Growth Analysis and Dry Matter Portioning in Quinoa (*Chenopodium quinoa* Willd.) under Plant Density Effect

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Abstract
A field experiment was conducted at Homs Agricultural Research Center, General Commission for Scientific Agricultural Research (GCSAR), Syria, during 2021 season, to study the effect of plant density on five quinoa varieties leaves and stems fresh and dry weight, leaf area, crop growth rate and net assimilation rate in the middle region of Syria. The experiment was laid out according to randomized completely block design (RCBD) in split plot arrangement with three replicates. Experimental factors included five introduced varieties (Giza-1, Titicaca, Red Carina, Q26 and NSL) and six plant densities (50×20, 50×15, 50×10, 25×20, 25×15 and 25×10 cm). The results of statistical analysis showed significant differences (P≤0.05) among studied varieties, plant densities and interaction between varieties and plant densities for all investigated traits. 100.000 plant/ha (50×20 cm) was the most suitable plant density for all investigated traits compared with higher densities, followed by 133.333 plant/ha (50×15 cm). Giza-1 and Q26 varieties were the best for all agronomical traits so it recommended to be grown in Homs region.
Key words: Growth, Dry matter, Plant density, Quinoa.

Introduction:

Quinoa (*Chenopodium quinoa* willd.*)* a pseudo-cereal crop native to the South American and member of *Chenopodiaceae* family. Despite their similarities with cereals, quinoa, amaranths and kaniwa (*Chenopodium pallidicaule)* do not belong to the family *Gramineae*. For this reason, they are botanically defined as pseudo-cereals instead of cereals (Sanodiya *et al*., 2022).

This crop is well adapted to a wide range of climatic conditions and has significant potential for increased production as a new crop in the Mediterranean region and in other parts of the world, including northern Europe, North America, Asia, and Africa. (Bilalis *et al*., 2019).

The seeds of quinoa can be ground into flour and used in the same way as a cereal grain for either direct consumption or food development. It's mainly used for cooking, baking, and various value added products for people allergic from gluten, animal feed, green fodder, and pellets (Jacobson, 2003). The organization of the United Nations for Food and Agriculture (FAO) has declared the year 2013 as the “year of quinoa” (Anonymous, 2013). The plant is highly resistant to a wide range of abiotic stresses like cold, salinity, frost (Asif *et al*., 2022), and drought (Al-Jbawi *et al*., 2020)

Quinoa is an annual broad-leaved plant, also adaptable to the conditions of marginal lands (Rana *et al*., 2009). It's a quick-rising plant, grows up to 2 m tall with exchange, thickly ragged, triangular to ovate vegetation. Every inflorescence produced hundreds of little achiness, approximately 2 mm in width. Quinoa is an achene (a seed-similar to fruit with a firm fur) with diversified colors ranging from white or pale yellow to orange, red, brown and black. An ideal average temperature for quinoa would be around 15–20°C, but some specific landraces can also withstand extreme temperatures from −8°C to +38°C (Bazile *et al.*, 2015). It is only the single food which can supply complete protein, all essential life sustaining nutrients and can reduce the risk of various diseases like blood cholesterol, blood pressure, diabetes, sexual weakness etc. in very effective and preventive way.

The plant development is mainly affected by plant stand, planting geometry, soil fertility and soil-moisture availability. Planting density is one of the most important agricultural practices affecting crop yield (Cha *et al.,* 2016). A key factor for successful crop production is the capacity to produce sufficient yield from the lowest possible area, volume and energy inputs such as light intensity (Beaman *et al.,* 2009). The amount of light reaching the plant canopy and absorbed by photosynthesis process changes mainly with plant density (Francescangeli *et al.*, 2006).

Smith *et al*., (2011) reported that the row spacing of 45 cm recorded significant higher green forage yield (36,77 t/ha), higher dry matter yield (2.33 t/ha) as compared to 30 cm row spacing. In interaction significantly higher green forage yield (43.53 t/ha) and dry matter yield (3.01 t/ha) was recorded in 45 cm row spacing. He recorded that the superiority of 45 cm spacing was mainly due to significant higher total fresh weight and higher number of leaves, higher leaf area and total dry matter accumulation.

Seif *et al*., (2015) concluded that the best treatment for growing quinoa produced from the inter and intra spacing may be attributed to the appropriate distribution of plants, which decrease completion among plants and allows it to maximum were of the circumstance surrounding it in the caption soil

Erazzú *et al.* (2016) reported that with increasing plant sowing density from 70.000 to 460.000 plants/ha, quinoa grain yield decreased from 5389 to 3049 kg/ha, respectively.

Eisa *et al*., (2018) examined two planting densities namely, 56.000 plant ha^{-1} (Low) and 167.000 plant ha^{-1} (High). Results showed that seed yield increased by 34.7% with increase of plant density from 56.000 plant ha^{-1} to 167.000 plant ha^{-1}. The increase of plant density significantly decreased weight of 1000-seeds and weight of hectoliter. Protein and ash concentrations in seeds increased at low planting density, whereas carbohydrate concentration decreased. However, there were no significant differences between the two planting densities on the seed concentration of the crude fiber or total fat.

Sanodiya *et al*., (2022) studied the Influence of crop geometry and Nitrogen Levels on growth indices of Quinoa (*Chenopodium quinoa* Willd.). The experiment consisted of four crop geometry (15 cm × 10 cm, 25 cm × 10 cm, 35 cm × 10 cm, 45 cm × 10 cm,). Their ressults indicate that, at 45cm × 10 cm spacing produced significantly superior plant dry weight (30.77 and 33.61 g) and absolute growth rate AGR (1.18 and 0.17 g/day). The highest AGR produced at 35 cm × 10 cm spacing. However, the highest crop growth rate CGR produced at 15 cm × 10 cm was found to be significantly. However, the highest relative growth rate RGR absorbed at 25 kg N/ha at 35 cm × 10 cm was found to be non-significant.

The objective of this study was to study the effect of six plant densities on dry matter portioning and some growth attributes for six quinoa varieties at Homs conditions in the middle region of Syria.

Materials and Methods

Experimental site: The experiment was conducted at Homs Agricultural Research Center, General Commission for Scientific Agriculture Researches (GCSAR), Syria. during growing season 2021.

The site has a latitude of 43.77° N, and longitude of 36.71° E with an altitude of 485 meters above sea level. Table (1) shows the meteorological data during the growing season in 2021.

Table (1): Summary of meteorological data during the growing season 2021

Month	Mean of Min. temperature (°C)	Mean of Max. temperature (°C)	Precipitation (mm)	Max. relative humidity	Min. relative humidity
February	4.81	16.08	24.2	94.32	51.29
March	6.80	16.78	32.9	90.32	49.23
April	10.35	23.62	53.6	87.53	45.77
May	16.38	30.10	0	83.94	32.13
June	18.36	30.24	0	86.06	36.30
July	23.21	34.52	0	80.87	34.97

According to Table (1), the mean maximum temperature during the studied period belongs to July with an average of 34.52 °C, and the average minimum temperature belongs to February 4.81 °C. Total precipitation during the experimental period in 2021 was 110.7 mm. The results of physical and chemical analysis of the field soil are shown in Table (2).

Table (2): Physical and Chemical Analysis of Soil

EC ds.cm^{-1}	pH	OM %	N ppm	P ppm	K ppm	Sand %	Silt %	Clay %
0.12	8.42	1.37	30.45	10.00	204.25	26	14	60

According to the results in Table (2), the experiment field soil is clay, alkaline acidity, low organic matter, moderate to good phosphorus, potassium, and nitrogen content.

Experiment treatments

Proposed treatments were as follow:

1. Varieties: This study used five introduced quinoa varieties i.e., Giza, Titicaca, Red carina, Q26 and NSL-106398 (Table, 3).

Table (3): The studied varieties and their sources

No.	Variety name	source
1	Giza	Seed and Plant Improvement Institute (Iran)
2	Titicaca	
3	Red Carina	
4	Q26	
5	NSL-106398	International Center for Bio saline Agriculture ICBA

2. Densities: The densities were a combination of tow inter spacing (row spacing) and three intra spacing (plant spacing) as follow: 50 ×20, 50 ×15, 50 ×10, 25 ×20, 25 ×15, 25 ×10 cm which achieved a plant density equal to 100.000, 133.333, 200.000, 200.000, 266.666, 400.000 plant/ha respectively.

Agricultural practices:

Quinoa seeds were sown by hand on February 15, 2021 at 1 cm depth. Each plot consisted of five rows with length of 3 m and width ranging from 1.50 to 2.5 m according to proposed densities. Phosphorus was used in the form of triple superphosphate (46% P_2O_5) and was added at a rate of 108 kg/ha, and potassium was used in the form of potash sulfate (50% K_2O) and was applied at a rate of 100 kg/ha K_2O during soil preparation, nitrogen fertilizer was used in the form of urea (46% N) and was added at a rate of 261 kg/ha (split into two applications, half was applied with sowing and the remaining half was applied after thinning at 4-6 true leaves stage). Quinoa plants grew under rain-fed conditions with water supplements at the sowing date to ensure seed germination, and thinning was carried out two times to retain one plant per hole. The preceding crop was chickpea in 2019/2020.There were regular crop management practices to control pests, diseases, and weeds.

Experimental design and statistical analysis: The experiment was laid out according to randomized complete block design (RCBD) in split plot arrangement with three replicates, and densities were assigned the main plot, while varieties in the split plots. The treatment means were compared using LSD values at 5% level of significance. All statistical analysis was performed using Gen Stat.V12 computer software.

Data collection

1- Fresh and dry weight: Leaves fresh and dry weight, stem fresh and dry weight were taken before anthesis at 85 days after sowing. 10 plants were randomly selected in each plot then weighted and the dry weight was determined after drying for 72 h at 70ºC.

2-Leaf area (LA): Leaf area was estimated according to the method of (Dosbiekhov, 1968), where five plants were taken from each plot, the leaves were collected and weighed, then circular sections were taken from them by a drill with a circular hole of known area, and according to the weight of the green circular sections, then the leaf area was calculated from the following equation:

LA=SW/Z

LA: green leaf area per plant (cm^2)

S: the sum of the area of circular sections taken from one plant (cm^2)

W: the total weight of green leaves per plant (g).

Z: weight of the total circular sections taken from the plant (g)

3-Crop growth rate (CGR) is the increase in plant dry materials per unit area of land per unit time. CGR values were estimated at 22-day interval as described by Watson (1952) [20], CGR was calculated using the formula

CGR = $[(W2 - W1)/(T2 - T1)][1/S]$,

where $W1$ is total dry weight at time $T1$ and $W2$ is the total dry weight at time $T2$ and S is the ground spacing and expressed in g/m^2/day.

4-Net Assimilation Rate (NAR) is the increase in plant dry materials per unit area of leaves per unit time. according to Radfords (1967):

$$\mathrm{NAR} = \frac{(\mathrm{W2} - \mathrm{W1})(\mathrm{LnLA2} - \mathrm{LnLA1})}{(\mathrm{T2} - \mathrm{T1})(\mathrm{LA2} - \mathrm{LA1})}$$

Where: W_1, W_2 and LA_1, LA_2 refer to dry weight to plant, and leaf area at time T_1 and T_2 (first and second sampling), respectively, and ln is natural logarithm and expressed in g/g/day.

Results and Discussion:

Fresh weight:

The results of statistical analysis show significant differences ($P \leq 0.05$) among varieties, plant spacing and V.S interaction for leaves and stems fresh weight (Table 4 and 5).

The obtained results clearly showed that the increase in planting density led to significant decrease in leaves fresh weight for individual plants, so the mean of leaves fresh weight was 190.56, 141.83, 91.33, 95.80, 66.81, 46.19 g/plant at plant spacing 50 × 20, 50 × 15, 50 × 10, 25 × 20, 25 × 15, and 25 × 10 respectively. The varieties Giza-1 and Q26 achieved the highest values 111.10 and 110.86 g/plant respectively with no significant differences and significant with NSL and Titicaca. It was noticed for the interaction between varieties and plant densities that variety Giza-1 recorded the highest value of leaves fresh weight at density of 50 × 20 (205.46 g/plant), while the lowest value of this trait was produced by variety Titicaca at density of 25 × 10 (39.27 g/plant) (Table 4).

The increase in planting density also led to a significant decrease in stem fresh weight for individual plants, so the mean of stem fresh weight was 375.60, 281.03, 181.99, 186.47, 153.57, 92.45 g/plant at plant spacing 50 × 20, 50 × 15, 50 × 10, 25 × 20, 25 × 15, and 25 × 10 respectively. The differences between varieties Q26, Giza-1, Red Carina and NSL weren't significant and surpassed significantly on Titicaca variety. It was noticed for the interaction between varieties and plant densities that variety Giza-1 achieved the highest value of stem fresh weight at density of 50 × 20 (405.25 g/plant), on the other hand the lowest value of studied trait was obtained from variety Titicaca at density of 25 × 10 (81.50 g/plant) (Table 5). It was noticed that leaves and stems fresh weights decreased gradually by increasing plant density from 100.000 (50 × 20 cm) to 400.000 plant/ha (25 × 10 cm). These results agree with Nguyen *et al*., (2020) who concluded that the low density 8 plant/m^2 seems to be the optimal density for quinoa compared to higher densities 10.0 and 13.3 plant/m^2.

Such results agree with Naneli *et al.*, (2017), Präger *et al.*, (2018), Tan and Temel, (2018), and Maliro and Njala, (2019) who found differences among quinoa cultivars in agronomical and growth traits.

Table(4): Effect of crop stand geometry on leaves fresh weight g. plant^{-1} in five quinoa varieties

Plant density Plant/ha	Plant spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	50 × 20	205.46	193.57	197.15	169.66	186.98	190.56
133.333	50 × 15	150.12	138.98	153.18	127.74	139.29	141.86
200.000	50 × 10	98.29	93.27	94.69	78.96	91.46	91.33
200.000	25 × 20	102.33	95.29	100.72	85.66	95.01	95.80
266.666	25 × 15	64.68	71.26	70.36	55.84	71.89	66.81
400.000	25 × 10	45.69	49.29	49.08	39.27	47.61	46.19
Means (V)		111.1	106.94	110.86	92.86	105.38	105.43
$LSD_{0.05}$ (S)=5.433 , $LSD_{0.05}$ (V) =4.960, $LSD_{0.05}$ (S.V)=12.149 , CV=7.1 %							

Table (5): Effect of crop stand geometry on Stem fresh weight g. plant^{-1} in five quinoa varieties

Plant density Plant/ha	Plant spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	404.25	383.21	384.10	334.34	372.09	375.60
133.333	15×50	292.84	273.36	299.58	252.67	286.70	281.03
200.000	10×50	192.54	182.54	191.88	164.57	178.42	181.99
200.000	20×25	193.99	185.97	199.84	165.64	186.91	186.47
266.666	15×25	132.94	137.43	139.06	116.62	141.79	133.57
400.000	10×25	89.17	101.14	97.75	81.50	92.67	92.45
Means (V)		217.62	210.61	218.70	185.89	209.76	208.52
$LSD_{0.05}$ (S)=10.17 , $LSD_{0.05}$ (V) =9.28, $LSD_{0.05}$ (S.V)=22.74 , CV=6.7 %							

Dry weight:

The results of statistical analysis show significant differences ($P \leq 0.05$) among varieties, plant spacing and V.S interaction for leaves and stems dry weight (Table 6 and 7).

The obtained results clearly showed that the increase in planting density led to significant decrease in leaves dry weight for individual plants, so the mean of leaves dry weight was 17.52, 13.28, 8.60, 8.72, 6.23, 4.16 g/plant at plant spacing 50 × 20, 50 × 15, 50 × 10, 25 × 20, 25 × 15, and 25 × 10 respectively. The varieties Giza-1 and Q26 achieved the highest values 10.20 and 10.21 g/plant respectively with no significant differences and significant with the other varieties. It was noticed for the interaction between varieties and plant densities that variety Giza-1 had the highest value of leaves dry weight at density of 50 × 20 (18.87 g/plant), while the lowest value of above trait was produced by variety Titicaca at density of 25 × 10 (3.54 g/plant) (Table 6).

The increase in planting density also led to significant decrease in stem dry weight for individual plants, so the mean of stem dry weight was 38.98, 29.56, 19.17, 19.26, 13.96, 9.37 g/plant at plant spacing 50 × 20, 50 × 15, 50 × 10, 25 × 20, 25 × 15, and 25 × 10 respectively. The differences between varieties Giza-1, Q26, and Red Carina weren't significant and surpassed significantly on Titicaca variety. For the interaction between varieties and plant densities, variety Giza-1 recorded the highest value of stem dry weight at density of 50 × 20 (42.07 g/plant), while the lowest value of this trait was produced by variety Titicaca at density of 25 × 10 (8.07 g/plant) (Table 7). It was noticed that leaves and stems dry weights decreased gradually by increasing plant density from 100.000 (50 × 20 cm) to 400.000 plant/ha (25 × 10 cm).

The increase in dry weight of the plant can be attributed to proportionately increase with spacing between plants (Sanodiya *et al*., 2022). This increase in dry matter might be due to lesser competition for nutrients, water, and light. Similar results on another plants species were also reported by Barzinjy *et al*., (1999) in oilseed rape, Kumari (2009) in mustard, Sharma *et al*. (2001) in lettuce and Al-Ramamneh *et al*. (2013) in strawberry.

Table (6): Effect of crop stand geometry on leaves dry weight g. plant^{-1} in five quinoa varieties

Plant density Plant/ha	Plant spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	18.87	17.88	17.91	15.62	17.31	17.52
133.333	15×50	14.06	13.40	14.20	11.75	12.99	13.28
200.000	10×50	9.06	8.79	8.97	7.75	8.42	8.60
200.000	20×25	9.25	8.60	9.18	7.80	8.77	8.72
266.666	15×25	5.90	6.66	6.61	5.44	6.55	6.23
400.000	10×25	4.08	4.41	4.42	3.54	4.35	4.16
Means (V)		10.20	9.96	10.21	8.65	9.73	9.75
$LSD_{0.05}$ (S)=0.413 , $LSD_{0.05}$ (V)=0.377 , $LSD_{0.05}$ (S.V)=0.923 , CV=5.8 %							

Table (7): Effect of crop stand geometry on Stem dry weight g. plant^{-1} in five quinoa varieties

Plant density Plant/ha	Plant spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	42.07	39.94	39.63	34.58	38.69	38.98
133.333	15×50	31.08	29.74	31.47	26.31	29.19	29.56
200.000	10×50	20.06	19.50	20.16	17.43	18.69	19.17
200.000	20×25	20.59	19.02	20.30	17.08	19.31	19.26
266.666	15×25	13.73	14.46	14.63	12.33	14.63	13.96
400.000	10×25	8.96	10.25	9.98	8.07	9.58	9.37
Means (V)		22.75	22.15	22.69	19.30	21.68	21.71
$LSD_{0.05}$ (S)=0.925 , $LSD_{0.05}$ (V)=0.844 , $LSD_{0.05}$ (S.V)=2.068 , CV=5.8 %							

Leaf Area:

The results of statistical analysis show significant differences (P≤0.05) among plant densities, varieties, and interaction between varieties and plant densities for leaf area (Table 8).

The green leaf area was significantly decreased with increasing plant density, so the highest value of leaf area was recorded at density of 50 × 20 cm (1700.6 cm^2/plant), while the lowest value of leaf area was achieved at density of 25 × 10 (413.7 cm^2/plant). The highest value of the studied trait was obtained from varieties Giza-1, Q26 and Red Carina 990.0, 989.5, and 954.2 Cm^2/plant respectively. The differences among these varieties weren't significant and significant with Titicaca. for the interaction between varieties and plant densities, variety Giza-1 showed the highest value of leaf area at density of 50 × 20 (1832.7 cm^2/plant), whereas the lowest value of this trait was observed in variety Titicaca at density of 25 × 10 (354.8 cm^2/plant) (Table 8). Leaf area indicator is considered one of the most important traits which affecting dry matter accumulation crop yield The amount of light reaching the plant canopy and absorbed by photosynthesis process changes mainly with plant density. The results are in conformity with the James and Fowler (1996). The current study found the differences among quinoa varieties for all traits, investigated varieties Giza-1 and Q26 were the best for all agronomical traits, with its significantly higher values for dry matter, leaf area and CGR.

Table (8): Effect of crop stand geometry on leaf area cm^2. $plant^{-1}$ in five quinoa varieties

Plant density Plant/ha	Plant spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	1832.7	1729.2	1754.6	1514.0	1672.3	1700.6
133.333	15×50	1336.4	1239.7	1364.5	1140.9	1255.8	1267.5
200.000	10×50	875.9	831.0	850.5	714.0	814.3	817.1
200.000	20×25	905.1	848.4	900.2	761.1	847.5	852.5
266.666	15×25	582.9	632.7	628.3	505.2	641.6	598.2
400.000	10×25	406.8	444.1	439.0	354.8	423.7	413.7
Means (V)		990.0	954.2	989.5	831.6	942.5	941.6
$LSD_{0.05}$ (S)=47.38 , $LSD_{0.05}$ (V)=43.25 , $LSD_{0.05}$ (S.V)=105.95 , CV=.6.9 %							

Crop growth rate (CGR):

Crop growth rate (CGR) express as the increment in weight of dry matter per unit of land per unit of time. Among the different Plant densities there was a significant difference, the values of CGR decreased with increasing plant density. The maximum CGR values 6.96, and 6.73 g/m^2/day were recorded by spacing 50 × 20 and 50 × 15 respectively, while the minimum CGR values 4.39, and 4.41 g/m^2/day were recorded by spacing 25 × 15 and 25 × 10 respectively (table 9).

The higher Crop Growth Rate (CGR), may be attributed to the optimum number of plants and higher dry matter production on unit area basis. Followed to this, wider spacing produced significantly higher CGR at all varieties. Though the individual plant canopy was increased in these spacing, CGR was increased as the plant population was less and dry matter production was higher on unit area, these results dis agree with Ramesh *et al*., (2017), but agree with. Erazzú *et al,* (2016) who reported that plant growth parameters were higher in sowing density of 70,000 plants/ha compared to 460,000 plants/ ha, and with. Spehar and Rocha (2009) found that increasing density from 100,000 to 600,000 plants/ha had a negative effect on plant growth.

Q26 variety achieved the highest CGR value 5.61 g/m^2/day with no significant differences with Giza-1 and Red Carina and significant with NSL and Titicaca (table 9). The results agree with Mahmood and Al-Taweel (2022) which concluded some variations between white and red genotypes, their results showed the superiority of the white seeds genotype by giving the highest average leaves number, leaf area, and dry weight. for the interaction between varieties and plant densities that variety Giza-1 gave the highest value of CGR at density of 50 × 20 (7.51 g/m^2/day), in contrast the variety Titicaca had the lowest value of this trait at density of 25 × 10 (3.79 g/m^2/day) (Table 9).

Table (9): Effect of crop stand geometry on crop growth rate g.m^{-2}. day^{-1} in five quinoa varieties

Plant density Plant/ha	Crop spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	7.51	7.12	7.09	6.18	6.90	6.96
133.333	15×50	7.10	6.78	7.18	5.98	6.63	6.73
200.000	10×50	5.00	4.85	5.00	4.32	4.65	4.76
200.000	20×25	5.17	4.78	5.11	4.31	4.86	4.85
266.666	15×25	4.27	4.59	4.62	3.87	4.61	4.39
400.000	10×25	4.25	4.78	4.69	3.79	4.54	4.41
Means (V)		5.55	5.49	5.61	4.74	5.37	5.35
$LSD_{0.05}$ (S)=0.212 , $LSD_{0.05}$ (V)=0.193 , $LSD_{0.05}$ (S.V)=0.473 , CV=5.4 %							

Net assimilation rate (NAR)

Net assimilation rate (NAR) express as the increment in weight of dry matter per unit of leaf area per unit of time. Among the different Plant densities there was a significant difference, the values of NAR decreased with increasing plant density. The maximum NAR values 5.35, and 5.18 g/m^2/day were recorded by spacing 50 × 20 and 50 × 15 respectively, while the minimum NAR value 3.41 was recorded by spacing 25 × 10. The differences between varieties weren't significant, it ranged between 4.10 and 4.19 g/m^2/day (table 10). For the interaction between varieties and plant densities that variety red carina exhibited the highest value of NAR at density of 50 × 20 (5.35 g/m^2/day), and density 50 × 15 (5.36 g/m^2/day), while the lowest value of NAR was attained in variety Giza-1 at density of 25 × 10 (3.25 g/m^2/day) (Table 10).

In the current study, we found that dry matter and leaf area increased when plant density decreased. With increasing density, the competition in sunlight leads to higher competition on nutrient and water which may lead to reductions of plant weight and other growth parameters in the denser population owing to shortages in nutrient supplement. An optimal density will support the growth balance to achieve the highest dry matter accumulation and leaf area. NAR or efficiency of the leaf surface in producing dry matter was reduced as plant population increased. This was apparently the result of less favorable light relationships or perhaps some other modification of the micro-environment of the crop as a result of the moderating effect of the leaf canopy in the closer spacing, these results agree with Sangeeta and Surakod (2018).

Table (10): Effect of crop stand geometry on net assimilation rate g.m^{-2}. day^{-1} in five quinoa varieties

Plant density Plant/ha	Crop spacing (S)	Varieties (V)					Means (S)
		Giza-1	Red Carina	Q26	Titicaca	NSL-	
100.000	20×50	5.29	5.35	5.23	5.36	5.53	5.35
133.333	15×50	5.04	5.36	5.20	5.06	5.23	5.18
200.000	10×50	3.78	3.83	3.85	4.05	3.72	3.85
200.000	20×25	3.64	3.56	3.54	3.56	3.61	3.58
266.666	15×25	3.63	3.58	3.57	3.70	3.50	3.60
400.000	10×25	3.25	3.33	3.59	3.35	3.52	3.41
Means (V)		4.10	4.17	4.16	4.18	4.19	4.16
$LSD_{0.05}$ (S)=0.097 , $LSD_{0.05}$ (V)=0.099 , $LSD_{0.05}$ (S.V)=0.217 , CV=3.2 %							

Conclusion:

In conclusion, variation in plant density significantly affected individual fresh weight, individual dry weight, individual leaf area, CGR per unit of land and NAR per unit of leaf area. 100.000 plant/ha (50 × 20 cm) was the most suitable plant density for all investigated traits compared to the highest densities, followed by 133.333 plant/ha (50× 15 cm). Among quinoa varieties, Giza-1 and Q26 were the best for all agronomical traits, with its significantly higher values for dry matter, leaf area and CGR.

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تحليل النمو وتوزع المادة الجافة في الكينوا (*Chenopodium quinoa* Willd.) تحت تأثير الكثافة النباتية

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الملخص:

أجريت تجربة حقلية في الهيئة العامة للبحوث العلمية الزراعية، مركز بحوث حمص خلال العام 2021 بهدف دراسة تأثير الكثافة النباتية في بعض مؤشرات النمو (الوزن الرطب والجاف للأوراق والسوق، مساحة المسطح الورقي للنبات، معدل نمو المحصول وصافي إنتاجية التمثيل الضوئي) لخمسة أصناف من الكينوا تحت ظروف المنطقة الوسطى من سورية، مدينة حمص. صممت التجربة وفق تصميم القطاعات العشوائية الكاملة بترتيب القطع المنشقة من الدرجة الأولى. تضمنت معاملات التجربة خمسة أصناف (Giza-1، Titicaca، Red carina، Q26 وNSL) وستة كثافات نباتية تم تشكيلها من خلال الزراعة على خطوط 50 و25 سم، وثلاثة مسافات بين النباتات على الخط نفسه 10، 15، 20 سم كالتالي: (50×20، 50×15، 50×10، 25×20، 25×15، 25×10) سم. أظهرت النتائج التأثير المعنوي ($P\leq0.05$) لكل من الأصناف والكثافات النباتية والتفاعل بينهما في كل الصفات المدروسة، وحققت الكثافة 100.000 نبات/هكتار (50×20) سم أفضل النتائج تلتها الكثافة 133.333 نبات/هكتار (50×15) سم. كما حقق الصنفان Giza-1 وQ26 أفضل القيم بالنسبة لجميع الصفات المدروسة، وبالتالي خلصت الدراسة إلى اقتراح زراعة هذين الصنفين في منطقة حمص بالكثافة 100.000–133.333 نبات/هكتار.

الكلمات المفتاحية: النمو، المادة الجافة، الكثافة النباتية، الكينوا.