Journal of Soil Science and Plant Nutrition (2021) 21:2472–2488
https://doi.org/10.1007/s42729-021-00538-5

ORIGINAL PAPER

Co-application of Organic Manure and Bio-fertilizer to Improve Soil Fertility and Production of Quinoa and Proceeding Jew's Mallow Crops

Mohamed Ahmed Youssef[1] · Mohamed Ibrahim Hassan Farag[2]

Received: 2 March 2021 / Accepted: 14 June 2021 / Published online: 24 June 2021

Abstract

Organic manure and bio-fertilizers are a vital source of plant nutrients during the plant growth period, which leads to increased yield. This field investigation was carried out through two cropping (2017–2018/2018–2019) seasons to study the effects of using farmyard manure (FYM) and bio-fertilizers as "(TS) and (EM)" on soil fertility and productivity of both quinoa and Jew's mallow plants. The experiment was laid in a randomized complete block design with three replications in the strip plot arrangement. The experimental treatments include (1) inorganic fertilization (NPK) as a control treatment, (2) NPK with TS bio-fertilizer, (3) NPK with EM bio-fertilizer, (4) FYM (24 t ha^{-1}), (5) FYM with TS bio-fertilizer, and (6) FYM with EM bio-fertilizer. Generally, the application of FYM with bio-fertilizers treatments increased the soil organic carbon and relatively reduced the soil pH. The interestingly, all-tested soil characteristics as well as productivity of quinoa crops performed better when FYM and bio-fertilizers were used in fertilization compared to inorganic fertilizer treatment. The highest improvement in seed quinoa yield was 15.22 and 15.26 t ha^{-1}, oil content was 9.76 and10.72% during two growing seasons, and were achieved when FYM and bio-fertilizers were used. Furthermore, the residual effect persisted to the effect that productivity of Jew's mallow plants in the two subsequent growing seasons were improved. Also, economic evaluation presented that productivity was increased by the application of FYM and bio-fertilizers treatments. Finally, FYM with EM bio-fertilizer treatment had the greatest enhancement in all measured parameters relative to the control. This will lead to a reduction in the use of chemical fertilizers in agriculture.

Keywords Quinoa · Jew's mallow · Farmyard manure · Soil properties · Bio-fertilizers · Residual effect

1 Introduction

Continuous overuse of synthetic fertilizers is causing several issues, in particular, at high application rates; it results in several environmental and human health issues in addition to the negative impact on sustainable agriculture (Singh 2000). It increased surface water and air pollution, which contribute to the release of greenhouse gases in the atmosphere (Wu et al. 2005). Also, over-usage of synthetic fertilizers has serious negative effects on soil health such as soil degradation, soil acidification, loss of organic matter, humus content, and beneficial soil organisms (Hepperly et al. 2009; Bhatt et al. 2019). Likewise, accumulation of heavy metals activity in soil plant system (Khandaker et al. 2017), their entry into the food chain, and consequently their accumulation in the human body, which is very dangerous (Savci 2012). The excessive use of inorganic fertilizers also causes many other problems such as increased incidence of pests, toxic ion concentration in the soil, inhibition of crop growth, and ground water pollution by nitrate leaching (Rahimi et al. 2019). Moreover, using chemical fertilizers has some problems for farmers due to the short residual effect and high cost (Ali et al. 2019).

Recent agricultural trends has focused on limiting the use of inorganic fertilizers by using organic manures and applying bio-fertilizers, which influence plant growth by enhancing root biomass; total root surface area facilitates higher absorption of nutrients and increase yields of crops (Darzi et al. 2011). In the sustainable agriculture techniques,

✉ Mohamed Ahmed Youssef
dr.mayousssef@gmail.com; dr_mayoussef@azhar.edu.eg

Mohamed Ibrahim Hassan Farag
m_h_2025@yahoo.com

[1] Department of Soils and Water Sciences, Faculty of Agriculture, Al-Azhar University, Assiut 71524, Egypt

[2] Horticulture Research Institute – Agricultural Research Center, Giza, Egypt

bio-fertilization has great importance to alleviate the deterioration of natural and environmental pollution and also reduce the requirement of chemical fertilizers. Bio-fertilizers consist mainly of co-existing beneficial microorganisms such as *Azotobacter*, *phosphate-solublizing bacteria*, *lactobacilli*, *yeast*, *and Actinomycetes* that can release nutrients from raw organic materials in the soil and consequently enhance soil health, microbial diversity, improve the fertility of the soil, and nutrient uptake and crop (Mosa et al. 2014a, b; Singh et al. 2016). There is an increasing need to manage the traditional processes of nutrient management, resulting in higher nutrient concentration in soil while reducing environmental pollution, and becomes known as a low cost of inputs in agriculture (Bhatt et al. 2019). A considerable number of bacterial species can benefit plant growth, which improves crop yield by increasing photosynthesis, producing bioactive substances, such as hormones and enzymes, controlling soil diseases, and accelerating the decomposition of lignin materials in the soil (Javaid, 2011).

Organic fertilizers are natural materials of either plant or animal sources, including livestock manure, green manures, crop residues, household waste, and compost (Basel and Sami 2014). Additionally, organic fertilizers can increase the biomass and productivity of a wide range of crops (Prasad et al. 2017). Moreover, organic farming is a new agricultural production system involving locally and naturally available organic materials or agro inputs to meet the production system with limited effects on the natural resources. Organic fertilizers play a major role to achieve sustainable agriculture and it's a suitable source of macro- and micro-nutrient (Taheri et al. 2011). Organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved. Several studies have proved that the application of organic fertilizers has the potential to increase the biomass and productivity of a wide range of crops (Al-Sayed et al. 2019). Farmyard manure (FYM) refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from fodder fed to the cattle; the FYM occupies an important position among bulky organic manures. The FYM seems to act directly by increasing crop yield by accelerating the respiratory process by cell permeability or by hormone growth action. It supplies N, P, and K in available forms to plants through biological decomposition (Rosati 2005; Rana et al. 2007; Mahadeen 2009). However, organic fertilizers indirectly influences the chemical, physical, and biological properties of soil, but they have comparatively low nutrient content, so larger quantities of organic fertilizers are required for plant growth (Basel and Sami 2014; Bhatt et al. 2019).

Recently, the integrated effect of organic manure and bio-fertilizers become the best choice in the agricultural sector due to the many benefits of using fertilizers combinations. Bio-fertilizer used as a replacement for chemical fertilizers (Gryndler et al. 2003; Al-Sayed et al. 2019; Abdel-Gawad and Youssef 2019) produces direct and indirect effects on soil properties, plant growth characteristics, component yield, and quality parameters for organic products, such as quinoa crop that has been documented in some studies (Gomaa 2013; Ortuño et al. 2013; Mosa et al. 2014a, b) through different mechanisms such benefits including the release of nutrients from organic materials in the soil, better seed germination expansion of plant root system, and improving the productivity of plants (Sameera et al. 2005; Chang et al. 2010; Zhang et al. 2012; Ahamd et al. 2015). Perhaps the greatest advantage of integrated effects of organic manure and bio-fertilizers besides supplying plant nutrients and their environment-friendly nature, their residual effect on the succeeding crops go a long way to reduce the input cost of farmers (Youssef 2011; Ortuño et al. 2013; Ahamd et al. 2015; Khandaker et al. 2017; Singh et al. 2017; Rahimi et al. 2019; Bhalshankar 2020). Thus, of organic manures viz. farmyard manure, compost, vermicompost, and bio-fertilizers such as *azotobacter* and *phosphate-solublizing* bacteria decrease the input cost of production and increase output of production (Taheri et al. 2011; Singh et al. 2016; Bhatt et al. 2019; Bhalshankar 2020).

Over the years, Egypt has heavily relied on cereals and pseudo cereals to ensure food self-sufficiency (Graf et al. 2015; Marzouk et al. 2016; Awadalla and Morsy 2017); however, recent negative impact of climate change and reducing soil fertility has necessitated the introduction of new non-traditional crops in Egypt, such as quinoa (*Chenopodium quinoa* Wild.). This crop is considered a stress-tolerant and a multi-purpose plant for farmers and agro-industries and survives in semi-arid and arid regions (Adolf et al. 2013; Peterson et al. 2015; Nowak et al. 2016) and climatic conditions inhospitable to other cereals (Gomaa 2013; Sun et al. 2014). Soil salinity is up to 40 dSm^{-1} (Adolf et al. 2013), and so is the minimum requirement of water and nutrients (Garcia et al. 2007) because of its wide genetic variability (Zurita-Silva et al. 2014; Peterson et al. 2015; Choukr-Allah et al. 2016; Eisa et al. 2017; Bilalis et al. 2019).

Quinoa plant is grown for edible purpose. For example, leaves can be eaten as a leafy green vegetable with an excellent source of nutrients, like spinach (Bhargava et al. 2006; Pathan et al. 2019), and seeds can be used for both human food and animal feed (Kakabouki et al. 2014). Moreover, the whole plant is used as green fodder for livestock, including sheep, cattle, buffaloes, and poultry, owing to its high nutritive value (Vega-Galvez et al. 2010; Nowak et al. 2016). Its production is of economic value because of its high content of protein, oil, minerals, vitamins, saponin, and better amino acid profile as well as health beneficial compounds when compared to other cereals (Jancurova et al. 2009; Escuredo et al.

2014; Kakabouki et al. 2014; Nowak et al. 2016; Jacobsen 2017). In general, quinoa seeds have a higher nutritional value than other cereals such as rye, barley, wheat, oats, rice, and corn. Moreover, because the quinoa seeds are free from gluten proteins, they can be used to produce gluten-free products such as pasta, bun, bread, gateau, cookies, muffins, and pancakes for human consumption (Pulvento et al. 2010; Bilalis et al. 2017).

In addition, the Jew's mallow (*Corchorus olitorus*) is one of the importances of green leafy vegetables in Egypt. Its leaves are edible and available as fresh, dry, and frozen for all Egyptians (Yousef et al. 2020). Jew's mallow is a source of income for smallholders and low-income families in Egypt. Farmers cultivate Jew's mallow in many marginal areas. Recently, Jew's mallow has received great international recognition because of its role in providing food and nutrition security and income opportunities among smallholder farmers. Moreover, it can be utilized to adapt to agriculture and food systems climate change. Jew's mallow plays an important role in human nutrition because its leaves contain an average vitamin A, Ca, Mg, Fe, protein, foliates, ascorbic acid, nicotinamide, folic acid, oil, carbohydrate, and fiber on edible leaves. Additionally, the seeds of *Corchorus olitorius* can be integrated into livestock feeds and human diets (Mabhaudhi et al. 2017; Isuosuo et al. 2019; Yousef et al. 2020).

The number of studies on integrated organic manure and bio-fertilizers of quinoa plants is still quite limited, especially in Egypt. This point is considered one of the most important recent trends in studies related to the environment, soil, and plants. There are no studies on the residual effect of using farmyard manure with bio-fertilizer on soil, growth, and subsequent crop yield. Therefore, this study investigates the effect of the combined application of farmyard manure with bio-fertilizer on growth and yield of quinoa plants and soil fertility. Moreover, this study is concerned with the evaluation of the residual effects of these treatments on the subsequent crop Jew's mallow.

2 Material and Methods

2.1 Site Description

This 2-year-field study was conducted out at the Experimental Farm of Agriculture Faculty, Al-Azahar University, Assuit (branch), located at (27° 12′ 16.67″ N latitude; 31° 09′ 36.86″ E longitude) in Assiut governorate, Egypt, during two successive growing seasons. The study is aimed to study the effect of using farmyard manure (FYM) and bio-fertilizers as "(TS) and (EM)" on soil fertility and productivity of quinoa and Jew's mallow plants. The experimental soil was classified as silty loam according to the Soil Survey Staff (2014); particle size analysis was done according to Embrapa (2017). Before planting of quinoa, some other characteristics of the experimental soil were evaluated following Carter and Gregorich (2007) during both growing seasons. Physico-chemical characteristics of experimental soil before sowing of quinoa during both growing seasons are given in Table 1.

The region's climate is semi-arid according to the aridity index of Ponce et al. (2000). The microclimate data during the experiment were calculated as a monthly average of the maximum and minimum air temperatures (°C) and relative air humidity (%) and were recorded by using a digital thermo/hygrometer Art. No. 30.5000/30.5002 (Produced by TFA, Germany) placed at the middle of each treatment, and the possible sunshine duration (hours/day) was measured using the meteorological station of Central Lap for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Cairo, Egypt.

2.2 Experimental Design and Treatments

The experiment was laid down in a randomized complete block design with three replications in the strip plot arrangement. The first factor was fertilization types including inorganic NPK fertilizers (as ammonium nitrate; N 33% (190 N kg ha^{-1}), calcium super phosphate; $P_2O_5$18% (110 P_2O_5 kg ha^{-1}) and potassium sulfate; K_2O 48% (114 K_2O

Table 1 Physico-chemical characteristics of experimental soil before sowing of quinoa during both growing seasons

Physical characteristics		Values		Chemical characteristics	Values	
		2017–2018	2018–2019		2017–2018	2018–2019
Particle size (g kg^{-1})	Sand	552 ± 4.11	532.5 ± 1.87	CEC (cmol kg^{-1})	16.76 ± 0.01	16.93 ± 0.02
	Silt	296 ± 0.94	301.2 ± 0.72	EC (dSm^{-1}) (1:2.5) extract	0.864 ± 0.00	0.906 ± 0.00
	Clay	152 ± 1.70	166.3 ± 0.98	pH (1:2.5 soil–water) susp.	7.85 ± 0.02	7.89 ± 0.02
Texture		Silty loam	Silty loam	Organic matter (g kg^{-1})	14.05 ± 0.01	14.23 ± 0.03
Bulk density (g/cm^3)		1.48 ± 0.01	1.45 ± 0.01	$CaCO_3$ (g kg^{-1})	0.14 ± 0.02	0.15 ± 0.01

Each value represents a mean of 3 replicates ± standard error. *CEC*, cation exchange capacity; *EC*, electrical conductivity kg ha^{-1})) and organic manure (FYM) (applied at 24 t ha^{-1}) laid out horizontally, while the second factor, laid out in the vertical direction, was bio-fertilizers (TS and EM) (applied at 36 L ha^{-1}). The experiment consisted of six fertilization treatments were applied as follows: (1) inorganic fertilizers (NPK) as a control treatment, (2) NPK with TS bio-fertilizer, (3) NPK with EM bio-fertilizer, (4) FYM (24 t ha^{-1}), (5) FYM with TS bio-fertilizer, and (6) FYM with EM bio-fertilizer.

Seeds of quinoa cv. CICA were sown in plots measuring 4 m × 3 m; the plot contained 50-cm apart 6 rows. Seeds were manually planted at a depth of 2–3 cm in row 30 cm spaced hills on November 15, 2017 and November 20, 2018, respectively. Seeds of quinoa were obtained from Desert Research Center, Cairo, Egypt. While Jew's mallow seeds (Seady cv.) were planted on April 28 an April 30 as summer crops after harvesting quinoa plants, in both growing seasons 2017–2018 and 2018–2019 to study the residual effect of these treatments. Farmyard manure and phosphatic fertilizer were applied during soil preparation, whereas the N fertilizer was applied in three equal splits at 25, 50, and 70 days after sowing date, and K fertilizer was added once at heading during both growing seasons.

The liquid bio-fertilizer "TS" contained molasse as the organic material carrier of microorganisms, and a set of mixed cultures of *Bacillus circulans* 0.5×10^9 (cfu), *B. poylmyxa* 2×10^7 (cfu), *B. megatherium* 1.5×10^9 (cfu), *Candida* spp. 1.5×10^7 (cfu), and *Trichoderma* spp. 0.5×10^6 (cfu) mL^{-1}. Whereas, liquid bio-fertilizer of effective microorganisms "EM" contained *Lactobacillus casei* 9×10^7 (cfu), *Lactococcus lactis* 5×10^7 (cfu), *Saccharomices cerevisiae* 2×10^6 (cfu), *Rhodopseudomonas palustris* 4×10^6 (cfu) mL^{-1}, including photosynthetic bacteria, lactic acid bacteria, and yeast (https://www.emrojapan.com). Both bio-fertilizers were applied at 25, 50, and 70 days after sowing through a drip irrigation system, and both types (TS and EM) were used as 36 L ha^{-1}.

The bio-fertilizer was obtained from the Agricultural Research Center, Giza, Egypt. However, farmyard manure was received from the Animal Production Farm, Al-Azhar University, Assiut, Egypt. The farmyard manure was analyzed for pH and electrical conductivity (EC) by portable pH/EC/TDS meter, nitrogen (N) by Kjeldahl method, P by calorimetry, and potassium (K) by flame photometer following Silva (2009). The composition of farmyard manure used in the experiments during both growing seasons is given in Table 2.

2.3 Observations and Measurements

After 145 days from sowing, ten plant samples of quinoa were randomly collected from each replicate for every treatment to study the direct effect of treatments. Plant height (cm) was measured using a meter rod and the number of branches/plant was counted. Dry biomass weight was recorded with an electronic balance (0.01 g) days and drying temperature. The SPAD chlorophyll index from the leaves was determined using a SPAD meter (SPAD-502-m Konica Minolta, Inc., Tokyo, Japan). After threshing the harvested plants to separate the seeds, 1000-seed weight, seed weight per plant, and seed yield were recorded using an electronic balance.

The chemical composition of quinoa seed such as NPK-content in seed (g kg^{-1}) was determined using the Kjeldahl procedure, colorimeter method using a spectrophotometer, and photometrically using a Flame Photometer, respectively, as described by FAO (2008). The crude protein content (%) was calculated as N-content (%) × 6.25 and oil content (%) was determined following AOAC (2009).

For studying the residual effect of experimental treatments, Jew's mallow plants were harvested from an area of 0.5 m × 1.0 m from the middle of each replicate for every unit treatment 65 days from sowing during both growing seasons. Plant height (cm) was measured with a meter rod, number of branches per plant was counted, and fresh biomass yield (kg m^{-2}) was recorded with an electric balance (0.01 g). The plants were dried to constant weight to record the dry biomass yield (g m^{-2}) and dry leaf yield (g m^{-2}) using an electronic balance. Nitrogen was determined by

Table 2 Composition of farmyard manure used in the experiments on dry weigh basis during both growing seasons

Characteristics		Values	
		2017–2018	2018–2019
Macro elements (mg/kg)	Total-N	105 ± 1.66	118 ± 2.16
	Total-P	185 ± 1.70	205 ± 0.94
	Total-K	236 ± 0.54	279 ± 3.03
Chemical characteristics	Organic matter (g kg^{-1})	205 ± 2.23	229 ± 2.84
	pH (1:5) Susp.	8.25 ± 0.02	8.20 ± 0.02
	EC (dSm^{-1}) (1:5) extract	4.060 ± 0.02	4.228 ± 0.00
	C/N ratio	11.22 ± 0.02	11.15 ± 0.02

Each value represents a mean of 3 replicates ± standard error

Kjeldahl method, whereas the protein contents (%) were calculated as N-content (%) × 6.25.

2.4 Soil properties

The soil samples were collected from the top 0–30 cm soil layer from each treatment plot at the final harvest of quinoa plants, mixed to make a composite soil sample, air-dried, and pulverized to pass a 2-mm sieve for calculating the soil status post-harvest. Soil reaction (pH) values were measured with a glass-electrode pH meter (Jenway™ 351,201 Inc., Göteborg, Sweden) at a 1:2.5 (w: v soil: distilled water ratio) suspension; after 30 min of shaking, electrical conductivity (EC; μdSm^{-1}) was identified from the same soil–water ratio extracting with an EC-meter (AD 3000 Inc., Szeged, Hungary), soil organic carbon (SOC; g kg^{-1}), determined according to Walkley–Black procedure as described by Petric et al. (2009). Also, soil N P K-available (mg kg^{-1}) was analyzed according to Carter and Gregorich (2007).

2.5 Statistical Analysis

The experimental data were analyzed statistically using Fisher's analysis of variance (ANOVA) technique using the statistical software SAS version 9.2 (SAS 2008). The treatment means were separated by Duncan's new multiple range test at the 5% level of probability (Steel et al. 1997).

2.6 Economic Evaluation

Economic analysis was conducted to determine the economic feasibility of applying organic and inorganic fertilizers in combination with bio-fertilizers in quinoa crop production. The cost involved tillage: seed, planting, irrigation, fertilizers, land rent, and crop harvesting were determined and recorded. Gross income was estimated according to the current average market prices of quinoa seeds and straw. After that, net income was estimated by deducting total expenses from gross income, and the benefit–cost ratio (BCR) was determined as gross income ratio to total production cost.

2.7 Weather Conditions During the Experiment:

Presented data in Fig. 1 indicated that the month of April recorded the highest average maximum, minimum air temperatures, and possible sunshine duration throughout the duration of the experiment, while January recorded the lowest values of them in both growing seasons. However, December and January recorded the greatest average of relative humidity (RH), while, March and April obtained the lowest relative humidity values through 2017–2018 and 2018–2019 seasons. Moreover, the second season

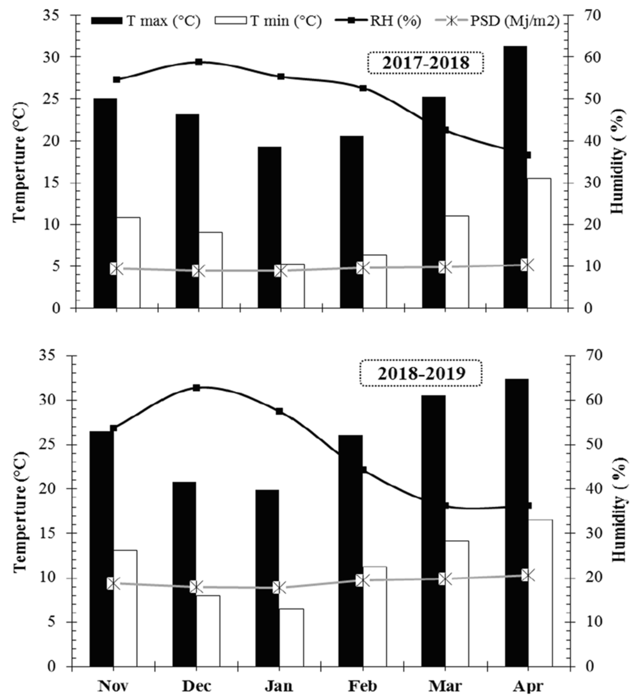

Fig. 1 Weather data of the experimental site during two growing seasons. T-max, maximum air temperature; T-min, minimum air temperature; RH, relative humidity; PSD, possible sunshine duration. Source: Central Laboratory for Agricultural Climate, Giza, Egypt

2018–2019 recorded the highest average values of climatic factories, more than the first season 2017–2018 as given in Fig. 1.

3 Results

3.1 Effect of Farmyard Manure and Bio-fertilizers on Post-harvest Soil Status

The chemical properties of soil after harvesting quinoa plants treated by different treatments and general soil properties were significantly ($p \leq 0.05$) affected due to different combinations in fertilizers treatment applications in the two growing seasons (Table 3; Fig. 2). Illustrated data in Table 3 show the effect of using organic manure, bio-fertilizer, and their combination on soil properties such as electrical conductivity (EC), soil reaction (pH), and soil organic carbon (SOC).

3.1.1 Soil electrical conductivity

Data in Table 3 reflect the positive effects of using organic manure, bio-fertilizer, and their combination on EC (μdSm^{-1}). The greatest soil EC was obtained, in general, with NPK + EM (chemicals NPK fertilizers with EM

Table 3 Influence of farmyard manure and bio-fertilizers on soil properties during two growing seasons

Treatments		EC (µdSm^{-1})		pH (unit)		SOC (g kg^{-1})	
Fertilization	Bio-fert	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019
NPK	Without	955 ± 4.50^{a} [!!]	988 ± 28.74^{b}	7.72 ± 0.02^{a}	7.87 ± 0.02^{a}	8.75 ± 0.39^{e}	7.17 ± 1.63^{d}
	TS	968 ± 28.74^{a}	1007 ± 4.50^{b}	7.62 ± 0.01^{b}	7.79 ± 0.02^{b}	19.32 ± 0.10^{d}	20.92 ± 0.10^{c}
	EM	998 ± 4.48^{a}	1070 ± 12.74^{a}	7.61 ± 0.03^{bc}	7.63 ± 0.02^{c}	20.65 ± 0.17^{c}	22.55 ± 0.17^{bc}
Means		**973.67**	**1021.67**	**7.65**	**7.76**	**16.24**	**16.88**
FYM	Without	648 ± 2.60^{b}	668 ± 2.60^{d}	7.60 ± 0.00^{bc}	7.83 ± 0.01^{ab}	27.17 ± 0.17^{a}	29.27 ± 0.17^{a}
	TS	659 ± 1.44^{b}	707 ± 1.44 ^{cd}	7.58 ± 0.02^{bc}	7.66 ± 0.01^{b}	21.93 ± 0.20^{b}	23.75 ± 0.26^{b}
	EM	674 ± 2.36^{b}	742 ± 2.36^{c}	7.54 ± 0.01^{c}	7.62 ± 0.03^{bc}	22.10 ± 0.17^{b}	24.30 ± 0.10^{b}
Means		**660.33**	**705.67**	**7.57**	**7.70**	**23.73**	**25.77**
Source of variation	d.f	Mean square					
Replication	2	730.17 ^{NS}	1293.50 ^{NS}	0.0005 ^{NS}	0.0006 ^{NS}	0.034 ^{NS}	2.937 ^{NS}
Fertilization (F)	1	443,054.22 **	450,616.89 **	0.0264 *	0.0072 ^{NS}	252.77 **	356.007 **
Error a	2	595.72	812.39	0.0002	0.0013	0.354	0.882
Bio-fert. (B)	2	1875.17 ^{NS}	8975.17 **	0.013 ^{NS}	0.0651 **	19.018 **	45.216 **
Error b	4	660.33	727.92	0.0017	0.0004	0.201	2.259
F × B	2	127.39 ^{NS}	314.05 ^{NS}	0.0024 ^{NS}	0.0098 *	135.110 **	196.488 **
Error c	4	657.89	520.30	0.0020	0.0011	0.253	2.128

NPK, inorganic fertilization (chemicals NPK fertilizers); *FYM*,, organic fertilization (farmyard manure; 24 t ha^{-1}); *TS*, TS biofertilizer; *EM*, EM bio-fertilizer; *EC*, electrical conductivity; ***pH*****,** soil reaction; *SOC*, soil organic carbon. ± Refers to standard error of the mean ($n = 3$)

[!!]Numbers with same letters in the same column means there no significant between them following Duncan's multiple range test at ($p \leq 0.05$)

*, **, and ***Means that there are significant, highly significant and very highly significant effects ($p < 0.05$, $p < 0.01$, and $p < 0.001$ respectively)

bio-fertilizer) treatment in both tested seasons except, in the first season, where NPK + EM, NPK + TS (chemicals NPK fertilizers with TS bio-fertilizer) and NPK without bio-fertilizer treatments, were lowery, while the EC values were higher without any significant difference. Moreover, the lowest value of EC was obtained with FYM (farmyard manure) treatment.

3.1.2 Soil Reaction

According to the presented data in Table 3, soil pH recorded the highest value in NPK without bio-fertilizer treatment followed by NPK + TS and NPK + EM treatments, respectively. However, the lowest soil pH was found with FYM + EM (FYM with EM bio-fertilizer) followed by FYM + TS treatment, respectively. These results were recorded in the second season.

3.1.3 Soil Organic Carbon

The data for soil organic carbon (SOC) recorded during the 2017–2018 and 2018–2019 seasons are presented in Table 3. The greatest value of SOC was, in general, detected in FYM treatment followed by NPK + TS and NPK + EM treatments. However, the lowest SOC was found at NPK treatment. This trend was true in the two tested seasons as given in Table 3.

3.1.4 Soil Nutrients (N, P, and K) Availability

A significant increase in the soil N, P, and K-availability with the application of different fertilizers was noted during both seasons Fig. 2a, b, and c. Results show that the application of FYM + EM treatment gave the highest values (75 and 114 mg kg^{-1}) for the availability of N nutrient in the soil compared to other studied treatments. Whereas, the lowest values available of N nutrient were recorded in inorganic fertilization NPK treatment in both seasons, respectively (Fig. 2a). At the same time, P nutrient availability values in the soil were not affected by all tested treatments. The highest values for available of P (23 and 25 mg kg^{-1}) were noticed for organic fertilizer FYM with EM bio-fertilizer and lowest values were observed in the NPK treatment in both seasons, respectively (Fig. 2b). Moreover, the application of NPK + EM treatment gave the highest values (361 and 385 mg kg^{-1}) of K nutrient availability in the soil, among other treatments. Whereas, the lowest values were recorded for FYM treatment, these results were found in two growing seasons are given as Fig. 2c.

3.2 Effect of Farmyard Manure and Bio-fertilizers on Morphological Traits of Quinoa

Illustrated data in Table 4, the positive role of using organic manure FYM, bio-fertilizers, and their combination on the

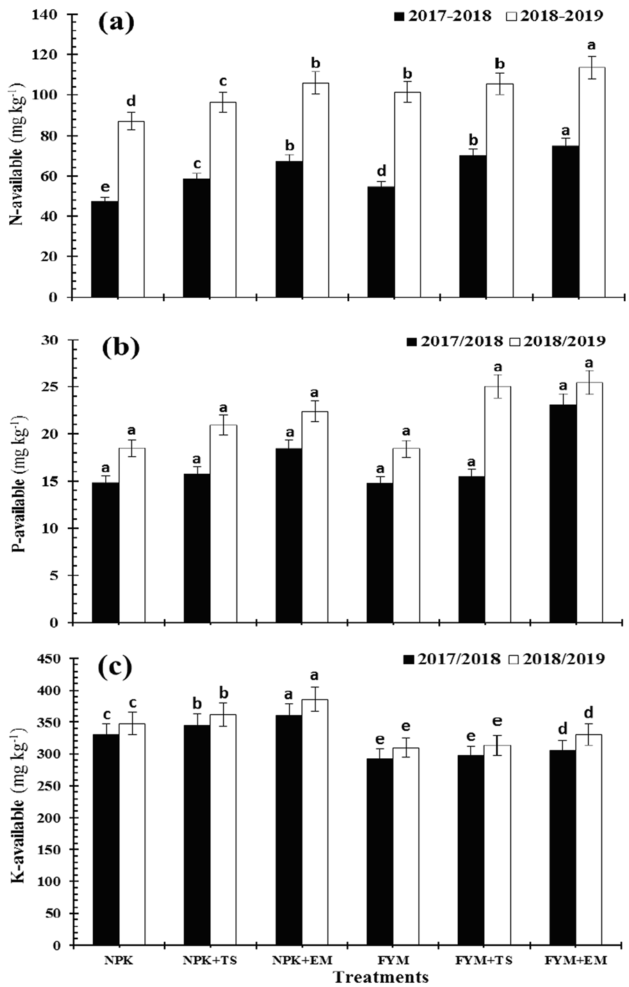

Fig. 2 Influence of farmyard manure and bio-fertilizers on available nitrogen (**a**), available phosphorus (**b**), and available potassium (**c**) during two growing seasons. NPK, inorganic fertilization (chemicals NPK fertilizers); FYM, organic fertilization (farmyard manure; 24 t ha^{-1}); TS, TS bio-fertilizer; EM, EM bio-fertilizer. Different letters in the same bars indicate statistically significant following Duncan's multiple range test at ($p \leq 0.05$)

morphological traits of quinoa (plant height, number of branches, dry biomass weight) are clearly seen.

3.2.1 Plant Height

Data in Table 4 indicated the effect of using different organic manure, bio-fertilizer, and their combination on plant height of quinoa plants. In general, the highest values of plant height were obtained with plants which fertilization by organic manure, bio-fertilizer, and their combination. The FYM + EM treatment had the highest plant height values of 111 cm and 116 cm followed by 110 cm and 114 cm from FYM + TS treatment in the two growing seasons, respectively. The effect of using different fertilization treatments on plant height was observed with plant fertilizer by inorganic NPK treatment. This trend was true in two tested seasons are given in Table 4.

3.2.2 Number of Branches/Plant

Data in Table 4 indicated that the number of branches per plant for quinoa showed no significant difference from all treatments. The highest values of branch numbers per plant were recorded with FYM + EM treatment. While, the FYM treatment tends to a decrease in this parameter. This result was obtained in both tested seasons.

3.2.3 Dry Biomass Weight

Illustrated data in Table 4, in general, FYM + EM treatment produced the highest value 551.90 and 544.07 g plant^{-1} to biomass weight of the quinoa plant during both seasons, respectively. While, lowest values were recorded with inorganic NPK and FYM treatments without any significant difference in the first season. Whereas, in the second season, the FYM treatment was reduced.

3.3 Effect of Farmyard Manure and Bio-fertilizers on Yield Characters of Quinoa

Illustrated data in Table 5, the positive role of using organic FYM, bio-fertilizers, and their combination on quinoa yield characteristics (plant yield, 1000 seed weight, and seed yield) are shown.

3.3.1 Plant Yield

Data presented in Table 5 show application of different fertilization significantly affected the quinoa yield results and indicated that, in general, the application of FYM + EM treatment gave the highest values 133.22 and 133.53 g plant^{-1} for plant yield over the two growing seasons, respectively. The lowest plant yield was observed in FYM treatment all over-tested seasons.

3.3.2 1000-Seeds Weight

Data in Table 5 showed that the effect of using organic FYM, bio-fertilizers, and their combination on 1000-seeds weight and showed that the tested factor was affected positively. The 1000-seeds weight was increased by FYM + EM treatment followed by FYM + TS and FYM treatments without any significant difference. However, the inorganic NPK treatment gave the lowest values 1000-seeds weight compared to other treatments.

Table 4 Influence of farmyard manure and bio-fertilizers on morphological traits of quinoa (*Chenopodium quinoa* Willd.) during two growing seasons

Treatments		Plant height (cm)		No. of branches plant^{-1}		Dry biomass weight (g plant^{-1})	
Fertilization	Bio-fert	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019
NPK	Without	103 ± 1.44^{b} !!	106 ± 1.79^{d}	21.33 ± 0.72^{a}	23.67 ± 0.61^{a}	427.88 ± 3.50^{e}	449.60 ± 2.05^{d}
	TS	106 ± 0.72^{ab}	108 ± 0.59^{bcd}	22.33 ± 1.09^{a}	24.73 ± 1.05^{a}	440.67 ± 1.44^{d}	458.18 ± 1.64^{c}
	EM	108 ± 0.94^{ab}	112 ± 0.57^{abc}	23.00 ± 1.70^{a}	25.47 ± 1.78^{a}	458.58 ± 1.14^{c}	464.90 ± 0.59^{c}
Means		**105.67**	**108.67**	**22.22**	**24.62**	**442.38**	**457.56**
FYM	Without	104 ± 0.47^{b}	108 ± 0.43^{cd}	19.00 ± 0.47^{a}	21.47 ± 0.50^{a}	428.08 ± 2.85^{e}	434.50 ± 0.96^{e}
	TS	110 ± 1.44^{a}	114 ± 1.47^{ab}	21.67 ± 0.72^{a}	24.27 ± 0.71^{a}	492.52 ± 1.50^{b}	499.33 ± 0.92^{b}
	EM	111 ± 1.89^{a}	116 ± 2.10^{a}	22.33 ± 0.98^{a}	24.93 ± 0.98^{a}	551.90 ± 3.05^{a}	544.07 ± 3.29^{a}
Means		**108.33**	**112.67**	**21.00**	**23.56**	**490.83**	**492.63**
Source of variation	d.f	Mean square					
Replication	2	3.389 NS	1.694 NS	2.056 NS	1.709 NS	2.983 NS	2.351 NS
Fertilization (F)	1	9.389 NS	25.920 NS	6.722 NS	5.120 NS	10,566.703 ***	5535.273 ***
Error a	2	4.389	9.482	4.389	5.227	56.183	40.352
Bio-fert. (B)	2	66.722 NS	96.091 NS	10.056 NS	11.162 NS	8953.662 ***	5906.795 ***
Error b	4	9.306	4.085	6.639	6.809	27.553	16.092
F×B	2	1.056 NS	2.555 NS	1.289 NS	1.447 NS	3264.712 ***	3374.636 ***
Error c	4	7.806	14.274	4.306	4.033	22.303	7.138

NPK, inorganic fertilization (chemicals NPK fertilizers); *FYM*, organic fertilization (farmyard manure; 24 t ha^{-1}); *TS*, TS biofertilizer; *EM*, EM biofertilizer

± Refers to standard error of the mean ($n = 3$). !!Numbers with same letters in the same column means there no significant between them following Duncan's multiple range test at ($p \leq 0.05$)

*, **, and ***Means that there are significant, highly significant and very highly significant effects ($p < 0.05$, $p < 0.01$, and $p < 0.001$ respectively)

3.3.3 Seed Yield

As shown in Table 5, the application of the tested factors had significantly affected the seed yield value. The highest value 3.62 t ha^{-1} of seed yield was recorded at FYM + EM treatment. The lowest value 2.83 t ha^{-1} of seed yield was obtained, generally, in plants applied with the FYM treatment. The results obtained the similar trend in the second season as given in Table 5.

3.4 Initial Effect of Farmyard Manure and Bio-fertilizers on Chemical Composition of Quinoa

Data based on the chlorophyll content in leaves and its chemical composition (nitrogen, phosphorus, potassium, total protein, and oil content) of the studied seed of quinoa presented in Table 5 and illustrated by Figs. 3, 4, and 5 show the positive effect of using organic FYM, bio-fertilizers, and their combination on the chemical composition of quinoa seed content.

3.4.1 Chlorophyll Content Index

The result in Table 5 showed that the SPAD chlorophyll index values were higher during the second season than in the first season. The highest SPAD chlorophyll index values (127.47 and 132.57) were observed in the application of NPK + EM treatment during both seasons. At the same time, the FYM and FYM + TS treatments recorded the lowest values of this parameter without any significant differences. These results were true in both growing seasons.

3.4.2 NPK-Contents in Seed

Results showed that the nitrogen, phosphorus, and potassium contents in the seed under study were increased under the combination of fertilizer treatments as compared to NPK treatment in both seasons as shown in Fig. 3 (N-content a, P-content b and K-content c).

The statistical analysis showed that the highest values of nitrogen content (N-content; g kg^{-1}) in quinoa seeds were obtained with applied NPK + TS, NPK + EM, and FYM + EM treatments in the first season without any

Table 5 Influence of farmyard manure and bio-fertilizers on seeds yield of quinoa (*Chenopodium quinoa* Willd.) plants and chlorophyll content during two growing seasons

Treatments			Plant yield (g plant^{-1})		1000 Seed weight (g)		Seed yield (t ha^{-1})		Chlorophyll content (SPAD-value)	
Fertilization		Bio-fert	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019
NPK		Without	$104.11\pm2.68^{d\,!!}$	120.00 ± 1.33^{c}	3.23 ± 0.02^{c}	3.18 ± 0.03^{e}	2.83 ± 0.07^{d}	3.26 ± 0.04^{c}	113.40 ± 041^{ab}	116.97 ± 0.97^{cd}
		TS	115.20 ± 0.63^{c}	126.47 ± 0.64^{b}	3.25 ± 0.00^{c}	3.24 ± 0.00^{d}	3.13 ± 0.02^{c}	3.44 ± 0.02^{b}	115.33 ± 7.68^{ab}	122.47 ± 1.72^{b}
		EM	125.82 ± 0.99^{b}	129.32 ± 0.99^{b}	3.29 ± 0.01^{c}	3.25 ± 0.01^{d}	3.42 ± 0.03^{b}	3.52 ± 0.03^{b}	127.47 ± 6.09^{a}	132.57 ± 1.44^{a}
Means			**115.04**	**125.26**	**3.26**	**3.22**	**3.13**	**3.41**	**118.73**	**124.00**
FYM	Without		104.06 ± 0.77^{d}	109.06 ± 1.01^{d}	3.44 ± 0.01^{b}	3.34 ± 0.01^{c}	2.83 ± 0.02^{d}	2.97 ± 0.03^{d}	101.47 ± 2.63^{b}	111.37 ± 0.50^{e}
	TS		122.94 ± 0.57^{b}	126.74 ± 0.57^{b}	3.50 ± 0.03^{b}	3.47 ± 0.01^{b}	3.34 ± 0.02^{b}	3.45 ± 0.02^{b}	102.90 ± 3.68^{b}	113.37 ± 0.79^{de}
	EM		133.22 ± 0.86^{a}	133.53 ± 1.15^{a}	3.69 ± 0.00^{a}	3.59 ± 0.01^{a}	3.62 ± 0.02^{a}	3.63 ± 0.03^{a}	117.40 ± 3.24^{ab}	118.37 ± 0.86^{bc}
Means			**120.07**	**123.11**	**3.54**	**3.47**	**3.26**	**3.35**	**107.26**	**114.37**
Source of variation	d.f		Mean square							
Replication	2		8.014^{NS}	0.371^{NS}	0.0001^{NS}	0.0006^{NS}	0.104^{NS}	0.005^{NS}	149.037^{NS}	1.442^{NS}
Fertilization (F)	1		113.955^{*}	20.758^{*}	0.367^{***}	0.271^{***}	1.487^{*}	0.271^{*}	595.125^{*}	417.607^{***}
Error a	2		14.896	23.013	0.002	0.0002	0.194	0.300	108.485	3.098
Bio-fert. (B)	2		980.857^{***}	454.382^{***}	0.041^{***}	0.0396^{***}	12.801^{***}	5.930^{***}	404.057^{*}	198.756^{**}
Error b	4		5.788	0.308	0.002	0.001	0.075	0.004	123.431	11.377
F×B	2		29.101^{NS}	92.721^{***}	0.014^{*}	0.0130^{**}	0.380^{NS}	1.210^{***}	2.382^{NS}	28.056^{NS}
Error c	4		5.708	1.068	0.001	0.000	0.074	0.014	34.159	3.392

NPK, inorganic fertilization (chemicals NPK fertilizers); *FYM*, organic fertilization (farmyard manure; 24 t ha^{-1}); *TS*, TS biofertilizer; *EM*, EM bio-fertilizer

± Refers to standard error of the mean ($n=3$). !!Numbers with same letters in the same column means there no significant between them following Duncan's multiple range test at ($p\leq0.05$)

*, **, and ***Means that there are significant, highly significant and very highly significant effects ($p<0.05$, $p<0.01$, and $p<0.001$ respectively)

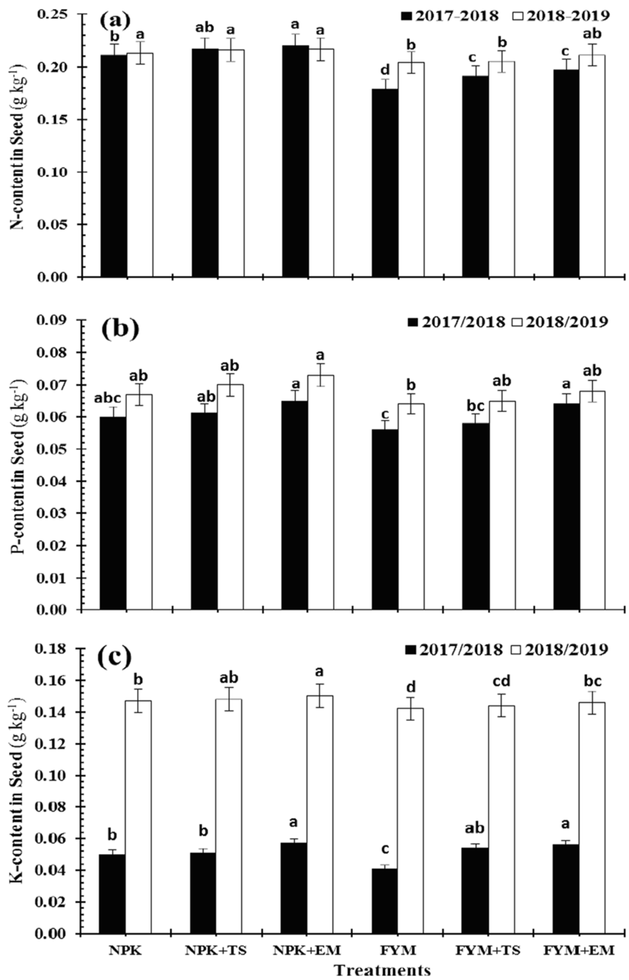

Fig. 3 Influence of farmyard manure and bio-fertilizers on seed N-content (**a**), P-content (**b**), and K-content (**c**) during two growing seasons. NPK, inorganic fertilization (chemicals NPK fertilizers); FYM, organic fertilization (farmyard manure; 24 t ha^{-1}); TS, TS bio-fertilizer; EM, EM bio-fertilizer. Different letters in the same bars indicate statistically significant following Duncan's multiple range test at ($p \leq 0.05$)

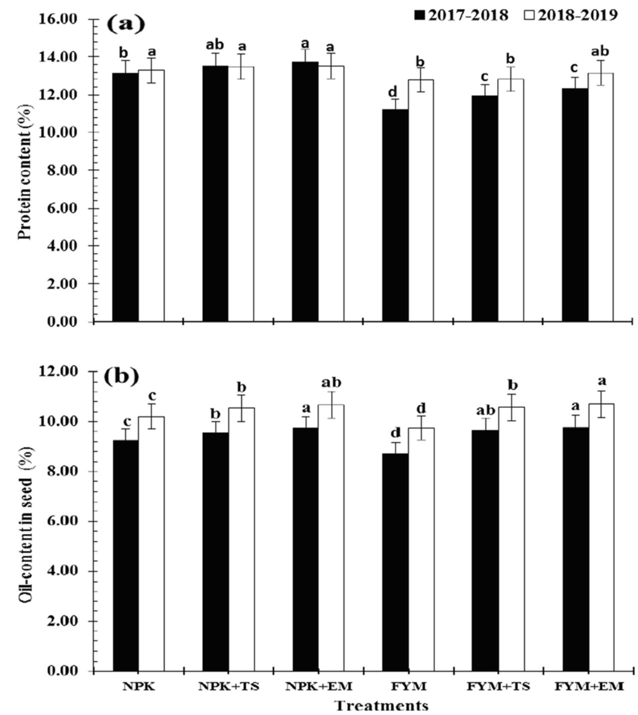

Fig. 4 Influence of farmyard manure and bio-fertilizers on quinoa seed protein contents (**a**) and seed oil contents (**b**) during two growing seasons. NPK, inorganic fertilization (chemicals NPK fertilizers); FYM, organic fertilization (farmyard manure; 24 t ha^{-1}); TS, TS bio-fertilizer; EM, EM bio-fertilizer. Different letters in the same bars indicate statistically significant following Duncan's multiple range test at ($p \leq 0.05$)

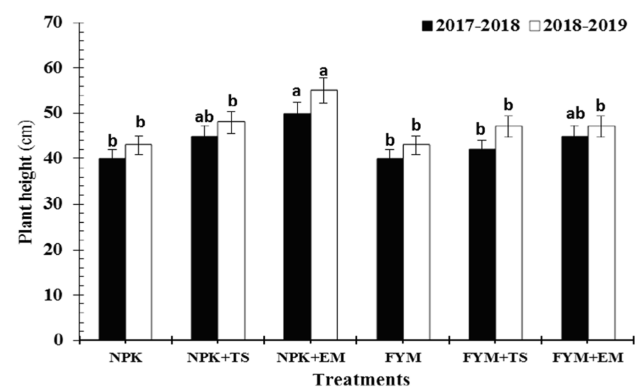

Fig. 5 Residual effect of farmyard manure and bio-fertilizers on height of Jew's mallow during two growing seasons. NPK, inorganic fertilization (chemicals NPK fertilizers); FYM, organic fertilization (farmyard manure; 24 t ha^{-1}); TS, TS bio-fertilizer; EM, EM bio-fertilizer. Different letters in the same bars indicate statistically significant following Duncan's multiple range test at ($p \leq 0.05$)

significant difference. Whereas, in the second season, NPK, NPK + EM, NPK + TS, and NPK + EM treatments also achieved without any significant differences. Moreover, the lowest values were indicated by FYM treatment in the first season, while in the second season, FYM and FYM + TS treatments obtained without any significant difference decreased as showed in Fig. 3a.

In addition, phosphorus content (P-content; g kg^{-1}) in the seeds were noticed to give the greatest values with all tested treatments without any significant difference except FYM and FYM + TS treatments in the first season, whereas in the second season, the same trend was found without any significant difference except, the FYM treatment. While, lowest values were noticed with NPK, FYM, and FYM + TS treatments without any significant difference in the first season and all treatments without any significant difference with the exception of NPK + EM treatment in the second season as shown in Fig. 3b.

On the other hand, potassium content (K-content; g kg^{-1}) in the seeds was increased with NPK + EM, FYM + TS, and FYM + EM treatments without EM bio-fertilizer treatments without any significant difference in the second season. Although, the lowest values were recorded with FYM treatment in the first season and FYM and FYM + TS treatments without any significant difference in the second season as shown in Fig. 3c.

3.4.3 Protein and Oil Contents in Seed

Presented data in Fig. 4a and b reflected the positive role of using organic FYM, bio-fertilizers, and their combination on the accumulation of protein and oil contents in seed of quinoa plants in both seasons. Data indicated that value of protein content in quinoa seeds was taken which mentioned in N-content in seeds under NPK with EM treatment was the highest values of 13.72 and 13.54% in the first and second growing seasons than other treatments in both growing seasons, respectively. In contrast, the lowest values 11.20 and 12.77% in the first and second growing seasons were recorded in FYM treatment, respectively as shown in Fig. 4a.

With respect to, the effect of different combination fertilizer treatments on oil percentage content in the seed of quinoa it was observed that the effect of different treatments on oil content was significant ($P < 0.05$). The highest values 9.76 and 10.72% of oil content in the first and the second growing seasons were obtained from FYM + EM treatment, respectively. Meanwhile, the NPK + EM treatment was the second with 9.73 and 10.68% in the two growing seasons, respectively, while the FYM treatment gave the lowest values 8.74 and 9.75% of oil content in both growing seasons, respectively as shown in Fig. 4b.

3.5 Economic of Quinoa Cultivation

The total cost of production in the cultivation of the quinoa from the sowing of the crop to its harvest is presented in Table 6. In the collected data, the higher monetary (income) cost of cultivation 2199 and 2292 \$ ha^{-1} in the first and the second growing seasons were recorded in FYM with EM treatment, respectively. Due to an increase in total variable cost of cultivation with increased dose of farmyard manure, the highest gross incomes ranged of 4856 and 5993 \$ ha^{-1} were recorded in the same application of FYM with EM the net returns (outcome). The highest net returns ranged 2657 and 3701 \$ ha^{-1} was recorded in FYM with EM in both seasons, respectively. The lowest net returns 1614 and 2627 \$ ha^{-1} was recorded with FYM treatment during the two seasons, respectively, shown in Table 6.

3.6 Residual effect of Farmyard Manure and Bio-fertilizers on Jew's mallow Plants

The secondary objective of this experiment to study the positive the residual effect of using FYM, bio-fertilizers, and their combination treatments on morphological traits of Jew's mallow plants (plant height, number of branches), and yields (fresh, dry biomass yields, and dry leaf yield). As well as chemical component (protein, P, and K-content) leave of Jew's mallow are illustrated in Figs. 6 and 7 and Table 7.

3.6.1 Plant Height

Presented data in Fig. 5 indicated the residual effect of using different treatments on plant height of Jew's mallow plants. The highest values of plant height 50 and 55 cm were observed in the residual effect of NPK + EM treatment in the

Table 6 Economic analysis of the farmyard manure and bio-fertilizers application in quinoa (*Chenopodium quinoa* Willd.) during two growing seasons

Treatments		Cost of production (\$ ha^{-1})		Gross incomes (\$ ha^{-1})		Net returns (\$ ha^{-1})		Benefit:cost ratio	
Fertilization	Bio-fert	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019
NPK	Without	1969	2058	3722 ± 97 cd	5386 ± 60bc	1825 ± 97 cd	3328 ± 60bc	0.93 ± 0.05ab	1.62 ± 0.03ab
	TS	1985	2077	4199 ± 23bc	5676 ± 29ab	2214 ± 23bc	3599 ± 29ab	1.12 ± 0.01a	1.73 ± 0.01a
	EM	1989	2082	4586 ± 36a	5773 ± 20a	2597 ± 36ab	3691 ± 20a	1.31 ± 0.02a	1.77 ± 0.01a
Means		**1981.00**	**2072.33**	**4169.00**	**5611.67**	**2212.00**	**3539.33**	**1.12**	**1.71**
FYM	Without	2179	2268	3793 ± 28 cd	4895 ± 45d	1614 ± 28d	2627 ± 45c	0.74 ± 0.01c	1.16 ± 0.02 cd
	TS	2195	2287	4481 ± 21ab	5688 ± 25ab	2286 ± 21bc	3401 ± 25bc	1.04 ± 0.01bc	1.49 ± 0.01 cd
	EM	2199	2292	4856 ± 31a	5993 ± 51a	2657 ± 31a	3701 ± 51a	1.21 ± 0.01ab	1.61 ± 0.02bc
Means		**2191.00**	**2282.33**	**4367.67**	**5525.33**	**2185.67**	**3243.00**	**1.00**	**1.42**

NPK, inorganic fertilization (chemicals NPK fertilizers); *FYM*, organic fertilization (farmyard manure; 24 t ha^{-1}); *TS*, TS biofertilizer; *EM*, EM bio-fertilizer

± Refers to standard error of the mean ($n = 3$). *\$*, sign of US dollar; *Benefit:Cost ratio*, net returns total production costs

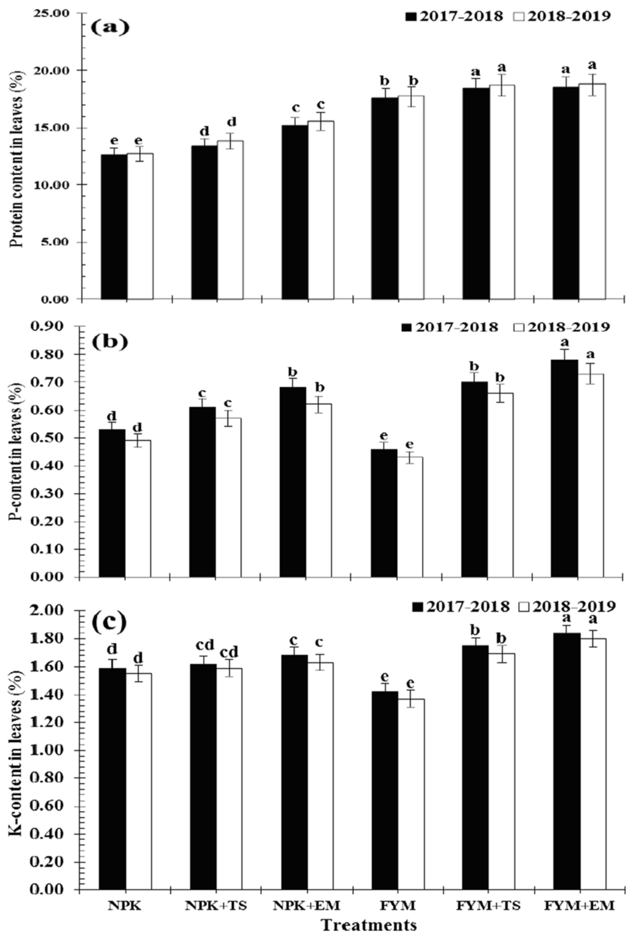

Fig. 6 Residual effect of farmyard manure and bio-fertilizers on protein content (**a**), P-content (**b**) and K-content (**c**) in Jew's mallow leaves during two growing seasons. NPK, inorganic fertilization (chemicals NPK fertilizers); FYM, organic fertilization (farmyard manure; 24 t ha^{-1}); TS, TS bio-fertilizer; EM, EM bio-fertilizer. Different letters in the same bars indicate statistically significant following Duncan's multiple range test at ($p \leq 0.05$)

first and second growing seasons, respectively. By contrast, the residual effect of using organic FYM, bio-fertilizers, and their combination on plant height was observed with plant fertilizer by FYM treatment. This trend was true in two tested seasons in Fig. 5.

3.6.2 Number of Branches/Plant

Data in Table 7 indicated that the number of branches per plant for Jew's mallow plants was not affected by the residual effect of organic FYM, bio-fertilizers, and their combination. In general, the greatest values of branch numbers per plant were recorded with the residual effect of FYM + EM treatment. While FYM treatment decreased the number of branches per plant, this result was obtained in both tested seasons.

3.6.3 Fresh Biomass Weight

Illustrated data in Table 7 present the residual effect of organic FYM, bio-fertilizer, and their combinations on fresh biomass weight of the plant. The residual effect of application of organic FYM, bio-fertilizer, and their combination recorded the highest fresh biomass weight values all over the two growing seasons. While, the lowest value of this parameter was observed with NPK treatment all over-tested seasons.

3.6.4 Dry Biomass Weight

Regarding data in Table 7 show that FYM + EM and NPK + EM treatments gave the highest value of dry biomass weight without any significant difference in the first season. Whereas, in the second season, the FYM + EM treatment increased it. Moreover, the lowest values were recorded with FYM treatment through both tested seasons.

3.6.5 Dry Leaf Yield

The data in Table 7 show clearly that the dry leaf yield of Jew's mallow plants was significantly affected by the residual effect of application organic FYM, bio-fertilizers, and their combination treatments. The FYM + EM treatment in the first season, whereas in the second season, the residual effect of FYM + EM and NPK + EM treatments were the most favorable for producing the greatest value of dry leaf yield. Moreover, FYM treatment leads to a decrease in this parameter in both seasons, respectively, shown in Table 7.

3.6.6 Chemical Component of Leaves

The data in Fig. 6 shows the positive effect of the residual effect of using organic FYM, bio-fertilizers, and their combination on protein, phosphorus, and potassium contents in Jew's mallow leaves. Regarding data in Fig. 6, (protein content **a**, P-content **b**, and K-content **c**) indicated that the highest value of N, P, and K contents in leaves were observed with the residual effect of application FYM + EM treatment, respectively. When, the residual effect of FYM treatment recorded the lowest value of those parameters, these results were true in both growing seasons show in Fig. 6.

4 Discussion

The illustrated data in Table 3 and in Fig. 2 revealed that all soil properties of the post-harvest soils such as EC, pH, SOC, soil N, P, and K-available and soil temperature were significantly affected by the application of different combination treatments. The greatest decrease of soil pH

Table 7 Residual effect of farmyard manure and bio-fertilizers on morphological traits and yields of Jew's mallow (*Corchorus olitorius* L.) during two growing seasons

Treatments		No. of branches		Fresh biomass yield (kg m^{-2})		Dry biomass yield (g m^{-2})		Dry leaf yield (g m^{-2})	
Fertilization	Bio-fert	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019	2017–2018	2018–2019
NPK	Without	$2.33 \pm 0.27^{a!!}$	2.17 ± 0.14^{a}	1.43 ± 0.00^{d}	1.67 ± 0.0^{1b}	302.50 ± 18.84^{b}	339.17 ± 4.31^{d}	143.69 ± 5.15^{d}	162.74 ± 3.22^{d}
	TS	2.67 ± 0.27^{a}	2.33 ± 0.27^{a}	1.98 ± 0.04^{c}	2.48 ± 0.20^{a}	343.83 ± 12.47^{b}	343.83 ± 12.44^{d}	163.69 ± 2.84^{c}	180.35 ± 4.30^{cd}
	EM	3.00 ± 0.47^{a}	2.50 ± 0.24^{a}	2.19 ± 0.00^{b}	2.83 ± 0.22^{a}	427.67 ± 20.98^{a}	434.60 ± 3.04^{b}	217.57 ± 0.57^{b}	233.48 ± 11.84^{ab}
Means		2.67	2.33	1.87	2.33	358.00	372.53	174.98	192.19
FYM	Without	2.33 ± 0.27^{a}	2.50 ± 0.24^{a}	1.18 ± 0.02^{e}	$1.61 \pm 0.\text{-}9^{b}$	234.92 ± 5.38^{c}	241.58 ± 5.48^{e}	104.25 ± 0.85^{e}	114.25 ± 0.85^{e}
	TS	2.67 ± 0.27^{a}	2.60 ± 0.25^{a}	1.95 ± 0.01^{c}	2.38 ± 0.15^{a}	306.08 ± 12.37^{b}	406.08 ± 12.34^{c}	153.38 ± 5.38^{cd}	209.71 ± 13.83^{bc}
	EM	3.33 ± 0.27^{a}	2.87 ± 0.11^{a}	2.53 ± 0.05^{a}	3.03 ± 0.20^{a}	468.08 ± 10.90^{a}	458.08 ± 6.79^{a}	248.27 ± 4.25^{a}	251.27 ± 19.39^{a}
Means		2.78	2.66	1.89	2.34	336.36	368.58	168.63	191.74
Source of variation	d.f	Mean square							
Replication	2	0.389 ^{NS}	0.150 ^{NS}	0.002 ^{NS}	0.059 ^{NS}	389.347 ^{NS}	1226.722 *	30.663 ^{NS}	1883.094 **
Fertilization (F)	1	0.056 ^{NS}	0.467 ^{NS}	0.002 ^{NS}	0.001 ^{NS}	2107.087 ^{NS}	70.211 ^{NS}	181.451 ^{NS}	0.907 ^{NS}
Error a	2	0.056	0.167	0.005	0.219	666.014	95.055	42.198	360.857
Bio-fert. (B)	2	1.056 ^{NS}	0.187 ^{NS}	1.689 ***	2.532 **	50,373.264 **	36,575.522 ***	18,598.235 ***	16,228.306 ***
Error b	4	0.305	0.099	0.004	0.122	972.227	177.773	62.636	442.626
F X B	2	0.056 ^{NS}	0.004 ^{NS}	0.134 ***	0.038 ^{NS}	4666.014 ^{NS}	10,426.672 ***	1861.797 **	2646.309 **
Error c	4	0.306	0.366	0.002	0.098	1314.238	89.049	87.044	94.082

NPK, inorganic fertilization (chemicals NPK fertilizers); *FYM*, organic fertilization (farmyard manure; 24 t ha^{-1}); *TS*, TS biofertilizer; *EM*, EM bio-fertilizer. ± Refers to standard error of the mean ($n = 3$)

[!!]Numbers with same letters in the same column means there no significant between them following Duncan's multiple range test at ($p \leq 0.05$)

[*], [**], and [***]Means that there are significant, highly significant and very highly significant effects ($p < 0.05$, $p < 0.01$, and $p < 0.001$ respectively)

registered in FYM + EM bio-fertilizer treatment up to 7.60. This may be due to the application of FYM with microorganism in the bio-fertilizer application to the soil that led to accumulation of organic acids during the decomposition of organic manure in the soil. These results were in harmony with those obtained by Khandaker et al. (2017) who found that the application of FYM is significant due to the increase in SOC and N available content. Also, these results are in accordance with (Zaman et al. 2017) indicating that soil pH would reduce soil acidity due to FYM application. Also, after quinoa plants harvest in the same treatment by FYM + EM bio-fertilizer were significantly greater and the average highest values of the soil N and P available content, respectively. This increased case might be due to the fact that FYM + EM bio-fertilizer contains a high N and P-content. It helps in the conversion of unavailable nutrients to available form through increasing microbial activity in the soil. Moreover, FYM with microorganisms in the bio-fertilizer improved the physical, chemical, and biological factors and fertility status of soil and increases the supply of nutrients in their available form (Balyan et al. 2002; Umesha et al. 2011). These results are in harmony with many studies which explained the beneficial effects of combined organic manures with bio-fertilizers application on SOC, availability of nutrients, and the improvement of soil properties, and significantly decreased soil pH with the increased levels of organic manure. By contrast, EC content and K-available content were significantly greater in the NPK + EM treatment compared to other treatments. EC and K-available increased over positive control as a range of the average of 988 to 1070 µScm^{-1} and 47 to 114 mg kg^{-1}, respectively. This may be due to positive interaction among the NPK chemicals and FYM + EM bio-fertilizer, which enhanced the K-available and other nutrients, consequently increasing soil EC values which improves properties of the soil. The above results agree with those obtained by (Kumar et al. 2013; Guo et al. 2014; Leghari et al. 2016; Kakabouki et al. 2018; Tadesse 2019; Bhalshankar 2020).

The effect of combinations of farmyard manure, NPK chemical fertilizers, and bio-fertilizers were obtained significantly on the morphological parameters of quinoa crop. When, lowest values of morphological performance indicated with NPK chemical fertilizer treatment which reflected the shortage of soil fertility, on the other hand, our results indicated that NPK + EM bio-fertilizer treatment gave the highest values of morphological quinoa crop in both tested seasons followed by FYM + EM bio-fertilizer treatment. This may be due to increasing N availability in the soil through a different growing stage of the plant which helps to increase the number of branches because N is an essential component a building block for plant tissue. On the contrary, FYM + EM bio-fertilizer treatment advanced by slow release nutrients because slow decomposing organic manure gave the highest values of plant height at the end of both seasons. This trend was agreed with by different studies conducted by (Gomaa, 2013; Ortuño et al. 2013). Another study showed that the application of a combined FYM with bio fertilizer had a positive effect on the plant growth parameters and productivity of cucumber (Ahamd et al. 2015). In addition, all yield characteristics and chemical content in quinoa crop were affected significantly by the application of different combinations of fertilization. In the current study, the maximum values of dry biomass, g seeds plan^{-1}, 1000-seed weights, seed yield, oil seed, and protein contents were recorded with FYM + EM bio-fertilizer treatment. This result was in harmony with several studies that demonstrated an increase yield characteristics and chemical composition of quinoa was as a result of the positive effects of applied FYM + EM bio-fertilizers. They may be attributed to the improved available nutrients that led to vigorous growth, sequentially improving yield characteristics and chemical composition status. Furthermore, Yadav et al. (2018) found that the application of FYM under bio fertilizers positively affected plant growth parameters and subsequent increases in the yield of dwarf pea. So, using FYM + bio-fertilizers can be improving the growth characteristics and yield of quinoa crops. Many authors had pointed the positive effect of using FYM + bio-fertilizers on yield characteristics and its chemical components at quinoa plants (Sugar et al. 2017; Roussis et al. 2019; Yousef et al. 2020; Bhalshankar 2020).

It was noted that the highest values of chlorophyll, N, P, and K contents were recorded in NPK + EM bio-fertilizer treatment due to the positive role of the beneficial effects of NPK chemical fertilizers + EM bio-fertilizer on stimulating the meristem-a-tic activity for producing more organs and nitrogen which played a major role in structural chlorophyll. Kakabouki et al. (2018) reported that quinoa yield might be increased when fertilized by soluble inorganic nitrogen as quickly as available.

Furthermore, economics data of quinoa crop shown in Table 6 revealed that, significantly maximum yield quinoa, higher productive and profitable \$ ha^{-1} were obtained with FYM + EM bio-fertilizer treatment in both growing seasons. This was so due to the lower cost and highest monetary return compared to other treatments. Similar results had been reported by (Youssef 2011; Yang et al. 2013; Abdel-Gawad and Youssef 2019).

Moreover, the benefits of residual effect of FYM + bio-fertilizers on the soil properties and Jew's mallow plants parameters were determined in this study. The positive effect on tested parameters such as plant height, number of branches, fresh and dry biomass yield, chlorophyll, protein, and P and K contents in leaves of Jew's mallow plants were observed with the application of FYM + EM bio-fertilizer treatment. This positive effect may be attributed to the role of organic manure incorporated microorganisms in improving the soil properties, increasing biological activity, increasing organic matter as well as nutrients availability, and subsequently increasing the growth and yield of Jew's mallow plants. These results are consistent with the findings obtained by Youssef (2011), who demonstrated that the residual effect of the combined application of organic manures + EM bio-fertilizer increases significantly, growth and yield components of sunflower and in maize plants (Adediran et al. 2004; Aguilera et al. 2012; Ali et al. 2020; Yousef et al. 2020).

5 Conclusions

Based on the obtained results, we can conclude that using organic manure (FYM), bio-fertilizers and their combination had a positive role in improving all-tested soil properties (EC, pH, SOC, soil N P K-availability, and soil temperature) and increase vegetative growth parameters, yield and its components for quinoa crop as well as quinoa seed quality (protein, oil, and chemical composition content of quinoa seed). Moreover, the residual effect of using organic manure (FYM), bio-fertilizers, and their combination has a positive effect on growth parameters, yield and its components for next crop (Jew's mallow). Furthermore, using a combination of organic manure (FYM) and bio-fertilizers are considered an environment-friendly system that leads to reducing the application of chemical fertilizers. From this investigation obtained, the integrated use of FYM and EM bio-fertilizer treatment increased almost all tested parameters in both growing seasons for the two crops.

Acknowledgements Thanks to all field technicians at Faculty of Agriculture, Al-Azhar University branch Assiut, Egypt and Ass. Prof. Mamdouh A. Eissa—Assistant professor of Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut, Egypt, 71526, (mamdouhessa@gmail.com) for her critical reading and revision of this research article.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

References

Abdel-Gawad AM, Youssef MA (2019) Effects of soil application of different fertilizers and foliar spray with yeast extract on growth and yield of faba bean plants. Bull Fac Agric Cairo Univ 70:461–472

Adediran AJ, Taiwo BL, Akande OM, Sobule AR, Idowu JO (2004) Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. J Plant Nutri 27:1163–1181. https://doi.org/10.1081/PLN-120038542

Adolf VI, Jacobsen SE, Shabala S (2013) Salt tolerance mechanisms in quinoa (Chenopodium quinoa Willd.). Environ Exp Bot 92:43–54

Aguilera J, Motavalli PP, Gonzales MA, Valdivia C (2012) Initial and residual effects of organic and inorganic amendments on soil properties in a potato-based cropping system in the Bolivian and high lands. Amer J Exper Agric 2:641–666. https://doi.org/10.9734/AJEA/2012/2006

Ahamd M, Zeshan MSH, Nasim M, Zahir ZAS, Nadeem M, Nazli F, Jamil M (2015) Improving the productivity of cucumber through combined application of organic fertilizers and pseudomonas fluorescens. Pak J Agric Sci 52:1011–1016

Ali S, Chattha MU, Hassan MU, Khan I, Chattha MB, Iqbal B, Rehman M, Nawaz M, Amin MZ (2020) Growth, biomass production, and yield potential of quinoa (Chenopodium quinoa Willd.) as affected by planting techniques under irrigated conditions. Int J Plant Prod 14:427–441. https://doi.org/10.1007/s42106-020-00094-5

Ali W, Ali M, Iqbal J, Khalil MK, Ahmad Z (2019) Impact of zinc and organic manure on wheat productivity and soil fertility. Adv Crop Sci Tech 7:414. https://doi.org/10.4172/2329-8863.1000414

Al-Sayed HM, Hegab SA, Youssef MA, Khalafalla MY (2019) Integrated effect of inorganic and organic nitrogen sources on growth and yield of Roselle (Hibiscus sabdariffa L.). Ass J Agric Sci 50:164–183

AOAC (2009) Official methods of analysis, 15th edn. Association of Official Analytical Chemists, Washington, DC

Awadalla A, Morsy ASM (2017) Influence of planting dates and nitrogen fertilization on the performance of quinoa genotypes under Toshka Conditions. Egyptian. J of Agron 39:27–40. https://doi.org/10.21608/agro.2017.440.1047

Balyan SK, Chandra R, Pareek RP (2002) Enhancing nodulation in urdbean by applying higher quantity of Rhizobium in planting furrows and PSB. Legume Res 25:160–164

Basel N, Sami M (2014) Effect of organic and inorganic fertilizers application on soil and cucumber (Cucumis sativa L.) plant productivity. Inte J Agric and Fores 4:166–170. https://doi.org/10.5923/j.ijaf.20140403.03

Bhalshankar C (2020) Study of the impact of organic manures and bio-fertilizers on growth of Phaseolus aureus roxb. Nepal J Biotechnol 8:76–81

Bhargava A, Shukla S, Ohri D (2006) Chenopodium quinoa an Indian perspective. Ind Crops Prod 23:73–87. https://doi.org/10.1016/j.indcrop.2005.04.002

Bhatt MK, Labanya RH, Joshi C (2019) Influence of long-term chemical fertilizers and organic manures on soil fertility - a review. Universal J Agric Rese 7:177–188. https://doi.org/10.13189/ujar.2019.070502

Bilalis DJ, Roussis I, Fuentes F, Kakabouki I, Travlos I (2017) Organic agriculture and innovative crops under Mediterranean conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 45:323–331. https://doi.org/10.15835/nbha45210867

Bilalis DJ, Roussis I, Kakabouki I, Folina A (2019) Quinoa (Chenopodium quinoa Willd.) crop under Mediterranean conditions: a review. Ciencia e Investigation Agraria 46:51–68. https://doi.org/10.7764/rcia.v46i2.2151

Carter MR, Gregorich EG (2007) Soil sampling and methods of analysis. 2nd (Ed), CRC Press, Boca Raton. FL. https://doi.org/10.1201/9781420005271

Chang KH, Wu RY, Chuang KC, Hsieh TF, Chung RS (2010) Effects of chemical and organic fertilizers on the growth, flower quality and nutrient uptake of Anthurium andreanum, cultivated for cut flower production. Sci Hort 125:434–441

Choukr-allah R, Rao NK, Hirich A, Shahid M, Alshankiti A, Toderich K, Gill S, Butt KR (2016) Quinoa for marginal environments toward future food and nutritional security in MENA and central Asia regions. Front Plant Sci 7:346. https://doi.org/10.3389/fpls.2016.00346

Darzi MT, Hadi MH, Rejali F (2011) Effects of vermicompost and phosphate bio-fertilizer application on yield and yield components in Anise (Pimpinella anisum L.). Iranian J Med and Aro Plants 26:401–465

Eisa SS, Abd El-Samad EH, Hussin SA, Ali EA, Ebrahim M, Juan A, González MO, Ordano LE, El-Bordeny NE, Abdel-Ati AA (2018) Quinoa in Egypt-plant density effects on seed yield and nutritional quality in marginal regions. Middle East J Appl Sci 8:515–522. http://hdl.handle.net/11336/86404

Eisa SS, Eid MA, Abd El-Samad EH, Hussin SA, Abdel-Ati AA, El-Bordeny NE, El-Bordeny SH, Ali MA, Hanan ME, Lotfy AM, El-Naggar AM, Ebrahim M (2017) Chenopodium quinoa Willd. A new cash crop halophyte for saline regions of Egypt. Aust J Crop Sci 11:343–351

Embrapa (2017) Manual of soil analysis methods (in Portuguese). Centro Nacional de Pesquisa de Solos, Rio de Janeiro, p 575

Escuredo O, Martín MIG, Moncada GW, Fischer S, Hierro JMH (2014) Amino acid profile of the quinoa (Chenopodium quinoa Willd.) using near infrared spectroscopy and chemometric techniques. J Cereal Sci 60:67–74. https://doi.org/10.1016/j.jcs.2014.01.016

FAO (2008) Guide to laboratory establishment for plant nutrient analysis. Fertilizer and Plant Nutrition Bulletin 19.

FAO (2011) Quinoa: an ancient crop to contribute to world food security. Regional Office for Latin America and the Caribbean.

FAO (2013) Launch of the international year of quinoa: UN celebrates Andean super food.

Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 105:731–738

Garcia M, Raes D, Jacobsen SE, Michel T (2007) Agro climatic constraints for rainfed agriculture in the Bolivian Altiplano. J Arid Environ 71:109–121

Gomaa EF (2013) Effect of nitrogen, phosphorus and bio-fertilizers on quinoa plant. J of Applied Sci Research 9:5210–5222

Graf BL, Rojas-Silva P, Rojo LE, Delatorre-Herrera J, Balde ME, Raskin I (2015) Innovations in health value and functional food development of quinoa (Chenopodium quinoa Willd.). Comp Rev Food Sci Food Safety 14:431–445

Gryndler M, Hršelová H, Klír J, Kubát J, Votruba J (2003) Long-term fertilization affects the abundance of saprotrophic microfungi degrading resistant forms of soil organic matter. Folia Microbiol 48(1):76–82

Guo C, Guo L, Li X, Gu J, Zhao M, Duan W, Ma C, Lu W, Xiao K (2014) Tapt2, a high-affinity phosphate transporter gene in wheat (Triticum aestivum L.), is crucial in plant P uptake under phosphorus deprivation. Acta Physiol Plant 36:1373–1384. https://doi.org/10.1007/s11738-014-1516-x

Hepperly P, Lotter D, Ulsh CZ, Siedel R, Reider C (2009) Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. Compost Sci Utilization 17:117–126. https://doi.org/10.1080/1065657X.2009.10702410

Isuosuo C, Akaneme F, Abu N (2019) Nutritional evaluation of the seeds of Corchorus olitorius: a neglected and underutilized species in Nigeria. Pak J Nutr 18:692–703. https://doi.org/10.3923/pjn.2019.692.703

Jacobsen SE (2017) The scope for adaptation of quinoa in northern latitudes of Europe. J Agron Crop Sci 203:603–613. https://doi.org/10.1111/jac.12228

Jancurova M, Minarovičova L, Dandar A (2009) Quinoa-a review. Czech. J Food Sci 27:71–79

Javaid A (2011) Effects of bio-fertilizers combined with different soil amendments on potted rice plants. Chilean J Agric Res 71:157–163

Kakabouki I, Bilalis D, Karkanis A, Zervas G, Tsiplakou E, Hela D (2014) Effects of fertilization and tillage system on growth and crude protein content of quinoa (Chenopodium quinoa Willd.): an alternative forage crop. Emir J Food Agric 26:18–24. https://doi.org/10.9755/ejfa.v26i1.16831

Kakabouki OP, Hela D, Roussis I, Papastylianou P, Sestras AF, Bilalis DJ (2018) Influence of fertilization and soil tillage on nitrogen uptake and utilization efficiency of quinoa crop (Chenopodium quinoa Willd.). J Soil Sci Plant Nutri 18:220–235

Khandaker MM, Jusoh NNH, AlA R, Ismail SZ (2017) The effect of different types of organic fertilizers on growth and yield of (Abelmoschus esculentus L). Moench (okra). Bulg J Agric Sci 23:119–125. https://doi.org/10.1038/s41598-020-73291-x

Kumar R, Sharma S, Prasad R (2013) Yield, nutrient uptake, and quality of Stevia as affected by organic sources of nutrient. Commun Soil Sci Plant Analy 44:3137–3149

Leghari SJ, Ahmed N, Bhabhan GM, Hussain K, Lashari AA (2016) Role of nitrogen for plant growth and development: a review. J Adv Environ Biol 10:209–218

Mabhaudhi T, Chimonyo VG, Chibarabada TP, Modi AT (2017) Developing a roadmap for improving neglected and underutilized crops: a case study of South Africa. Front Plant Sci 8:2143. https://doi.org/10.3389/fpls.2017.02143

Mahadeen AY (2009) Influence of organic and chemical fertilization on fruit yield and quality of plastic house grown strawberry. Jordan J Agric Sci 5:167–177

Marzouk NM, Hassan NM, Salehand SA, Tantawy AS (2016) Enhancement of Cassava productivity in Egyptian new reclaimed lands by using different foliar application treatments. Intern J of Pharm Tech Rese 9:204–214

Mosa WF, Paszt LS, EL-Megeed NAA (2014) The role of bio-fertilization in improving fruits productivity—a review. Advances in Microbio 4:1057–1064. https://doi.org/10.4236/aim.2014.415116

Mosa WFA, Paszt LS, Abd El-Megeed NA (2014) The Role of Biofertilization in Improving Fruits Productivity-A Rev Adv Microbiol 4:1057–1064. https://doi.org/10.4236/aim.2014.415116

Nowak V, Du J, Charrondière UR (2016) Assessment of the nutritional composition of quinoa (Chenopodium quinoa Willd.). Food Chem 193:47–54. https://doi.org/10.1016/j.foodchem.2015.02.111

Ortuño N, Castillo JA, Claros M, Navia O, Angulo M, Barja D, Gutiérrez C, Angulo V (2013) Enhancing the sustainability of quinoa production and soil resilience by using bio products made with native microorganisms. Agron 3:732–746

Pathan S, Eivazi F, Valliyodan B, Paul K, Ndunguru G, Clark K (2019) Nutritional composition of the green leaves of quinoa (Chenopodium quinoa Willd.). J of Food Res 8:55–65. https://doi.org/10.5539/jfr.v8n6p55

Peterson A, Jacobsen SE, Bonifacio A, Murphy K (2015) A Crossing Method for Quinoa Sustainability 7:3230–3243

Petric I, Šestan A, Šestan I (2009) Influence of wheat straw addition on composting of poultry manure. Process Saf Environ Prot 87:206–212

Ponce VM, Pandey RP, Ercan S (2000) Characterization of drought across the climate spectrum. J Hydrol Eng ASCE 5:222–224

Prasad H, Sajwan P, Kumari M, Solanki SPS (2017) Effect of organic manures and bio-fertilizer on plant growth, yield and quality of horticultural crop: a review. Inte J Chem Stud 5:217–221

Pulvento C, Riccardi M, Lavini A, d'Andria R, Iafelice G, Marconi E (2010) Field trial evaluation of two Chenopodium quinoa genotypes grown under rain-fed conditions in a typical Mediterranean environment in southern Italy. J Agron Crop Sci 196:407–411. https://doi.org/10.1111/j.1439-037X.2010.00431.x

Rahimi A, Moghaddam SS, Ghiyas M, Heydarzadeh S, Ghazizadeh K, Djordjevic JP (2019) The influence of chemical, organic and biological fertilizers on agrobiological and antioxidant properties of syrian cephalaria (*Cephalaria Syriaca* L.). Agriculture 9:122. https://doi.org/10.3390/agriculture9060122

Rana MC, Rana SS, Sharma SK, Kumar S, Sharma GD (2007) Influence of FYM and fertility levels on the productivity, economics and nutrient use efficiency of French bean (*Phaseolus vulgaris* L.) under high altitude of North-western Himalayas. Himachal J Agri Res 33:4–6

Rosati A (2005) Organic farming in Europe. Livest Prod Sci 90:41–51

Roussis I, Kakabouki I, Bilalis D (2019) Comparison of growth indices of (Nigella sativa L.) under different plant densities and fertilization. Emirates J Food Agric 31:231–247. https://doi.org/10.9755/ejfa.2019.v31.i4.1934

Sameera DL, Shankaraiah V, Srihari D (2005) Effect of packaging and storage on organic manures grown okra (Abelmoschus esculentus L. Moench). J of Res ANGRAU 33:30–35

SAS Institute (2008) The SAS System for Windows, release 9.2. Cary NC: SAS Institute.

Savci S (2012) Investigation of effect of chemical fertilizers on environment. APCBEE Proc 1:287–292. https://doi.org/10.1016/j.apcbee.2012.03.047

Silva FCDS (2009) Manual de análises químicas de solos, plantas e fertilizantes, Embrapa Informação Tecnológica. Embrapa Solos Brasília, Rio de Janeiro

Singh RB (2000) Intensive agriculture during the green revolution has brought significant land and water problems relating to soil degradation over exploitation of ground water and soil pollution due to the uses of high doses of fertilizers and pesticides. Agric Ecosyst Environ 82:97–103

Singh A, Singh K, Wasnik K, Singh RP (2017) Vermicompost and farmyard manure increase fertility of sodic soil and the productivity of green vegetables. Int J Adv Res 5:2623–2632. https://doi.org/10.21474/IJAR01/3451

Singh M, Dotaniya ML, Mishra A, Dotaniya CK, Regar KL, Lata M (2016) Role of bio-fertilizers in conservation agriculture. In Cons Agric 113-134. https://doi.org/10.1007/978-981-10-2558-7-4

Soil Survey Staff (2014) Keys to soil taxonomy, twelfh^{ed}. USDA. Natural Resources Conservation Service, Washington.

Steel RGD, Torrie JH, Dicky DA (1997) Principles and procedures of statistics, 3rd edn. McGraw-Hill Book Company, Inc., New York

Sugar E, Berzsenyi Z, Bonis P, Arendas T (2017) Growth analysis of winter wheat cultivars as affected by nitrogen fertilization (Wachstumsanalyse von Winterweizensorten in Abhangigkeit von Stickstoffdungung. Die Bodenkultur). J Land Manage Food Environ 68:57–70. https://doi.org/10.1515/boku-2017-0005

Sun Y, Liu F, Bendevis M, Shabala S, Jacobse SE (2014) Sensitivity of two quinoa (Chenopodium quinoa Willd.) varieties to progressive drought stress. J Agron Crop Sci 200:12–23. https://doi.org/10.1111/jac.12042

Tadesse N (2019) The response of Stevia (Stevia Rebaudiana L.) to nitrogen and phosphorous fertilizer rates at menagesha, west Ethiopia. Int J Res Stud Agric Sci 5:34–39. https://doi.org/10.19080/IJESNR.2019.22.556090

Taheri N, Heidari SAH, Yousefi KS, Mousavi R (2011) Effect of organic manure with phosphorus and zinc on yield of seed potato. Australian J of Basic and Appl Sci 5:775–780

Umesha K, Smitha GR, Sreeramu BS, Waman AA (2011) Organic manures and bio-fertilizers effectively improve yield and quality of stevia (Stevia rebaudiana). J Appl Hort 13:157–162

Vega-Gálvez A, Miranda M, Vergara J, Uribe E, Puente L, Martinez EA (2010) Nutrition facts and functional potential of quinoa (Chenopodium quinoa Willd.). An Ancient Andean Grain: a Review J Sci Food Agric 90:2541–2547. https://doi.org/10.1002/jsfa.4158

Wu SC, Caob ZH, Lib ZG, Cheunga KC, Wong MH (2005) Effects of bio-fertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial. Geoderma 125:155–166

Yadav AK, Singh S, Dhyani D, Ahuja PS (2011) A review on the improvement of stevia (Stevia rebaudiana B.). Can J Plant Sci 91:1–27

Yadav DD, Kumar Y, Balaji R, Pandey AK (2018) Efficacy of organic manures and bio fertilizers on growth and productivity of dwarf pea (Pisum sativum L.). J Pharm Phytochem 7:3823–3826

Yang J, Liu X, Shi Y (2013) Effect of different mixed fertilizer on yield, quality and economic benefits in Stevia rebaudiana Bertoni. Adv J Food Sci Technol 5:588–591. https://doi.org/10.19026/ajfst.5.3132

Yousef AF, Youssef MA, Ali MM, Ibrahim MM, Xu Y, Mauro RP (2020) Improved growth and yield response of Jew's mallow (Corchorus olitorius L.) plants through bio fertilization under semi-arid climate conditions in Egypt. Agron 10:1801–1815. https://doi.org/10.3390/agronomy10111801

Youssef MA (2011) Synergistic impact of effective microorganisms and organic manures on growth and yield of wheat and marjoram-plants. Ph.D. Thesis, Fac Agric Assiut Univ Egypt.

Zaman MM, Nahar K, Chowdhury T, Chowdhury MAH (2017) Growth, leaf biomass yield of stevia and post-harvest soil fertility as influenced by different levels of poultry manure. J Bangladesh Agri Univ 15:212–218. https://www.banglajol.info/index.php/JBAU/article/view/35065

Zhang QC, Shamsi IH, Xu DT, Wang GH, Lin XY, Jilani G (2012) Chemical fertilizer and organic manure inputs in soil exhibit a vice versa pattern of microbial community structure. Appl Soil Ecol 57:1–8. https://doi.org/10.1016/j.apsoil.2012.02.012

Zurita-Silva A, Fuentes F, Zamora P, Jacobsen SE, Schwember A (2014) Breeding quinoa (Chenopodium quinoa Willd.): potential and perspectives. Mol Breed 34:13–30. https://doi.org/10.1007/s11032-014-0023-5