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EFFECT OF VARIOUS INTER AND INTRA SPACES ON THE YIELD AND QUALITY OF QUINOA (*Chenopodium quinoa willd.)*

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ABSTRACT

In order to determine the best planting procedures where three inter spacing (row spacing) and three intra spacing (plant spacing) and their combination. The inter spacing were 20, 30 and 40 cm distances between rows, and the intra spacing between plants were 10, 15 and 20 cm distances between plants and their combinations. Field experiments were conducted at Ismailia Agriculture Research Station, Agriculture Research Center, Ismailia, Egypt during two winter successive seasons of 2012/2013, 2013/2014.

Results indicated that highest grain yield of quinoa was produced when using the narrowest inter species of rows (20 cm) and the narrowest intra spaces of plants (20 cm) with significant interaction effect in each of the two seasons. This result could be accepted due to the well even distribution of plants which reduced the compotation for all of prevailing enormous essential requirements of plants as germination seed line emergence, growth and development which reflected on production and quality. A significant reduction of grain yield was obtained by increasing intra spacing between plants *i.e.*10, 15, 20 cm. This reduction was notical only at the lowest inter spacing of rows at 20 cm. However at wider inter spaces of plant *i.e.*30 and 40 cm, increases of intra spaces between plants *i.e.*10, 15, 20 cm cause sub stand increase in grain yield in the first and second seasons with significant differences in the first seasons.

It could be concluded the best treatment for growing quinoa produced from the inter and intra spacing were the lowest. This 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
Keywords: Quinoa, inter and intra spaces, Exotic plants. Chemical constituents of grain.

INTRODUCTION

Quinoa is a high nutrition food. Its protein quality is much higher than that of other grains. Lysine and amino acid in Quinoa are higher than that in wheat. Its content of amino acid is well-balanced for human and animal feeding, like that of casein. As for iron, phosphorus, potassium, magnesium, zinc, calcium, copper and manganese, they are also higher in quinoa than in corn, and wheat; However, quinoa has a lower sodium content.

The marketable seed is usually white. Its leaves are eaten as any leafy vegetable. In the US, the seeds are sold in health food stores at high prices due to their nutritive value.

This crop is drought and salinity tolerant and can grow in sandy soil of aried and semi-aried regions and with other most harmful abiotic adverse factors which affect crop production.

Galwey (1984) reported that seeds are placed in rows in row seeding. When the width of the row is 40-80 cm, seed should be placed at the bottom of the furrow in dry soil or at the top of the ridge in an area with a lot of rain. In south Altiplano, mechanical sowing_is performed with the Satiri drill, which has two furrows with chutes through which the seed is nurtured. He added that the opening of the lines should be adapted to a space between 0.8 and 1 m.

Bubenheim (1991) studied optimum quinoa density using controlled environment hydroponic systems. He demonstrated that dramatic increases in yield and harvest index resulted in part from a higher planting density when compared with average field seeding rates. Further, the higher planting density that is reported for quinoa grown in controlled enviornments is approximately 32 plants m^{-2} .

Oelke et al (1992) found that the field trial in Great Britain indicated that increasing plant density resulted in a slightly earlier maturity. Greater seed also resulted in a slightly earlier maturity. *Henderson et al (1993)* found that the lowest established population 74000 plant/ha consistently produced the maximum grain yield. There was no impact of row space at the_lowest population. However, at higher populations, more grain was produced with the wider (76.2 cm) row spacing. Wider rows, where plants were spaced closer together within each row, increased rivalry at high established populations. Grain yield of the surviving plant was higher as a result of the lowered plant population in the wider rows.

Jacobsen et al (1994) noticed that plots with a row space of 50 cm. which were hoed gave a more yield than plots with 25 or 12.5 cm row spaces, which were unhoed. The yield increased when changing from combined harvesting to swathing unhoed.

Aufhammer et al (1995), Myers and pertnam (1998), and Gimplinger et al (2007) failed to observe growth, yield, and yield component responses to row space.

Meanwhile, *Henderson et al (2000)* obtained no yield response to row spacing and suggested that the plasticity of grain amaranth morphology may limit its response to seeding rate and row spacing.

Maligawad and patil (2001) reported that grain yield increased with the increase in the plantpopulation. A study at Thomas Jefferson Agriculture Institute in Missouri, comparing different row spaces, showed that wider row spacing produced the higher most yield. Important interaction for green forage yield and dry matter yield was recorded when using 30 cm row spaces. The next important higher interaction for green forage yield and dry matter yield was recorded when using 45 cm row spaces. The row spaces of 45 cm. recorded important higher net returns and benefit cost ratio compared to row space of 30 cm.Rojas *et al* (2004) reported that sowing is an important initial step for planting quinoa. The crop can be planted in either rows or groups and by either broadcasting or transplanting.

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But Schlick and Bubemheim (2005) researched “yield per unit area, harvest index and biomass accumulated data". They said that the ideal field planting density for quinoa is 640 plant m^{-2}

Spehar and Rocha (2009) studied the effect of densities varying between 100 x 10^3 to 600x10^3 plants ha^{-1} on yield and interrelated parameters. In the highest density, the number of observed branching was smaller, when compared to low density. Moreover, plants in great density reached maturing slightly earlier than in low density, for every increment of 100.000 plants ha^{-1} there was a reduction of 4.0 cm in plant height. Further, they indicated that these results illustrate the ability of quinoa to compensate for high density. They concluded that the height of the plant shows reduction with increasing density, in the 50 cm row spacing, when population increases from 100.000 to 600.000 plant ha^{-1}. Plants at low densities tended to increase branching to fill the gaps and to delay maturity.

In a recent study, the effect of phosphorus fertilizer and intra row spacing on the growth and yield of grain Amaranth (Amaranth cruentus) was studied by *Olofintoye et al (2011).* Three spacing (30x50, 40x50 and 50x50 cm) resulted in the highest plant height, number of leaves, dry matter yield, biological yield and grain yield. They explained that inferiority of growth, yield and yield component traits was due to inter and intra competition among the planted seeds.

Smith a patel et al (2011) reported that the row spacing of 45 cm recorded significant higher green forage yield (36,77 t ha^{-1}), higher dry matter yield (2.33 t ha^{-1}) as compared to 30 cm row spacing. In interaction significantly higher green forage yield (43.53 t ha^{-1}) and dry matter yield (3.01 t ha^{-1}) 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.

Row spacing and plant density in field experiments were performed in different regions of the world according to the diverse agro climatic conditions as the following example show:- In England, 20, 40 and 80 cm row spaces with plant seeds rates of 15, 20 and 30 kg/ha, respectively. Row spacing 25 cm in the Netherlands of 0.7 grain seeds/ha; row spaces of 30 cm seeding rate. In India of 30 plants/m^2 in 30 cm row spacing 150 cm. In Chili of seeding rate of 25 cm plants. Its plants spaces, rows spaces of 25, 50 cm in Denmark of 200 plants/m^2 *(Atul Bhargavaand Shilpi. srivastava 2013).*

MATERIALS AND METHODS

Two field experiments were conducted at Ismaillia Experiment research station to study the effect of seeding in inter and intra spacing on the vegetative growth, behaverious, grain yield and yield components of chenopodium quinoa grain in 2012/2013 and 2013/2014 seasons respectively. Proposed treatments were the combination of three inter spacing (row spacing) and three intra spacing (plant spacing). The treatments were as follow:-

A- Inter spacing treatments.

- 20 cm between rows.
- 30 cm between rows.
- 40 cm between rows.

B- Intra spacing treatments.

- 10 cm between plants.
- 15 cm between plants.
- 20 cm between plants.

Statistical design: The treatments were assigned in split plot design in three replicates. Plot area was $15m^2$ sequence meter of 5 meters in length and 3 meters in width.

The preceding crop was peanut in 2013 and 2014 seasons. Quinoa seeds variety Danish KVL 3704 (the Royal Faculty of Agriculture, Copenhagen, Denmark) were sown on the 6^{th}, 11^{th} of December in first and second, respectively. Calcium super phosphate was added at a rate of 15.5% P_2O_5 per fedden during land preparation. Potassium sulphate was applied at the rate of 100 kg per fadden (48 kg K_2O) during soil preparation. Magnesium sulphate was drilled in rows after seeding emergence (20 days after sowing quinoa seeds) at a rate of 50 kg/fed. Nitrogen fertilizer was added at a rate of 50 kg/feddan in the form of ammonium nitrate (33.5 % N).

Quinoa seeds were sown at 5 cm depth under ground surface, covered with sands and immediately irrigated using sprinklers irrigation which system was at 5 days internals until harvest.

Weedsing practiced as previously mentioned and harvesting was practiced as previously mentioned in the first study.

Studied paramaters:

Yield and yield components , grain yield, and its components: samples of ten plants were taken from each two inner rows of each plot and taken immediately to the laboratory, the flowering manually, then the following traits were measured and recorded.

- Plants height (cm).
- Average number of branches/plant.
- Average of head length/plant (cm.).
- Average of head weight/plant (cm.).
- Grain weight/plant (g).
- Weight of 1000 grain (g).
- Grain yield (kg/feddan).

Physical and chemical analysisthe soil of the experimental site.

Clay %		**Slit%**		**Sand%**		**Soil texture**	
8.64		0		91.36		sandy	
pH	EC (dS/m)	OM%	CaCO3 (%)	Macro nutrient			
				N (mg/Kg)	P (mg/Kg)	K (mg/Kg)	
8.45	0.20	0.15	0.64	10	18	84	
Soluble Cations (meq/L)				Soluble Anions (meq/L)			
K^+	Na^+	Mg^{++}	Ca^{++}	$So4^-$	Cl^-	$HCO3^-$	$CO3^-$
0.09	0.7	0.9	0.9	1.37	0.78	0.45	-

Sample preparation for chemical analysis of leaves and seed samples were cleaned and dried using oven air forced at during oven 75^{o}c till constant weight before analysis. Whole mature leaves and seeds of quinoa were ground in laboratory hummer mill 120 (per ten instruments AB, Huddinge, Sweden) through a 60 mesh screen and stored at 4^{o}c in an airtight plastic bottle until needed for analysis.

Determination of nitrogen contents:

The nitrogen determination was condacted using Dumes method and an outomated LECD CN analyzer model CN2000 (Sweaney and Rexroad, 1987).

Crude protein : crude protein content was determined using the Dumas method with the automated LECO CN analyzer model CN 2000 and the protein conversion factor of 5.85 was used (Sweaney and Rexroad, 1987).

Determination of phosphorus contents:

Phosphorus was determined with spectro photometer in the acid digest according to the method described by Troug and Meyer (1993).

Determination of potassium contents:

Potassium was photo metrically determined in the acid digest, Where the method of Brown and Lilleland (1946) was followed.

- Statistical analysis

The measured variables were analyzed by ANOVA using MSTATC statistical packing *(Freed, 1991).* Mean comparisons were done by using the new multiple range test (Duncan's test) followed by *Le Clerg et al (1962).*

RESULTS AND DISCUSSION

1- The effect of row spacing on yield and yield components of quinoa.

Table (1) revealed that quinoa growth, yield and its components were significantly affected by inter row spacing in each of the two seasons. Further the trend predominated the effect on these traits behaved the same in both season, although the values obtained in 2012 season were conspicuously lower than those obtained in 2013 season.

The results evidenced that plant height slightly decreased with widening distances between rows up to 40 cm. apart but with insignificant difference for plant grown between 20 and 40 cm in the first seasons. In the second season differences were wider enough to reach the 5% level of significance and reached the level of significance. These results are in agreement with the result obtained by *Spehar and Rocha (2009)* who reported that quinoa plant has the ability to compensate for the height for plant densities.

On other hand, row spacing significantly affected quinoa branching. However, the trend of change was reversed. Branching increased gradually with increasing row spacing from 20 to 30 and 40 cm between rows. The interpretation is feasible, since growing quinoa at wider rows provides plant with more illumination and less underground competition for nutrient and water. Several investigators reached same results such as *Mailigawadit patil (2001) and Smith patel et al (2011).* The effect on head length was significant in first seasons but insignificant in the second seasons. there were gradual increases in head length with increasing row spacing from 20 to 40 cm. The effect of row spacing on head weight behaved the same as the means of head length, but was more pronounced in the second seasons.

Grain weight /plant followed the same pattern of change as in the first year but with little deviation in the second seasons where the grain weight of plant grown at 30 cm row spacing was heavier than plants raised on 40 cm row spacing. Row spacing had no effect on the weight of 1000 grain in both year. Further the trend of the yield per feddan was contrary to the trend of the yield components to head length, head weight, and grain weight. This contradiction might be due to the increase of number of plants per unit area with dense rowing at 20cm apart over rowing at 30 cm apart and 40 cm apart. The data revealed decrease in the yield of grain/fed. with increasing row spacing up to the widest. The reductions are estimated to 158.80 and 23.20 kg of grain when row spacing increased from 20 to 30 cm in the first and the second sesons. Which equal (26.63 and 3.43%) and (431.3 and 316.5 kg). This calculation indicate that 20 cm rowing resulted in sharp increases in yield per feddan.. Several workers studied the effect row spacing on growth yield components and yield of grain and defined optimum row spacing as influenced by environmental factor and the variety used such *Henderson et al (1993) and Malligawadit and patil (2001).*

Table (1): Effect of inter spacing of rows on yield and yield components of quinoa grain.

Characters / Row spacing (cm)	Plant height cm	Branches No.	Head length mean cm	Head Weight /plant g	Grain Weight /plant g	1000 grain weight	Yield Kg/fed
1st Seasons (2012 / 2013)							
20	35.46 a	9.922 b	11.20 c	15.37 b	9.022 b	2.24 a	596.4 a
30	33.69 a	10.91 ab	12.96 b	20.90 a	14.02 a	2.24 a	337.6 b
40	33.09 a	11.60 a	15.58 a	21.09 a	15.03 a	2.25 a	165.1 c
LSD 5%	N.S	1.28	1.13	1.14	2.21	N.S	0.03
2nd Seasons 2013 / 2014)							
20	51.07 a	10.07 b	14.93 a	19.04 c	10.51 b	2.35 a	677.0 a
30	49.44 ab	13.26 a	15.06 a	24.08 b	19.92 a	2.30 a	643.8 a
40	45.10 b	14.80 a	15.79 a	29.31 a	18.60 a	2.32 a	327.3 b
LSD 5%	4.71	2.28	N.S	3.89	2.71	N.S	89.6

The average number of branches per plant behaved the reverse. Differences between the treatments imposed were significant in the first season but did not reach the 5% level of significance in the second seasons. Gradual increase in branching was associated with widening distances between plants supporting the results obtained by *Sherif Sahar et al (2005).* Head length, head weight and grain weight plant and the weight of 100 grain followed the same pattern of change with increasing distances between plants. The data obtained indicated gradual increases in these traits which represent, the yield components with widening distances between plants up to 20 cm apart. However, differences in the values of these traits between the moderate and widest distance (15 and 20 cm) did not reach the 5% level of significance in case of the head weight and grain weight/plant in both seasons and the weight of 1000grain in the second seasons. The increases 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 concordant with these obtained by *Bhargava et al (2006).* The yield of quinoa grain per feddan behaved the converse as the yield components traits behaved. There were decreases in grain yield/fed with increasing the distances between plants up to the widest (20 cm apart). However differences were significant in the first year only and these differences among the treatment imposed was also significant, i.e, between 10 and 15 cm apart and 15 and 20 cm apart. The reductions are estimated to 117.3 and 3.3 kg of grain when plant spacing increased from 10 to 15 cm in the first and second year (25.6 and 0.581%) and 158.2 and 45.1 kg when plant spacing increased from 10 cm to 20 cm apart in the first and second seasons, respectively (34.53 and 7.98%) However, these results are concordant with those obtained by *Abdel zahar and El-Gendy (2014).*

Table (2) : Effect of intra spacing of plants on yield and yield components of quinoa grains.

Characters hill spacing	Plant Height cm	Branches No.	Head length mean cm	Head Weight /plant g	Grain Weight /plant g	1000 grain weight g	Yield Kg/fed
	1st Seasons (2012 / 2013)						
10	37.31 a	9.744 b	11.92 b	17.56 b	11.93 a	2.24 ab	458.2 a
15	33.88 b	10.77 ab	13.83 a	19.59 a	12.74 a	2.18 b	340.9 b
20	31.04 b	11.92 a	13.98 a	20.21 a	13.40 a	2.31 a	300.0 c
LSD 5%	3.28	1.3	1.13	1.14	N.S	0.10	0.03
	2nd Seasons (2013 / 2014)						
10	52.19 a	11.54 a	14.34 b	20.74 b	13.82 b	2.31 a	565.5 a
15	47.42 b	12.83 a	14.94 b	24.99 a	16.78 a	2.31 a	562.2 a
20	46.00 b	13.74 a	16.49 a	26.70 a	18.43 a	2.35 a	520.4 a
LSD 5%	4.71	N.S	1.37	3.89	2.71	N.S	N.S

3-Effect of inter spacing of rows and intra spacing between plants.

Result in table (3) presented the interaction effect between the inter and intra spacing on growth behavior and grain yield and its components.

Table (3) interaction effect of inter and intra spacing on yield and yield components of quinoa grains.

Characters Inter spacing cm	Intra spacing cm	Plant Height cm	branches No.	Head length mean cm	Head weight g	Grain weight /plant g	1000 grain weight g	Yield kg/fed
		1st Seasons (2012 / 2013)						
20	10	41.57 a	9.567 bc	11.00 e	13.39 f	7.867 c	2.26 a	913.3 a
	15	35.50 b	9.900 bc	11.40 de	16.73 e	9.600 bc	2.16 a	512.0 b
	20	29.30 c	10.30 bc	11.20 de	16.00 e	9.600 bc	2.30 a	364.0 c
30	10	34.43 bc	10.87 bc	10.07 e	20.60 bcd	13.47 a	2.200 a	316.0 f
	15	33.73 bc	11.00 bc	13.00 cd	22.10 ab	13.27 ab	2.200 a	340.0 e
	20	32.90 bc	10.87 bc	15.80 ab	20.00 cd	15.33 a	2.33 a	356.7 d
40	10	35.93 ab	8.800 c	14.70 bc	18.70 d	14.47 a	2.26 a	145.3 i
	15	32.40 bc	11.40 b	17.10 a	21.80 abc	15.37 a	2.200 a	170.7 h
	20	30.93 bc	14.60 a	14.93 bc	22.77 a	15.27 a	2.300 a	179.3 g
LSD 5%			2.22	1.95	1.97	3.83	0.17	0.05
		2nd Seasons (2013 / 2014)						
20	10	55.07 a	9.300 d	14.40 b	15.50 d	9.533 e	2.30 a	756.6 a
	15	49.33 ab	9.800 d	14.83 b	19.53 cd	9.667 e	2.33 a	683.9 ab
	20	48.80 ab	11.10 bcd	15.57 b	22.10 bcd	12.33 de	2.43 a	590.5 b
30	10	53.40 a	10.93 cd	14.30 b	20.37 bcd	16.77 bcd	2.26 b	617.0 ab
	15	47.93 ab	13.90 abc	15.07 b	25.50 abc	21.03 ab	2.30 b	619.6 ab
	20	47.00 ab	14.93 ab	15.80 ab	26.37 ab	21.97 a	2.33 ab	694.6 ab
40	10	48.10 ab	14.40 abc	14.33 b	26.37 ab	15.17 cd	2.36 ab	276.1 c
	15	45.00 b	14.80 abc	14.93 b	29.93 a	19.63 abc	2.30 b	310.2 c
	20	42.20 b	15.20 a	18.10 a	31.63 a	21.00 ab	2.30 b	395.6 c
LSD 5%		8.16	3.94	2.37	6.73	4.69	0.11	155.1

Highest grain yield of quinoa was obtained when using the narrowest distance between rows and between plants. More over; at the lowest inter spacing between rows (20 cm), increasing the intra spacing between plants to from 10 to 15 and 20 cm) caused substantial significant decrease in grain yield being 756, 684 and 590 kg/fed in the second seasons with significant differences in each seasons. However widening the inter spacing between rows to 30 and up to 40 cm, the increase of the intra spacing from to 15 and up to 20 cm between hills caused slight significant increase in grain yield of quinoa, This trend was noticed for each of two growing seasons with significant interaction effect of the two factors (inter and intra spacing) in the first seasons. This is not the situation for producing the highest grain yield at the intra spacing between hills. These results is very well accepted because of the even distribution of plants in the field which provid the equidistant plants with better distribution of the required environmental factor as light, water, nutrients, space and the edaphic balance and actives. In other ward, the even distribution of plant may reduce the competention of plants for their essential requests. Morever, this inter and intra spacing produced relatively more grain yield of quinoa than at either widening the inter spacing 30 or 40 cm and the intra spacing 15 and 20 cm (Table 1). This trend was noticed in each of the two growing seasons with significantly variable magnitudes.

The above present situation is more of less reflected on the other studied parameters of litte fluctuation, but came out with the currently studies results which accumulated in grain yield of quinoa.

1- Effect on chemical content of quinoa grain.

a- Effect of inter spaces of rows

Results in table (4) indicate that row spacing had appreciable effect on nitrogen and protein concentrations in quinoa grain. Data revealed gradual increases in both nitrogen and protein concentrations with widening the inter spaces between rows up to 40 cm apart. Moreover differences diminished between 30 cm and 40 cm inter spaces between rows.

The increases in both components might be due to plant to plant less competition for available nitrogen in soil. This could be due to more availability and less competition for such wider space around the rows which gave a better chance for plant to absorb such nutrients.

On other hand, phosphorus behaved the reverse, i.e, phosphorus concentration decreased with increasing row spacing indicating the normal antagonistic criterion between nitrogen and phosphorus. Also, the distribution of phosphorus fertilizer around the narrower rows could mining the phosphorus from soil as compared with the wider distance between rows where the phosphorus fertilizer will be spreaded on relatively wider spaces of soil around the plants which may allow more unavailibility of phosphores.

b- Effect intra spacing of plant

The effect of plant spacing on nitrogen and protein concentrations in quinoa grains was similar to the effect of row spacing. Gradual increases in the concentrations of nitrogen and Protein was associated with increasing plant spacing up to 20 cm. apart. Similar differences between the narrowest 10 cm apart and 15 cm apart was greater than between 15 and 20 cm, apart. However, these results were supported by Kamel et al (1967) Potassium concentration followed the same pattern of nitrogen supporting. The less competition between plants grown at wider spacing seemed to be the cause and effect. The data also revealed relative increases in phosphorus concentration with widening plant spacing. (Akbari et al 2011).

The interaction effect of row and plant spacing on nitrogen and protein concentrations in quinoa grain was regular. With increasing row and plant spacing, nitrogen and protein concentrations increased up to the widest (40 x 20). Although, highest grain was associated with relatively higher protein yield in case of the interacted treatment (20 x 10) which scored 834.95 kg of grain/fed and 114.39 kg of protein/fed, yet, the intensive stand might diminish farmer popularity to apply such intensive population and prepare (30 x 20) which scored 525.65 kg of grain and 199.35 kg protein/fed (table 6).