



## EFFECT OF DIFFERENT NITROGEN FERTILIZER RATES AND SOURCES ON LEAF CHEMICAL COMPOSITIONS AND YIELD OF QUINOA PLANT AS A NEW LEAFY VEGETABLE CROP

[62]

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### ABSTRACT

Quinoa (*Chenopodium quinoa* Willd.) has gained increased a worldwide attention since 1970s when it has been revived as a new food crop, due to the attractive nutritive value and potential health benefits as well as to its exceptional tolerance to several environmental stresses. It is considered as a new non-traditional leafy vegetable crop newly introduced to Egypt. Nitrogen requirements for quinoa plants are not clarified yet and the numbers of studies is still quite limited. The present study was conducted to evaluate the effect of nitrogen sources as ammonium sulfate 20.6% or calcium nitrate 15.5% used at rates of 40, 60 or 80 kg N/feddan on leaf chemical compositions and yield of two quinoa cultivars of Cica and Hualhuas harvested after 40 days from sowing date. A field experiment was carried out at the Experimental Farm of the Horticulture Dept., the Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Cairo, Egypt, during the two winter seasons of 2015 and 2016. The treatments were laid out in a split plot design, with three replicates. The obtained results revealed that Cica cultivar was superior to Hualhuas concerning all measured chemical parameters of leaves and leaf yield during both seasons, except for leaf contents of chlorophyll a, b and total chlorophyll, ash, fats, Ca and Fe, where Hualhuas cultivar was superior to Cica in these parameters. However, no significant differences were detected between both cultivars regarding leaf carbohydrates content in both seasons. Re-

garding nitrogen rates and sources, quinoa plants received 80 kg N/feddan as calcium nitrate gave the highest significant values of carotenoids, nitrate, proteins, ash, N, K and Fe contents in both seasons of the study. Whereas, nitrogen treatment of 80 kg N/feddan from ammonium sulfate gave the highest values of leaf contents of Ca and leaf yield in both seasons. Nitrogen treatment of 60 kg N/feddan from calcium nitrate showed the highest significant values of chlorophyll a, b and total chlorophyll contents during both seasons. No significant differences were realized among all nitrogen treatments (rates and sources) on P content in both seasons. In relation to the interaction effect, the results clearly revealed that leaves of Cica plants received 80 kg N/feddan either from ammonium sulfate or calcium nitrate recorded significant increases in carotenoids, nitrate, proteins, ash, N, P, K and Na contents as well as yield without significant differences between them. On the other hand, the best values of chlorophyll a, b, total chlorophyll in both seasons were attained when Hualhuas plants received 60 kg N/feddan from calcium nitrate. Moreover, there were no significant differences noticed among nitrogen treatments applied to Cica plants in both seasons on Na. Furthermore, the best values of Zn content were obtained when Cica plants treated with 40 kg N/feddan from ammonium sulfate or 60 kg N/feddan from calcium nitrate without significant differences between them in both seasons of the study. Given the experimental conditions of this study, it is concluded that Cica plants received 80

kg N/feddan either from ammonium sulfate or calcium nitrate gave the highest yield of leaves with acceptable quality attributes.

**Keywords:** *Chenopodium quinoa*, Nitrogen, Mineral fertilization, Chemical compositions, leaf yield

## INTRODUCTION

Leafy vegetables are important elements of human diet, since they are well known as a cheap source of vitamins, pigments, health promoting agents, minerals and dietary fibers. In addition, they are low in fats and calories (Toledo et al 2003). So they are essential and important to human health, preventing the major chronic diseases such as cardiovascular diseases and certain cancers (Patil et al 2009). Unfortunately, the consumption of leafy vegetables is still too little; it is not exceeding even half of the recommended daily intake requirement 80 g per day (FAO, 2003).

Nitrogen is an essential element for plant growth and development. It is required by all plants in comparatively larger amounts than any other elements (constitutes 2-4% of plant dry matter). It has an important role as a basic element of protein, amino acids, nucleic acids (nitrogenous bases), enzymes, growth hormones and secondary products (Madan and Munjal, 2009). Also, nitrogen plays a role in chlorophyll formation and hence the photosynthesis and carbon dioxide assimilation processes (Jasso-Chaverria et al 2005). It is generally the most limiting nutrient factor for the growth, yield and quality of leafy vegetables including quinoa which are characterized by short-life cycle plants (Shaheen et al 2012). Farmers have increased application of N fertilizers to their land yearly without considering the response of different plant species to nitrogen rates or forms. A major drawback of excessive application of chemical nitrogen fertilizers, leads to groundwater pollution, negative implications on the environment and aggravate the climate change (Korkmaz et al 2008; Ravishankara et al 2009 and Reay et al 2012), and serious health hazards due to the accumulation of high levels of nitrate in edible portions of the crops (Crawford & Glass, 1998 and Hord et al 2009). In addition to the amount of nitrogen applied, the form of the available nitrogen; ammonia nitrogen ( $\text{NH}_4^+$ -N) or nitrite nitrogen ( $\text{NO}_3^-$ -N) has a significant effect on the growth, photosynthesis (Ali et al 2013), yield and quality of plants (Lošák et al 2008). However, nitrogen requirements for quinoa as a new crop are not clarified yet and the number of studies is still quite limited.

Quinoa (*Chenopodium quinoa* Willd.), is a member of *Amaranthaceae* family. It is a very important cultivated staple food crop in the Andean countries for more than 5000 years and known as Inca rice (Brinegar et al 1996). Recently, quinoa has gained an increased worldwide attention since 1970s, when it has been revived as a new food crop, due to the attractive nutritive value and potential health benefits as well as to its exceptional tolerance to several environmental stresses. It is cultivated globally in more than 70 countries outside of Andean region (Comai et al 2007). It is considered as a new non-traditional multipurpose cash crop halophyte newly introduced to Egypt (Eisa et al 2017). Quinoa has a variety of uses in the food, feed, food processing and other non-food/industrial uses (Bhargava et al 2006). Quinoa leaves are a good source of protein containing an average of 20% protein with well-balanced amino acids, and it has all of the essential amino acids including lysine, methionine and threonine that are scarce in cereals and legumes (Abugoch, 2009; Escuredo et al 2014). Bhathal et al (2015) revealed that quinoa leaves contain chlorophyll a (0.48-1.82 mg/g), chlorophyll b (0.25-0.07 mg/g), high amount of leaf carotenoids (230.23-669.57 mg/kg) and moisture (83.92-89.11%). *Chenopodium* spp. has been cultivated as a leafy vegetable and subsidiary grain crop in different parts of the world. In addition, it is a rich source of K (6.329 mg/100g), Ca (1.154 mg/100g), Na (8.350 mg/100g) and Fe (83.92 mg/100g) as reported by Bhargava et al (2010). Quinoa leaves are different in their color (green, purple, red), with the reddish color due to the presence of a type of betacyanins pigment called betalains (Gallardo et al 2000). They are typically cooked and served as a side dish, similar to amaranth leaves (Mlakar et al 2010) or spinach. Fresh leaves and sprouts of quinoa are edible and may be consumed in salad, and also used as a valuable supplement for functional or complete foods and fortification (Gawlik-Dziki et al 2009 & 2015), also they have a high nutritional value, as well as high antioxidant and anticancer activities (Gawlik-Dziki et al 2013; Świeca et al 2014). Young quinoa leaves showed no detectable amounts of saponins approximately less than 0.015% (Burnouf-Radosevich and Paupardin, 1983). Accordingly, FAO has selected quinoa as one of the crops that ensuring food security in this century, and declared the year 2013 as the "International Year of Quinoa" (FAO, 2013).

Mujica et al (2001) stated that quinoa has high requirements for nitrogen (N) and calcium (Ca),

moderate for phosphorous (P), and minimal for potassium (K). However, quinoa is highly responsive to soil nitrogen application (Erley et al 2005). The response of growth, development and yield of two quinoa genotypes to nitrogen fertilizer application was studied by Basra et al. (2014). Nitrogen fertilization affects protein and increasing essential amino acid contents of quinoa and amaranth (Thanapornpoonpong et al 2008). Plants can utilize both nitrate (NO<sub>3</sub><sup>-</sup>) and ammonium (NH<sub>4</sub><sup>+</sup>) as a nitrogen source (Marschner, 1995 and Tschoep et al 2009). Amongst many N sources, ammonium sulfate (20.6%) and calcium nitrate (15.5%) are commonly used in Egypt. In this regard, increasing the application rate of ammonium sulphate and urea fertilizers from 0 to 150 kg N ha<sup>-1</sup> led to significant increases in yield, leaf N and NO<sub>3</sub> but they decreased P, Zn and Mn contents of spinach plants, and also significant differences were realized between the studied cultivars on leaf nitrate content (Gülser, 2005). In the same regard, increasing the N levels from 0 to 120 kg N ha<sup>-1</sup> significantly increased the yield of lettuce while yield decreased at the highest nitrogen dose 180 kg N ha<sup>-1</sup> (Boroujerdnia and Ansari, 2007). Increasing ammonium rate of application enhanced the level of P, but decreased the levels of K, Ca and Mg in leaves of lettuce (Guo et al, 2007). Not only nitrogen rates, but also nitrogen forms (Stagnari et al., 2007) as well as nitrate-ammonium fertilization ratio (Conesa et al 2009) affect nitrate accumulation in plant tissue. Leaf nitrate content increased with increasing nitrogen fertilizer levels of Swiss chard (Engelbrecht et al 2010), lettuce (Liu et al 2014) and spinach (Hammad et al 2007). In addition, calcium nitrate fertilizer was the best source of nitrogen for lettuce head production which resulted in significantly higher yields as compared to ammonium sulfate (Piotr and Kolota, 2011). Conversely, Wang and Li (2003) reported that nitrate

N fertilizers tended to increase leaf nitrate accumulation compared to the ammonium N fertilizers. In addition, Ezzo et al (2008) studied the effect of three nitrogen fertilizer rates and three nitrogen sources on head productivity and nitrate accumulation in two salad cabbage cultivars. They stated that the highest head weight and the lowest nitrate accumulation were obtained with the medium level (17.5 g N/m<sup>2</sup>) of ammonium sulphate application.

Nitrogen requirements for quinoa as a new non-traditional crop are not clarified yet and the number of studies is still quite limited. Also, little information is available concerning the nutritional value and chemical compositions of quinoa leaves as affected by rates and sources of nitrogen fertilizers. Therefore, the current study was undertaken to evaluate the influence of different nitrogen rates and sources on leaf chemical compositions and plant yield of two promising quinoa genotypes (Cica and Hualhuas) harvested after 40 days from sowing date as a new leafy vegetable crop in Egypt.

## MATERIALS AND METHODS

The field experiment was carried out during the two successive winter growing seasons of 2015 and 2016 at the Experimental Farm of Horticulture Dept. (altitude 22 m above sea level, latitude 30° 06' 48" N and longitude 31° 14' 52" E), Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Cairo, Egypt. In order to determine the effect of nitrogen fertilizer rates (40, 60 or 80 kg N/feddan) and sources, i.e. ammonium sulphate [(NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> 20.6% N-NH<sub>4</sub><sup>+</sup>] or calcium nitrate [Ca(NO<sub>3</sub>)<sub>2</sub> 15.5% N-NO<sub>3</sub><sup>-</sup>] on leaf chemical compositions and plant yield of two quinoa genotypes. The physical and chemical properties of the experimental soil are presented in Table 1.

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

Soil physical properties											
Sand (%)			Clay (%)			Silt (%)			Texture		
28.1			33.3			38.6			Clay Loam		
Soil chemical analysis											
ECe (dSm <sup>-1</sup> )	pH	OM (%)	CaCO <sub>3</sub> (%)	meq/l							
				Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	SO <sub>4</sub> <sup>=</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	
1.9	7.46	1.51	1.72	7.2	4.1	6.4	1.4	6.7	3.8	9.0	

### Experimental design

The experiment was laid out in a split-plot design with 3 replicates. The two quinoa cultivars

(Cica and Hualhuas) were randomly distributed within the main plot, while the six nitrogen treatments (source of nitrogen combined with the nitrogen rate; calcium nitrate at 40 kg N/feddan, calcium nitrate at 60 kg N/feddan, calcium nitrate at 80 kg N/feddan, ammonium sulphate at 40 kg N/feddan, ammonium sulphate at 60 kg N/feddan and ammonium sulphate at 80 kg N/feddan) were randomly arranged within the sub-plots. The net area of each sub-plot was 2 m<sup>2</sup> (1 m width x 2 m length). Furthermore, each sub-plot was surrounded by a guard border of 0.5 m from all sides to avoid the interaction of nitrogen fertilization treatments.

#### Experimental soil preparation and quinoa cultivation

Experimental soil was prepared by land plough in two perpendicular directions and the organic manure as compost at rate of 10 ton/feddan, and phosphorus at 30 kg P<sub>2</sub>O<sub>5</sub>/feddan as calcium super-phosphate (15.5% P<sub>2</sub>O<sub>5</sub>) were applied during the final preparation of experimental soil and thoroughly mixed with the soil. The three nitrogen rates from both sources were divided into two doses, the first dose was one third added during land preparation while the second dose was two thirds of amount, added after 20 days after seed sowing.

Seeds of the two quinoa cultivars Cica (Centro Internacional de Cultivos Andinos, Peru) and Hualhuas (International Potato Center CIP, Lima, Peru) were surface sterilized firstly before sowing with ethanol 70% for 10 sec., then with sodium hypochlorite solution (5% active chloride) for 10 minutes. Then, the seeds were thoroughly washed with a plenty of distilled water several times to ensure complete elimination of chloride traces and then the seeds were dried between two layers of tissue paper. After that, seeds were left to dry in air before planting. Washed dried seeds of both quinoa genotypes were sown in the second week of November, in both seasons, in rows with 2 m length and 20 cm inter-row distance with a capacity of 5 rows per each experimental sub-plot. However, the first and fifth rows were left as an additional guard plant border among experimental sub-plots to avoid the interaction of nitrogen fertilization treatments. The normal agricultural practices of the regular irrigation, controlling of pest, disease and weed were followed. A plant density was maintained in a range of 275-290 plants/m<sup>2</sup>; this was achieved through seeding rate of about 15 and 10 g of seeds per each experimental sub-plot of cvs

Cica and Hualhuas, respectively. Young quinoa plants of the two quinoa cultivars were randomly harvested from the middle of each experimental sub-plot after 40 days from sowing date (six weeks later) in the fourth week of December in both seasons of the study.

#### Data recorded

At 40 days after seed sowing, a sample of 25 young plants of the two quinoa cultivars were randomly harvested by cutting the plants at the soil surface early in the morning after evaporation of dew, from the middle of each experimental sub-plot. Then the leaves were separated from their stalks, washed under running distilled water, and then were spread on filter paper at room temperature for 1 h. then, were dried in an oven at 70°C till constant weight. The dried leaf samples were finely ground in a high speed grinder stainless-steel miller to pass a 1 mm sieve and subjected to different analysis of chemical compositions and nutritional values parameters.

#### Leaf pigment contents

Chlorophyll a, b and total (a+b) as well as carotenoids were determined according to **Moran (1982)**.

#### Percentage of ash, crude fiber, crude fat and crude protein

Ash content, crude fiber and crude fat of ground dried leaf samples was determined according to the methods described in **AOAC (2016)**. The percentage of total nitrogen in dried leaf samples was converted to crude protein by using the conversion factor of 6.25.

#### Total carbohydrate

Total carbohydrate was determined using the phenol-sulfuric acid method as described by **Du-Bois et al (1956)**.

#### Nitrate content

Nitrate content in dried leaves was determined according to **Al-Moshleh et al (2004)** using the HORIBA LAQUA twin NO<sub>3</sub><sup>-</sup> Nitrate Meter (Spectrum Technologies, Inc., Aurora, IL, USA).

### Leaf mineral

Total nitrogen was determined using the Kjeldahl method and phosphorus was also assayed according to the modified colorimetric method (molybdenum blue) using spectrophotometer (SPECTRONIC 20D, Milton Roy Co. Ltd., NY, USA) according to the procedures described by **Cottenie et al (1982)**. Potassium and sodium were measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., Staffordshire, UK). In addition, calcium, iron and zinc were determined using atomic absorption spectroscopy (AAAnalyst 200, Perkin Elmer Inc., MA, USA), as described by **Chapman and Pratt (1982)**.

### Yield of quinoa plants

Another sample of 15 young plants were randomly harvested as previously described. The average plant fresh weight was recorded and plant yield/m<sup>2</sup> was estimated by multiplying the average plant fresh weight by the average number of plant per square meter (180-200 plants).

### Statistical analysis

All data sets were tabulated and subjected to statistical analysis according to the procedures reported by **Gomez and Gomez (1984)**.

## RESULTS

### Leaf pigments

Data presented in **Table 2** showed that Hualhuas was superior to Cica cultivar in leaf chlorophyll contents (chlorophyll a, b and total). On the other hand, Cica was superior to Hualhuas cultivar in content of carotenoids. The same trends were similar in both seasons of the study.

Regarding the effect of nitrogen rates of the different nitrogen sources, the treatment of 60 kg N/feddan of calcium nitrate gave the highest significant values of chlorophyll a, b and total in both seasons of the study. On the other hand, the highest significant value of carotenoids was obtained by 80 kg N/feddan of calcium nitrate in the first season and without significant differences in the second one. On the contrary, the lowest values were obtained with the lowest amounts of nitrogen of both sources.

As for the interaction, plants of Hualhuas cultivar fertilized with 40 or 60 kg N/feddan of calcium nitrate recorded the highest significant values of chlorophyll a content, without a significant difference between both of them. The highest significant value of leaf chlorophyll b and total chlorophyll contents were obtained by plants of Hualhuas cultivar fertilized with 60 or 80 kg N/feddan of ammonium sulfate or with 60 kg N/feddan of calcium nitrate, without significant differences among them. Furthermore, quinoa plants of Cica cultivar received 80 kg N/feddan of calcium nitrate recorded the highest significant values of carotenoids content in both growing seasons.

### Ash, crude fibers and crude fats

Hualhuas cultivar gave significantly higher values of ash and fats than Cica cultivar in both seasons of the study. While Cica cultivar recorded the higher significant value of the percentage of crude fibers in the first season, with insignificant differences in the second one (**Table 3**).

Concerning the effect of nitrogen treatments, application of 80 kg N/feddan of calcium nitrate gave the highest value of ash percentage in both seasons. The highest significant values of crude fiber and fat percentages were obtained by the applying 40 kg N/feddan of ammonium sulfate in both seasons.

Concerning the interaction, the obtained results strongly indicated that leaves of young quinoa plants of Cica or Hualhuas cultivar fertilized by 40 kg N/feddan of calcium nitrate showed the highest significant values of ash percentage in both seasons.

The highest values of crude fibers were noticed with plants of Cica cultivar received 60 kg N/feddan of ammonium and those of Hualhuas cultivar treated by 40 kg N/feddan of ammonium sulfate in both seasons without significant differences between them.

In respect of the percentage of fats in leaves of the young plants, the highest significant value was obtained by plants of Hualhuas when treated with 40 kg N/feddan of ammonium sulfate followed by those the same cultivar applied with 40 kg N/feddan calcium nitrate in both seasons of the study. The lowest values were detected when Cica plants received 80 kg N/feddan of calcium nitrate in both seasons of the study (**Table 3**).

**Table 2.** Effect of cultivars and nitrogen rates of different sources on chlorophyll and carotenoids contents of leaves of quinoa plants harvested at 40 days after sowing, in winter seasons of 2015 and 2016.

Treatments	Chlorophyll a (mg/g fresh weight)		Chlorophyll b (mg/g fresh weight)		Total chlorophyll (mg/g fresh weight)		Carotenoids (mg/g fresh weight)		
	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	
	<b>Cultivars</b>								
<b>Cica</b>	13.33 B	15.73 B	4.44 B	4.87 B	17.77 B	20.60 B	1.91 A	2.01 A	
<b>Hualhuas</b>	18.61 A	19.63 A	6.96 A	7.61 A	25.57 A	27.24 A	1.57 B	1.73 B	
<b>Nitrogen rates of different sources</b>									
<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	13.86 B	16.14 C	5.94 B	5.55 C	19.80 B	21.69 C	1.68 C	1.83 A	
<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	16.15 A	17.29 BC	5.97 A	6.28 B	22.12 A	23.57 B	1.68 C	1.86 A	
<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	16.21 A	16.82 C	5.93 B	6.45 B	22.14 A	23.27 B	1.73 BC	1.94 A	
<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	16.98 A	18.49 B	5.39 C	5.61 C	22.37 A	24.10 B	1.74 BC	1.87 A	
<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	16.87 A	19.84 A	6.00 A	7.27 A	22.87 A	27.11 A	1.76 B	1.86 A	
<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	15.75 A	17.53 BC	5.97 A	6.26 B	21.72 A	23.79 B	1.87 A	1.88 A	
<b>Cultivars x Nitrogen rates of different sources</b>									
<b>Cica</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	12.24 d	13.44 f	3.73 e	4.29 d	15.97 e	17.73 e	1.75 d	1.92 c
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	13.28 d	14.59 ef	4.57 cd	4.53 d	17.85 de	19.12 e	1.88 c	2.00 bc
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	13.81 cd	14.41 ef	4.50 cd	4.66 d	18.31 d	19.07 e	2.01 b	2.19 a
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	12.74 d	17.00 cd	4.25 d	4.43 d	16.99 de	21.43 d	1.76 d	1.89 cd
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	14.12 cd	18.62 bc	4.68 cd	5.93 c	18.80 d	24.55 c	1.91 c	2.01 bc
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	13.79 cd	16.34 de	4.92 c	5.36 c	18.71 d	21.70 d	2.18 a	2.09 ab
<b>Hualhuas</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	15.47 c	18.84 bc	6.14 b	6.80 b	21.61 c	25.64 bc	1.62 e	1.73 de
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	19.01 b	19.99 ab	7.36 a	8.03 a	26.37 ab	28.02 ab	1.47 fg	1.71 e
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	18.61 b	19.22 ab	7.36 a	8.25 a	25.97 ab	27.47 ab	1.46 g	1.70 e
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	21.23 a	19.98 ab	6.53 b	6.80 b	27.76 a	26.78 bc	1.72 d	1.86 cde
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	19.62 ab	21.05 a	7.33 a	8.60 a	26.95 a	29.65 a	1.61 e	1.71 e
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	17.71 b	18.72 bc	7.02 a	7.16 b	24.73 b	25.88 bc	1.55 ef	1.68 e

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

**Table 3.** Effect of cultivars and nitrogen rates of different sources on ash, crude fibers and fats of plants harvested at 40 days after sowing, as in winter seasons of 2015 and 2016.

Treatments	Ash (%)		Crude fibers (%)		Crude fats (%)		
	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	
<b>Cultivars</b>							
Cica Hualhuas	2.36 B	2.32 B	10.87 A	12.67 A	0.82 B	0.99 B	
	2.38 A	2.37 A	9.50 B	12.98 A	1.25 A	1.28 A	
<b>Nitrogen rates of different sources</b>							
40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.23 C	2.26 CD	12.84 A	13.05 AB	1.30 A	1.40 A	
60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.35 B	2.25 CD	9.02 C	13.33 A	1.11 B	1.04 BC	
80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.41 A	2.30 C	9.41 C	13.37 A	0.93 C	0.93 CD	
40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.42 A	2.41 B	9.17 C	12.92 AB	1.11 B	1.45 A	
60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.42 A	2.31 C	9.73 C	12.03 BC	0.90 C	1.14 B	
80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.40 A	2.54 A	10.93 B	11.98 C	0.88 C	0.86 D	
<b>Cultivars x Nitrogen rates of different sources</b>							
Cica	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.19 g	2.24 f	13.62 a	12.60 bcd	0.94 de	1.23 cd
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.33 e	2.17 g	10.85 bc	13.51 ab	0.89 ef	0.91 f
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.43 ab	2.24 f	10.10 cd	12.64 bc	0.78 fg	0.85 f
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.42 ab	2.37 bcd	9.82 cde	12.32 cd	0.88 ef	1.38 bc
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.37 cde	2.26 f	10.09 cd	12.43 bcd	0.74 g	0.93 f
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.41 bc	2.66 a	10.75 c	12.51 bcd	0.70 g	0.63 g
Hualhuas	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.27 f	2.29 ef	12.06 b	13.51 ab	1.66 a	1.56 a
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.36 de	2.33 de	7.20 g	13.10 abc	1.33 b	1.16 de
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.38 bcd	2.37 bcd	8.72 ef	14.10 a	1.08 c	1.01 ef
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.43 ab	2.44 b	8.52 f	13.52 ab	1.33 b	1.51 ab
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.46 a	2.36 cd	9.37 def	12.17 cd	1.07 cd	1.34 c
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.39 bcd	2.42 bc	11.11 bc	11.46 d	1.05 cd	1.10 de

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

### Crude proteins, total carbohydrates and nitrate

Data presented in **Table 4** showed that the young plants of Cica cultivar gave higher significant values of crude proteins in leaves than Hualhuas plants. However, those of Hualhuas cultivar recorded lower contents (195.55 and 174.44 ppm) of leaf nitrate content than Cica plants (280.0 and 223.89 ppm) during both seasons of the study. But, no significant differences were recorded between the two tested cultivars regarding total carbohydrates during both seasons of the study.

As for the effect of nitrogen treatments, application of 80 kg N/feddan of calcium nitrate gave significantly the highest values of protein percentage and nitrate content compared to the rest of nitrogen treatments in both seasons of the study. The lowest values of leaf nitrate content were attained by nitrogen treatment of 40 kg N/feddan of ammo-

nium sulfate in both seasons. In respect of the percentage of total carbohydrates, application of 60 or 80 kg N/feddan of calcium nitrate gave the highest percentages of total carbohydrates without significant differences between both treatments.

As to the interaction, the plants of Cica fertilized by 80 kg N/feddan either from ammonium sulfate or calcium nitrate gave the highest significant percentages of crude proteins compared to the rest of the treatments. On the other hand, the lowest percentages of crude proteins were attained when Hualhuas plants were supplied with 40 kg N/feddan of calcium nitrate. These findings were true in both seasons of the study. Leaves of Cica plants showed the highest significant percentages of total carbohydrates when received 80 kg N/feddan of calcium nitrate in relative to the other treatments whereas those of Hualhuas cultivar contained the highest values without differences between both treatments in the two seasons.

**Table 4.** Effect of cultivars and nitrogen rates of different sources on crude proteins, total carbohydrates and nitrate of quinoa plants harvested at 40 days after sowing, in winter seasons of 2015 and 2016.

Treatments	Crude proteins (%)		Total carbohydrates (%)		Nitrate (ppm)		
	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	
<b>Cultivars</b>							
<b>Cica</b>	21.84 A	21.85 A	15.43 A	14.02 A	280.00 A	223.89 A	
	20.72 B	19.27 B	15.27 A	14.48 A	195.55 B	174.44 B	
<b>Hualhuas</b>	21.84 A	21.85 A	15.43 A	14.02 A	280.00 A	223.89 A	
	20.72 B	19.27 B	15.27 A	14.48 A	195.55 B	174.44 B	
<b>Nitrogen rates of different sources</b>							
<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	20.15 D	19.16 E	14.02 B	14.11 AB	176.67 D	133.33 D	
<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	21.82 C	20.43 D	13.90 B	15.25 A	215.00 C	181.67 C	
<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	22.81 B	22.28 B	16.04 A	12.33 C	226.67 C	225.00 B	
<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	18.64 E	18.58 E	16.27 A	13.62 B	216.67 C	181.67 C	
<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	20.11 D	21.48 C	16.00 A	14.76 AB	278.33 B	218.33 B	
<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	24.17 A	23.52 A	15.88 A	15.43 A	313.33 A	255.00 A	
<b>Cultivars x Nitrogen rates of different sources</b>							
<b>Cica</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	20.63 cd	18.98 e	11.04 g	13.60 cde	213.33 de	150.00 gh
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	22.42 b	21.44 c	13.35 f	16.42 a	263.33 c	220.00 bcde
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	24.15 a	24.21 a	15.50 cd	12.02 e	286.67 bc	260.00 ab
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	19.33 e	19.12 e	18.63 a	12.83 de	250.00 cd	200.00 cdef
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	20.10 de	23.17 b	17.51 ab	13.29 cde	306.67 b	240.00 abc
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	24.44 a	24.19 a	16.52 bc	15.95 ab	360.00 a	273.33 a
<b>Hualhuas</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	19.67 e	19.34 e	16.99 b	14.62 abcd	140.00 g	116.67 h
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	21.23 c	19.42 e	14.46 def	14.10 bcd	166.67 fg	143.33 gh
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	21.46 c	20.36 d	16.57 bc	12.64 de	166.67 fg	190.00 ef
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	17.94 f	18.04 f	13.90 ef	14.41 abcd	183.33 ef	163.33 fg
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	20.15 de	19.79 de	14.48 def	16.24 a	250.00 cd	196.67 def
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	23.89 a	22.85 b	15.24 cde	14.91 abc	266.67 c	236.67 abcd

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

Regarding leaf nitrate content, the plants of Cica cultivar treated with 80 kg N/feddan from calcium nitrate recorded significantly the highest value in both seasons. In contrast, young quinoa plants of Hualhuas cultivar which received 40 kg N/feddan of ammonium sulfate gave the lowest significant values in both seasons.

#### Leaf minerals

Data shown in **Tables 5 and 6** indicated that the plants of Cica cultivar gave higher significant values of N, P, K, Na and Zn in leaves than those of Hualhuas cultivar. On the contrary, those of Hualhuas cultivar gave higher significant values of

Ca and Fe than those of Cica cultivar in both growing seasons.

Relating to the effect of nitrogen rates of the different sources, the nitrogen treatment of 80 kg N/feddan of calcium nitrate recorded the highest values of N and Fe compared to other nitrogen treatments, followed significantly by 80 kg N/feddan from ammonium sulfate treatment in both seasons of the study. On the contrary, the lowest value of N % was attained by 40 kg N/feddan of calcium nitrate treatment, while the lowest value of Fe was obtained by nitrogen treatment of 40 kg N/feddan from ammonium sulfate in both seasons of study. No significant differences were realized among nitrogen treatments on P percentages in



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both seasons and on Na percentage in the first season only. However, in the second season treatment of 40 kg N/feddan from calcium nitrate gave the highest significant percentage of Na compared to the rest of nitrogen treatments. The

highest significant percentage of K was recorded by nitrogen treatment of 60 or 80 kg N/feddan of either ammonium sulfate or calcium nitrate in both seasons.

**Table 5.** Effect of cultivars and nitrogen rates of different sources on nitrogen, phosphorus and potassium of quinoa plants harvested at 40 days after sowing, in winter seasons of 2015 and 2016.

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
		1 <sup>st</sup> Season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season
<b>Cultivars</b>							
<b>Cica</b>		3.49 A	3.50 A	0.22 A	0.13 A	2.71 A	2.17 A
<b>Hualhuas</b>		3.32 B	3.19 B	0.19 B	0.12 B	2.38 B	2.03 B
<b>Nitrogen rates of different sources</b>							
<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>		3.22 D	3.07 E	0.20 A	0.12 A	2.35 C	1.97 B
<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>		3.49 C	3.27 D	0.20 A	0.13 A	2.57 AB	2.08 AB
<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>		3.65 B	3.57 B	0.21 A	0.11 A	2.70 A	2.08 AB
<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>		2.98 E	2.97 E	0.21 A	0.12 A	2.48 BC	2.07 AB
<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>		3.22 D	3.44 C	0.20 A	0.12 A	2.53 AB	2.17 A
<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>		3.87 A	3.76 A	0.21 A	0.13 A	2.65 AB	2.23 A
<b>Cultivars x Nitrogen rates of different sources</b>							
<b>Cica</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.30 cd	3.04 e	0.20 cd	0.13 ab	2.57 abcd	1.93 c
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.59 b	3.43 c	0.21 abc	0.15 a	2.70 ab	2.70 bc
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.86 a	3.87 a	0.23 a	0.12 bc	2.80 a	2.70 bc
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	3.09 e	3.06 e	0.22 ab	0.12 bc	2.70 ab	2.17 bc
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	3.21 de	3.71 b	0.21 abc	0.13 ab	2.73 ab	2.30 ab
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	3.91 a	3.87 a	0.22 ab	0.13 ab	2.77 ab	2.50 a
<b>Hualhuas</b>	<b>40 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.15 e	3.09 e	0.20 cd	0.11 bc	2.13 f	2.00 c
	<b>60 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.40 c	3.11 e	0.18 e	0.11 bc	2.43 cde	2.10 bc
	<b>80 kg N-NH<sub>4</sub><sup>+</sup>/feddan</b>	3.43 c	3.26 d	0.19 de	0.10 c	2.60 abc	2.10 bc
	<b>40 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	2.87 f	2.89 f	0.19 de	0.12 bc	2.27 ef	1.97 c
	<b>60 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	3.22 de	3.17 de	0.19 de	0.12 bc	2.33 def	2.03 bc
	<b>80 kg N-NO<sub>3</sub><sup>-</sup>/feddan</b>	3.82 a	3.66 b	0.19 de	0.13 ab	2.53 bcd	1.97 c

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

**Table 6.** Effect of cultivars and nitrogen rates of different sources on calcium, sodium, iron and zinc of quinoa plants harvested at 40 days after sowing, in winter seasons of 2015 and 2016.

Treatments	Calcium (%)		Sodium (%)		Iron (ppm)		Zinc (ppm)		
	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	1 <sup>st</sup> season	2 <sup>nd</sup> season	
<b>Cultivars</b>									
Cica	2.06 B	1.64 B	0.36 A	0.31 A	135.77 B	172.06 B	20.53 A	18.93 A	
Hualhuas	2.53 A	1.86 A	0.31 B	0.28 B	163.41 A	176.41 A	16.53 B	14.13 B	
<b>Nitrogen rates of different sources</b>									
40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.99 D	1.54 D	0.32 A	0.28 C	109.50 B	126.73 D	17.92 B	16.32 B	
60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.14 C	1.72 BC	0.34 A	0.30 B	143.25 C	167.05 C	18.02 B	14.17 C	
80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.50 A	1.92 A	0.34 A	0.29 BC	157.42 B	191.72 B	18.32 B	16.65 B	
40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.38 B	1.82 AB	0.34 A	0.31 A	145.72 BC	163.72 C	19.55 A	16.58 B	
60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.34 B	1.63 CD	0.33 A	0.30 B	151.65 BC	173.85 BC	18.68 AB	17.38 AB	
80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.42 AB	1.87 A	0.34 A	0.29 BC	190.02 A	222.33 A	18.72 AB	18.08 A	
<b>Cultivars x Nitrogen rates of different sources</b>									
Cica	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.79 f	1.44 gh	0.33 bc	0.31 ab	100.57 g	138.03 de	22.10 a	20.17 a
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.99 e	1.66 def	0.36 ab	0.30 abc	133.57 ef	168.30 c	20.23 bc	16.60 cd
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.30 b	1.88 bc	0.37 a	0.31 ab	139.73 de	198.10 b	19.03 cd	17.23 cd
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.04 de	1.31 h	0.36 ab	0.32 a	112.63 g	162.30 cd	20.43 bc	19.97 ab
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.06 cde	1.69 cdef	0.36 ab	0.30 abc	136.50 def	177.47 bc	20.77 ab	21.33 a
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.17 bcd	1.84 bcd	0.36 ab	0.30 abc	191.63 a	188.20 bc	20.77 ab	18.30 bc
Hualhuas	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.20 bc	1.63 efg	0.31 c	0.25 d	118.43 fg	115.43 e	13.77 g	12.47 e
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.29 b	1.78 bcde	0.32 c	0.29 bc	152.93 cd	165.80 cd	15.80 f	11.73 e
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	2.70 a	1.96 b	0.32 c	0.26 d	175.10 ab	185.37 bc	17.60 de	16.10 d
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.71 a	2.34 a	0.31 c	0.31 ab	178.80 ab	165.13 cd	18.67 d	13.20 e
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.62 a	1.56 fg	0.31 c	0.30 abc	166.80 bc	170.23 bc	16.60 ef	13.43 e
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.67 a	1.91 b	0.32 c	0.28 c	188.40 a	256.47 a	16.77 ef	17.87 cd

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

On the other hand, the lowest percentage of K was obtained by nitrogen treatment of 40 kg N/feddan from ammonium sulfate in both seasons of the study. Nitrogen treatments of 80 kg N/feddan either from ammonium sulfate or calcium nitrate gave the highest significant percentages of Ca. Conversely, the lowest values of Ca were obtained by nitrogen treatment of 40 kg N/feddan from ammonium sulfate in both seasons. Regarding, Zn content, the gained results strongly demonstrated that nitrogen treatments of 60 or 80 kg N/feddan of calcium nitrate showed the highest significant values compared with the rest of treatments in both seasons.

Regarding the interaction, the plants of Cica fertilized with calcium nitrate or ammonium sulfate at any rate were superior to Hualhuas plants concerning N, P, K, Na and Zn contents in both seasons. Cica plants fertilized with 80 kg N/feddan from calcium nitrate or ammonium sulfate recorded the highest significant values of leaf nitrogen percentage in both seasons. Application of 60 or 80 kg N/feddan on Cica plants showed the highest values of leaves P and K in both seasons. In the same regards, Cica plants recorded the highest value of Zn content when supplied with 40 kg N/feddan of ammonium sulfate and with 60 kg N/feddan of calcium nitrate in both seasons.

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Quinoa plants of Hualhuas fertilized with calcium nitrate or ammonium sulfate were superior to Cica plants concerning Ca content in both seasons and Fe content when plants were applied with 80 kg N/feddan calcium nitrate. Hualhuas plants treated with 40 kg N/feddan of calcium nitrate gave the highest significant value of Ca content compared with the other treatments in both seasons. Furthermore, nitrogen treatment of 80 kg N/feddan of calcium nitrate showed the highest significant values of Fe content with Hualhuas cultivar in both seasons.

**Leaf yield of quinoa plants**

Data shown in **Table 7** clearly revealed that young quinoa plants of Cica cultivar gave the highest significant values of leaf yield in both seasons of the study.

Concerning the nitrogen fertilizer treatments, the highest leaf yield of quinoa plants was obtained by using 80 kg N/feddan of ammonium sulfate followed by 80 kg N/feddan of calcium nitrate in both seasons.

Concerning the interaction, young quinoa plants of Cica cultivar recorded the highest significant values of leaf yield when fertilized by 80 kg N/feddan of both nitrogen sources in both seasons of 2015 and 2016, without significant differences between them.

**DISCUSSION**

The obtained results herein strongly indicated that young quinoa plants of Cica cultivar gave a higher leaf yield compared with Hualhuas cultivar in both seasons. The obtained results may be attributed to varietal difference according to different genetic background or different geographic distribution of both studied quinoa genotypes. In this respect, **Tapia (2015)** reported that there are five quinoa ecotypes: Valley quinoa, "Altiplano" quinoa, "Salar" quinoa, "Sea level" quinoa, and "Subtropical" quinoa, according to the adaption to different environments, wide variations and a great genetic diversity. The two quinoa cultivars belong to different ecotypes, since Cica is a Peruvian cultivar belonging to a Valley type, while Hualhuas is a Peruvian cultivar belonging to a Altiplano type. In addition, the obtained results are in a good agreement with the results obtained by **Ebrahim et al (2018)** who found that Cica cultivar is highly adapted for cultivation under Egyptian conditions. In addition, the increments of plant yield in Cica (**Table 7**) are in good accordance with the increments of N, P,

and K accumulation (**Table 5**) and protein content (**Table 4**) in leaves of this cultivar.

**Table 7.** Effect of cultivars and nitrogen rates of different sources on yield of quinoa plants harvested at 40 days after sowing, in the winter seasons of 2015 and 2016.

Treatments		Yield (kg/m <sup>2</sup> )	
		1 <sup>st</sup> season	2 <sup>nd</sup> season
<b>Cultivars</b>			
Cica		1.68 A	1.76 A
Hualhuas		1.27 B	1.39 B
<b>Nitrogen rates of different sources</b>			
	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.28 D	1.19 C
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.46 C	1.61 B
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.87 A	1.91 A
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.06 E	1.26 C
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.38 C	1.55 B
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.78 B	1.90 A
<b>Cultivars x Nitrogen rates of different sources</b>			
Cica	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.55 c	1.32 d
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.79 b	1.84 b
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.96 a	2.12 a
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.20 d	1.31 d
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.53 c	1.80 bc
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	2.05 a	2.16 a
Hualhuas	40 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.00 e	1.07 e
	60 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.13 d	1.38 d
	80 kg N-NH <sub>4</sub> <sup>+</sup> /feddan	1.79 b	1.71 bc
	40 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	0.93 e	1.20 de
	60 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.23 d	1.31 d
	80 kg N-NO <sub>3</sub> <sup>-</sup> /feddan	1.52 c	1.65 c

Means into every group within a column followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Duncan's multiple range test

For newly introduced crops, it is necessary to assess the appropriate agricultural practices. Amongst many others, the nutritional requirements of the crop are considered to be the most important factor. Nitrogen is generally the most limiting nutrient factor for the growth of leafy vegetables including quinoa which is characterized by a short-life cycle plants and a considerable high requirement for nitrogen nutrition. For efficient fertilizer use of nitrogen, adequate rate and appropriate source during the crop growth cycle are important (**Fageria et al 2006**).

Concerning the adequate rate of nitrogen, the obtained results demonstrated that increasing nitrogen rate up to 60 kg N/feddan led to increases in chlorophyll contents in the two tested cultivars and these results are in a good agreement with the results obtained by **Basra et al (2014)**. The enhancement of chlorophyll may be attributed to the fact that nitrogen plays a role in chlorophyll formation and hence the photosynthesis and carbon dioxide assimilation processes (**Jasso-Chaverria et al 2005**). In addition, nitrogen soil application level up to 80 kg N/feddan was proved to be the best level for the accumulation of carotenoids (**Table 2**), ash (**Table 3**), crude proteins and total carbohydrates (**Table 4**) and all determined nutrients except for Na (Tables 5 and 6) in the leaves of quinoa. These enhancements of these parameters may be attributed to the fact that nitrogen is a constituent of amino acids, which are the building units of proteins and enzymes (**Epstein & Bloom, 2004 and Phillips et al 2005**). In addition, nitrogen is important in the chlorophyll formation thus it is necessary for the photosynthesis process in the plant (**Epstein and Bloom, 2004**), resulting carbohydrate accumulation. Moreover, nitrogen promotes the uptake of other nutrients and thus enhancing growth of plant (**Bloom, 2015**). In this concern, increasing nitrogen application led to increments in leaf yield of quinoa plants (**Table 7**), since nitrogen, which is an important yield-increasing nutrient for plants, has a positive effect on their growth and fresh weight yield (**Cavarianni et al 2008; Chochura and Kolota, 2011**). The obtained results herein are in good agreement with findings of **Gülser (2005) and Stagnari et al (2007)** who indicated that spinach yield was increased by increasing nitrogen fertilizer rate. They also reported that there were differences responses among different cultivars. The positive effects of nitrogen on growth and yield of leafy vegetables including quinoa as vegetable crop may be attributed to its effect on cell division, expansion, and elongation (**Onyango, 2002**) and on the processes of photosynthesis and carbon dioxide assimilation (**Epstein and Bloom, 2004; Jasso-Chaverria et al 2005**) via its role in chlorophyll formation. Regarding the nitrate content in leaves, it is known that high nitrate accumulation in leafy vegetables is harmful to human health (**Hord et al 2009**). Several factors affecting nitrate accumulation in plant tissues, e.g. genetic background, environmental conditions (temperature, photoperiod) and agricultural factors (nitrogen doses and forms), but the

most important factor is soil nitrogen content due to nitrogen fertilization (**Santamaria, 2006**). In this concern, the obtained results demonstrated that increasing nitrogen rate increased the accumulation of nitrate in the leaves of quinoa (**Table 4**) and vice versa. The obtained results of our study are in harmony with that reported by **Engelbrecht et al (2010)** on Swiss chard, **Liu et al (2014)** on lettuce, and **Hammad et al (2007) and Mondal & Nad (2012)** on spinach who stated that the accumulation of leaf nitrate content increased with increasing nitrogen fertilizer levels. It could be stated that the acceptable daily intake (ADI) of nitrate set by European Commission's Scientific Committee for Food (ECSCF), is 0-3.7 mg/kg body weight (**Anonymous, 2005**), and it means that the accumulated nitrate in the leaves of young quinoa plants still within the permitted level to be found in leafy vegetables.

As for the forms of nitrogen, it is known that plants can utilize both nitrate ( $\text{NO}_3^-$ ) and ammonium ( $\text{NH}_4^+$ ) as a nitrogen source (**Marschner, 1995**). In this study, two nitrogen sources; ammonium sulfate 20.6% or calcium nitrate 15.5% were used. The obtained results indicated that application of calcium nitrate led to increases in chlorophyll and carotenoid contents, ash, proteins, total carbohydrates and accumulation of N, Na, Fe, and Zn, while ammonium sulfate application was proved to be the best source for accumulation of crude fibers and fats in the leaves. In addition, quinoa fertilization with calcium nitrate increased accumulation of nitrate in the leaves, while ammonium sulfate reduced nitrate content. These results coincide with those obtained by **Wang and Li (2003)** who reported that nitrate N fertilizers tended to increase leaf nitrate accumulation compared to the ammonium N fertilizers. Also, the obtained results are in a good agreement with those obtained by **Ezzo et al (2008)** who stated that the lowest leaf nitrate accumulations were obtained with the medium level (17.5 g N/m<sup>2</sup>) of ammonium sulphate application. This may be attributed to the imbalance between nitrate absorption and reduction within the plants leading to nitrate accumulation in plant tissues, since plants usually absorb much more nitrate than they can reduce (**Wang et al 2008**). In addition, the highest yield of quinoa plants was obtained when the plants fertilized with ammonium sulfate in both seasons.

Finally, the obtained results demonstrated that there are significant interactions between the between the two quinoa cultivars and different nitro-

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gen treatments (2 sources x 3 rates) for all studied parameters.

### CONCLUSIONS

The present study demonstrates that leaf chemical compositions and yield of quinoa (*Chenopodium quinoa* Willd.) are significantly affected by cultivars and nitrogen sources and rates. Given the experimental conditions of this study, it is concluded that Cica plants received 80 kg N/feddan either from ammonium sulfate or calcium nitrate gave the highest yield of leaves with acceptable quality attributes.

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## تأثير المعدلات والمصادر المختلفة من الأسمدة النيتروجينية على التركيب الكيماوى للأوراق ومحصول نبات الكينوا كمحصول خضر ورقي جديد

[62]

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### الموجز

بجميع الصفات الكيمائية التى تم قياسها فى الأوراق والمحصول خلال كلا الموسمين، باستثناء محتوى الأوراق من الكلوروفيل أ، ب والكلوروفيل الكلى، الرماد، الدهون، الكالسيوم، الحديد، حيث كان الصنف هوالمهوس متفوق على الصنف سيكا فى هذه الصفات. فى حين لم يكن هناك فروق معنوية بين كلا الصنفين فيما يتعلق بمحتوى الأوراق من الكربوهيدرات فى كلا الموسمين وكذلك محتوى الألياف فى الموسم الثانى.

وفىما يتعلق بمعدلات ومصادر النيتروجين، فقد أظهرت نباتات الكينوا التى سمدت بمعدل 80 كجم نيتروجين/فدان من نترات الكالسيوم أعلى القيم معنويًا فى المحتوى من الكاروتينات والنترات والبروتينات والرماد وكذلك المحتوى من النيتروجين والحديد والكالسيوم والمحصول فى كلا الموسمين من الدراسة. كما أظهرت المعاملة 60 كجم نيتروجين/فدان من نترات الكالسيوم أعلى القيم معنوية لمحتوى الأوراق من الكلوروفيل أ، ب وكذا الكلوروفيل الكلى فى كلا الموسمين. فى حين لم تكن هناك أى فروق معنوية بين جميع معاملات النيتروجين (معدلات ومصادر) على محتوى الأوراق من الفوسفور فى كلا الموسمين.

فىما يتعلق بتأثير التفاعل، أوضحت النتائج بوضوح أن أوراق نباتات الصنف سيكا التى سمدت بمعدل 80

اكتسب نبات الكينوا زيادة فى الإهتمام العالمى منذ سبعينيات القرن العشرين عندما أُعيد استخدامه كمحصول غذائى جديد، وذلك نسبة للقيمة الغذائية المرتفعة والفوائد الصحية له بالإضافة إلى تحمله غير العادى للعديد من الإجهادات البيئية. ويعتبر نبات الكينوا محصول خضر ورقي غير تقليدى جديد تم إدخاله حديثًا إلى مصر. لم يتم حتى الآن تحديد الإحتياجات السمادية من النيتروجين لنباتات الكينوا، كما لا تزال أعداد الدراسات فى هذا المجال محدودة للغاية. وقد أجريت هذه الدراسة لتقييم تأثير مصدرين من النيتروجين (كبريتات الأمونيوم 20.6% أو نترات الكالسيوم 15.5%) باستخدامها بمعدلات 40، 60، 80 كجم نيتروجين/فدان على التركيب الكيماوى للأوراق والمحصول على صنفين من الكينوا هما سيكا وهوالمهوس والتي تم حصادها بعد 40 يومًا من تاريخ الزراعة. وقد أجريت تجربة حقلية فى المزرعة التجريبية لقسم البساتين، كلية الزراعة، جامعة عين شمس، شبرا الخيمة، القاهرة، مصر، خلال الموسم الشتوى لعامي 2015 و 2016 وقد صممت التجربة فى قطع منشقة مرة واحدة من ثلاثة مكررات.

وأظهرت النتائج التى تم الحصول عليها تفوق الصنف سيكا على الصنف هوالمهوس فيما يتعلق

الحصول على أفضل القيم للمحتوى من الزنك عندما عوملت نباتات الصنف سيكا بمعدل 40 كجم نيتروجين/فدان من كبريتات الأمونيوم أو 60 كجم نيتروجين/فدان من نترات الكالسيوم دون ظهور فروق معنوية بينهما في كلا الموسمين. بالنظر إلى الظروف التجريبية لهذه الدراسة، يمكن استنتاج أن نباتات الصنف سيكا التي عوملت بمعدل 80 كجم نيتروجين/فدان سواء من كبريتات الأمونيوم أو نترات الكالسيوم قد أعطت أعلى إنتاجية من الأوراق ذات خصائص جودة مقبولة.

الكلمات الدالة: الكينوا، النيتروجين، التسميد المعدني، التركيب الكيماوي، المحصول الورقي

كجم نيتروجين/فدان سواء من كبريتات الأمونيوم أو نترات الكالسيوم قد سجلت زيادات كبيرة في محتوى الأوراق من الكاروتينات، النترات، البروتين، الرماد، النيتروجين، الفوسفور، البوتاسيوم، الصوديوم، المحصول دون تسجيل أى إختلافات معنوية بينهما. من ناحية أخرى، تم الحصول على أفضل قيم للكلوروفيل أ ، ب والكلوروفيل الكلى في كلا الموسمين عند معاملة نباتات الصنف هوليهوس بمعدل 60 كجم نيتروجين/فدان من سماد نترات الكالسيوم. علاوة على ذلك، لم تظهر فروق معنوية بين معاملات النيتروجين المختلفة على نباتات الصنف سيكا في كلا الموسمين بالنسبة لمحتوى الأوراق من الصوديوم. كما تم أيضا

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