stem and other aerial parts of the plant., It also resulted in a decrease in material re-transmission, an increase in the ratio of abscisic acid to cytokinin in leaves, a decrease in leaf area density (LAD), increased plant tissue death, leaf shedding, increased respiration due to shading, and light degeneration leading to a decrease in dry matter accumulation and increased remobilization (Awasthi et al., 2017).

Transplantation has been studied as one of the solutions to compensate for late sowing date in many crops. We found that transplantation was better than direct seed sowing, but it reduced the efficiency of the plant on the optimal sowing date, causing a 17% decrease in seed yield in the first year and 70% in the second year. Numerous studies have reported poor yields under transplanting compared to direct seed sowing (Ludvigson et al., 2019; Dao et al., 2020). The response of quinoa to transplanting depends on the cultivar: it can reduce or increase yield components (Bazile et al., 2016a; Dao et al., 2020). In our 2020 study, transplanting at the optimal planting date reduced grain yield by 30% in Q26 and by 25% and 20% in Gizal and Titicaca varieties, respectively (Table 6).

Transplantation can affect plant growth rate and yield by altering the length of the plant's growing season and increasing the proportion of current photosynthesis to remobilization efficiency. In our study, the slow development of leaf area under late planting was only partially compensated by transplanting. The negative effects of transplanting on the optimal planting date are also due to the environmental shock to the seedlings and the time needed for the seedlings to adapt to the soil. Transplanting shortens the time of vegetative growth and root system development and also reduces the remobilization rate and ultimately production through early plant maturity (Badran, 2002).

In contrast to grain yield, delayed planting improved quinoa grain quality in terms of gran oil and protein. Delaying the sowing date by 20 days and direct sowing increased grain protein by 7% and oil by 21% in Gizal and Titicaca varieties. Oil and protein content in grain is affected by environmental conditions such as temperature and drought during the grain filling period (Pípolo et al., 2015; Naoe et al., 2021). Therefore, delayed sowing affects grain quality by increasing temperature and shortening the period of grain filling and seedling planting, as well as accelerating growth.

CONCLUSIONS

The results of this study showed that planting date had a significant effect on LAI, height of plant, grain yield and components of grain yield, protein and oil content. Among the sowing dates, sowing on October 21 had the highest growth rate and grain yield and components of grain yield, while a later sowing date reduced quinoa yield. Among the varieties studied, the Q26 variety had the highest growth rate and yield and always had the highest yield in both years studied and at all planting dates. It was also found that transplanting had a negative effect at the October 21 and November 10 planting dates, but performed better than direct seed sowing at the late planting dates (November 10-20) and mitigated the negative effects of late planting. In addition, protein and oil content in the grains increased due to the delay in sowing date. Overall, direct seed sowing of the Q26 variety on October 21 is recommended under hot and dry conditions, and transplanting cannot compensate for all the negative effects of the delayed planting date.

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Table 1. Meteorology parameter long coincided experiment in two years 2018 and 2019

Months	Mean (◦C) temperature		GDD		Rainfall (mm)		Evaporation (mm)	
	2018	2019	2018	2019	2018	2019	2018	**2019**
Oct	28.3	29.2	666	639	37.8	62.5	194.9	169.2
Nov	19.4	18.9	357	372	37.8	37.0	74.7	83.1
Dec	15.3	14.4	222	249	20.5	119.2	44.7	46.0
Jan	14.2	13.4	192	216	45.1	31.0	49.5	63.2
Feb	15.5	15.7	261	255	13.8	21.5	71.9	85.4
Mar	16.2	17.2	249	319	9.2	11.0	89.7	96.8
April	21.2	23.4	396	436	2.2	4.1	96.8	102.1

Table 2. Origin of the quinoa cultivars used in the field experiment.

No	Varieties	**Origin**	**Type**	**Seed Sources**
1	Gizal	Bolivia	Cultivar	Seed and Plant Improvement Institute (SPII)
2*	Q26	Chile	Accession	Seed and Plant Improvement Institute (SPII)
3	Titicaca	Peru& Bolivia	Cultivar	Seed and Plant Improvement Institute (SPII)

* Seed of the Q26 accession was supplied to SPII by CREA-CI (ex CRA-CER) of Foggia-Italy, (Bazile et al. 2016 a; 2016 b) where it was evaluated and selected as part of a Genetic Improvement Program on quinoa (still in study) for the constitution of a quinoa variety made in Italy.

Table 3. Some physical and chemical properties of the test site soil in 2018 and 2019

Years	Depth (cm)	salinity (ds.m)	PH	C (%)	N (mg.kg)	P (mg.kg)	K (mg.kg)	clay (%)	silt (%)	sand (%)	soil texture
2018	0-60	5.4	9.7	0.58	0.058	10.5	245	22	30	48	**lomy**
2019	0-60	4.4	8	0.53	0.053	11.2	265	24	30	46	**lomy**

Table 4 . Effect of data panting, planting method and variety on plant height (PH), LAI, number beachs (NB), number panicle (NP), number grain per panicle (NG), 1000grain weight (WG), grain yield (GY), biological yield (BY), harvest index (HI), protein and oil contentof quinoa in 2018 and 2019.

Treatment	Level	PH (cm)	LAI	NB	NP	NG	WG (g)	GY (kg/h)	BY (kg/h)	HI (%)	Protein (%)	Oil (%)
Year	2018	53.6^{a}	4.97^{a}	21.9^{a}	8.18^{a}	382.4^{a}	4.42^{a}	1532.2^{a}	6314.7^{a}	22.5^{a}	15.0^{a}	5.66^{a}
	2019	53.4^{a}	4.29^{b}	20.6^{b}	8.14^{a}	376.8^{a}	4.41^{a}	1480.2^{a}	6282.3^{b}	20.9^{b}	14.9^{a}	5.54^{b}
LSD$_{0.05}$		0.70	0.43	0.29	0.63	37.4	0.036	61.9	64.2	1.4	0.22	0.048
Data planting	21.Oct	64.4^{a}	5.23^{a}	26.0^{a}	11.33^{a}	426.9^{a}	4.52^{a}	2585.2^{a}	7765.5^{a}	30.7^{a}	14.8^{c}	5.49^{b}
	31.Oct	56.6^{b}	5.16^{a}	22.6^{b}	7.88^{b}	397.7^{ab}	5.57^{a}	1445.3^{b}	6139.0^{a}	22.8^{a}	14.7^{c}	5.16^{c}
	10 Nov.	47.4^{c}	4.08^{b}	19.6^{c}	6.50^{c}	315.8^{c}	4.01^{a}	934.3^{b}	6548.0^{a}	13.9^{b}	15.0^{b}	5.62^{b}
	20 Nov.	45.5^{c}	4.06^{b}	16.8^{d}	6.96^{c}	378.2^{b}	3.56^{a}	1060.4^{b}	4741.6a	19.3^{b}	15.5^{a}	6.13^{a}
LSD$_{0.05}$		2.27	0.64	1.08	0.87	42.8	1.25	1016.2	6267.1	7.9	0.14	0.15
Planting method	Transplanting	52.1^{a}	4.52^{a}	20.0^{b}	6.83^{a}	340.7^{a}	4.34^{a}	1432.9^{a}	5614.1$_{a}$	20.6^{a}	15.0^{a}	5.54^{a}
	Seed	54.9^{a}	4.73^{a}	22.5^{a}	9.50^{a}	418.6^{a}	4.48^{a}	1579.6^{a}	6982.9^{a}	22.7^{a}	14.9^{a}	5.67^{a}
LSD$_{0.05}$		7.8	3.64	1.45	3.7	238.1	1.5	2575	2407.2	1.6	0.69	1.03
Variety	Giza1	52.3^{b}	4.78^{a}	21.3^{b}	8.44^{ab}	354.5^{a}	4.45^{b}	1487.7^{b}	6307.1^{b}	21.7^{b}	14.8^{b}	5.33^{b}
	Q26	60.0^{a}	4.87^{a}	24.5^{a}	9.72^{a}	361.2^{a}	4.81^{a}	1813.8^{a}	6397.0^{a}	25.3^{a}	14.9^{b}	5.69^{ab}
	Titicaca	48.2^{c}	4.25^{b}	18.0^{c}	6.34^{b}	423.2^{a}	3.98^{c}	1217.3^{c}	6191.4^{c}	18.1^{c}	15.2^{a}	5.78^{a}
LSD$_{0.05}$		1.70	0.33	0.32	2.58	189.5	0.039	55.7	66.1	2.4	0.21	0.37
F value	Year(Y)	ns	**	**	ns	ns	ns	ns	*	**	ns	**
	Data planting(D)	**	*	**	**	*	ns	*	ns	ns	**	**
	Planting method (S)	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
	Variety (V)	**	*	**	ns	ns	**	**	**	**	*	ns
	Y×D	*	ns	ns	ns	ns	**	**	**	**	ns	ns
	Y×S	**	ns	ns	ns	ns	**	**	**	**	*	**
	Y×V	ns	ns	ns	*	*	ns	ns	ns	ns	ns	*
	D×S	ns	**	ns	ns	ns	ns	ns	ns	**	ns	**
	D×V	**	*	**	**	**	ns	**	ns	ns	**	**
	S×V	ns	*	*	*	ns	ns	ns	*	ns	**	ns
	Y×D×S	**	ns	ns	ns	ns	**	**	**	ns	ns	ns
	Y×D×V	**	ns	ns	ns	ns	ns	ns	**	**	ns	ns
	Y×S×V	*	ns	ns	ns	ns	ns	*	ns	**	ns	ns
	D×S×V	ns	ns	**	ns	ns	ns	ns	ns	*	*	**
	Y×D×S×V	*	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
CV (%)	-	3.13	17.84	4.86	20.41	25.82	5.08	8.0	2.4	6.0	2.2	5.1

ns, * and ** mean non-significant and significant at 5% and 1% probability levels, respectively

The different letters in each column indicate a significant difference by LSD's test at the 5% level

Table 5 . Effect of interaction data panting× planting method × variety on number beachs (NB), number panicle (NP), grain yield (GY), harvest index (HI), oil content, protein yield (PY) and oil yield (OY) of quinoa and interaction data panting× planting method × variety × years on plant height (PH) and biological yield (BY) of quinoa

Data planting	Planting method	variety	PH (cm)		NB	BY (kg/h)		HI (%)	Protein (%)	Oil (%)
			2018	2019		2018	2019			
21.Oct	Transplanting	Giza1	63.8^{de}	53.5^{f}	24.9^{d}	7942.6^{e}	6647.5^{g}	22.80^{ef}	14.4^{jk}	5.15^{hi}
		Q26	72.3^{b}	72.5^{b}	27.3^{b}	8360.4^{d}	6959.2^{f}	27.41^{cd}	14.9^{fgh}	5.54^{e-h}
		Titicaca	56.5^{fg}	56.8^{e}	21.8^{ef}	8551.1^{d}	6323.7^{h}	21.34^{e-h}	15.2^{b-e}	5.35^{fgh}
	Seed	Giza1	65.3^{d}	64.3^{d}	26.0^{c}	9237.9^{c}	10484.2^{b}	38.43^{a}	14.5^{ijk}	5.25^{ghi}
		Q26	76.5^{a}	77.0^{a}	33.6^{a}	9805.1^{b}	11211.4^{a}	41.80^{a}	14.5^{ijk}	5.60^{efg}
		Titicaca	56.8^{fg}	57.8^{e}	22.5^{e}	8477.6^{d}	9375.3^{c}	32.64^{b}	15.1^{c-f}	6.06^{bcd}
31.Oct	Transplanting	Giza1	53.5^{hi}	52.5^{f}	21.8^{ef}	6277.5^{g}	7587.8^{e}	20.34^{e-i}	14.3^{k}	4.70^{j}
		Q26	62.8^{e}	63.0^{d}	24.4^{d}	6555.5^{f}	7812.6^{e}	24.03^{de}	14.4^{ijk}	5.22^{ghi}
		Titicaca	47.3^{j}	47.3^{gh}	17.9^{gh}	5972.6^{hi}	8492.6^{d}	16.82^{ijk}	14.9^{fgh}	5.34^{fgh}
	Seed	Giza1	57.0^{f}	56.0^{e}	24.4^{d}	9719.2^{b}	10455.9^{b}	26.70^{cd}	14.5^{ijk}	4.86^{ij}
		Q26	67.8^{c}	67.0^{c}	26.0^{c}	10105.6^{a}	10557.7^{b}	30.46^{bc}	14.8^{ghi}	5.44^{e-h}
		Titicaca	52.5^{hi}	53.3^{f}	21.0^{f}	9251.9^{c}	9485.0^{c}	18.60^{g-j}	15.1^{c-f}	5.41^{e-h}
10 Nov.	Transplanting	Giza1	47.5^{j}	48.8^{g}	17.4^{h}	4670.4^{m}	4286.2^{o}	15.06^{jkl}	14.7^{ghi}	5.30^{gh}
		Q26	54.5^{gh}	56.0^{e}	21.3^{f}	4936.7^{l}	4463.6^{o}	18.08^{g-k}	14.9^{fgh}	5.61^{efg}
		Titicaca	44.3^{klm}	45.0^{ijk}	15.0^{i}	5226.5^{k}	4798.8^{n}	12.51^{l}	15.2^{b-e}	5.47^{e-h}
	Seed	Giza1	46.3^{jkl}	46.5^{hij}	16.0^{i}	5826.6^{hij}	5032.6^{mn}	14.74^{l}	14.8^{ghi}	5.50^{e-h}
		Q26	47.3^{j}	47.5^{gh}	18.3^{gh}	5989.1^{h}	5325.6^{kl}	16.74^{kl}	15.0^{c-f}	5.78^{cde}
		Titicaca	42.5^{m}	43.3^{kl}	13.0^{j}	5591.6^{j}	5353.8^{kl}	12.31^{l}	15.2^{b-e}	6.06^{bcd}
20 Nov.	Transplanting	Giza1	44.8^{klm}	46.8^{ghi}	21.3^{f}	5315.0^{k}	5206.5^{lm}	17.54^{ijk}	15.3^{a-d}	5.73^{def}
		Q26	50.5^{i}	52.8^{f}	22.4^{e}	5710.7^{j}	5467.9^{jk}	21.88^{efg}	15.4^{abc}	6.03^{bcd}
		Titicaca	47.3^{j}	42.5^{l}	17.5^{h}	4852.8^{lm}	4845.4^{n}	14.85^{jkl}	15.4^{abc}	6.05^{def}
	Seed	Giza1	43.0^{m}	42.5^{l}	18.5^{g}	5745.9^{ij}	5622.7^{j}	20.08^{f-i}	15.6^{a}	6.16^{abc}
		Q26	46.5^{jk}	47.5^{gh}	20.8^{f}	6000.8^{h}	6000.2^{i}	23.68^{def}	15.5^{ab}	6.33^{ab}
		Titicaca	44.0^{lm}	41.0^{im}	16.5^{i}	5266.5^{k}	5183.3^{lm}	17.74^{ijk}	15.5^{ab}	6.49^{a}
LSD 0.05			3.1		1.13	459.7		7.9	0.081	0.13

The different letters in each column indicate a significant difference by LSD's test at the 5% level.

Table 6 . Effect of interaction planting method × variety on LAI and number panicle (NP) and planting method × variety × year on grain yield (GY) of quinoa.

planting method	Variety	LAI	NP	Grain yield (kg/h)	
				2018	2019
Transplanting	Giza1	5.31^{b}	6.88^{cd}	1441.4^{bc}	1342.0^{cd}
	Q26	5.61^{a}	7.88^{bc}	1776.3^{ab}	1587.2^{bc}
	Titicaca	4.56^{c}	5.75^{d}	1138.8^{c}	1143.7^{d}
Seed	Giza1	5.47^{ab}	10.00^{ab}	1480.1^{bc}	1687.5^{b}
	Q26	5.66^{a}	11.56^{a}	1818.0^{a}	2073.6^{a}
	Titicaca	5.15^{b}	6.94^{cd}	1226.5^{c}	1360.3^{cd}
LSD 0.05		0.18	0.55	84.7	

year was separate comparison and the different letters in each column indicate a significant difference by LSD's test at the 5% level.

Table 7 . Effect of interaction data of panting× planting method × year on 1000grain weight (WG), grain yield (GY) of quinoa

Data planting	Planting method	WG (g)		G Y (kg/h)	
		2018	2019	2018	2019
21.Oct	Transplanting	1.70^{e}	2.15^{c}	2700.6^{b}	1618.1^{c}
	Seed	2.19^{c}	3.00^{b}	3148.7^{a}	2873.2^{a}
31.Oct	Transplanting	3.03^{b}	1.85^{de}	967.3^{d}	1214.8^{d}
	Seed	3.27^{a}	3.19^{a}	1532.2^{c}	2066.7^{b}
10 Nov.	Transplanting	2.11^{c}	2.12^{c}	895.4^{d}	926.2^{e}
	Seed	1.90^{d}	2.01^{cd}	867.3^{d}	924.7^{e}
20 Nov.	Transplanting	1.78^{de}	1.65^{f}	1128.6^{d}	1199.0^{d}
	Seed	1.68^{e}	1.69^{ef}	1019.0^{d}	1018.8^{de}
LSD 0.05		0.10		79.8	

year was separate comparison and the different letters in each column indicate a significant difference by LSD's test at the 5% level.

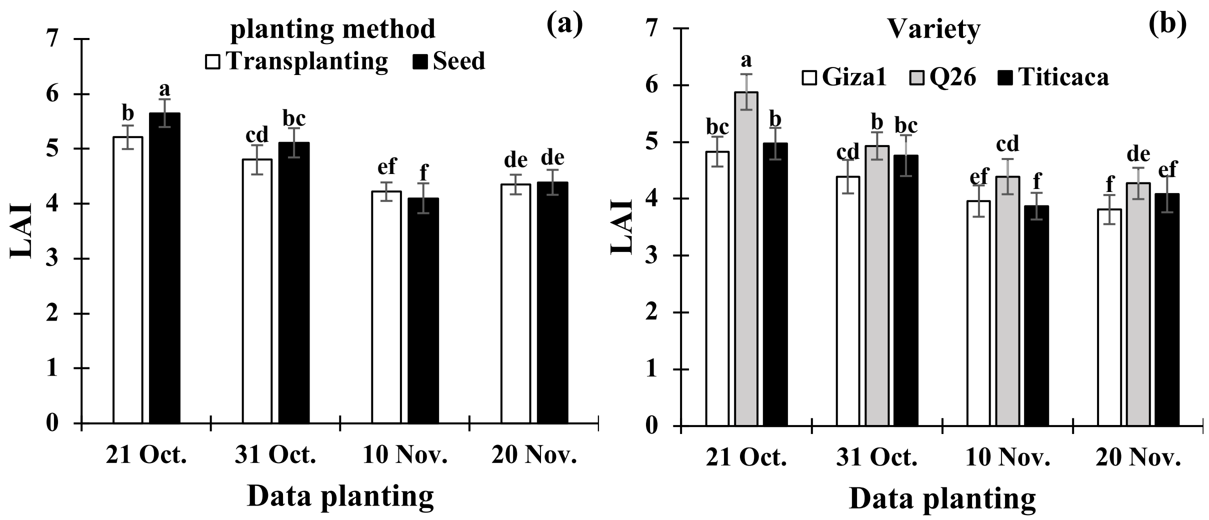

Figure 1. Effect the data of planting ×planting method (a) and data planting × variety (b) on LAI of quinoa. The different letters in each column indicate a significant difference by LSD's test at the 5% level.

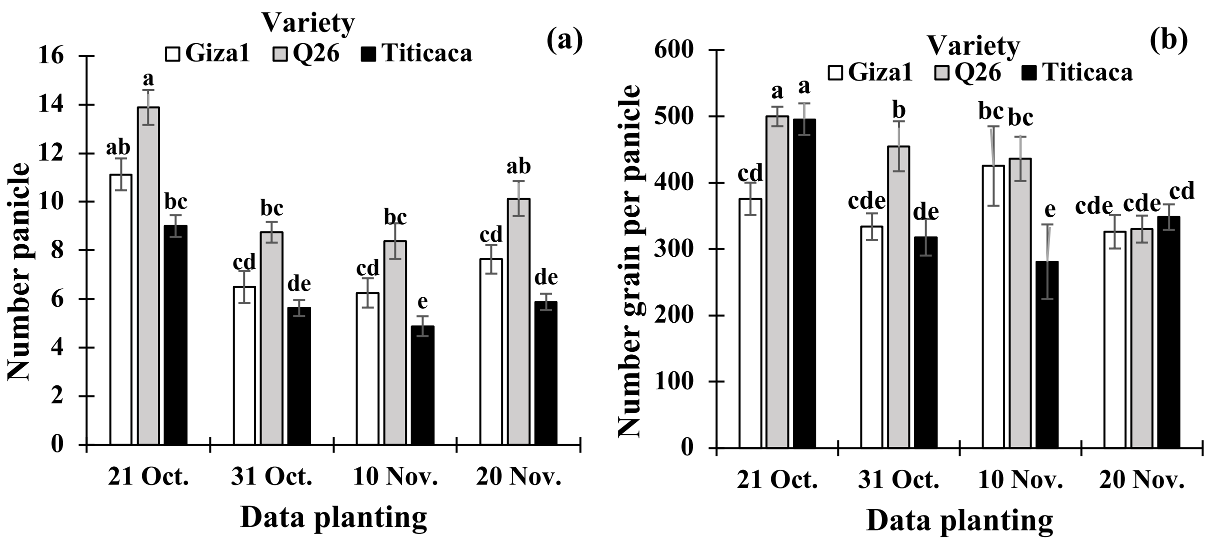

Figure 2. Effect the data of planting × variety on number panicle per plant (a) and number grain of quinoa (b). The different letters in each column indicate a significant difference by LSD's test at the 5% level.