Egypt. J. Plant Breed. 24(1):159– 175(2020)

PATH COEFFICIENT ANALYSIS OF YIELD AND ITS COMPONENTS IN QUINOA (*Chenopodium quinoa* Willd.) UNDER DIFFERENT NITROGEN LEVELS

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ABSTRACT

Application of nitrogen fertilizer is the most important practice that determines the grain yield and its quality. The field experiment was performed to determine differential response of 4 quinoa genotypes under 3 different levels of nitrogen fertilization. The results indicated that, Chipaya and Line 14 genotype are superior in the grain yield / hectare. While, Q5 genotype recorded the highest value of protein at 160 kg N/ha. Use efficiency showed that, the rate of increase of nitrogen fertilization from 0 to 80 kg/ha is greater than increasing nitrogen fertilization from 80 to 160 kg. With regard to correlation, the strong relationships with grain yield/ha were recorded with plant height and grain yield/plant. Concerning path analysis, the grain yield and weight of 1000 grain followed by fat % exhibited high positive direct effects on grain yield/ha. We can conclude that, plant height is useful in indirect selection during early stages of growth while, grain yield/ plant and weight of 1000 grains are useful in direct selection at harvesting for grain yield/ ha.

Key words: ***Quinoa genotypes, Fertilization, Direct effects, Grain yield.***

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) plant has been grown in the Andean region for thousands of years, providing highly nutritious food to low income farmers (Pearsall 1992). *Chenopodium* spp. have been planted as a leafy vegetable (*Chenopodium album*) also as helpful secondary grain crop (*Chenopodium quinoa* and *C. album*) for human and animal food stuff due to high-protein content and essential amino acids (Bhargava *et al* 2003); a wide range of vitamins and source of minerals (Repo-Carrasco et al. 2003). So, the Food and Agriculture organization (FAO) has been selected it as one of the crops intend to offer food security in the 21st century (Jacobsen 2003). With increasing competition for finite food resources in worldwide, the invitation appeared to evaluate and improve cultivated varieties depending on genetic drift and selection in different environmental conditions to ensure future food security (Steduto *et al* 2012 and Badran and Moustafa 2014).

The fertilizer requirements of nitrogen for quinoa yield are still under assessment in many regions of the world under different environmental conditions. Jacobsen *et al*. (1994) found that quinoa yield increased with increasing the rates of nitrogen fertilization from 40 to 160 kg N ha^{-1}. In the same manner, Basra *et al* (2014) showed that 75 kg N ha^{-1} was confirmed to be optimal level for nitrogen supplementation for the growth of quinoa plant under soil ecological conditions in Egypt. Also, many studies evaluated the response of quinoa yield to nitrogen fertilization rates (0, 80 and 1٦0 kg N ha-1), as well as the efficiency of nitrogen use, where they found a high response in the yield for nitrogen fertilization treatments (Johnson and Ward 1993; Risi and Galwey 1994 and Schulte *et al.* 2005).

It is important that any study involving the correlation coefficient, the evaluation of the path analysis to determine the relationship between the yield and its components by determining the direct and indirect contribution of each trait to the assessment of the relative importance in selection during any breeding program for higher yield. Singh and Narayanan (1993) reported that, the information obtained by path-coefficient assists in indirect selection for genetic progress of plant yield. The analysis of path coefficient is partial regression coefficient estimate the separation of a correlation coefficient of each character with yield to direct and indirect effects. Consequently, the importance of each character was determined by the extent of its contribution (direct and indirect) to increase the yield of crop (Board *et al* 1997 and Badran and Moustafa 2014).

There is still an urgent requirement for detailed studies on the relationship between quinoa growth and the different levels of nitrogen fertilization when cultivation in newly reclaimed regions. So, our aim here is to assess the response of a number of genotypes to these levels of nitrogen and determine the contribution of each trait to the grain yield.

MATERIALS AND METHODS

Experimental conditions

Four genotypes of *Chenopodium quinoa* willd were used as follows: one commercial cultivar (Chipaya cv.) from the Desert Research Center in Egypt while the second genotype (Line 14) from N.B.R.I., Lucknow in India and two varieties (Q-3 and Q-5 cv.) from International Center for Biosaline Agriculture (ICBA) in United Arab Emirates. The experiment was carried out in Beni Suef governorate, Egypt during 2016 and 2017 seasons using three levels of nitrogen fertilization (0, 80,160 kg ha^{-1}) in three replicates. The soil samples were collected at a depth ranging from 0 to 30 cm then, the chemical analyses were done according to Page *et al*. 1982 (Table 1-a). Also, the irrigation water samples were analyzed and the data were recorded as shown in Table (1-b).

Table 1-a. Chemical analysis of saturated soil paste.

Character	Value	Soluble ions (mmol L^{-1})	Value	Nutrients available (ppm)	Value
Depth (cm)	0:0	Na^+	11.8	Total N	90.0
EC (dSm^{-1})	4.1	K^+	0.4	Extractable (P)	6.00
pH	8.1	Ca^{++}	8.0	Extractable (K)	96.0
		Mg^{++}	15.0	Extractable (Fe)	0.38
		Cl^-	17.5	Extractable (Cu)	0.14
		HCO^{3-}	2.0	Extractable (Zn)	0.38
		SO^{4--}	25.7	Extractable (Mn)	0.64
		CO^{3--}	-		

Table 1-b. Chemical composition of irrigation water.

pH	EC (dSm^{-1})	TDS*	Soluble cations meq/L				Soluble anions (meq L^{-1})			
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}
7.51	3.15	3.6	16.50	0.72	6.20	7.00	26.00	1.42	3.00	-

Note: TDS= Total of dissolved salts.

Nitrogen fertilizer levels were added in the form of NH_4NO_3 (33.5 % N) as nitrogen sources. The second and the third treatment of nitrogen fertilizer (80 and 160 kg ha^{-1}) were divided to three equal doses added after 20, 40 and 60 days sequentially from the date of planting. Phosphate fertilizer was added during the preparation of the soil for agriculture, in the form of superphosphate (48% P_2O_5) at the rate of 100 kg per hectare in the form of calcium tri-phosphate while potassium phosphate fertilizer was added in the form of potassium sulphate (15% K_2O) at 100 kg per hectare.

Measurements of studied characters

Mean leaf area (cm) and chlorophyll content (SPAD) of tested quinoa genotypes under nitrogen fertilization levels were taken after 70 days of cultivating and every sample consisted of 5 plants collected randomly from each line. At harvest, plant height (cm), yield of grains/plant (g), weight of 1000 (g) and grain yield (kg ha^{-1}) were recorded. Nitrogen fertilizer efficiency was calculated from the following equation: Nitrogen use efficiency = Grain yield kg ha^{-1}/amount of mineral nitrogen added. Relative increase was estimated as follows: Relative increase index = (the value of tested trait under upper level of treatment x 100)/(2 x the value of tested trait under the lower level of treatment).

Determination of total crude protein, starch and fat content in grain

Total grain nitrogen was estimated using the Kjeldahl method as described by Pearson (1976), then protein percentage was estimated using the following equation: Protein (%) = N% x 6.25. The grain content of the starch was measured by the polarimetrically method using HCl according to ICC Standard No. 123/1 (ICC Standards, 1999). The grain fat content was estimated by extraction using the Soxhlet, according to ICC Standard No. 136 (ICC standards, 1999).

Statistical Analysis

The data of this study during the two growth seasons (2016 and 2107), confirmed a homogeneity between the two seasons according to Levene test (Levent, 1960) so, the combined analysis of data across seasons was applied according to Steel and Torrie (1980). Analysis of variance was conducted by F-test using MSTATC software program according to Michigan State University 1991. Means separation was performed using LSD test at 0.05 probability level according to Gomez and Gomez (1984). Statistical analysis for all studied characters for correlation coefficient analysis was done according to Singh and Chaudhary (1995) while, path coefficient analysis was estimated according to Dewey and Lu (1959).

RESULTS

Differential responses of the tested genotypes

The homogeneity test of the two growing seasons found that, there was homogeneity of all the tested characters, allowing the application of the combined analysis across the two growing seasons. Data averages of the studied characters in presented Table (2) (a, b and c) indicates significant differences between the nitrogen fertilization levels across tested genotypes through analysis of the variance and the estimation of LSD.

Table 2-a. Mean performance vegetative characters under three levels of nitrogen fertilization during the two growing of seasons and combined across

Nitrogen treatment (kg ha^{-1})	Vegetative characters								
	Plant height (cm)			Leaf area (cm^2)			Chlorophyll content (SPAD)		
	2016	2017	Comb.	2016	2017	Comb.	2016	2017	Comb.
0	51.2	54.8	53.00	10.1	11.88	10.99	34.4	31.68	33.04
80	69.1	71.4	70.25	15.99	17.17	16.58	49.9	47.76	48.83
160	91.9	94.48	93.19	19.7	22.3	21.00	62.8	59.96	61.38
LSD $_{(0.05)}$	0.992	1.103	1.077	0.173	0.191	0.184	1.081	0.997	1.002

Note: comb. = combined analysis across two seasons.

Table 2-b. Mean performance of agronomic characters under three levels of nitrogen fertilization during the two growing seasons and combined across them.

Nitrogen treatment (kg ha^{-1})	Agronomic characters					
	Weight of 1000 grain (g)			Grain yield plant $^{-1}$ (g)		
	2016	2017	Comb.	2016	2017	Comb.
0	1.61	1.77	1.69	2.91	3.19	3.05
80	2.29	2.57	2.43	7.19	7.81	7.5
160	3.08	3.34	3.21	12.87	13.15	13.01
LSD $_{(0.05)}$	0.11	0.086	0.095	0.221	0.301	0.268
Nitrogen treatment (kg ha^{-1})	Grain yield ha^{-1} (kg)			N U E^{+} (g/g)		
	2016	2017	Comb.	2016	2017	Comb.
0	529.43	549.19	539.31	0.00	0.00	0.00
80	947.2	981.18	964.19	11.84	12.26	12.05
160	1522.8	1556.4	1539.6	9.52	9.73	9.62
LSD $_{(0.05)}$	5.981	7.137	6.820	0.081	0.070	0.077

Note: comb. = combined analysis across two seasons, NUE= nitrogen use efficiency

Table 2-c. Mean performance of chemical characters under three levels of nitrogen fertilization during the two growing seasons and combined across them.

Nitrogen treatment (kg ha^{-1})	Chemical characters								
	Crude protein (%)			Starch (%)			Fat (%)		
	2016	2017	Comb.	2016	2017	Comb.	2016	2017	Comb.
0	13.2	14.64	13.92	44.5	43.62	44.06	2.54	2.72	2.63
80	14.5	15.00	14.75	49.93	51.37	50.65	4.01	4.21	4.11
160	15.3	15.90	15.60	52.86	56.36	54.61	5.86	6.58	6.22
LSD (0.05)	0.114	0.202	0.119	1.117	1.406	1.318	0.077	0.103	0.086

Note: comb. = combined analysis across two seasons.

Data also confirms that, nitrogen use efficiency (NUE) recorded the highest value (12.05) at 80 kg nitrogen fertilizer level compared with fertilization at the level of 160 kg (9.62). The data in the Table 3 show that, the vegetative characteristics (plant height, leaf area and chlorophyll content) at level 80 kg N recorded the highest value of leaf area, while the differences were limited at 160 kg of both plant height and chlorophyll content. As for, the agronomical characteristics (weight of 1000 grain, grain yield/plant and weight of grain yield/hectare), the grain yield per plant recorded the highest value at 80 and 160 kg N. For, the chemical characters, the percentage of seed fat ranked the top level at 80 and 160 kg N. Generally, as shown in Table 4, the rate of increase of nitrogen fertilization from 0 to 80 kg is greater than the rate of increase in the addition of nitrogen fertilization from 80 to 160 kg for most of studied traits particularly, for the grain yield /plant (122.95 and 86.73 kg respectively) and the grain yield per hectare (89.39 and kg 79.84, respectively).

Table 3. Relative increase index of different nitrogen levels for all tested traits.

Trait	Relative increasing index from 0 to 80 kg N (%)	Relative increasing index from 80 to160 kg N (%)
Vegetative characters		
Plant height	66.27	66.33
Leaf area	75.43	63.33
Chlorophyll content	73.89	62.85
Agronomic characters		
Weight of 1000 grain	71.89	66.05
Grain yield plant $^{-1}$	122.95	86.73
Weight of grain ha^{-1}	89.39	79.84
Chemical characters		
Crude protein	52.98	52.88
Starch	57.48	53.91
Fat	78.14	75.67

Table 4. Mean performance of studied characters of four tested genotypes.

Genotype	Plant height (cm)	Leaf area (cm^2)	Chloro-phyll content (SPAD)	Weight of 1000 grain (g)	Grain yield plant $^{-1}$ (g)
Q3	63.00	14.96	43.67	2.26	6.20
Chipaya	76.67	16.83	45.44	2.30	9.00
Line 14	77.08	16.51	50.93	2.52	8.38
Q5	71.83	16.72	50.95	2.70	7.83
LSD $_{(0.05)}$	1.207	0.132	0.717	0.103	0.195
Genotype	**Grain yield ha^{-1} (kg)**	**N U E^{+} (g/g)**	**Crude protein (%)**	**Starch (%)**	**Fat (%)**
Q3	789.92	5.457	14.87	52.60	4.25
Chipaya	1108.4	7.927	14.49	47.98	4.37
Line 14	1127.3	8.207	14.40	50.22	4.53
Q5	1031.8	7.293	15.27	48.28	4.13
LSD $_{(0.05)}$	6.761	0.084	0.112	0.533	0.079

Note: N U E = Nitrogen use efficiency.

The data in Table (5) (a, b and c) and Figure 1 show significant differences between the tested genotypes. Also, the values showed that Line 14 and Chibaya genotypes were superior in the grain yield/plant (8.38 and

9.00 kg respectively) and the grain yield/hectare (1127.3 and 1108.4 kg, respectively), while Q3 genotype ranked the last place (6.20 and 789.92 kg).

Table 5-a. Mean performance of vegetative characters of four tested genotypes during the two growing seasons and combined analysis across them.

Nitrogen treatment (kg ha^{-1})	Vegetative characters								
	Plant height (cm)			Leaf area (cm^2)			Chlorophyll content (SPAD)		
	2016	2017	Comb.	2016	2017	Comb.	2016	2017	Comb.
Q3	61.90	64.10	63.00	13.78	16.14	14.96	41.24	46.1	43.67
Chipaya	75.10	78.24	76.67	15.65	18.01	16.83	43.11	47.77	45.44
Line 14	75.76	78.40	77.08	15.10	17.92	16.51	49.10	52.76	50.93
Q5	69.80	73.86	71.83	15.99	17.45	16.72	48.79	53.11	50.95
LSD $_{(0.05)}$	1.075	1.333	1.207	0.121	0.213	0.132	0.903	0.612	0.717

Note: comb. = combined analysis across two seasons.

Table 5-b. Mean performance of agronomic characters of four tested genotypes during the two growing seasons and combined analysis across them.

Nitrogen treatment (kg ha^{-1}	Agronomic characters					
	Weight of 1000 grain (g)			Grain yield plant $^{-1}$ (g)		
	2016	2017	Comb.	2016	2017	Comb.
Q3	2.18	2.34	2.26	5.97	6.43	6.20
Chipaya	2.28	2.32	2.30	8.83	9.17	9.00
Line 14	2.43	2.61	2.52	8.02	8.74	8.38
Q5	2.61	2.79	2.70	7.64	8.02	7.83
LSD $_{(0.05)}$	0.111	0.087	0.103	0.210	0.199	0.195
Nitrogen treatment (kg ha^{-1})	Grain yield ha^{-1} (kg)			N U E^{+} (g/g)		
	2016	2017	Comb.	2016	2017	Comb.
Q3	710.4	869.44	789.92	4.908	6.006	5.457
Chipaya	998.5	1218.3	1108.4	7.141	8.713	7.927
Line 14	1001.2	1253.4	1127.3	7.289	9.125	8.207
Q5	978.6	1085	1031.8	6.917	7.669	7.293
LSD $_{(0.05)}$	7.720	5.800	6.761	0.142	0.078	0.084

Note: comb. = combined analysis across two seasons; N U E+ = nitrogen use efficiency.

Table 5-c. Mean performance chemical characters of four tested genotypes during the two growing seasons and combined analysis across them.

Nitrogen treatment (kg ha^{-1})	Chemical characters								
	Crude protein (%)			Starch (%)			Fat (%)		
	2016	2017	Comb.	2016	2017	Comb.	2016	2017	Comb.
Q3	14.88	14.86	14.87	49.30	55.90	52.60	3.73	4.77	4.25
Chipaya	14.52	14.46	14.49	44.53	51.43	47.98	4.11	4.63	4.37
Line 14	14.41	14.39	14.40	48.73	51.71	50.22	4.61	4.45	4.53
Q5	15.26	15.28	15.27	48.12	48.44	48.28	3.99	4.27	4.13
LSD $_{(0.05)}$	0.122	0.102	0.112	0.602	0.465	0.533	0.093	0.061	0.079

Note: comb. = combined analysis across two seasons.

The data of Table (6) showed a significant effect of the interaction between N fertilization levels and tested genotypes of all tested characters using the average of both growing seasons. According to vegetative characters, there was a clear superiority in the Line 14 and Chipaya genotypes for the plant height and leaf area, while the Q 5 was superior in Chlorophyll content at 160 kg N ha^{-1}. For agronomical traits, both Q 5 and Line 14 genotypes are superior in weight of 1000 grains, while Chipaya and Line 14 genotype are superior in the grain yield per plant (15.8 and 14.1 kg, respectively) and grain yield per hectare (1803 and 1743 kg) at 160 kg N fertilizer ha^{-1} while the highest use efficiency of added nitrogen (N U E) was recorded at the level of 80 kg ha^{-1} for Line 14 followed by Chipaya genotype (13.73 and 12.52, g/g respectively). Regarding to chemical characters, Q5 genotype recorded the highest value of protein (16.2 %) at 160 kg N fertilizer while, Q3 genotype ranked first in starch % at all N fertilization levels, while fat% increased clearly for all genotypes with increasing nitrogen added rates especially with Line 14 and Chipaya genotype.

Simple correlation and path coefficient analysis across nitrogen fertilizer levels

Simple correlation coefficients among tested traits of plant and grain yield are great aim to determine the most effective trait for yielding during any plant breeding program. Correlation coefficient confirms that the relationships between tested traits through the interaction between the tested genotypes and levels of nitrogen fertilization of this study were significant and positive with differences among them (Table 6). The values of correlation coefficient among the vegetative traits (plant height, leaf area and chlorophyll content) and grain yield/ha ranged from 0.94 in chlorophyll content to 0.99 in plant height.

Table 6. Means performance across all tested genotypes under different nitrogen fertilization levels.

Interaction		Plant Height (cm)	Leaf area (cm^2)	Chlorop-hyll content (SPAD)	Weight of 1000 grain (g)	grain yield $plant^{-1}$ (g)
0 kg ha-1 Nitrogen	Q3	50.0	10.5	34.3	1.67	3.1
	Chipaya	53.0	11.1	32.1	1.60	3.0
	Line 14	55.0	10.3	33.2	1.50	3.3
	Q5	54.0	12.0	32.6	2.00	2.8
80 kg ha^{-1} Nitrogen	Q3	62.0	15.5	44.7	2.29	6.2
	Chipaya	76.0	16.6	45.0	2.20	8.2
	Line 14	73.0	17.0	53.6	2.63	7.7
	Q5	70.0	17.2	52.0	2.60	7.9
160 kg ha^{-1} Nitrogen	Q3	77.0	18.9	52.0	2.81	9.3
	Chipaya	101.0	22.8	59.3	3.10	15.8
	Line 14	103.3	22.2	66.0	3.42	14.1
	Q5	91.5	20.9	68.3	3.50	12.8
LSD $_{(0.05)}$		2.090	0.229	1.242	0.177	0.337
Interaction		Weight of grain ha^{-1} (kg)	N U E^{+} (g/g)	Crude protein (%)	Starch (%)	Fat (%)
0 kg ha-1 Nitrogen	Q3	550.3	0.0	14.1	47.5	2.61
	Chipaya	520.3	0.0	13.5	41.0	2.60
	Line 14	539.8	0.0	13.8	44.1	2.84
	Q5	547.0	0.0	14.3	43.7	2.49
80 kg ha^{-1} Nitrogen	Q3	800.5	10.01	14.9	53.0	4.11
	Chipaya	1002	12.52	14.4	49.2	3.98
	Line 14	1099	13.73	14.4	51.3	4.15
	Q5	955.3	11.93	15.3	49.1	4.20
160 kg ha^{-1} Nitrogen	Q3	1019	6.36	15.6	57.3	6.02
	Chipaya	1803	11.26	15.6	53.8	6.54
	Line 14	1743	10.89	15.0	55.3	6.61
	Q5	1593	9.95	16.2	52.1	5.70
LSD $_{(0.05)}$		11.71	0.145	0.195	0.923	0.138

Note: N U E+ = nitrogen use efficiency.

Table 7. Simple correlation coefficient among tested characters.

Trait	Plant height	Leaf area	Chloro-phyll content	Weight of 1000 grain	Grain yield plant^{-1}	Weight of grain ha^{-1}	N U E^{+}	Crude protein	Starch
Leaf area	0.97*								
Chlorophyll content	0.93*	0.95*							
Weight of 1000 grain	0.92*	0.96*	0.98*						
Grain yield plant^{-1}	0.99*	0.98*	0.93*	0.93*					
Weight of grain ha^{-1}	0.99*	0.96*	0.94*	0.93*	0.99*				
N U E*	0.71*	0.79*	0.78*	0.73*	0.73*	0.71*			
Crude protein	0.74*	0.84*	0.84*	0.88*	0.80*	0.76*	0.60*		
Starch	0.75*	0.83*	0.80*	0.81*	0.78*	0.73*	0.69*	0.78*	
Fat	0.95*	0.96*	0.91*	0.92*	0.96*	0.93*	0.67*	0.83*	0.88*

Note: * = Significant at 0.05; N U E+ = nitrogen use efficiency.

In the same manner, simple correlation coefficients among agronomic traits (weight of 1000 grain, grain yield plant^{-1} and nitrogen fertilizer efficiency) clearly indicate that nitrogen fertilizer efficiency recorded the lowest value (0.71) while the grain yield plant^{-1} was the highest (0.99) with grain yield ha^{-1} under overall studied treatments conditions of all tested genotypes (Table 7).

In Table (8) and Fig 2, the contribution of the direct effects of vegetative traits (plant height, leaf area and chlorophyll content) in the grain yield per hectare were negative and the highest value of the leaf area was recorded (-2.0992). Also, the data indicate that the highest contribution to plant height trait in grain yield/hectare indirectly was through grain yield/plant trait (2.0921) while, chlorophyll content recorded the highest positive value indirectly through weight of 1000 grain (1.6458) and the highest negative value was (-2.0005) through leaf area for grain yield/hectare. For agronomic traits at harvesting, the direct effects of them were positive and grain yield/plant recorded the highest value (2.1175) in contribution of grain yield/hectare. The data also indicate that the weight of 1000 grain and NUE recorded the highest readings for them through the indirect contribution through the grain yield/plant to support the grain yield/hectare. While, direct effects of protein and starch were negative and negligible (-0.2516 and -0.1172, respectively) for grain yield/hectare and they recorded the highest values for them indirectly through weight of 1000 grain and grain yield / plant, while correlation of fat trait was positive (0.4408).

Table 8. Partitioning of correlation coefficients into direct and indirect effect of tested traits with grain yield ha^{-1} of quinoa genotypes under different nitrogen levels.

Trait	Plant height	Leaf area	Chloro-phyll content	Weight of 1000 grain	Grain yield plant $^{-1}$	NUE^{+}	Protein	Starch	Fat
	Direct effect								
	-0.2928	-2.0992	-0.8354	1.6811	2.1175	0.4220	-0.2516	-0.1172	0.4408
	Indirect effect								
Plant height		-0.2834	-0.2717	-0.2703	-0.2893	-0.2091	-0.2164	-0.2190	-0.2767
Leaf area	-2.0320		-2.0005	-2.0194	-2.0530	-1.6647	-1.7654	-1.7528	-2.0257
Chlorophyll content	-0.7752	-0.7961		-0.8178	-0.7794	-0.6533	-0.7042	-0.6675	-0.7635
Weight of 1000 grain	1.5517	1.6173	.6458		1.5567	1.2188	1.4760	1.3533	1.5517
Grain yield plant $^{-1}$	2.0921	2.0709	1.6458	1.9608		1.5373	1.6897	1.6516	2.0285
N U E^{+}	0.3013	0.3347	0.3300	0.3060	0.3064		0.2545	0.2929	0.2823
Protein	-0.1859	-0.2116	-0.2121	-0.2209	-0.2007	-0.1517		-0.1970	-0.2078
Starch	-0.0877	-0.0979	-0.0937	-0.0944	-0.0914	-0.0813	-0.0918		-0.1036
Fat	0.4166	0.4254	0.4029	0.4069	0.4223	0.2949	0.3641	0.3897	
Weight of grain ha^{-1}	0.988	0.960	0.941	0.932	0.989	0.713	0.755	0.734	0.926

Note: N U E+ = nitrogen use efficiency.

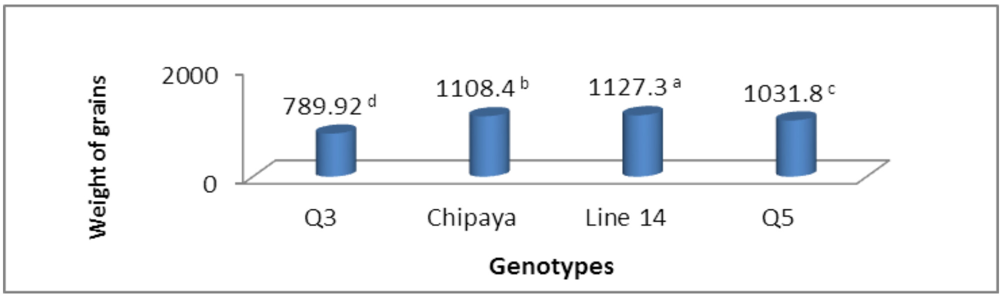

Fig.1. The differential response of tested genotypes for grain yield ha^{-1}.

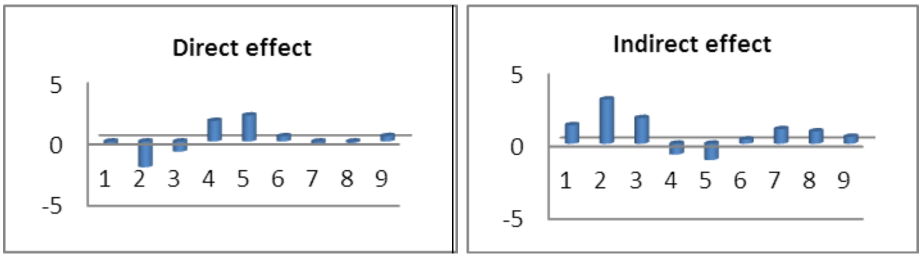

Fig. 2. The effect of direct and indirect contributions to the tested traits on the yield.

Note:1, plant height; 2, leaf area;3, chlorophyll content; 4, weight of 1000 grain;5, grain yield per plant; 6, N U E; 7, protein; 8, starch; 9,fat.

DISCUSSION

The application of nitrogen fertilization and the contribution directly or indirectly of each character are the most important topics that play an important role in determining the grain yield and its quality. Cereal crops are dependent on N compounds to be used for grain filling stage, which was taken during the pre-synthesis period; therefore, good grain crops are characterized by their ability to N-remobilization processes (Gonzalez-Dugo *et al.* 2010).

The data in Table 2 indicate that, nitrogen use efficiency recorded the highest value at 80 kg nitrogen fertilizer level compared with fertilization at the level of 160 kg and this is in harmony with the data of the grain yield in table 3, which was superior in the relative increase of grain yield/plant and grain yield/hectare when increasing nitrogen fertilization level from 0 to 80 kg compared with relative increasing of both grain yield/plant and grain yield/ hectare with increasing nitrogen fertilization level from 80 to 160 kg and These results are in harmony with Erley *et al* (2005) and Bhargava *et al* (2006) who stated that grain yield of quinoa plant/hectare was affected by nitrogen fertilization from 0 nitrogen (1790 kg grain) to 120 kg nitrogen (3495 kg grain). Also, the results in Table 2 are in harmony with Basra et al. (2014) who confirmed that the protein content of the grain depends on the availability of nitrogen, and that quinoa plant is responsive to nitrogen fertilization. In the same manner, the studies have confirmed that the plant height of quinoa plant increases with the increase in the level of nitrogen due to the role of metabolic activity that stimulates nitrogen, which contributes to the increase in the amount of metabolites and the result of elongation of the internodes and thus increase the length of the plant with the increase of nitrogen level (Jacobsen *et al* 1994 and Erley *et al* 2005.

On the other hand, there are some characteristics which were almost equal in the relative increasing index using nitrogen fertilization level from 0 to 80 kg or from 80 to 160 kg as plant height and crude protein while the other characters decrease with increasing nitrogen fertilizers levels (Table 3) and this result is consistent with Erley *et al* (2005) and Bhargava *et al* (2006) who explained that plant height, maturation stage and grain yield of quinoa increased under optimum soil conditions, but increasing of nitrogen fertilizer levels, grain yield was decreased use result of plant lodging.

Correlation coefficients between studied traits and yield are very important in plant breeding programs for indirect selection and have also been of major value in the evaluation of the most effective plant breeding methods, The relationship between the grains yield to a single variable may not provide a complete understanding about the importance of each component in determining seed yield of crop (Dewy and Lu 1959). So, they added that, path coefficient analysis is a statistical technique of partitioning the correlation coefficient into its direct and indirect effects so that, the contributions of each trait to grain yield of crop could be estimated. In general, the results for correlation coefficient between the studied traits, which ranged from 0.71 to 0.99, indicate the success of selecting of these traits for evaluating their role in contributing to the grain yield / hectare in particular plant height, grain yield/plant and fat%.

The results in Table 7 and Fig 2 emphasize that selection of both leaf area and chlorophyll content (direct selection) would not be reliable criteria for improving grain yield and this should be done through grainy yield/plant and weight of 1000 grain (indirect selection). This trend is consistent with the plant breeders who prefer yield components that indirectly increase yield (Yasin and Singh 2010). On the other hand, the direct effect of grain yield/plant (at harvesting) and fat% (as an estimate laboratory post-harvest) on grain yield/hectare is greater than indirect effect of other traits indicates that direct selection of grain yield/plant may be reliable criteria for improving grain yield/hectare. These results agreement with Singh and Kakar (1977) and Singh and Chaudhary (1995), who reported that, if the correlation between a causal factor and the effect is almost equal to its direct, then correlation explains the true relationship and a direct selection through this trait well be effective.

CONCLUSIONS

Application of N fertilizer and the contribution of each studied character are the most important points that determine the grain yield of crop and its quality with different significant values between tested genotypes. The rate of increase of nitrogen fertilization from 0 to 80 kg is greater than the rate of increase in the addition of nitrogen fertilization from 80 to 160 kg for grain yield. The variety of quinoa differs significantly according to the level of nitrogen fertilization and both Chipaya yield and Line14 showed their superiority in the grain yield. The direct effect of grain/plant (at harvest) and the percentage of fat (post-harvest estimate) on grain yield/hectare can be relied upon as criteria for selection to improve grain yield/hectare.

ACKNOWLEDGEMENT

The authors are grateful to the staff members at Beni-Suief, Egypt during 2016 and 2017 seasons for assistance during the field work and researches Centers for support using tested genotypes.

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تحليل معامل المرور للمحصول ومكوناته فى الكينوا
تحت مستويات النيتروجين المختلفة

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إن تطبيق التسميد النيتروجيني من أهم النقاط التي تحدد محصول الحبوب وجودته. وقد تم إجراء تلك التجربة الحقلية لتحديد الاستجابة المختلفة لأربعة تراكيب وراثية من الكينوا تحت ٣ مستويات مختلفة من التسميد النيتروجيني. وقد أشارت النتائج إلى أن النمط الوراثي Chipaya و Line 14 تفوقا في محصول الحبوب/هكتار. بينما سجل التركيب الوراثي Q5 أعلى قيمة للبروتين عند استخدام ١٦٠ كجم نيتروجين. كما أظهرت كفاءة استخدام النيتروجين أن نسبة كفاءة استخدام النيتروجين عند زيادة التسميد النيتروجيني من صفر الي ٨٠ كجم نيتروجين أعلي من نسبة كفاءة استخدام النيتروجين عند زيادة التسميد النيتروجيني من ٨٠ الي ١٦٠ كجم نيتروجين. وفيما يتعلق بمعامل الارتباط فقد سجلت اقوي علاقة بين محصول الحبوب للهكتار وكلا من إرتفاع النبات ومحصول الحبوب للنبات . وبالنظر الي تحليل معامل المرور، أظهر محصول الحبوب ووزن ١٠٠٠حبة متبوعين بنسبة الدهون (%) تأثيرات مباشرة موجبة عالية على محصول الحبوب/هكتار. من النتائج السابقة يمكننا أن نخلص الي أن صفة ارتفاع النبات فعالة في الانتخاب غير المباشر خلال المراحل المبكرة للنمو، في حين أن صفتي محصول الحبوب للنبات، وزن ١٠٠٠ حبة كانا الأكثر فاعلية في الانتخاب المباشر لمحصول الحبوب/هكتار عند مرحلة الحصاد.