Journal of Nuts 13(3) (2022) 183-197

Journal of Nuts

Journal homepage: ijnrs.damghaniau.ac.ir

ORIGINAL ARTICLE

Evaluating the Yield, Fatty Acid Composition, and the Seed Micronutrients Content in Peanut Cultivars under the Influence of Various Rates of Sulfur and Zinc Application

Ziba Shokri, Majid Ashouri*, Hamid Reza Doroudian, Naser Mohammadian Roshan, Seyyed Mostafa Sadeghi

Department of Agronomy and Plant Breeding, Lahijan Branch, Islamic Azad University, Lahijan, Iran

A R T I C L E I N F O

Keywords:

Oleic acid;

Oil;

Iron;

Peanut

A B S T R A C T

To investigate the effect of sulfur (S) and zinc (Zn) fertilizers on yield, fatty acid composition, and micronutrients of two peanut cultivars, a factorial experiment in a randomized complete block design with three replications was conducted in a farm in Guilan province, Astana Ashrafieh city in 2019 and 2020. The effects of S and Zn on peanut seed yield, fatty acids, and micronutrients were significant at the 1% level. The simultaneous application of Zn foliar application at a rate of 2 per thousand and S fertilizer at a rate of 40 kg ha^{-1} produced the maximum grain yield of the Spanish cultivar (with an average of 5770 kg ha^{-1}). With an average of 5331 kg ha^{-1}, the North Carolina 2 (CN2) cultivar produced the maximum yield when treated with 60 kg ha^{-1} of S and Zn foliar application at 2 per thousand. In terms of the number of fatty acids that make up the oil structure based on the average of the treatments tested, Oleic acid (56.9% in the Spanish cultivar and 61.1% in the CN2 cultivar) and Linoleic acid (28.6%) had the highest amount. The highest amount of palmitic acid was significantly higher in the treatment of the application of 40 kg ha^{-1} of S with a foliar application at 2 per thousand Zn (8.8%) and the lowest amount was found in the treatment without S and Zn (7.2%). According to the results of this experiment, both S and Zn factors were effective on most traits, so it is better to use Zn fertilizer if S is used to better absorb this element and can be effective in the growth and development of peanut plants. Therefore, simultaneous use of S fertilizer and Zn foliar application at high levels to improve the quality of fatty acids and grain micronutrients in the Guilan region is recommended.

Introduction

The increase in cropping intensity and accompanying changes in the soil and fertilizer-management practices have altered the S and Zn status of the soils and their availability. Peanut (*Arachis hypogaea* L.) is cultivated as a human and livestock food in tropical and subtropical climates, and it may tend a significant source of protein and oil (Sanderfur *et al*., 2017). Peanut nuts contain 43 to 55 % oil and 25 to 28 % protein, making them a good source of edible oil (Boukid, 2022). World production of peanuts was approximately 47 million metric tons in 2020, about 56% of the peanuts grown were made into peanut butter (FAO, 2020), demonstrating the plant's value as an oil plant (Akhtar *et al*., 2014). About two-thirds of the world's peanut crop is utilized to produce oil, demonstrating the plant's value as an oil plant (Janila *et al*., 2013). Proper plant nutrition is an important agricultural practice that highly determines crop yield and its quality. A proper plant nutrition practice not only

***Corresponding author**: Email address: mashouri48@yahoo.com

Received: 16 March 2022; Received in revised form: 2 May 2022; Accepted: 11 July 2022

DOI: 10.22034/jon.2022.1955111.1160

provides an appropriate amount of all nutrients for the plant but also keeps the right balance of nutrients in the soil (Ijaz *et al*., 2020). The importance of Zn on improving plants growth and crop quality have been reported in several studies (Keshavarz *et al.*, 2011; Hosseinifarahi *et al*., 2022; Maliha et al., 2022; Mohit Rabary *et al*., 2022). Fertilizers enhance soil fertility and optimize the important traits in plants, particularly crops, to promote growth, production, and quality (Yadav *et al*., 2022). The availability of plant nutrients, particularly micronutrients, is critical for enhancing the quality of food produced and population health (Barman *et al*., 2022). Besides, proper use of fertilizers is an approach to improve postharvest quality of horticultural crops (Nazoori *et al*., 2022). The peanut plant, like other plants, requires various nutrients; however, unlike other pea plants, peanut pods develop underground, consequently receive the majority of its calcium requirements directly from the soil via the growth of pods and thrive in calcium-rich soils (Pegues *et al*., 2019; He *et al*., 2018). Peanuts are deficient in several elements such as sulfur (S), zinc (Zn), and iron due to their cultivation on calcareous soils and the large level of soil bicarbonate in them (Fei *et al*., 2019). S is vital for seed quality and development in oilseeds, and these plants often need more S for appropriate growth and yield. S is also vital in the synthesis of the plant's main and secondary metabolisms (Saini *et al*., 2017; Radwan, 2017). In peanuts, S plays a critical role in the creation of vital amino acids cysteine, cysteine, and methionine, nitrogen fixation, grain development, and oil and protein biosynthesis (Aier and Nongmaithem, 2020). Because S is involved in the synthesis of proteins, oils, and many vitamins, it is oxidized and converted to sulfate. S also plays an important role in the formation of sulfolipids, which are found in cell membranes and are responsible for the formation of plant oils. S is a structural component of protein disulfide bonds, amino acids, vitamins, and cofactors. Most of the S in soil is present in organic matter and hence not accessible to the plants (Narayan *et al*., 2022). Because the soils used to grow peanuts in Gilan province include those near the river and along the shore, these soils have a calcareous mother bed. As a result, these soils are high in calcium bicarbonate and dissolved calcium, and their pH is often greater than 7, so peanuts during various phases of development, particularly towards the conclusion of the pod growth period. And the absence of S may be seen in the early stages of grain development beneath the soil (Abdzad Gohari and Sadeghipour 2019). According to research, consuming gypsum may help eliminate S shortage in peanuts (El-Kader, 2010). In addition to supplying calcium, gypsum also offers the S that peanuts need, which plays a significant role in enhancing this plant's yield (Kannan *et al*., 2017; Laxmanarayanan *et al*., 2020). S ingestion, in general, promotes a nutrient-balanced environment for peanuts, with one of the outcomes being the maintenance of physiological iron activity for chlorophyll production (Devi *et al*., 2012; Ruksar *et al*., 2017). Yield, fatty acid composition, and micronutrient content in seeds were tested in high-yielding canola cultivars using varying levels of S, and it was found that S administration boosts micronutrient supply and absorption, as well as quality and quality. (Mostafavi Rad *et al*., 2011).

Zn is an element that is lacking in the majority of Iranian soils. Zn insufficiency is one of the world’s most common and serious micronutrient deficits in peanuts (Aboyeji *et al*., 2019). Although plants have a modest demand for Zn, if there isn't enough of it, they will experience physiological stress due to the inefficiency of various enzyme systems and other Zn-related metabolic activities. Zn is a necessary component of plant development because it aids in the synthesis of indole acetic acid and controls plant growth (Pavithra *et al*., 2018; Meresa *et al*., 2020). Carbonic anhydrase, dehydrogenases, aldolases, carboxypeptidase, superoxide dismutase, Arana polymerase, ribose phosphate carboxylase, and phospholipase all need Zn as a cofactor (Srivastava and Gupta, 1996). Zn treatment in the form of soil and foliar spraying, as well as their combination, has been shown to increase the yield components of peanuts (Kamarki and Galavi, 2012). Zn treatment changed the fatty acid composition of cotton, reducing saturated fatty acids (palmitic, and stearic) while increasing unsaturated fatty acids (oleic and linoleic) (Zakaria *et al*., 2006). The influence of three elements, S, Zn, and iron, on safflower growth and yield, revealed that combining S with Zn and iron considerably boosted safflower growth, yield, and seed oil quantity (Ravi *et al*., 2008). Although peanuts have been grown in Iran for over a century, this plant has yet to be properly evaluated as a crop for oil extraction (Safarlu and Hemmati, 2014). Due to excessive rainfall in Gilan province, S seeping from the soil horizon, no use of S fertilizers in peanut agriculture, and soil S deficit, as well as a lack of knowledge on the influence of S intake on peanut development and production, The goal of this research was to look into the effects of S and Zn fertilizer levels on grain yield and peanut oil production, as well as to determine the ideal fertilizer composition for Gilan's climatic circumstances.

Materials and Methods

This experiment was conducted during two growing seasons (2019 and 2020) in Gilan province and Astana Ashrafieh city (latitude: 37° 05´ N; longitude: 48° 20´ E; altitude: 15 m). The experiment was a complete randomized block design in a factorial arrangement with three replications. Experimental factors were included: a) Zn foliar fertilization (EDTA) at 0, 1 and 2 mg l^{-1} concentrations b) S fertilizer ($CaSO_4.2H_2O$) at 0, 20, 40 and 60 kg ha^{-1} rates c) Two cultivars of Spanish Flora (Spanish) and North Carolina 2 (NC2). Each experimental unit was 4 m×2.5 with five rows. This area has a warm humid climate, with an average annual rainfall of 1308.5 millimeters. Tables 1 and 2 indicate the average temperature and humidity, total rainfall, and monthly sunlight hours throughout a two-year growth season, as well as the physical and chemical qualities of the soil. Peanuts were planted on May 15th in both years. Gilan Support Services Company provided the peanut seeds. The seeds were disinfected with the carboxy thiram fungicide at a rate of 2 per thousand before being planted at a depth of 3 cm in the soil. Three rounds of weeding to manage weeds and dirt surrounding the roots were done throughout the plant development period and during the maintenance stage. To supply the required S, gypsum with the chemical formula CaSO4.2H2O (containing 18% S and 22% calcium) was used as a base (for the treatment of 20, 40, and 60 kg ha^{-1} of S, 111, 222, and 333 kg ha^{-1} of gypsum are required, respectively) and was applied as a strip next to plants at a depth of 5 cm at the time of sowing seeds with other fertilizers, and Zn chelate (EDTA) was used to supply Zn, which was sprayed for 2 liters per plot in two stages (3 to 4 leaves and full flowering plants) during the growing season on aerial parts The plants were doused with pesticides. The peanut crop was picked by hand and physiologically cared for in both years (11 September). Ripe pods were picked and peeled to evaluate grain yield after marginal effects were removed. They were then dried for 48 hours at 48 degrees Celsius in an oven. Finally, grain yield was computed in each plot using a scale with a one-hundredth-gram precision. Gas chromatography was used to determine the number of fatty acids present. Varian Company manufactured the gas chromatographic apparatus utilized in this investigation, type CP-3800 (USA). The amounts of iron, manganese, Zn, and copper were determined using atomic absorption spectroscopy (Flame AA-7000) and hydrochloric acid dry combustion. SAS software version 9.1 was used to analyze the data once it was collected and recorded. The least significant difference test (LSD) was used to compare mean values at the 5% probability level. EXCEL software was used to create the diagrams.

Table 1. Meteorological information from the years 2019 and 2020 at the site of the project.

year	climatic item	21Mar-20Apr	21Apri-16Ma	17May-16Jun	17Jun-18Jul	19Jul-18Agu	20Agu-19Sep
2019	T Mean (°C)	13.7	19.4	23.1	28.1	27	25.1
	Rainfall (mm)	20.4	37.2	48.7	30.8	68.4	13.8
	Humidity (%)	76	74	75	73	77	74
	Sunny Hours(h)	145.9	170.4	230.3	295.4	164.9	209.7
2020	T Mean (°C)	12.8	19.2	24.6	27.2	25.4	23
	Rainfall (mm)	131	64.5	9.9	58.3	25.3	156
	Humidity (%)	85	73	67	76	71	83
	Sunny Hours(h)	100.3	222	306.4	253.3	226.1	123.5

Table 2. Physico-chemical characteristics of the soil.

Year	Soil type	pH	Electrical Conductivity(dS m^{-1})	Organic Carbon (%)	Total Nitrogen (%)	Phosphorus (mg kg^{-1})	Potassium (mg kg^{-1})	Soluble sulfate (meq L^{-1})	Zn (mg kg^{-1})
2019	Loam	7.3	0.32	2	0.054	18.1	140	0.04	2.5
2020		7.4	0.3	1.9	0.053	19.5	131	0.06	2.7

Results

Seed yield

The interaction between cultivar, S fertilizer, and Zn foliar application was significant ($p < 0.05$) on grain yield (Table 3). The maximum grain yield of the Spanish cultivar (an average of 5770 kg ha^{-1}) was produced by Zn foliar application at 2 per thousand and S fertilizer at a rate of 40 kg ha^{-1} simultaneously. The best yield of peanut seeds (NC2 cultivar) was achieved using 60 kg ha^{-1} of S in combination with a foliar application at 2 per thousand Zn at an average of 5331 kg ha^{-1}, while the lowest yield was produced using no S and Zn foliar application at 2 per thousand at an average of 3675 kg ha^{-1} (Table 4).

Fatty acid composition

The simple effects of S and year, cultivar, and S on Palmitic acid ($p < 0.05$) and the interaction impact of S fertilizer and Zn foliar application on palmitic acid ($p < 0.05$) were significant. Additionally, a comparison of mean data revealed that the treatments of 40 kg ha^{-1} of S with foliar application of 2 per thousand Zn (8.77 %) and 60 kg ha^{-1} of S with foliar application of 1 per thousand Zn (8.76%) produced the maximum amounts of Palmitic acid.

The lowest amount of Palmitic acid was observed in the treatment without S and Zn foliar application with an average of 7.28%. The treatment without S consumption and foliar application of 1 per thousand Zn with an average of 3.84% had the highest amount of Stearic acid. The lowest amount was observed in the treatment of 60 kg ha^{-1} of S and foliar application of 1 per thousand Zn with an average of 2.82% (Tables 3 and 4). The analysis of variance revealed that the interaction impact of cultivar, S, and Zn fertilizer on the quantity of Oleic and Linoleic acid was statistically significant at the 5% probability level (Table 3). Additionally, a comparison of the mean data revealed that the highest concentration of Oleic acid in the Spanish cultivar was obtained with no S consumption and foliar application of 1 per thousand Zn at an average of 56.9 %, while the lowest concentration was obtained with 60 kg ha^{-1} of S and without Zn foliar application at an average of 50.4 % (Table 4). However, the maximum concentration of Oleic acid was achieved in the CN2 cultivar when 60 kg ha^{-1} of S was combined with Zn foliar application at 2 per thousand treatments, yielding an average of 61.1 %. The lowest result was 50.2 % in the treatment without S intake and 1 per thousand Zn foliar applications, which was not statistically significant in the treatment without S consumption and 1 per thousand Zn foliar applications. The largest concentrations of oleic fatty acids were detected in the urea fertilizer and 40 kg ha^{-1} of S. Comparing average data revealed that in the Spanish cultivar, plants treated with 60 kg ha^{-1} of S and foliar application of 2 per thousand Zn had the greatest level of Linoleic acid at an average of 28.56 %.

The cultivar with the lowest level of Linoleic acid included 20 kg ha^{-1} of S and a foliar application of 1 per thousand Zn at an average of 24.41 %.

However, the maximum level of this feature was attained in the CN2 cultivar with no S consumption and foliar application of 2 per thousand Zn at an average of 28.48 %. The lowest quantity was seen with a S treatment of 60 kg ha^{-1} combined with a foliar application of 1 per thousand Zn (with an average of 23.43 %), which was statistically applied with a S treatment of 20 kg ha^{-1} alone. There was no discernible difference between the groups.

Table 3. Results of combined analysis of variance of seed yield, grain micronutrients, and composition of peanut fatty acids.

S.O.V	df	Seed Yield (kg ha^{-1})	Fe (ppm)	Cu (ppm)	Mn (ppm)	Oil (%)	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Behenic acid (%)	Arachidic acid (%)
Year	1	11401^{**}	176.3^{**}	42.2^{**}	18.4^{ns}	2523^{**}	0.716^{ns}	1.16^{ns}	108.9^{*}	3.12^{ns}	0.940^{ns}	0.279^{*}
Rep (Year)	4	147.4	4.602	0.166	13.18	59.32	0.519	0.841	6.51	2.26	0.174	0.0152
C	1	29090^{*}	5.146^{ns}	0.696^{ns}	214.9^{ns}	12.39^{ns}	6.078^{ns}	0.368^{ns}	0.375^{ns}	1.12^{ns}	1.614^{ns}	0.224^{ns}
S	3	521.9^{ns}	6.403^{ns}	17.17^{*}	126.1^{ns}	1234.48^{*}	1.312^{*}	0.1658^{ns}	0.954^{ns}	0.316^{ns}	0.199^{ns}	0.0317^{ns}
Zn	2	18.29^{ns}	22.17^{ns}	4.27^{ns}	337.4^{*}	265.6^{*}	1.216^{ns}	0.237^{ns}	5.59^{ns}	27.8^{ns}	0.089^{ns}	0.0264^{ns}
Y*C	1	1335.4^{ns}	36.5^{*}	18.9^{**}	446^{**}	197.5^{**}	0.509^{ns}	0.286^{ns}	14.58^{*}	6.09^{ns}	0.231^{*}	0.032^{ns}
C*S	3	1230^{ns}	9.020^{ns}	6.685^{*}	512.7^{**}	32.03^{ns}	0.172^{ns}	0.0376^{ns}	66.5^{*}	4.26^{ns}	0.455^{**}	0.0695^{ns}
C*Z	2	368.8^{ns}	108.0^{*}	5.49^{ns}	289.7^{*}	0.311^{ns}	0.192^{ns}	0.522^{ns}	25.4^{ns}	9.71^{ns}	0.109^{ns}	0.0795^{ns}
Y*S	3	979^{**}	21.6^{ns}	0.667^{ns}	33.18^{*}	129.21^{**}	0.210^{ns}	0.296^{ns}	0.685^{ns}	4.29^{ns}	0.315^{**}	0.0171^{ns}
S*Z	6	737^{*}	18.08^{ns}	12.98^{**}	263.6^{**}	86.76^{**}	0.260^{ns}	0.601^{*}	15.5^{*}	2.36^{ns}	0.166^{*}	0.0289^{*}
Y*Z	2	355.9^{ns}	5.70^{ns}	3.72^{ns}	8.06^{ns}	9.84^{ns}	0.359^{ns}	0.0477^{ns}	3.14^{ns}	4.41^{ns}	0.0818^{ns}	0.0061^{ns}
Y*C*S	3	544.5^{ns}	23.2^{ns}	0.416^{ns}	7.43^{ns}	21.71^{ns}	1.127^{*}	0.293^{ns}	4.59^{ns}	2.55^{ns}	0.0119^{ns}	0.0125^{ns}
Y*C*Z	2	547.91^{ns}	5.23^{ns}	0.445^{ns}	14.7^{ns}	8.31^{ns}	0.379^{ns}	0.179^{ns}	1.42^{ns}	3.73^{ns}	0.067^{ns}	0.0143^{ns}
Y*S*Z	6	180.7^{ns}	6.51^{ns}	1.16^{ns}	3.68^{ns}	19.06^{ns}	0.331^{ns}	0.095^{ns}	3.13^{ns}	2.64^{ns}	0.021^{ns}	0.0050^{ns}
C*S*Z	6	1403.0^{*}	36.55^{*}	18.95^{**}	446.9^{**}	20.62^{ns}	0.509^{ns}	0.286^{ns}	14.5^{*}	6.09^{*}	0.231^{ns}	0.0329^{ns}
Y*C*S*Z	6	265.90^{ns}	8.16^{ns}	1.47^{ns}	9.98^{ns}	19.12^{ns}	0.182^{ns}	0.108^{ns}	3.36^{ns}	2.06^{ns}	0.074^{ns}	0.0102^{ns}
Error	92	207.5	9.993	1.81	11.35	23.36	0.363	0.1481	3.658	2.77	0.0716	0.0115
CV (%)	_	19.1	12.35	16.71	9.95	12.01	7.01	11.07	3.54	6.38	9.54	7.12

ns, *, ** are non-significant, significant at 5% and 1% probability level, respectively

Table 4. Comparison of the mean effect of the interaction of cultivar, different levels of S and Zn fertilizer on yield, grain micronutrients, and composition of peanut fatty acids

Cultivar	S×Zn	Seed Yield ($kg\ ha^{-1}$)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Oleic acid (%)	Linoleic acid (%)
Spanish	S1Zn1	5290 abc	27.250abc	6.01cd	22.22d	55.48ab	25.95abcd
	S1Zn2	5243abcd	30.05a	7.92bc	35.56c	56.95a	24.91cd
	S1Zn3	4193bcd	21.53d	11.2a	46.67b	55.49ab	26.14abcd
	S2Zn1	4612abcd	24.75bcd	5.61cd	20.56de	51.77bc	27.74ab
	S2Zn2	5256abc	29.30ab	9.53ab	53.33a	54.55abc	24.41d
	S2Zn3	5002abcd	23.55cd	8.13bc	34.44c	54.38abc	26.74abcd
	S3Zn1	5447ab	24.50bcd	9.51ab	21.39de	53.76abc	27.31abcc
	S3Zn2	4626abcd	24.35bcd	9.24ab	45.56b	55.88ab	25.31bcd
	S3Zn3	5770a	23.20cd	4.43d	16.67de	54.48abc	26.78abcd
	S4Zn1	3975d	25.50abcd	11.61a	36.67c	50.40c	25.20bcd
	S4Zn2	5275abc	24.25bcd	6.03cd	15.56e	51.60bc	25.20bcd
	S4Zn3	4093cd	25.60abcd	9.50ab	36.94c	52.32bc	28.56a
NC2	S1Zn1	4581abcd	25.6bcd	6.50de	24.44de	53.96cd	25.2 bcd
	S1Zn2	3844d	20.7d	8.00cd	27.78cd	50.20e	26.88 abc
	S1Zn3	3675d	29.ab	5.500e	23.61e	52.60d	28.48a
	S2Zn1	5325abc	29.3ab	8.50bc	38.89b	55.40bc	23.52d
	S2Zn2	4694abcd	23.0d	6.67de	38.79b	52.60d	26.8 abc
	S2Zn3	5368abc	24.0cd	5.670e	29.67c	53.20d	26.8 abc
	S3Zn1	4400abcd	23.4d	6.330de	40.91b	56.96b	24.5cd
	S3Zn2	4019bcd	24.0cd	11.00a	42.22ab	50.60e	24.83bcd
	S3Zn3	3940cd	29.0abc	7.67cd	44.99a	52.80d	27.1abc
	S4Zn1	3962bcd	33.0a	9.82ab	40.75b	52.40d	26.1 abcd
	S4Zn2	4494abcd	23.0d	10.12ab	45.31a	56.96b	23.43d
	S4Zn3	5331a	25.4bcd	9.86ab	29.67c	61.12a	27.6ab

Zn fertilizer (Zn1: no foliar application, Zn2: 1 per thousand foliar application, Zn3: 2 per thousand foliar application)
S fertilizer (S1 without fertilizer: S2 20, S340, and S4 60 kg ha^{-1}), two cultivars of Spanish Flora (Spanish) and North Carolina 2 (NC2)

The interaction impact of S fertilizer and Zn foliar application on the levels of Behenic acid and Arachidic acid was significant (P<0.05) (Table 3). The comparison of the mean of the data also revealed that the highest amount of Behenic acid in the Spanish cultivar was obtained with S treatment in 60 kg ha^{-1} and a spray of 2 per thousand Zn with an average of 2.96 % and the lowest amount was obtained with S treatment in 60 kg ha^{-1} and no Zn foliar application with an average of 2.21 %, which was not statistically significant with S treatment in 60 kg ha^{-1}; Additionally, the maximum concentration of Behenic acid in the CN2 cultivar was obtained from plants treated with 40 kg ha^{-1} of S in combination with a foliar spray of 1 per thousand Zn at an average concentration of 3.46 %. This feature had the lowest average value of 2.18 % in S treatment in 60 kg ha^{-1} with foliar spray of 2 per thousand Zn. Additionally, a comparison of the mean data revealed that S treatment in 60 kg ha^{-1} with a foliar spray of 2 per thousand Zn with an average of 1.6 % had the greatest level of Arachidic acid in the Spanish cultivar. With certain S and Zn therapies, this therapy was not statistically significant. This feature had the lowest average value of 1.61 % in the treatment without S ingestion and Zn foliar spray. However, in the CN2 cultivar, plants treated with 60 kg ha^{-1} of Sand 1 per thousand Zn foliar treatments had the greatest level of Arachidic acid at an average of 4.97 %. The lowest quantity was associated with S treatment in 60 kg ha^{-1} with a 2 per thousand Zn sprays, which resulted in an average of 3.33 %.

The amount of oil

The interaction impact of S fertilizer and Zn foliar application was significant ($P<0.01$) on the percentage of oil (Table 3). The mean comparisons revealed that the greatest percentage of oil was achieved when 40 kg ha^{-1} of S was combined with a foliar spray of 1 per thousand Zn, averaging 46.09 %. The treatment with the lowest proportion of oil without S consumption was followed by a foliar spray of 2 per thousand ZnZn at a rate of 32.61 % on average (Table 4). The simultaneous application of S and Zn at high concentrations improved the oil content of peanuts in this research. This is due to the presence of S in the fatty acid composition; S increases the number of fatty acids in the plant and hence the percentage of oil.

Micronutrients

The interaction impact of cultivar, S, and Zn fertilizer on Fe ($P<0.05$), Cu, and Mn content ($P<0.01$) of grain was significant (Table 3). Additionally, the maximum concentration of iron grain in the Spanish cultivar was produced with 20 kg ha^{-1} of S treatment and without Zn spraying, with an average of 30.05 ppm, and the lowest with no S consumption. Additionally, a foliar treatment of Zn foliar application at 2 per thousand was achieved (with an average of 21.53 ppm). However, the maximum concentration of iron grain was recorded in cultivar CN2 when S treatment in 60 kg ha^{-1} was applied without Zn foliar spray, with an average of 33 ppm. The treatment without S consumption combined with foliar application of one per thousand Zn had the lowest average value of 20.7 %, followed by the treatments with S consumption of 20 kg ha^{-1} combined with foliar application of 1 per thousand Zn and S consumption of 40 kg ha^{-1} combined with foliar application of one per thousand Zn. Without Zn foliar treatment, there was no statistically significant change per acre.

A comparison of the mean values revealed that the greatest Cu grain concentrations in the Spanish cultivar were produced with treatments of 60 kg ha^{-1} of S and without Zn spraying and S consumption with Zn foliar application at 2 per thousand, with an average of 61.11 and 11.2 ppm, respectively, with an average of 4.43 ppm in the treatment of 40 kg ha^{-1} of S with Zn foliar application at 2 per thousand. The maximum concentration of Cu of grain was related to the CN2 cultivar when 40 kg ha^{-1} of S was combined with Zn foliar application at 1 per thousand, yielding an average of 53.27 ppm. The lowest value was in the treatment without S consumption with Zn foliar application at 2 per thousand at an average of 5.5 ppm, followed by the treatment with 20 kg ha^{-1} of S and 2 per thousand Zn spraying at an average of 5.5 ppm; there was no statistically significant difference between the treatments. The quantity of Cu and Zn micronutrients in seeds climbed to a level of 40 kg ha^{-1} of S, but reduced to a rate of 80 kg ha^{-1} of S, while the amount of iron and manganese in seeds increased. The comparison of average data revealed that the highest Mn concentration in the grain belonged to the treatment of 20 kg ha^{-1} of S with foliar application of 1 per thousand Zn with an average of 53.33 ppm and the lowest concentration belonged to the treatment of 20 kg ha^{-1} of S with foliar application of 1 per thousand Zn with an average of 53.33 ppm. 60 kg ha^{-1} of S was used in conjunction with Zn foliar application at 1 per thousand at an average concentration of 15.56 ppm. The highest Mn concentrations in grain NC2 cultivar were obtained with 60 kg ha^{-1} of S combined with a foliar application of 1 per thousand Zn and 40 kg ha^{-1} of S combined with a foliar application of 2 per thousand Zn, respectively, with an average of 45.31 and 44.99 ppm. This feature had the lowest average value of 23.61 ppm in the treatment without S application but with Zn foliar application at 2 per thousand.

Discussion

Grain and oil yields are critical in peanuts, and nutrition plays a significant role in accomplishing these goals. S and Zn applied in combination improved grain yield because fruits or peanut pods develop underground and may create a variety of nutrients. Because these elements are absorbed directly from the surrounding soil, their presence around the pods and their absorption by the pods throughout growth, pod development, and eventually seed formation has a beneficial impact. It is critical for enhancing peanut seed yields. Increased S levels seem to boost S and other nutrient intake, particularly phosphorus and calcium, with more photosynthetic material being moved from shoots to developing pods and seeds. These treatments have resulted in an improvement in grain yield. Zn-containing or Zn-activated enzymes are also involved in glucose metabolism, protein synthesis, cell membrane integrity maintenance, auxin control, and pollen development in plants (Marschner, 1995). These examples illustrate how Zn foliar treatment may be a beneficial component in enhancing grain production. Additionally, boosting yield via S consumption benefits the production of protein, oil, and several vitamins, as well as the absorption of micronutrients and the building of photosynthetic components (Rahimian, 2011). The influence of micronutrients on grain production may be explained by the fact that these elements boost yield by enhancing the durability of leaf surfaces, promoting photosynthesis, or improving material distribution inside the grain. As a result, micronutrients are mutually reinforcing (Kamkar *et al*., 2011; Malakouti *et al*., 2008). In another experiment, the maximum grain yield (1625 kg ha^{-1}) was produced with a 1000 kg ha^{-1} of S treatment per hectare, and the lowest grain yield (1273 kg ha^{-1}) with a 2000 kg ha^{-1} of S (Shabani *et al*., 2015). Application of 40 kg ha^{-1} and 5 kg ha^{-1} significantly increased the pod yield of peanuts (Singh and Mann, 2007). Saffari *et al*. (2001) and Ravi *et al*. (2010) reported that S had a substantial influence on safflower seed yield when compared to controls. S intake increased grain production and peanut pod yield significantly (Maleki *et al*., 2007). S, Zn, and Zn consumption all had an increasing influence on the quantity of Palmitic acid, and Zn treatments had a greater effect on the amount of rising than the other two elements (Shekhawat *et al*., 2012). Palmitic acid production rose with S intake, with the greatest increase occurring when 20 kg of S was applied at planting time, 10 kg before flowering, and 10 kg after flowering (Ahmad and Abdin, 2000). Zn and iron foliar applications increased Palmitic acid significantly in canola as compared to the control (Bybordi and Mamedov, 2000). The treatment with the lowest amount of stearic acid and the Zn and S treatment with an average of 15.5 mg g^{-1} had the largest amount of Palmitic acid in rapeseed oil, while the control treatment with an average of 12.7 mg g^{-1} had the lowest amount (Habibi *et al*., 2014). Palmitic and Stearic acids are significantly saturated acids, while Oleic, Linoleic, and Linolenic acids are significant unsaturated acids. Zn and manganese-enhanced Oleic and Linoleic acids in safflower while decreasing Stearic acid (Movahhedy-Dehnavy, 2009).

Peanut oil includes eight primary fatty acids, the most significant of which is Oleic acid, owing to its economic worth and health advantages (Yol *et al*., 2017). Peanut genotypes vary in terms of fatty acid content, although seeds generally contain 45 to 50% Oleic acid and 30 to 40% Linoleic acid (Tillman and Stalker, 2009). Between palmitic and oleic fatty acids, there is a negative association. By increasing Oleic acid, Palmitic acid is reduced. Additionally, an inverse association has been seen between the amounts of Oleic and Linoleic fatty acids in sunflower and rapeseed (Mostafavirad *et al*., 2011). S treatment raised the quantity of linoleic acid, which may be a useful predictor of improved canola grain yield under the impact of S treatments since linolenic acid is required for photosynthesis and pollen grain formation (Mc Conn and Browse 1996). The synergist effect of fertilizers is another important criterion that have been raised previously and studied thus far (Norozi et al., 2019). For instance, S fertilizer enhances the efficacy of urea fertilizer in the production of oleic fatty acids, hence preserving the fatty acid purity (Fismes *et al*., 2000). The fatty acids Linoleic and oleic are the most plentiful in peanut oil. Co-application of 125 kg nitrogen and 20 kg S boosted Palmitic acid, Oleic acid, Linoleic acid, and Linolenic acid in mustard seed while decreasing Stearic acid, Erotic acid, and Glucosinolate (Al, Shekhaw, 2012). When Zn sulfate intake in cotton was raised from zero to sixty kg ha^{-1}, the level of Linoleic acid rose from 53.4 to 54.5% (Zakaria *et al*., 2006). Increasing the proportion of Oleic acid indicates that the oil is more stable at high temperatures and of greater quality for frying meals while increasing the percentage of Linoleic fatty acid indicates that the oil has a higher nutritional value in direct nutrition (Rezvani Moghadam *et al*., 2014). Zn intake had a substantial influence on Oleic acid and final unsaturated fatty acids (Oleic and linoleic) in cotton, owing to Zn's beneficial effect on basal metabolic responses in tissues. Additionally, Zn activates a significant number of plant enzymes, the connection between the enzyme and the substrate, or both (Zakaria *et al*., 2006). In both cultivars, S enhanced unsaturated fatty acids (Oleic, Linoleic, and Linolenic) (He *et al*., 2018). Additionally, the Oleic to Linoleic ratio is critical for the stability of oxidative damage during refining (James *et al*., 1983). S, Zn, and barium all have a beneficial influence on the quantity of unsaturated fatty acids, which justifies their usage in boosting seed oil and, therefore, the amount of usable unsaturated fatty acids and decreasing Erosic acid in rapeseed (Habibi *et al*., 2014). According to Ravi *et al*. (2010), S is involved in the synthesis of glucosides and glycosinolates, as well as the activation of enzymes, hence boosting the oil content. The S shortage may inhibit the enzyme acetyl-coenzyme A carboxylase, hence inhibiting the manufacture of oil (Altaf *et al*., 2000). S deficiency reduces the yield of the raw material for fatty acid biosynthesis and its biochemical route, which may result in a drop in oil content (Marschner, 1995). According to Tisdal *et al*. (1985), oilseeds respond to trace quantities of S owing to S's function in amino acid synthesis and fatty acid synthesis. S has been shown to increase oil % in rapeseed by Rahimian (2012) and safflower by Saffari *et al*. (2011). However, in this experiment, using Zn on Blatter surfaces boosted this feature even when S fertilizer was not applied. Zn seems to be able to accelerate the metabolism of lipids, consequently affecting the proportion of oil in the diet (Kamraki and Golavi, 2012). Micronutrients improved the oil content in the current research by satisfying the plant's requirements on time. Nasri and Khalatbari (2008-2009) also observed that foliar micronutrient spray (iron, manganese, Zn, barium, and molybdenum) improved the oil content of canola. Numerous studies demonstrate that micronutrients influence the proportion of oil in the diet. The rise in yield and percentage of oil under micronutrient application circumstances is because the oil yield is proportional to the percentage of oil and grain yield, and since micronutrients raised the percentage of oil and grain production, they increased oil yield as well. Iron, Zn, and manganese micronutrients applied to foliar have been shown to considerably boost flaxseed oil yield when compared to the control treatment (Bakry *et al*., 2012). S application of 1000 kg is ideal for raising the percentage of oil and yield, and S levels have been shown to have a substantial effect on soybean yield at the 1% probability level (Babaei *et al*., 2012). In one experiment, S-containing treatments produced a larger proportion of oil in oily flax than S-free treatments (Shabani *et al*., 2015). S, Zn, and bar all have a favorable influence on the quantity of seed oil, which may be used to justify soil intake of these three elements to increase grain production and, subsequently, grain oil (Habibi *et al*., 2014). Iron and manganese concentrations in seeds may increase as a result of increased S application up to 80 kg ha^{-1}, perhaps owing to decreased acidity and availability, as well as their absorption into the soil by the plant (Mostafavirad *et al*., 2011).

Conclusions

Regarding the soil texture and climatic circumstances of the area where this crop is grown, it was discovered that applying S fertilizer and foliar treatment simultaneously improve grain production and quality. The maximum grain yield of the Spanish cultivar (an average of 5770 kg ha^{-1}) was produced by Zn foliar application at 2 per thousand and S fertilizer at a rate of 40 kg ha^{-1} simultaneously. The maximum concentration of Oleic acid was produced in the CN2 cultivar when 60 kg ha^{-1} of S was combined with Zn foliar application at 2 per thousand, yielding an average of 61.1%. The treatment without S consumption and Zn foliar application at 1 per thousand resulted in the lowest quantity, at 50.2% on average. Because both S and Zn factors were effective on the majority of features, it is preferable to use Zn fertilizer in conjunction with S to increase the absorption of this element, which may impact the growth and development of peanut plants. As a result, therefore, the simultaneous use of S fertilizer and Zn foliar application at high levels to improve the quality of fatty acids and grain micronutrients in the Guilan region is recommended.

Acknowledgments

The authors are grateful for the support of Lahijan Branch, Islamic Azad University.

Conflict of interests

The authors declare that they do not have any conflict of interest.

References

Abdzad Gohari A, Sadeghipour A (2019) The effect of poor irrigation and humic acid on yield and water use efficiency in beans. Journal of Water Research in Agriculture. 33(3), 383-396.

Aboyeji C, Dunsin O, Adekiya AO, Chinedum C, Suleiman KO, Okunlola FO, Olofintoye TA (2019) Zn sulfate and boron-based foliar fertilizer effect on growth, yield, minerals, and heavy metal composition of groundnut (*Arachis hypogaea* L.) grown on an Alfisol. International Journal of Agronomy. 20, 176-189.

Ahmad A, Abdin MZ (2000) Effect of S application on lipid, RNA and fatty acid content in developing seed of rapeseed (*Brassica napus* L.). Plant Science. 71-76.

Aier I, Nongmaithem D (2020) Response of groundnut (*Arachis hypogaea* L.) to lime and different levels of Sulphur. International Journal of Bio-resource and Stress Management. 11(6), 585-589.

Altaf A, Khanand V, Abdin MZ (2000) Effect of S fertilization on oil accumulation, acetyl-Co A concentration and acetyl-Co A carboxylase activity in the developing seeds of rapeseed (*Brassica napus* L.). Australian Journal Agriculture. 51, 1023-1029.

Babaei P, Golchin A, Besharati H, Afzali M (2012) Effect of microbial S fertilizer on nutrient uptake and soybean yield in the field. Journal of Soil Research (Soil and Water Science). 26(2), 145 To 151.

Bakry BA, Tawfik MM, Mekki BB, Zeidan MS (2012) Yield and yield components of three flax cultivars (*Linum usitatissimum* L.) in response to foliar application with Zn, Mn, and Fe under newly reclaimed sandy soil conditions. American-Eurasian Journal of Agricultural & Environmental Sciences. 12, 1075-1080.

Bybordi A, Mamedov G (2010) Evaluation of application methods efficiency of Zn and iron for Canola (*Brassica napus* L.). Notulae Scientia Biologicae. 2(1), 94 -103.

Boukid F (2022) Peanut protein – an underutilized by-product with great potential: a review. International Journal Food Science Technology. http://doi.org/10.1111/ijfs.15495

Devi KN, Singh LNK, Singh MS, Singh SB, Singh KK (2012) Influence of S and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max* L.) under upland conditions. Journal of Agricultural Science. 4(4), 1-11.

El-Kader MGA (2013) Effect of S application and foliar spraying with Zn and boron on yield, yield components, and seed quality of peanut (*Arachis hypogaea* L.). Research Journal of Agriculture and Biological Sciences. 9(4), 127-135.

Fismes J, Vong PC, Guckert A, Frossard E (2000) Influence of S on apparent N-use efficiency, yield, and quality of oilseed rape (*Brassica napus* L.) grown on calcareous soil. Europian Journal of Agronomy. 12, 127-141.

Guilan Meteorological Department. 2021. Statistics. pp. 24.

Habibi M, Majidian M, Rabiei M (2014) Effect of elements on Zn and S on grain yield and fatty acid composition of rapeseed oil. Agricultural Farming. 16(1), 84-69.

He C, Wang F, Li Q, Lin C, Li Y (2018) Effects of water and calcium coupling at a blossom-needling stage on peanut yield and photosynthetic response to light. Acta Agriculturae Jiangxi. 30(3), 17-22.

Hosseinifarahi M, Moazen HA, Amiri A, Jowkar MM, Mottaghipisheh J (2022) Evaluation of Seed Priming and Culture Media to Improve the Germination Performance and Quality of Sweet Pepper and Eggplant Seedlings. International Journal of Horticultural Science and Technology. 9(4), 415-28.

Ijaz M, Perveen S, Nawaz A, Ul-Allah S, Sattar A, Sher A, Rasheed I (2020) Eco-friendly alternatives to synthetic fertilizers for maximizing peanut (*Arachis hypogea* L.) production under arid regions in Punjab, Pakistan. Journal of Plant Nutrition. 43(5), 762-772.

Irmak S, Cil A N, Yucel H, Zulkuf K (2015) Effects of Zn Application on Yield and Some Yield Components in Peanut Arachis hypogaea in the Eastern Mediterranean Region. Journal of Agricultural Sciences. 22(1), 109-116.

Ivan J (2007) Micronutrient innovation. Potato Grower Magazine. Harris Publishing Inc. The USA. 1, 58-61.

James SLH, Young CT (1983) Comparison of fatty acids content of imported peanuts. Journal Am Oil Chem Society. 60, 945–947.

Janila P, Nigam SN, Manish K, Pandey P, Nagesh N, Varshney K (2013) Groundnut improvement: use of genetic and genomic tools. Plant Science. 25,125-136.

Kamaraki H, Galavi M (2012) Evaluation of foliar Fe, Zn and B micronutrients application on quantitative and qualitative traits of safflower (*Carthamus tinctorius* L.). Journal of Agroecology. 4(3), 201-206

Kamkar B, Safahani Langroudi AR, Mohammadi R (2011) Application of minerals in the nutrition of crops. Jahad University Publications in Mashhad. pp. 500.

Kannan P, Swaminathan C, Ponmani S (2017) S nutrition for enhancing rainfed groundnut productivity in typical alfisol of semi-arid regions in India. Journal of Plant Nutrition. 40(6), 828-840.

Keshavarz K, Vahdati K, Samar M, Azadegan B, Brown P (2011) Foliar application of zinc and boron improves walnut vegetative and reproductive growth. HortTechnology 21(2), 181-186.

Krishna G, Singh K, Kim EK, Morya K, Ramteke PR (2015) Progress in genetic engineering of peanut (*Arachis hypogaea* L.). Plant Biotechnology Journal. 13, 147–162.

Laxmanarayanan M, Prakash NB, Dhumgond P, Ashrit S (2020) Slag-based gypsum as a source of S, calcium, and silicon and its effect on soil fertility and yield and quality of groundnut in Southern India. Journal of Soil Science and Plant Nutrition. 20(4), 2698-2713.

Malakouti MJ, Keshavarz P, Karimian N (2008) Comprehensive method of diagnosis and optimal recommendation of fertilizer for sustainable agriculture. Tarbiat Modarres University Press. pp. 755.

Maleki SA, Amini E, Pirdashti H, Safarzadeh MT (2007) Effect of iron and S application on peanut yield and yield components. Abstracts of the 10th Iranian Congress of Agronomy and Plant Breeding Sciences.

Maliha MB, Nuruzzaman M, Hossain B, Trina FA, Uddin N, Sarkar S (2022) Assessment of Varietal Attributes of Okra under Foliar Application of Zn and Boron. International Journal of Horticultural Science and Technology. 9(2),143-9.

Marschner H (1995) Mineral nutrition of higher plants. 2nd ed. Academic Press. New York.

Mc Conn M, Browse J (1996) The critical requirement for linolenic acid is pollen development, and net photosynthesis, in an Arabidopsis mutant. The Plant Cell. 8, 403-416.

Meresa H, Assefa D, Tsehaye Y (2020) Response of groundnut (*Arachis hypogaea* L.) genotypes to combined application of phosphorus and foliar Zn fertilizers in Central Tigray, Ethiopia. Environmental Systems Research. 9(1), 1-9.

Mohit Rabary P, Movahedi Z, Ghabooli M, Rostami M (2022) Effects of Foliar Application of Zn Oxide Nanoparticles on Traits of Several Medicinal Plants Under Aeroponic System Conditions. International Journal of Horticultural Science and Technology. 9(4), 445-52.

Mostafavi-Rad M, Tahmasebi-Sarvestani ZM, Modares-Sanavy SA, Ghalav A (2012) Evaluation of some agronomic traits of rapeseed (*Brassica napus* L.) as affected by different S application rates. Iranian Journal of Field Crop research. 10(3), 495-503.

Movahhedy- Dehnavy M, Modarres- Sanavy SAM, Mokhtassi- Bidgoli A (2009) Foliar application of Zn and manganese improves seed yield and quality of safflower (*Carthamus tinctorius* L.) grown under water deficit stress. Industrial Crop and Products. 30, 82-92.

Narayan OP, Kumar, P, Yada, B, Dua M, Johri AK (2022). S nutrition and its role in plant growth and development. Plant Signaling & Behavior. DOI: 10.1080/ 15592324. 2022. 2030082.

Nasri M, Khalatbari M (2008) The effect of micro-nutrient spraying concentration on quantitative and qualitative characteristics of rapeseed cultivars in Varamin region. Iranian Journal of Agricultural Science. 2(5),107-213.

Nazoori F, ZamaniBahramabadi E, Mirdehghan SH (2022) Effect of S Pesticide on the Quality of Fresh Pistachios in Cold Storage. International Journal of Horticultural Science and Technology. 9(4), 453-62.

Norozi M, ValizadehKaji B, Karimi R, Nikoogoftar Sedghi M (2019) Effects of foliar application of potassium and Zn on pistachio (*Pistacia vera* L.) fruit yield. International Journal of Horticultural Science and Technology. 6(1), 113-23.

Pavithra GJ, Reddy BR, Salimath M, Geetha KN, Shankar AG (2018) Zn oxide nanoparticles increase Zn uptake, and translocation in rice with a positive effect on growth, yield, and moisture stress tolerance. Indian Journal of Plant Physiology. 22(3), 287-294.

Pegues KD, Tubbs RS, Harris GH, Monfort WS (2019) Effect of Calcium Source and Irrigation on Soil and Plant Cation Concentrations in Peanut (*Arachis hypogaea* L.). Peanut Science. 46(2), 206-212.

Radwan T (2017) Evaluation of Elemental Sulphur Application with Rhizobia Inoculation on Peanut Yield and its Quality Grown in Sandy Soil at Egypt. Egyptian Journal of Botany. 57(1), 217-240.

Rahimian Z (2012) Effect of S and thiobacillus with organic matter on quantitative and qualitative traits of canola. Crop Physiology Journal. 3(12), 19-27.

Ravi S, Channal HT, Hebsur NS, Patil BN, and Dharmatti PR (2008) Effect of S, Zn and iron nutrition on growth, yield, nutrient uptake and quality of Safflower (*Carthamus tinctorius* L.). Karantaka Journa of Agriculture Science. 21(3), 382-385.

Rezvani Moghaddam P, Amiri MB, Seyyedi SM (2014) Effect of organic and bio-fertilizers application on yield, oil content and fatty acids composition of sesame (*Sesamum indicum* L.). Iranian Journal of Crop Sciences. 16(3), 209-221.

Ruksar B, Shroff JC, Shah SN (2017) Effect of sources and levels of S and bio-fertilizer on growth, yield and quality of summer groundnut. International Journal of Agricultural Sciences. 13(1), 67-70.

Safarlu Z, Hemmati R (2014). Identification and study of the pathogenesis of Fusarium species involved in bean root rot in Zanjan province. Applied Research in Plant Medicine. 3(1), 77-92.

Saffari M, Madadizadeh M, Shari'ati Neya F (2011) Nutritional effects of nitrogen, boron, and S on quantitative and qualitative characteristics of safflower seeds. Iranian Journal of Crop Science. 42(1), 133-141.

Sandefur HN, McCarty JA, Boles EC, Matlock M D (2017) Peanut products as a protein source: Production, nutrition, and environmental impact. Academic Press. In Sustainable Protein Sources. pp. 209-221.

Saini C, Jain NK (2017) Influence of S and plant growth regulators on yield, quality and nutrient uptake in summer peanut (*Arachis hypogaea*). Annals of Agricultural Research. 2, 17.

Shabani G, Khoshkho M, Khorami M, Jafarzadeh M, Akbarabadi A (2015) Effect of S and Biofertilizers Application on Yield and Yield Components of linseed (*Linum ustatissimum* L.). Agronomy Journal (Pajouhesh & Sazandegi). 108, 35-42.

Shekhawat K, Rathore SS, Premi OP, Kandpal BK and Chauhan JS (2012) Advances in Agronomic management of Indian Mustard (*Brassica juncea* L. Czernj. Cosson). Agronomy. 10, 1-14.

Singh YP, Mann JS (2007) Interaction effect of S and Zn in peanut and their availability in Tonk district of Rajasthan. Indian Journal of Agronomy. 52(1), 70-73.

Srivastava PC, Gupta UC (1996) Trace elements in crop production. Science Publishers, Lebanon, NH. pp. 356.

Tillman BL, Stalker HT (2009) Peanut. In: Vollmann J, Rajcan I (eds) Handbook of plant breeding-oil crops. Springer, New York. pp. 287–316.

Tisdale SL, Nelson WL, Beaton JD (1985) Soil fertility and fertilizers. Collier Macmillan Publishers. Turkey. pp. 754.

Yadav AK, Gurnule GG, Gour NI, There U, Choudhar VC (2022) Micronutrients and Fertilizers for Improving and Maintaining Crop Value: A Review. International Journal of Environment, Agriculture and Biotechnology. 7, 1.

Yol E, Ustum R, Golukcu M, Uzun B (2017) Oil Content, Oil Yield and Fatty Acid Profile of

Groundnut Germplasm in Mediterranean Climates. Journal of the American Oil Chemists' Society. 94, 787–804.

Zakaria MS, Hafez SA, Basyony AE, Alkassas AER (2006) Cottonseed, protein, oil yields, and oil properties as affected by nitrogen fertilization and foliar application of potassium and a plant growth retardant. Agricultural Sciences. 2(1), 56-65.