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Determination of Water Requirements and Optimal Sowing Date for Quinoa (*Chenopodium quinoa* Willd.) in Selected Areas of Iraq

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Abstract **- Experiments were conducted at the Crop Research Station in Baghdad and the Forage Research Station in Haditha during the 2021 and 2022 growing seasons. Four quinoa varieties (REGALONA, Q37, KVL-SR2, and Q21) were selected, and three sowing dates (February 1, February 15, and March 15) were tested to identify the optimal planting date and the best variety in terms of yield. The experiment was laid out in a split-plot design with three replications. The results of the combined analysis of flowering days showed significant differences (P≤0.05) between locations, planting dates, and varieties. The earliest flowering was observed in Baghdad, on the third sowing date, and in the Q21 variety, with 75, 59, and 72 days, respectively. Similar differences were observed for physiological maturity on the third sowing date (114 days) and in the Q21 variety (120 days), with REGALONA and Q21 being the shortest in duration to maturity. In contrast, Q37 and KVL-SR2 had longer maturity durations. Significant differences in plant height were observed between locations and varieties, with the highest values recorded in Haditha (157 cm), on the second sowing date (149 cm), and in the KVL-SR2 variety (168 cm). The number of heads per plant also showed significant differences across locations, sowing dates, and varieties, with the highest values observed in Baghdad, on the first sowing date, and in the Q37 variety (8, 9, and 9 heads, respectively). Grain yield exhibited significant differences as well, with the highest yield recorded in Haditha (3.510 t/ha), on the first sowing date (2.980 t/ha), and in the Q21 variety (3.620 t/ha). Based on these findings, the Q21 and REGALONA varieties, along with early sowing dates between February 1st and 15th, are recommended for quinoa cultivation in Iraq.**
Keywords: **Quinoa, Sowing Dates, Sites, Morphological Phenomena, Quinoa Yield**

I. INTRODUCTION

The future of food security presents a global challenge. In response to this, the United Nations General Assembly designated 2013 as the "International Year of Quinoa" [1], recognizing the quinoa plant (Chenopodium quinoa Willd.) as one of the most promising crops with high production and nutritional value to help feed the world's population in the context of climate change [2]. Chenopodium quinoa Willd., belonging to the Amaranthaceae family, is a relatively new crop in most consuming countries. In Iraq, there is limited information available about quinoa, particularly regarding the optimal sowing date. (There is no data on the area of quinoa cultivation in Iraq because it is a new crop, and it is primarily cultivated in the eastern and central regions). This promising crop is known for its resistance to abiotic stresses such as drought [3] and salinity [4, 5]. Crop production in arid and semi-arid regions, including Iraq, can be improved by diversifying production and introducing new crops and cultivars, such as Chenopodium quinoa Willd., a tolerant plant with the potential to become an important crop in arid and saline areas, meeting the demands of a growing global market [6]. The broad genetic variation in salinity tolerance in quinoa provides an excellent resource for selecting and breeding high-tolerance varieties [7].

Quinoa originated in South America, where it held special reverence in ancient Andean civilizations [8, 9]. In the 1970s, the world began to recognize the importance of this grain and its distinctive characteristics, leading to its spread worldwide due to its high nutritional value and its resilience, which allows it to grow in conditions where other crops cannot [10]. It can be grown from sea level to altitudes of up to 4,500 meters above sea level, and it tolerates significant temperature fluctuations ranging from -8 to 38°C, requiring only small amounts of rainwater, typically less than 300 mm. One of the most remarkable features of quinoa is its variety of drought- and saline-tolerant cultivars [11, 12].

This plant is unique in that it contains all essential amino acids, with a protein content ranging from 12.5% to 16.7%. The fatty acids in raw quinoa grain include 8.1% omega-3, 52.3% omega-6, and 23% omega-9. It is also rich in trace elements and essential vitamins E, C, and B [13]. Quinoa is low in gluten, containing less than 20 mg/kg [14], making it suitable for patients with digestive disorders and contributing to blood sugar control [15, 16]. Additionally, it is rich in magnesium, phosphorus, copper, manganese, fiber, potassium, and thiamine. Quinoa grains can be roasted and ground to make different types of bread or cooked and added to soups.

Factors such as cultivation area, genotype, planting depth, and soil moisture are crucial for the successful cultivation and spread of quinoa [17]. The timing, quantity, and distribution of rainfall are also important in determining the sowing date, as seen in Colombia, where quinoa is planted from late August to early September [18]. In Morocco, quinoa yield decreased by 1.3 tons/ha when the sowing date was delayed from February to April under irrigated conditions [19, 20]. A study in Japan to determine the optimal sowing date for various quinoa genotypes from different environmental regions recommended planting in March. Early quinoa cultivars achieved acceptable economic productivity in southwestern Germany, with grain yields ranging from 1.7 to 2.4 t/ha. Improving their quality traits requires breeding and selection [21]. Jacobsen [6] emphasized the importance of early ripening in quinoa varieties cultivated in cold regions, as it plays a crucial role in achieving the desired productivity.

The quinoa crop was introduced to Iraq through personal efforts, given its high nutritional value and ability to grow in poor and marginal areas. Therefore, it is essential to determine the most suitable sowing date for this newly introduced crop in Iraq. Initial observations were conducted over 12 dates at multiple sites during the 2014/2015 season, and preliminary results indicate that the optimal period for quinoa growth ranges from February to March [22].

II. MATERIALS AND METHODS

The study aimed to determine the most suitable date for planting quinoa crop in some of the crop production areas in Iraq, as well as identifying the best productive tested varieties per unit area, and the best area for growing the quinoa crop from the two study areas as well.

The study was conducted at the two sites during 2021, 2022. The first site was Field Crops Research Station (Baghdad). The soil texture was classified as a clay loam. The location lies on longitude 44° 16' 36" east and latitude 33° 18' 23" north, and 34 m above sea level. The texture of soil was silt clay loam (123 sand), (391 clay), and (486 silt), the field capacity and wilting point was 0.313 cm^3/cm^3 and 0.135 cm^3/cm^3, respectively, pH and EC_e value was 7.8 and 1.87 dS m^{-1}, respectively. With soil bulk density of 1.32 g. the second site was the Fodder Research Centre - Ministry of Agriculture in Haditha District.

The irrigation schedule and the amount of water in each irrigation depended on a moisture depletion that approached to 50-55% of the available water for the 0-40 cm layer, as the available water reached a volumetric moisture content of 0.23 cm3 / cm3 (moisture content at KPa33 = 0.31 and at KPa 1500 = 0.10 cm3/ cm^{-3} (Table I). The water balance equation was used to estimate the storage in the time periods at the end of the root zone of the plant by the difference between two irrigations.

Irrigation practices conducted based on equation (1):
$\theta A.\mathrm{w} = (\theta f.c - \theta \mathrm{w}.p)$ … .1

Where A.W= available water

$\theta f.c$ =water content at field capacity cm^3 cm^{-3}
θwp = water content at field capacity cm^3 cm^{-3}

The layout of the experiment was split plots design, the main experimental plot was two dates (January 1 and 15) planted during 2020, and a third date (February 1) was added during 2021, through the results obtained from the previous cultivation date, while the sub main plots were four varieties (REGALONA, Q37, KVL-SR2, Q21), the area of the experimental plot was 3.6 m^2, and the entire area of the experiment with the two dates (4 variety x 2 lines x 3 m length x 0.6 m width x 3 replications x 3 dates = about 100 m2).

The cultivation was carried out manually, at a depth of 1-2 cm, the plant density was 50 plants/m^2, with 5 kg/ha. Phosphate fertilizer was added in the form of TSP (46% P2O5) at 60 kg before second irrigation, the potassium fertilizer (K2O 48%) was added in one step immediately prior to the second irrigation. According to the study treatments, nitrogen fertilizer was added in the form of urea (N 46.5%) as recommended by 200 kg h^{-1} N [23]. at two steps, the first after planting and the second before flowering [24].

TABLE I SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

Property	Unit	Value
Sand	gm kg^{-1}	428
Silt	gm kg^{-1}	396
Clay	gm kg^{-1}	176
Texture	Loam	-
porosity	51.36	cm^{-3} cm^{-3}
Bulk density	Mg kg^{-3}	1.26
Particle density	Mg kg^{-3}	2.59
Organic matter	gm kg^{-1}	14.72
Electrical conductivity	dSm^{-1}	0.9
pH	---	7.5
CEC	C mole kg^{-1}	0.28
Volumetric moisture content at tensions		
KPa_{33}	cm^3 cm^{-3}	0.31
KPa_{1500}	cm^3 cm^{-3}	0.10

All agricultural practices, thinning, weed control and fertilization were carried out for the second time 14 days after germination. Two plants were kept in one pit, and the harvest was done when the plant leaves turned yellow and reached the stage of physiological maturity.

III. OUTSTANDING RESULTS

Number of days until 50% flowering of Panicle (day) was calculated from the date of the first irrigation or rainfall after planting until 50% flowering of the main plants Panicle of the experimental plot, the height of the plant (cm) was measured from the surface of the ground to the top of the main Panicle, the number of Panicle on the plant (cob) was measured during the physiological maturity stage, the number of cobs was recorded as average in the experimental plot (5 cobs were counted, then the number was divided by 5 and was expressed as a mean average). The number of days until physiological maturity (day) was calculated from the date of the first irrigation or rainfall after planting until 50% of the cob matured, the leaves of their plants were colored yellow, and the appearance of the black pit at the bottom of the seed was noticed. The cobs were dried and the yield (ton/ha) of the experimental plot was calculated. The collected data were subjected to the statistical analysis (by using Mstat-C software), using the analysis of variance (ANOVA).

IV. RESULTS AND DISCUSSION

A. Baghdad Site 2020

1. Number of Days Until Flowering (Day)

a. The results exhibited that number of days until flowering was varied for the studied genotypes and dates (Table II), there were significant differences ($P \leq 0.05$) between the studied cultivars has shown. The two genotypes Q21 (45 days) and REGALONA (46 days) was superior over the two genotypes Q37 and AMS-3761, which had a flowering period of (50 days), the early flowering was due to the difference in the studied genotypes in maturity phenomenon [25]. The second date January 15 (45.88 days) was superior in the number of days until flowering over the third date February 1 (49.5 days). The result of early flowering belongs to a late planting dates, this agree with Hirich *et al.,* [19]. This is due to the fact that quinoa is one of the long-day plants and its transformation into the fruiting phase by increasing the number of daily lighting hours. While there were not significant differences interaction between cultivars and dates.

b. Plant height (cm): The mea of genotypes showed a significance variation at ($P \leq 0.05$) between them in plant height (Table III), the genotypes KVL-SR2, Q37 and REGALONA were significantly superior with values of (160, 155 and 141 cm), respectively, over Q21 (111 cm), and the first planting date February 15 (153.8 cm) gave the highest value for plant height with significant differences compared to the second date January 15 (130 days), and this could be explained by the fact that superior varieties have a relatively large plant vegetation which lead the increase in the contribution of photosynthesis products In growth and thus increase plant height under early cultivation conditions and low light hours [26, 27]. There was no significant interaction between Varieties and dates has shown.

c. Number of Panicle/plant (Cob): Table IV indicate that there were significant differences at ($P \leq 0.05$) for the characteristic of the number of cobs / plant, where each of the REGALONA, Q37, and Q21 genotypes were superior by the highest value of the number of cobs per plant, which was (15 Panicle), compared to the KVL- SR2 (14 cobs), and the high number of cobs/plant is attributed to the effectiveness of the photosynthesis process resulting from the large vegetative system, and to the fact that some genotypes have a good genetic ability potential that enables them to convert photosynthetic products with high efficiency in to form of more number of cobs [25]. There were insignificant differences mean between sowing dates and the interactions of dates and genotypes.

2. Number of Days to Physiological Maturity (Day)

The genotypes showed a big variation in the number of days until physiological maturity (Table V). however, genotype Q21, was the earliest in maturity which had the lowest value in number of days until maturity (110 days), followed by REGALONA genotype (111 days), which they gave a significant differences at ($P \leq 0.05$) over the two genotypes Q37 (121 days) and KVL-SR2 (123 days). The third sowing date February 1 (115.1 days) (Table 5) was superior over the second date January 15 (117.2 days) as well. There was insignificant interaction between the studied factors. The previous results differed from what was concluded by Hirich *et al.,* [20] regarding the variation in the performance of varieties when planted in the early dates compared to the late ones, due to increasing in the lighting hours' number, which lead plants turn to early maturity.

TABLE II EFFECT OF SOWING DATE ON NUMBER OF DAYS UNTIL FLOWERING FOR QUINOA GENOTYPES

Dates (D)	Varieties(V)				Date mean
	REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**	
1(15Feb.)	47.5 abc	Q37 (2)	51.0 c	47.5 abc	49.5 b
2(15Mar.)	44.5 ab	52.0c	48.5 bc	42.5 a	45.88 a
Variety (mean)	46.0 a	48.0abc	50.0 b	45.0 a	
L.S.D $_{0.05}$	V 2.04	50.0b	D . V 2.88		
%C.V	2.6 %				

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE III EFFECT OF PLANTING DATE ON PLANT HEIGHT (CM) OF QUINOA GENOTYPES

Dates (D)	**Varieties(V)**				**Date mean**
	REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**	
1(15Feb.)	147.5	160.0	185.0	122.5	153.8 a
2(15Mar.)	135.0	150.0	135.5	100.0	130.0 b
Variety(mean)	141 a	155 a	160 a	111 b	
L.S.D $_{0.05}$	V 20.75	D 14.65	D . V -		
%C.V	13.5				

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE IV EFFECT OF PLANTING DATE ON THE NUMBER OF COBS/PLANT (PANICLE) OF QUINOA GENOTYPES

Dates (D)	**Varieties(V)**				
	REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**	**Date mean**
1(15Feb.)	15.0	14.5	13.0	15.5	14.5
2(15Mar.)	15.0	16.0	14.5	14.5	15.0
Variety(mean)	15 a	15 a	14 b	15 a	
L.S.D $_{0.05}$	V 1.00	D 0.77	D. V -		
%C.V	13.5				

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%

TABLE V EFFECT OF SOWING DATE ON NUMBER OF DAYS TO PHYSIOLOGICAL MATURITY (DAY) FOR QUINOA GENOTYPES

Dates (D)	**Varieties(V)**				**Date mean**
	REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**	
1(15Feb.)	109.5	120.5	121.5	109.0	115.1 a
2(15Mar.)	112.0	122.0	123.5	111.5	117.2 b
Variety(mean)	111 a	121 b	123 c	110 a	
L.S.D $_{0.05}$	V 1.54	D 1.89	D . V -		
%C.V	13.5				

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

Grain yield (tons ha^{-1}): The results of grain yield in table V showed that there were a significant differences between genotypes in grain yield (tons ha^{-1}), at ($P \leq 0.05$), however REGALONA gave the highest value (1.468 tons ha.$^{-1}$), followed by the Q21 (1.295 tons ha.$^{-1}$) which superior over Q37 (0.613 tons ha.$^{-1}$) and KVL-SR2 (0.611 tons ha.$^{-1}$), the first sowing date February 15 (1.509 tons ha.$^{-1}$) was significantly superior over the second sowing date January 15 (0.484 tons ha.$^{-1}$). Both genotypes REGALONA (2.236 ton ha.$^{-1}$) and Q21 (1.979 tons ha.$^{-1}$) were superior in grain yield through their interaction with the first sowing date January 1 over the rest of the interactions, due to the fact that the late sowing dates of quinoa genotype negatively affect the yield through shortens their life cycle and moving from flowering to fruiting stage, on the other hand quinoa consider as a long-day plant [6] statistical cumulative analysis of Haditha and Baghdad sites for the 2022 year.

3. Number of Days Until Flowering (Day)

Table VI indicated that there was a significant difference between genotypes in number of days after emerging, for both REGALONA and Q21genotypes the data showed that the earliest value in the number of days until flowering was (72 days), which they were significantly superior over the rest of the genotypes, however the third sowing date February 1 (59 days) was superior in terms of the number of days until flowering over the two remaining dates. Baghdad site (75 days) was the earliest in flowering compared to

Haditha site (77 days), while the interaction between genotypes, dates, and sites showed the importance of REGALONA in the third date, February 1, in the first site, and Q21 in the third date and the second site, with a value of (55.5 days) for the two genotypes, on the other hand they distinguished by the lowest number of days until flowering and with significant differences with most treatments, which confirms the importance of the genotype which has high ability to respond to environment influence [19]. Plant height (cm): KVL-SR2 genotype was superior in the plant height parameter (168 cm) over the rest of the genotypes, while the second planting date January 15 and the first January 1 had the largest plant height, (149 and 145 cm), respectively, and with significant differences with the third date February 1 (136 cm), however, Haditha site was superior in plant height (157 cm) over the first site, Baghdad (129 cm). This is due to the genotype characteristics which had longer number of days to reach to the flowering stage. This contributes to directing photosynthesis products in to form vegetative system and increase growth and plant height as well. The results corresponded with Farinazzi *et al.,* [12] and Hirich *et al.,* [26] finding. On the other hand, there were insignificant interactions between cultivars, dates and sites (Table VII).

Number of Cobs/Plant (Cob): The results of number cob/plant (Table VIII) showed that the two genotypes Q37 (9 cobs) and KVL-SR2 (8 cobs) were superior with significant differences over Q21 genotype (5 cobs), while the first planting date January 1st (9 cobs) and the second date January 15 (8 cob), gave the largest number in cob/plant compared with third date February 1 (5 cob), with significant differences. The first site, Baghdad (8 cob), showed superiority in the number of cob/plant over the second site, Haditha (6 cob). This indicates that early planting dates allow the genotype to secure the food stock required to form cobs on the plant, which is one of the components of productivity [25]. The interactions of the studied factors did not show significant differences.

4. Number of Days after Emergence to Physiological Maturity (Day)

The results of Table IX showed that the superiority of Q21 genotype (120 days) in the number of days until physiological maturity and with significant differences (P≤0.05) over the rest of the REGALONA, Q37 and KVL-SR2 cultivars with values (128, 138 and 139 days), respectively, as well as the superiority of the date of the third cultivation is February 1 (114 days) in terms of the number of days until physiological maturity on the first date January 1 and the second date January 15 with values (148 and 132 days), respectively. As for the sites, the second site was superior to Haditha (124 days) and with significant differences over the first site, Baghdad (139 days), these results were largely agree with the results of the characteristic of the number of days until flowering, and are consistent with the results of Hirich *et al.,* [20], Saud Shehab *et al.,* [27], that early flowering varieties are usually early in maturity and the Q21 genotype was expressed through its interaction with the third date, February 1, and the second site, Haditha (97.5 days), showed significant differences with the rest of the studied factors in the early age in the number of days until physiological maturity.

TABLE VI EFFECT OF SOWING DATE ON THE NUMBER OF DAYS UNTIL FLOWERING (DAY) FOR QUINOA GENOTYPES AT HADITHA AND BAGHDAD SITES

Dates (D)		**Varieties(V)**				**Date mean**
		REGALO NA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**	
1(Hadith a site)	1 (January 1)	87.0 h	89.5 h	100 i	87.0 h	115.1 a
	2 (15b January)	77.5 ef	78.0 ef	86.5 h	77.0 ef	117.2 b
	3 (Februar y 1)	55.5 a	58.5 a	65.5 c	57.0 a	
2(Baghda d site)	1 (January 1)	81.0 fg	89.0 h	98.0 i	85.0 gh	
	2 (15 January)	75.5 de	75.5 de	89.0 h	71.5 d	
	3 (Februar y 1)	56.0 a	60.0 ab	64.0 bc	55.5 a	
Variety mean		72 a	75 b	84 c	72 a	
Date mean		90 c	79 b	59 a		
Sites mean		77 b	75 a			
L.S.D 0.05		V	D	L		
		1.000	0.866	0.707		
		D . V	L . V	L . D		
		1.732	1.414	1.225		
L..D.V 2.450						
%C.V	1.6					

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE VII EFFECT OF SOWING DATE ON PLANT HEIGHT (CM) FOR QUINOA GENOTYPES AT HADITHA AND BAGHDAD SITES (DURING THE YEAR 2022)

Dates (D)		Varieties(V)			
		REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**
1(Haditha site)	1 (January 1)	140.5	146.0	157.5	91.0
	2 (15 January)	127.5	149.0	151.5	95.0
	3 (February 1)	118.5	135.5	137.0	95.0
2(Baghdad site)	1 (January 1)	145.5	163.0	186.5	126.5
	2 (15 January)	165.0	177.0	192.5	132.5
	3 (February 1)	135.5	159.0	182.5	123.5
Variety mean		139 c	155 b	168 a	111 d
Date mean		145 a	149 a	136 b	
Sites mean		129 b	157 a		
L.S.D 0.05		V	D	L	
		8.44	7.31	5.96	
		D. V	L. V	L. D	
		-	-	-	
		L . D . V			
		-			
%C.V		14.6			

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE VIII EFFECT OF SOWING DATE ON NUMBER OF COB/PLANT COB FOR QUINOA GENOTYPES AT HADITHA AND BAGHDAD SITES

Dates (D)		Varieties(V)			
		REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**
1(Haditha site)	1 (January 1)	9.5	12.0	13.5	6.5
	2 (15 January)	8.0	13.0	8.5	5.5
	3 (February 1)	6.5	9.0	4.5	5.0
2(Baghdad site)	1 (January 1)	6.5	7.5	8.5	6.5
	2 (15 January)	6.5	7.0	8.0	4.5
	3 (February 1)	4.5	4.0	4.0	4.0
Variety mean		7 b	9 a	8 ab	5 c
Date mean		9 a	8 a	5 b	
Sites mean		8 a	6 b		
L.S.D 0.05		V	D	L	
		1.247	1.527	1.247	
		D . V	L . V	L . D	
		-	-	-	
		L . D . V			
		-			
%C.V	29				

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE IX EFFECT OF SOWING DATE ON THE NUMBER OF DAYS TO PHYSIOLOGICAL MATURITY (DAY) FOR QUINOA GENOTYPES AT HADITHA AND BAGHDAD SITES

Dates (D)		**Varieties(V)**			
		REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**
	1 (January 1)	146.0 i	170.0 j	171.0 j	138.0 ghi
1(Haditha site)	2 (15 January)	134.0 fghi	144.0 hi	145.0 i	126.0 efg
	3 (February 1)	123.0 defg	134.0 fghi	129.0 efgh	106.0 abc
	1 (January 1)	136.0 ghi	143.0 hi	144.5 hi	133.0efghi
2(Baghdad site)	2 (15 January)	120.5 cdef	132.5efghi	136.0 ghi	118.0bcde
	3 (February 1)	105.0 abc	104.0 ab	100.0abcd	97.5 a
Variety mean		127 b	137 c	138 c	119 a
Date mean		147 c	131 b	113 a	
Sites mean		138 b	123 a		
L.S.D 0.05		V	D	L	
		2.896	2.499	2.068	
		D . V	L . V	L . D	
		5.066	4.136	3.579	
		L . D . V			
		6.966			
%C.V		2.5			

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%

TABLE X EFFECT OF SOWING DATE ON GRAIN YIELD (TON/HA.) FOR QUINOA GENOTYPES AT HADITHA AND BAGHDAD SITES

Dates (D)		**Varieties(V)**			
		REGALONA (1)	**Q37 (2)**	**KVL-SR2 (3)**	**Q21 (4)**
1(Haditha site)	1 (January 1)	1.600 cdef	0.740 def	0.800	2.340cdef
	2 (15 January)	1.680 cdef	0.680 def	0.610 def	2.420cdef
	3 (February 1)	0.750 def	0.420 f	0.490 f	0.500 def
2(Baghdad site)	1 (January 1)	3.290bcdef	3.790bcde	3.380bcdef	7.900 a
	2 (15 January)	4.600 abc	2.300cbdef	3.870 bcd	6.400 ab
	3 (February 1)	1.890 cdef	0.750 def	1.800 cdef	2.170 cdef
Variety mean		2.300 b	1.450 c	1.820 bc	3.621 a
Date mean		2.980 a	2.820 a	1.090 b	
Sites mean		1.080 b	3.510 a		
. L.S.D 5%		V	D	L	
		0.626	0.542	0.443	
		D . V	L . V	L . D	
		1.085	0.886	0.767	
		L . D . V			
		1.534			
%C.V		30			

+The means that follow the same letter of the alphabet, there are no significant differences between them at the level of 5%.

TABLE XI IRRIGATION NUMBERS AND DEPTH OF IRRIGATION WATER (MM) FOR QUINOA GENOTYPES

Genotypes	Months	Irrigation No.	Water depth add in one irrigation (mm)	Water depth add in month (mm)	Total irrigation number	Total water depth (mm/ season^{-1})
REGA LONA	1 (January 1)	3	2.66	18.64	11	285.02
	2 (15 January)	3	13.32	39.96		
	3 (February 1)	5	21.31	98.56		
Q37	1 (January 1)	3	2.18	15.00	14	289.46
	2 (15 January)	4	10.64	42.56		
	3 (February 1)	7	17.02	112.76		
KVL- SR2	1 (January 1)	4	1.87	14.49	17	292.73
	2 (15 January)	5	8.88	44.40		
	3 (February 1)	8	14.06	107.30		
Q21	1 (January 1)	4	1.80	13.00	18	285.44
	2 (15 January)	6	7.60	45.60		
	3 (February 1)	8	12.18	92.86		

TABLE XII EFFECT OF IRRIGATION SCHEDULING ON ACTUAL MONTHLY AND SEASONAL EVAPOTRANSPIRATION USED DURING THE GROWTH SEASON OF QUINOA PLANT

Genotypes	Months of growth			Seasonal actual water consumption (mm)
	1 (January)	2(15 January)	3(February 1)	
	Water consumptive use (mm)			
REGALONA	52.5	44.2	98.0	302.9
Q37	45.1	50.5	116.5	323.3
KVL-SR2	44.8	45.7	120.8	323.0
Q21	40.2	51.4	100.7	325.5
Total	182.6	191.8	436	1 741.7

Seed production (tons/ha): The studied factors varied in their grain productivity (Table X), where Q21 genotype (3.621 ton/ha) was superior in grain productivity with significant differences ($P \leq 0.05$) over REGALONA, Q37 and KVL-SR2 genotypes (2.300, 1.450 and 1.820 ton/ha), respectively.

The first sowing date, January 1, had the highest grain productivity (2,980 tons/ha), followed by the second date, January 15 (2,820 tons/ha). The productivity of the third date, February 1 (1,090 tons/ha), declined from the first and second dates, with significant differences. Results indicated that the second site, Haditha, with an average production of (3,510 tons/ha), was superior to the first site, Baghdad (1,080 tons/ha). Whereas composition Q21 enjoyed the highest interaction value with the first sowing date, January 1, in the second site, Haditha, with a productivity of (7,900 tons/ha). Its growth was accompanied by the presence of a suitable genotype for the environmental conditions to meet its potential to transform it into grain productivity [28,12,29,30,2].

5. Water Requirements for Quinoa Genotypes

Table XI showed the Irrigation numbers and depth of irrigation water (mm) for Quinoa genotypes). The amount of water applied was varied between genotypes and date according to irrigation water applied and the growth months of the quinoa genotype. It could be resulted from different maturity stage dates which differ between genotypes. Its growth was accompanied by the presence of a suitable genotype for the environmental conditions to meet its water needs [22]. The variation may be resulted from different maturity stage dates which differ between genotypes according to water consumptive use, irrigation and date of planting (Table II). The table reveal that the heights amount of water added was 292.73 mm in season $^{-1}$ corresponded to KVL-SR2, while the water consumptive use was 289.46, for Q37 followed by 285.44 and 285.02 mm season $^{-1}$ for Q21 and REGALONA, respectively, although the differences were very limited, this difference is due to the variable of the water amount added to each irrigation and the irrigation depth (mm) [31, 27].

6. Daily Evapotranspiration

Table XII showed the effect of irrigation scheduling on daily actual evapotranspiration (ET_a) for quinoa genotypes, which was calculated by using equation (1) using water balance equation during the growing season. The genotypes varied in ETa, respect to studied genotypes, the actual water consumption were 302.9, 323.3, 323 and 325.5 mm season^{-1} for PEFREGALONA, Q37, KVL-SR2 and Q21 respectively.

The highest interaction value between the growing seasons and the genotypes were 325.5 mm month $^{-1}$ for Q21, while the lowest value was 302.9 mm month^{-1} for REGALONA genotype. This is because of the plant at the beginning of its growing stage is accompanied by a decrease in temperature which reduces the evaporation requirement, this, agree with [32] which he mentioned that the increase in actual water consumption use by the quinoa plant is attributed to the increase of the available water in the plant root zone (Hadithi, 2002); [33] and [34,35] indicated that soil available water depends on each type of soil, depth of roots, amount of available water, and the requirements for daily evaporation or potential evaporation ET as the potential evapotranspiration will govern the higher limit requirements for moisture extraction from the soil.

V. CONCLUSION

The previous results indicate significant differences between the studied factors at the level of (P≤0.05). The earliest in terms of the number of days to flowering were the Baghdad site, the third planting date (February 1), and the Q21 genotype, with values of 75, 59, and 72 days, respectively. Similarly, in the number of days to physiological maturity, the Haditha site (124 days), the third planting date (February 1, 114 days), and the Q21 genotype (120 days) were the earliest. For plant height, the values were 157 cm for the Haditha site, 149 cm for the second planting date, and 168 cm for the Q21 genotype. In terms of the number of cobs per plant, the highest values were observed at the Baghdad site, on the first planting date (January 1), and in the Q37 genotype, with 8, 9, and 9 cobs, respectively. Grain yield showed significant differences as well, with the highest yields recorded at the Haditha site (3.510 tons/ha), on the first planting date (January 1, 2.980 tons/ha), followed by the second planting date (January 15, 2.820 tons/ha). Among the genotypes, Q21 ranked first in grain productivity, particularly in its interaction with the third planting date at the Haditha site, with values of 2.980 and 7.900 tons/ha, respectively, followed by REGALONA at 2.300 tons/ha. The Haditha site is identified as the most suitable location for quinoa cultivation. The planting dates of January 1 and January 15, along with the Q21 and REGALONA genotypes, are recommended due to their early maturation and high productivity per unit area. The water consumption values for the genotypes were relatively similar.

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