

PRODUCTIVITY AND QUALITY OF QUINOA YIELD (CHENOPODIUM QUINOA, WILLD) AS AFFECTED BY PLANTING DATE AND PLANT SPACINGS

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ABSTRACT: A field experiment was conducted at the nursery of ornamental plants, Faculty of Agriculture, Minia University during 2018/2019 and 2019/2020 seasons to study the effect of three planting dates (November 1st, November 15th and December 1st) and three plant spacings (10, 15 and 20 cm) on growth, yield and chemical composition of quinoa plants to obtain the best agricultural transactions under the conditions of Central Egypt. The results showed significant effects of planting dates on all the studied traits, except for plant height, weight of 1000 seeds and protein% in both seasons, with the planting date of November 15th being the best date. The effect of plant spacing was significant for all studied characters, except for weight of 1000 seeds and protein % in the first season. Planting quinoa seeds at 15 cm. was superior to the other spacings in most cases. The interaction between planting dates and plant spacing between plants was insignificant except for number of panicles/plant and yield of seeds/plant (g) in both seasons and the weight of 1000 seed (g) and seed yield/fed (ton) in the second season. Therefore, it is recommended to cultivate the quinoa on November 15th at a distance of 15 cm apart under the conditions of Central Egypt because it gave the best values for economic characteristics.

Key words: Quinoa, planting dates, planting spacings and protein %.

INTRODUCTION

Quinoa (*Chenopodium quinoa*, Willd) plants are belonging to Family Chenopodiaceae. Quinoa is a stress-tolerant plant, cultivated in Andes, Peru, Bolivia, Chile, Ecuador, Colombia and Argentina. Its grains have high protein content with abundance of essential amino acids, wide range of vitamins, especially vit. E, minerals and saponin and it is a promising worldwide plant for human consumption, nutrition and medical industries (Vega-Galvez *et al.*, 2010, Bilalis *et al.*, 2012 and Ning *et al.*, 2020).

Optimum planting date and plant spacing had positive effects on growth, yield and chemical composition of different plant

species as emphasized by many authors Thalji and Shalalkeh (2006) on faba bean, Sudeep *et al.* (2006) and Badran *et al.* (2007) on fennel and Sajjad *et al.* (2014) on quinoa. However, Bhargava *et al.* (2007) and Sief *et al.* (2015) found that the best growth and yield of quinoa was obtained due to 25 cm spacing and 15 November sowing date, while late sowing date (during December 1st) gave the lowest yield regardless of plant spacings (10, 20 and 25 cm), as well as, Sayed *et al.* (2018) reported that sowing dates affected the growth and productivity due to differences in temperature, precipitation and radiation over the year. The highest seed yield and dry matter yield were obtained for quinoa sown in early date.

The main objective of this study was to describe the relationship of quinoa productivity and quality response to planting dates, with emphasis on the management effects of planting spaces under environmental condition of Minia Governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were conducted during both seasons of 2018/2019 and 2019/2020 at nursery of ornamental plants, Faculty of Agriculture, Minia University.

The experiment was arranged in split-plot design with three replicates. The main plots (A) included three planting dates (November 1st, 15th and December 1st). However, spacing distances between plants (10, 15 and 20 cm) were arranged in the sub-plots (B). Quinoa seeds variety Denish KVL 3704 were supplied from the Royal Faculty of Agriculture, Copenhagen. Each plot area was 12 m² consisting of 4 rows with 5 m long, and spacing was 0.6 m between rows, and both sides of the row were cultivated by seeds at a depth of 3 cm in hills (after 3 weeks, the plants were thinned to two plants/hill). Calcium super phosphate (15.5% P₂O₅) was applied to the soil at the rate of 150 kg/fed during land preparation. Ammonium nitrate (33.5% N) and potassium sulphate (48% K₂O) respectively were added

after thinning in two doses, one-month interval.

All agricultural practices were applied as commonly used for growing quinoa in the marginal soil agriculture in the two growth seasons. The physical and chemical properties of the experimental soil in both seasons are shown in Table (1) according to Page *et al.* (1982).

Data recorded:

At harvest, ten quinoa plants from each plot were chosen randomly to estimate the following characters, plant height (cm), number of panicles/plant, yield of seeds/plant (g) and per fed (kg), dry weight of foliage yield (ton/fed), 1000 seeds weight (g) and protein percentage according to Page *et al.* (1982), as well as, saponin (%) according to San Martun and Briones (2000).

Statistical analysis:

Data of the two seasons were subjected to the statistical analysis of variance (ANOVA) for the split-plot design with three replications by means of MSTAT-C (1986) computer software package according to Gomez and Gomez (1984). Least significant differences (LSD) test was used to compare means among treatments at 5% level of probability.

Table 1. Physical and chemical properties of the experimental soil.

Soil chemical	Values	Soil chemical properties	Values	Soil physical properties	Values	
pH (1:2.5 water)	7.70	Total P (g kg ⁻¹)	0.56	F.C. %	42.45	
CaCO ₃ (g kg ⁻¹)	17.90	Available P (mg kg ⁻¹)	13.11	PWP %	13.78	
CEC (cmol _c kg ⁻¹)	37.87	Total K (g kg ⁻¹)	4.37	WHC %	48.76	
EC (dS m ⁻¹ at 25 °C)	1.35	Exch. K ⁺ (mg 100 g ⁻¹ soil)	2.85	A.V. (F.C.- PWP) %	28.67	
OM (g kg ⁻¹)	28.61	Exch. Ca ⁺⁺ (mg 100 g ⁻¹ soil)	31.12	A.V. (WHC-PWP) %	34.98	
Total N (g kg ⁻¹)	1.29	Exch. Mg ⁺⁺ (mg 100 g ⁻¹ soil)	8.77	Bulk density (BD) g cm ⁻³	1.31	
Total C/N ratio	22.17	Exch. Na ⁺ (mg 100 g ⁻¹ soil)	2.52	Particle density (PD) g cm ⁻³	2.22	
SOC (g kg ⁻¹)	18.48	DTPA Ext. (mg kg ⁻¹)	Fe	8.23	Sand %	28.90
Organic N (g kg ⁻¹)	0.76		Cu	2.01	Silt %	32.80
Organic C/N ratio	24.31		Zn	2.87	Clay %	38.30
Mineral N (mg kg ⁻¹)	58.46		Mn	8.11	Soil texture	Clayey loam

RESULTS

Plant height:

Data presented in Table (2) showed that, no significant differences were detected between planting date treatments (November 1st, 15th and December 1st) in both seasons.

Plant height of quinoa was gradually increased by the gradual decrease in plant spaces (from 20, 15 up to 10 cm). The trend was evident in the two growing seasons.

Planting space at 10 cm between hills (140.000 plants/fed) gave the tallest plants of (129.9 and 151.1 cm) in the first and second seasons, respectively, while, the shortest plants of (107.2 cm in the first season and 118.5 cm in the second season) were recorded with planting space of 20 cm (70.000 plants/fed). These results are in

harmony with those obtained by Sief *et al.* (2015), Sayed *et al.* (2018) and Ning *et al.* (2020) on quinoa plants.

Plant height was significantly affected as influenced by planting date and planting space interaction in both seasons as shown in Table (2). The tallest plants of 130.1 and 150.1 cm were recorded for the narrowest distance (10 cm) and first planting date Nov 1st. in both seasons, respectively.

Number of panicles/plant:

Data presented in Table (2) indicated that there were significant differences among planting dates for number of panicles/plant in both seasons. The highest number of panicles/plant (15.2 and 16.2 in the first and second seasons, respectively) was performed from the middle planting date

Table 2. Effect of planting date, planting spacing and their interaction on plant height (cm), number of panicles/plant and yield of seeds/plant of quinoa plants during the first and second seasons.

Plant spacings (B)	Planting dates (A)							
	1 st season (2018/2019)				2 nd season (2019/2020)			
	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)
Plant height (cm)								
10 cm	130.1	130.3	129.1	129.9	150.1	147.8	131.4	151.1
15 cm	121.2	114.8	114.3	116.8	123.6	129.6	121.3	124.9
20 cm	109.3	107.6	104.3	107.1	117.4	123.1	114.9	118.5
Mean (A)	120.2	117.6	116.0		131.7	133.3	124.3	
L.S.D. at 5 %	A: N.S		B: 6.3	AB: 10.9	A: N.S		B: 7.4	AB: 12.8
Number of panicles/plant								
10 cm	5.5	10.7	10.3	8.9	3.9	11.6	11.4	9.6
15 cm	13.6	14.8	14.6	14.3	14.7	16.0	15.8	15.5
20 cm	18.4	20.2	18.7	19.1	19.9	21.8	20.2	20.4
Mean (A)	12.5	15.2	14.6		13.3	16.2	15.8	
L.S.D. at 5 %	A: 0.3		B: 1.3	AB: 2.25	A: 0.4		B: 1.8	AB: 3.1
Yield of seeds/plant (g)								
10 cm	1.1	13.9	7.0	7.3	1.6	7.8	8.4	6.6
15 cm	7.1	7.4	10.6	8.4	7.6	17.6	12.5	12.6
20 cm	11.9	14.6	11.7	12.7	12.3	21.1	18.1	17.2
Mean (A)	6.7	12.0	9.8		7.2	16.2	13.0	
L.S.D. at 5 %	A: 1.5		B: 1.0	AB: 1.7	A: 2.1		B: 1.3	AB: 2.6

(November 15th). On the other hand, the lowest number of panicles/plant (12.5 and 13.3 in the first and second seasons, respectively) was recorded from planting date of November 1st.

The suitable planting date caused an increase in yield components as emphasized by Mohan *et al.* (2001) and Ayub *et al.* (2008) on fennel, Botros (2013) on caraway plants, Sajjad *et al.* (2014) and Ning *et al.* (2020) on quinoa.

Data presented in Table (2) cleared that number of panicles/plant was gradually increased in both seasons, according to the gradual increase in planting spaces with significant differences being obtained among the different space treatments. So, the widest space (20 cm) produced the highest number of panicles/plant (19.1 and 20.4 in the first and second seasons, respectively).

The increase in number of panicles/plant due to increasing plant spaces was emphasized by Badran and Hafez (2002) on *Nigella sativa*, Badran *et al.* (2003) on anise, Badran *et al.* (2007) on fennel and Bhargava *et al.* (2007) on quinoa.

The interaction between planting date and plant space treatments was significant for number of panicles/plant in both seasons as shown in Table (2). The highest values (20.2 and 21.8 in first and second seasons, respectively) were obtained from the second planting date (November 15th) in combination with the widest planting space (20 cm).

Yield of seeds/plant:

Regarding planting date presented in Table (2) indicated significant differences in plant seeds yield, respocets planting dates in both seasons. The middle of November planting date produced the heaviest weight of seeds/plant as recorded 12.0 g in the first season and 16.2 in the second one. Similar results were obtained by Aaron *et al.* (2006) on winter triticale plant, Botros (2013) on caraway plants, Sajjad *et al.* (2014) and Ning *et al.* (2020) on quinoa.

Seed yield of quinoa plants was significantly increasing due to increasing plant space in both seasons as presented in Table (2). The increase in yield of seeds/plant was gradual and parallel to the gradual increase in plant spaces, the heaviest seeds yield being obtained from the widest space (20 cm). Such superior treatment recorded 12.7 and 17.2 g in the 1st and 2nd seasons, respectively. These results were found to be in harmony with the findings of Badran *et al.* (2007) on fennel, Sief *et al.* (2015), Sayed *et al.* (2018) and Ning *et al.* (2020) on quinoa.

The interaction between main and sub plots (A × B) treatments was significant for yield of seeds/plant in both seasons. The highest values of 14.6 and 21.1 g were obtained from second planting date with the widest plant space in both seasons, respectively.

Seed yield/fed:

Data presented in Table (3) showed that the treatment of November 15st planting date gave significantly the heaviest yield/fed than the first and third planting dates. The present results were in harmony with those obtained by Aaron *et al.* (2006) on winter triticale plant and Sajjad *et al.* (2014) on quinoa.

Regarding planting space, data exhibited in Table (3) cleared that there were significant differences between space treatments for seed yield/fed in both seasons. The narrowest space was more effective than the middle and large spaces as gave 2053.3 kg in the first season and 1848.0 in the second one. Similar results were obtained by Badran *et al.* (2007) on fennel, Sief *et al.* (2015), Sayed *et al.* (2018) and Ning *et al.* (2020) on quinoa.

The interaction between planting date and planting space treatments was significant for seed yield/fed in both seasons. The best interaction treatment was planting quinoa on November 15th in combination with 10 cm planting space in both growing seasons as cleared in Table (3).

Table 3. Effect of planting date, planting spacing and their interaction on seed yield/fed (kg), weight of 1000 seeds (g) and dry weight of foliage (ton) and yield of seeds/plant of quinoa plants during the first and second seasons.

Plant spacings (B)	Planting dates (A)							
	1 st season (2018/2019)				2 nd season (2019/2020)			
	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)
	Seed yield/fed (kg)							
10 cm	308	3892	1960	2053.3	448	2744	2352	1848.0
15 cm	994	1036	1484	1171.3	1064	2464	1750	1759.3
20 cm	833	1022	819	819.3	875	1477	1267	1206.3
Mean (A)	711.7	1983.3	1421.0		795.7	2228.3	1789.7	
L.S.D. at 5 %	A: 78.1	B: 55.2	AB: 95.6		A: 88.3	B: 67.3	AB: 116.6	
	Weight of 1000 seeds (g)							
10 cm	2.28	2.17	2.16	2.20	2.18	2.16	2.14	2.16
15 cm	2.70	2.23	2.12	2.18	2.24	2.19	2.15	2.19
20 cm	2.13	2.16	2.16	2.16	2.25	2.19	2.16	2.20
Mean (A)	2.21	2.19	2.15		2.22	2.18	2.15	
L.S.D. at 5 %	A: 0.05	B: N.S	AB: N.S		A: 0.05	B: N.S	AB: N.S	
	Dry weight of foliage (ton)							
10 cm	2.3	2.2	1.9	2.1	1.9	2.4	1.7	2.0
15 cm	2.0	2.1	2.0	2.0	2.3	2.5	1.8	2.2
20 cm	2.1	2.0	2.1	2.1	2.3	2.2	1.8	2.1
Mean (A)	2.1	2.1	2.0		2.2	2.4	1.8	
L.S.D. at 5 %	A: N.S	B: N.S	AB: N.S		A: 0.1	B: N.S	AB: N.S	

Weight of 1000 seeds:

Regarding planting date presented in Table (3) showed, significant differences among planting dates for weight of 1000 seeds (g) in both seasons. The heaviest weight of 1000 seeds were obtained from the first date (November 1st).

Weight of 1000 seeds was not significantly affected by plant spacing in both seasons. The interaction between treatments was dose not significant in both seasons.

Dry weight of foliage/fed:

Regarding the effect of planting date on dry weight of foliage, there were significant differences between treatments in the second season only as shown in Table (3). The second planting date (November 15th)

produced the heaviest dry weight of foliage/fed (ton) than either first and third planting dates (November 1st and December 1st). Similarly, were the fiend of Hirich *et al.* (2014) on quinoa.

Each of the effect of plant spacing and interaction between the main and sub plot treatments were not significant for dry weight of foliage/fed, (ton) in both seasons as shown in Table (3).

Protein percentage:

Data presented in Table (4) indicated that there were significant differences were detected between treatments for planting dates for protein (%) in both seasons. In the first season, the high percentage of protein was obtained from the first date of November (10.52%), while, the third

Table 4. Effect of planting date, planting spacing and their interaction on Protein (%) and saponin (%) of quinoa plants during the first and second seasons.

Plant spacings (B)	Planting dates (A)							
	1 st season (2018/2019)				2 nd season (2019/2020)			
	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)	1 st Nov.	15 th Nov.	1 st Dec.	Mean (B)
	Protein (%)							
10 cm	10.26	10.57	10.60	10.48	10.28	10.30	10.29	10.29
15 cm	10.59	10.61	10.36	10.52	11.10	11.22	11.10	11.14
20 cm	10.71	10.31	10.28	10.43	10.78	10.78	10.86	10.81
Mean (A)	10.52	10.50	10.41		10.72	10.73	10.80	
L.S.D. at 5 %	A: 0.02	B: 0.04		AB: 0.07	A: 0.01	B: 0.04		AB: 0.07
	Saponin (%)							
10 cm	0.25	0.31	0.30	0.31	0.25	0.31	0.30	0.31
15 cm	0.26	0.34	0.32	0.33	0.33	0.34	0.32	0.35
20 cm	0.24	0.30	0.30	0.30	0.24	0.31	0.30	0.30
Mean (A)	0.25	0.32	0.31		0.27	0.32	0.31	
L.S.D. at 5 %	A: 0.02	B: 0.02		AB: 0.03	A: 0.01	B: 0.04		AB: 0.07

planting date (December 1st) recorded the highest protein percentage (10.80%) in the second one.

With respect to plant spacing, either 15 cm in both seasons recorded the highest protein percentage as 10.52 and 11.14 %, respectively.

The interaction between the two factors was significant in both seasons with regard to protein percentage in case of planting quinoa in November 1th at 20 cm spacing in the first season and November 15th at 15cm spacing in the second one.

Saponin percentage:

Data presented in Table (4) showed significant differences were detected between treatments of planting dates in both seasons for saponin percentage. The second date recorded the highest saponin (%).

The plant spacing had significant differences in saponin percentage with high percentage of 0.32 and 0.35 in the first and second seasons, respectively detected by sowing quinoa plants at 15 cm, respectively.

The interaction between main and sub plot treatments was significant for saponin percentage in both seasons.

DISCUSSION

The suitable climatic conditions and environments of factors may enhance biosynthesis processes and photosynthesis to obtain good plant which could explain the obtained results (Ayub *et al.*, 2008; Botros, 2013; Hirich *et al.*, 2014, Sajjad *et al.*, 2014 and Ning *et al.*, 2020). As for increase in these traits with increasing plant spacing between quinoa plants might be due to the low below and above ground competition between plants for illumination and nutrients and water.

These results are in accordance with those obtained by Bhargava *et al.* (2007); Badran *et al.* (2007) and Sief *et al.* (2015). There were decreases in grain yield/fed with increasing the distances between plants up to the widest of 15 cm apart.

CONCLUSION

It can be concluded that the best growth and yield of quinoa plants were recorded

from sowing quinoa seeds in the middle of November at 15 cm apart.

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إنتاجية وجودة محصول الكنوا وتأثرها بمواعيد ومسافات الزراعة

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تم زراعة هذه التجربة الحقلية في مشتل كلية الزراعة، جامعة المنيا خلال موسمي ٢٠١٩/٢٠٢٠ و ٢٠١٨/٢٠١٩ و ٢٠ سم بين النباتات) على المحصول ومكوناته والتركيب الكيماوي لنباتات الكنوا للحصول على أفضل المعاملات الزراعية لزيادة الكنوا تحت ظروف مصر الوسطي. أوضحت النتائج أن تأثير موعد الزراعة كان معنوياً لكل الصفات المدروسة عدا ارتفاع النبات ووزن ١٠٠٠ بذرة والنسبة المئوية للبروتين في كلا الموسمين، وكان موعد الزراعة ١٥ نوفمبر هو أفضل موعد. بينما كان تأثير مسافات الزراعة معنوياً على كل الصفات المدروسة عدا وزن ١٠٠٠ بذرة والبروتين كنسبة مئوية في الموسم الأول وأفضل مسافة زراعة هي ١٥ سم. كان التفاعل بين مواعيد الزراعة ومسافات الزراعة بين النباتات غير معنوي ما عدا عدد العناقيد الزهرية ومحصول البذور للنبات بالجرام في الموسم الأول والثاني ووزن ١٠٠٠ بذرة بالجرام ومحصول البذور للفدان بالكيلوجرام في الموسم الثاني. لذلك يتم التوصية بزراعة الكنوا في ١٥ نوفمبر على مسافة ١٥ سم تحت ظروف مصر الوسطى لأنها أعطت أفضل القيم للصفات الاقتصادية.