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EFFECT OF PLANT REGULATORS ON OIL RATIO AND FATTY ACID COMPOSITION OF PEANUT (*Arachis hypogaea* L.)

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ABSTRACT

Plant growth regulators are organic substances that are synthesized naturally within the plant, and controlled the physiological events, can be transported from where they are formed to other parts of the plants, and can show their effects even at very low concentrations. In this study, it was aimed to determine the effect of different doses of plant growth regulators in different growth stages on oil content and fatty acid compositions of peanut (*Arachis hypogaea* L.). A total of twelve different treatments were preferred with different chemicals such as gibberallic acid (GA_3), mepiquat-chloride (MC), and seaweed (SW) in different growth stages (beginning bloom (BB), full bloom (FB) and beginning bloom + full bloom (BB+FB)). The highest oil content was obtained in MCFB200 (55.46%) treatment, while the lowest was obtained in GA_3BB20 (45.44%) treatment. Oleic acid ratio varied from 50.33% to 59.25%, and all treatments were higher than that of the control group. The highest and lowest linoleic acid ratios were observed in SWBBFB100 (26.72%) and GA_3FB10 (19.52%) treatments, respectively. MCFB200 and GA_3FB10 treatments could be recommended for the highest oil ratio and the highest oleic acid ratio, respectively.

Keywords: ***Arachis hypogaea*** **L., groundnut, iodine value, oil content, oleic acid, plant growth regulator**

INTRODUCTION

Peanut (*Arachis hypogaea* L.), originating from South America, is an oilseed plant that has an important place in human and animal nutrition. Peanut seeds consist of 40-50% oil and unsaturated fatty acids (approximately 80%) (Onemli, 2012; Yol and Uzun, 2018). The production of peanut was 53.9 million tonnes in 32.7 million ha area in the world. However, Turkey had a bit low contribution with 234 167 tonnes in 57 919 ha area. The most important producer countries were China and India contributed 52.9% of the total production with 18.3 million tonnes and 10.2 million tonnes. Despite of use of high inputs such as irrigation, fertilization and pesticides, yield of peanut is 165 kg da^{-1} in the world and 404 kg da^{-1} in Turkey in 2021 (FAOSTAT, 2023), respectively, mainly depends on plant growth regulators (PGR).

PGR play an important role in the growth and development of plants, protecting them against both biotic and abiotic stress conditions (Shaki et al., 2019; Heydari et al., 2021). Gibberellic acid (GA_3), which is among the growth regulators, stimulates plant tissues and cells, promotes plant growth, breaks dormancy in seeds, increases fertilization and germination in seeds (Erdemli and Kaya, 2015). Like GA_3, seaweed has been used in plants recently, however its full effect is not yet known (Fornes et al., 2002; Osman and Salem 2011). Seaweed facilitates the uptake of plant nutrients from the soil and enables plants to form a defense mechanism against stress conditions (Schmidt et al., 2003; Turan and Kose, 2004; Osman and Salem, 2011). Mepiquat-chloride, known as one of the PGR, has become widespread in recent years. It provides an increase in generative production by reducing excessive plant height (Sawan et al., 2007). In addition, it is seen that it increases the photosynthesis by decreasing the gibberellic acid ratio in plants and encourages flowering by contributing to plant root development (Kim et al., 2011; Arioglu et al., 2013).

Kim et al. (2011) conducted an experiment to determine the effects of PGRs such as mepiquat-chloride and trinexapac-ethyl on growth characteristics of flax and reported that increasing doses of PGRs increased the seed yield and oil content. Heydari et al. (2021) tried to determine the impact of PGRs on the safflower growth under drought stress, and reported that PGRs improved the unsaturated fatty acid compositions and increased the seed and oil yield even if under drought stress. Similar results were reported by Osman and Salem (2011), and it was stated that seaweed was effective in enhancing yield, nutrient uptake and oil content of sunflower due to the presence of growth promoting hormones and nutrients in more quantities.

Today, PGRs are applied to many plants in order to improve both yield and quality. Peanut is a plant that finds the most common cultivation area in the world, and many studies are carried out to increase the oil content and oil quality. Different from the previous studies, in this study, it was aimed to determine the effects of PGR such as gibberellic acid, mepiquat-chloride and seaweed treatments applied in different times on oil and fatty acid compositions of peanut.

MATERIALS AND METHODS

Materials

Virginia type NC 7 peanut variety was used in the experiment. A total of twelve different treatments were used with different chemicals such as gibberellic acid (GA_3), mepiquat-chloride (MC), and seaweed (SW) in different growth stages (beginning bloom (BB), full bloom (FB) and beginning bloom + full bloom (BB+FB)). Information on PGR applied in the experiment, treatment time and doses are given in Table 1.

Experimental site

The experiment was carried out in 2019 and 2020 at the Oil Seed Research Institute in Osmaniye (37º07'40.51"N; 36º12'02.08"E, 69 m asl), located in the eastern Mediterranean region of Turkey. The structure of the soil used in the study was clay, and its pH 8.4. The contents of organic matter, phosphorus, nitrogen, and potassium was low while lime and iron contents were mid-level. The climatic data were obtained from the agro-meteorological station located in a state farm about 6 km far from the experimental site. There were no significant differences among long year and studied years for the average temperatures. The total precipitation in 2020 was similar with long year (266.50 mm), however, the total precipitation was a bit low (193.80 mm) in 2019 compared to other data (Figure 1).

Table 1. Periods and doses of plant growth regulators used in the trial.

Abbreviation	Growth Regulator	Period and Dose
GA_3BB10	Giberallic Acid	Beginning Bloom – 10 ppm
GA_3BB20	Giberallic Acid	Beginning Bloom – 20 ppm
GA_3FB10	Giberallic Acid	Full Bloom – 10 ppm
GA_3FB20	Giberallic Acid	Full Bloom – 20 ppm
SWBB40	Seaweed	Beginning Bloom – 40 ppm
SWFB60	Seaweed	Full Bloom – 60 ppm
SWBBFB100	Seaweed	Beginning Bloom + Full Bloom – 100 ppm
MCBB150	Mepiquat-Chloride	Beginning Bloom – 150 ppm
MCBB200	Mepiquat-Chloride	Beginning Bloom – 200 ppm
MCFB150	Mepiquat-Chloride	Full Bloom – 150 ppm
MCFB200	Mepiquat-Chloride	Full Bloom – 200 ppm
Control	---	---

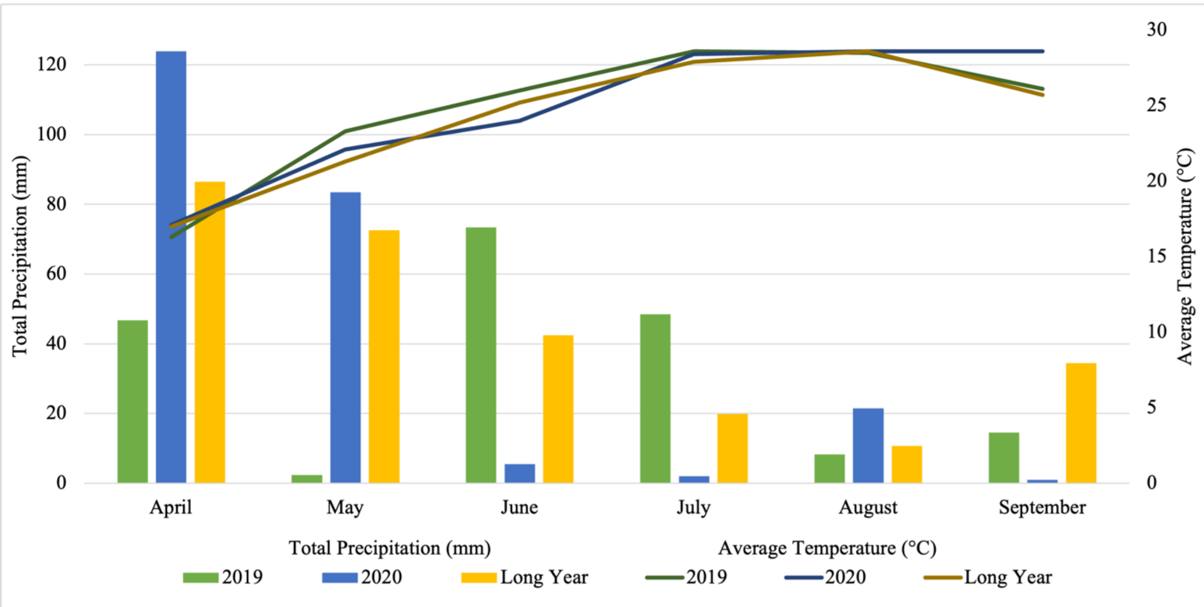

Figure 1. Climate parameters of the research field (2019, 2020 and long year average)

Methods

Experiments were conducted in randomized complete block design (RCBD) with three replications. The seeds were sown by hand in four-row, 5 m long with spacing of 70 cm between rows and 15 cm within rows in both years. Di-ammonium phosphate (18% N, 46% P_2O_5) fertilizer was used at the rates of 25 kg da^{-1} before sowing.

In the first year of the experiment, hand sowing was done on May 5, 2019. PGR in the first year as flowering start treatment were applied on 17 June 2019, while full flowering treatment was carried out on 27 June 2019. The plants that reached harvest maturity were harvested manually on September 28, 2019. In the second year of the experiment, hand sowing was done on May 2, 2020. PGR in the second year were applied as flowering start treatment on 13 June 2020, while the full flowering treatment was carried out on 24 June 2020. Plants that reached harvest maturity were harvested manually on September 21, 2020. The dosages of the PGR were determined according to previous studies (Osman and Salem, 2011; Saini and Jain, 2017; Mohamed et al., 2020), and applied with spraying machine to leaves of plant.

In both years, the peanut was grown under irrigated conditions with standard cultural inputs (hand weeding, irrigation, control of diseases and pests by using pesticides) practiced consistent with local agronomic practices. Seed samples were taken from 20 plants selected from the middle two rows of the experiment.

Oil and Fatty Acid Analyses

The seed oil was extracted by conventional soxhlet system using the diethyl ether as a solvent. Fatty acid compositions of peanut seeds were analyzed by Thermo Scientific ISQ Single Quadrupole TR-Fame Gas Chromatography–Mass Spectrometry (GC-MS) system. Column had these properties; 5% Phenyl Polysilphenylene-silohexane, 0.25 mm inner diameter x 60 m length, 0.25 µm film thickness. Helium (99.9%) was used as a carrier gas which had 1 mL min^{-1} flow rate. The ionization energy was set at 70 eV and the mass range m / z 1.2-1200 amu. Scan Mode was used for data collection. The structure of each compound was identified with the Xcalibur software using mass spectra (Wiley 9).

Temperature program involved the following steps. The temperature of machine was warmed up to 120°C and waited for 1 min, increased by 10°C per minute until 175°C and waited for 10 min, increased by 5°C per minute until 210°C and waited for 5 min, and increased by 5°C per minute until 230°C and waited for 6 min. Split flow rate was 20 mL min^{-1}. The formulas of the oil content and iodine value were calculated according to Sahin et al. (2022).

Statistical Analyses

Experimental data were subjected to analysis of variance in accordance with Randomized Complete Block Design (RCBD) joined years with the aid of MSTAT-C and SPSS v22. Means were compared with the aid of Duncan's multiple range test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Oil Content

The oil ratio was found to be significant for treatments and year × treatments in terms of PGR ($p< 0.01$) (Table 2). The minimum oil content was obtained from GA_3BB20 (45.44%), while the maximum oil content was recorded from the treatment MCFB200 (55.46%) and SWBBFB100 (52.48%) (Table 3). Many agronomical and breeding studies are carried out worldwide to increase the oil rate in peanuts, which is an oilseed crop (Arioglu et al., 2013). Saini and Jain (2017) stated that GA_3 treatments increased the oil rate in peanut. Hasan and Ismail (2018) determined that the oil ratio increased as the GA_3 treatment doses increased in peanut. Bibi et al. (2003) stated that GA_3 treatments increased the oil content of sunflower; Maliki (2022) stated that GA_3 treatments increased in sunflower. Baydar (2002), found that GA_3 treatments in safflower reduces the oil content whereas Heydari et al. (2021) stated that GA_3 treatments vary and decrease according to years in sunflower. Erdemli and Kaya (2015) reported that GA_3 treatments reduced the oil content of sunflower. Osman and Salem (2011) found that seaweed treatments increased the oil rate. Abd et al. (2005) reported that mepiquat chloride treatments increased the oil content in soybean. The variability in the oil ratio and the difference in cultivar and species are due to different plant growth doses.

Table 2. Results of the analysis of variance for characteristics studied in the experiment.

	Year (df=1)	Block (df=4)	Treatments (df=18)	Y × T (df=18)	CV (%)
Oil Content	ns	ns	**	**	0.3
Oleic Acid	ns	ns	**	**	0.5
Linoleic Acid	ns	ns	**	ns	6.5
Palmitic Acid	**	ns	**	**	0.4
Stearic Acid	**	ns	**	**	1.1
Behenic Acid	**	ns	**	**	1.4
Arachidic Acid	**	ns	**	**	1.3
Lignoceric Acid	**	ns	**	**	4.0
O/L Ratio	ns	ns	**	**	0.4
Iodine Value	ns	ns	**	ns	5.5
Oil Yield	**	ns	**	**	4.3

df: Degree of freedom; ns: Non-significant; CV: Coefficient of variation; ** $p < 0.01$

Oleic acid

The oleic acid content of peanut seeds was significantly affected by treatments and the year × treatments interaction (Table 2). The lowest oleic acid content was found in the control group (50.33%) while the highest was obtained from the GA_3FB10 treatment (59.25%) (Table 3). Fatty acids containing a double bond in their structure are called monounsaturated or monoenoic fatty acids. The high oleic acid ratio in peanuts is important in terms of both increasing the shelf life and nutrition. It was determined in the experiment that all PGR treatments increased the oleic acid ratio (Arioglu, 2014). Heydari et al. (2021) found that GA_3 treatments increased the oleic acid ratio in sunflower; on the other hand, Khan et al. (2020) reported that GA_3 treatments in rapeseed increased the oleic acid ratio, and Abd et al. (2005) reported that the dose of mepiquat chloride treatments in soybean is important and that increases with the dose rate decreases. Mohamed et al. (2020) and Hashem et al. (2022) stated that seaweed treatments in black cumin increased the oleic acid ratio. Our findings were found parallel with literature studies. It was found that the oleic acid ratio in our experiment under gibberellic acid, seaweed and mepiquat chloride treatments was higher than the control group.

Table 3. Average values (Mean±SEM) of oil content, oleic acid (C18:1), linoleic acid (C18:2), palmitic acid (C16:0), and stearic acid (C18:0)

	Oil Content (%)	Oleic Acid (%)	Linoleic Acid (%)	Palmitic Acid (%)	Stearic Acid (%)
Treatments					
GA_3BB10	50.51±0.20 c	51.85±0.31 i	26.79±1.56 a	8.96±0.27 gh	2.43±0.16 i
GA_3BB20	45.44±0.21 e	57.94±0.18 b	20.75±0.23 h	9.11±0.29 f	2.94±0.22 bc
GA_3FB10	50.07±0.17 c	59.25±0.33 a	19.52±0.13 i	8.89±0.27 h	2.91±0.21 cd
GA_3FB20	50.33±0.18 c	50.62±0.32 j	26.46±0.13 b	10.81±0.31 a	2.35±0.13 j
SWBB40	50.67±0.34 c	53.39±0.24 f	26.29±0.16 c	10.68±0.17 b	3.24±0.13 a
SWBBFB100	52.48±0.19 b	52.71±0.20 h	26.72±0.19 a	8.94±0.22 g	2.68±0.24 f
SWFB60	52.30±0.20 b	56.58±0.58 c	25.79±0.22 d	9.45±0.19 d	2.88±0.26 d
MCBB150	49.28±0.32 d	56.59±0.14 c	21.02±0.22 g	9.95±0.11 c	2.97±0.14 b
MCBB200	52.19±0.26 b	52.97±0.23 g	26.48±0.16 b	8.88±0.06 h	2.13±0.17 k
MCFB150	50.83±0.31 c	55.21±0.43 d	23.78±0.21 f	8.93±0.23 g	2.53±0.19 h
MCFB200	55.46±0.25 a	53.82±0.17 e	24.80±0.19 e	8.97±0.80 g	2.62±0.17 g
Control	50.36±0.11 c	50.33±0.19 k	26.42±0.19 bc	9.26±0.13 e	2.63±0.14 g
Years					
2019	50.76±0.39	54.24±0.46	24.56±0.45	9.37±0.12	2.67±0.52
2020	50.89±0.39	54.30±0.31	24.58±0.42	9.43±0.14	2.72±0.54
Mean	50.83±0.27	54.25±0.32	24.57±0.30	9.40±0.79	2.69±0.35

SEM: Standard Error of the Mean. Letters show different groups in each column.

Linoleic acid

The treatments of different PGR in peanuts were found to be significant among treatments in terms of linoleic acid ratio (Table 2). The lowest linoleic acid ratio was found to be 19.52% under GA_3FB10 treatment, while the highest was 26.79% and 26.72% under GA_3BB10 and SWBBFB100 treatments, respectively (Table 3). It is desirable to have low linoleic acid, which is the second-highest unsaturated fatty acid in peanuts. Heydari et al. (2021) reported that GA_3 treatments did not have a significant effect on the linoleic acid ratio in sunflower. Osman and Salem (2011) reported that seaweed treatments reduced the linoleic acid ratio in sunflower. Mohamed et al. (2020) showed that as the rate of seaweed treatments increased in black cumin, the rate of linoleic acid decreased found that seaweed treatments did not make a significant change in the linoleic acid ratio in bread wheat. Abd et al. (2005) showed that the mepiquat chloride treatments in soybean vary according to the doses and that the linoleic acid ratio decreases; Sawan et al. (2007) found that mepiquat chloride treatments in cotton increased the rate of linoleic acid; Kim et al. (2011) reported that mepiquat chloride treatments in flaxseed increased. While our findings were generally parallel with some studies, it was found that plant growth treatments differed significantly according to dose and treatment times. Other reasons for the difference in the findings may be due to different types and species and different ecological conditions.

Palmitic acid

The study found that the interactions of PGR, year, treatments, and year × treatments were significant in palmitic acid ratio (Table 2). Palmitic acid is one of the saturated fatty acids that constitutes a significant amount of approximately 8-10% in peanuts (Sahin et al., 2022). The highest amount of palmitic acid was found to be GA_3FB20 (10.81%), while the lowest was found to be MCBB200 (8.88%) (Table 3). Heydari et al. (2021) reported that GA_3 treatments differed in palmitic acid ratio and increased as the GA_3 dose increased. Khrmashow et al. (2022) reported that palmitic acid ratio increased as GA_3 treatment doses increased in okra. Mohamed et al. (2020) reported a decrease in palmitic acid in black cumin while Nasiroleslami et al. (2021) reported a decrease in wheat due to seaweed treatments. Abd et al. (2005) reported that mepiquat chloride treatment and doses showed difference and increase; Hashem et al. (2020) found that mepiquat chloride treatments in black cumin decreased when biofertilizer treatment was made. Kim et al. (2011) in flaxseed and Sawan et al. (2022) in cotton seed found that mepiquat chloride treatments reduced the palmitic acid ratio. Our experimental findings were similar to the literature studies.

Stearic acid

The study found that the interactions of different PGR treatments, stearic acid ratios, year, treatments and year × treatments were significant (Table 2). Stearic acid in PGR treatments of peanut ranged from 2.13% (MCBB200) to 3.24% (SWBB40) (Table 3). Heydari et al. (2021) reported that GA_3 treatments in sunflower decreased the stearic acid ratio, on the contrary, Khrmashow et al. (2022) in okra stated that determination of doses of GA_3 treatments is also important and the rate of stearic acid increases. Osman and Salem (2011) in sunflower and Mohamed et al. (2020) in black cumin stated that determination of doses of seaweed treatments is also important and increase the steraic acid ratio. Contrary to other researchers, Nasiroleslami et al. (2021) stated that seaweed treatments in wheat reduce the rate of stearic acid. Abd et al. (2005), mepiquat chloride treatments increase the rate of stearic acid, Sawan et al. (2007) in cottonseed and Kim et al. (2011) in flaxseed reported that the mepiquat chloride treatment doses are significant and reduce stearic acid. The stearic acid ratios found in our trials were similar to Sawan et al. (2007), Kim et al. (2011), Mohamed et al. (2020), Nasiroleslami et al. (2021) and Khrmashow et al. (2022), while different from the results found by Abd et al. (2005), Heydari et al. (2021) and Osman and Salem (2011). It is thought that the increase in the steraic acid ratio may have resulted due to different plant species at high altitudes, the different doses of PGR and different ecological conditions.

Behenic acid

The study found that the interactions of different PGR treatments, behenic acid ratios, year, treatments and year × treatments were significant (Table 2). The highest Behenic acid ratio was obtained from the control (3.74%) treatment, while the lowest was obtained from the SWFB60 (1.52%) treatment. The ratio of behenic acid found in all treatments was found to be lower than the control group. The highest GA_3BB10 (3.64%) treatment from GA_3 treatments, the highest SWBBFB100 (3.11%) treatment from seaweed treatments, and the highest MCBB200 (3.22%) treatment in mepiquat chloride treatment (Table 4). The fact that the ratios of behenic acid are so different may be due to the different PGR used and the different reactions of the peanut plant.

Table 4. Average values (Mean±SEM) of behenic acid (C22:0), arachidic acid (C20:0), lignoceric acid (C24:0), oleic acid/linoleic acid ratio (O/L), and iodine value (IV)

	Behenic Acid (%)	Arachidic Acid (%)	Lignoceric Acid (%)	O/L Ratio	Iodine Value (IV)	Oil Yield (kg da^{-1})
Treatments						
GA_3BB10	3.64±0.32 b	2.55±0.10 c	0.99±0.05 ef	1.94±0.11 k	90.99±0.27 c	249.04±2.71 c
GA_3BB20	2.81±0.26 g	2.42±0.20 de	1.04±0.01 de	2.79±0.02 b	85.78±0.48 f	239.02±2.69 d
GA_3FB10	3.04±0.01 e	2.45±0.07 d	1.32±0.13 b	3.04±0.01 a	84.77±0.35 g	282.19±2.51 b
GA_3FB20	3.09±0.16 d	2.71±0.25 a	0.99±0.12 ef	1.91±0.03 l	89.37±0.46 d	337.08±2.00 a
SWBB40	2.31±0.01 i	1.69±0.13 h	0.60±0.20 g	2.03±0.02 h	91.46±0.47 b	193.29±1.78 f
SWBBFB100	3.11±0.20 d	2.41±0.19 e	1.06±0.11 d	1.97±0.01 j	91.62±0.40 b	189.03±3.13 f
SWFB60	1.52±0.21 j	1.32±0.15 i	0.43±0.12 i	2.19±0.03 e	93.35±0.84 a	174.44±9.95 g
MCBB150	2.71±0.20 h	2.18±0.18 g	0.95±0.14 gh	2.69±0.01 c	85.07±0.14 g	189.03±3.14 f
MCBB200	3.22±0.21 c	2.27±0.23 f	1.36±0.03 ab	2.00±0.01 i	91.42±0.47 b	227.24±2.55 e
MCFB150	3.01±0.11 e	2.53±0.12 c	1.16±0.18 c	2.32±0.02 d	88.67±0.49 e	285.35±2.13 b
MCFB200	3.20±0.24 c	2.60±0.17 b	0.91±0.02 h	2.17±0.01 g	89.23±0.13 d	244.18±2.89 cd
Control	3.74±0.01 a	2.69±0.13 a	1.37±0.20 a	1.91±0.01 l	89.05±0.45 d	125.31±6.17 h
Years						
2019	2.92±0.09	2.29±0.07	0.99±0.04	2.25±0.65 A	89.19±0.45 A	221.89±9.85 B
2020	2.95±0.14	2.34±0.06	1.03±0.05	2.24±0.62 B	89.27±0.46 B	234.00±8.93 A
Mean	2.95±0.06	2.32±0.05	1.01±0.05	2.25±0.04	89.23±0.32	227.94±6.64

SEM: Standard Error of the Mean. Letters show different groups in each column.

Arachidic acid

The study found that the interactions of different PGR treatments, arachidic acid ratios, year, treatments and year × treatment were significant (Table 2). In PGR treatments, arachidic acid ratio was found to vary between 1.32% (SWFB60) and 2.71% (GA_3FB20) in peanuts (Table 4). Osman and Salem (2011) in sunflower showed that the dose rate of seaweed treatment is essential and reported the increase in arachidic acid ratio while Mohamed et al. (2020) in black cumin found that the dose rate of seaweed is important and stated that the rate of arachidic acid decreases as the dose rate increase. Abd et al. (2005) stated that the dose rate of mepiquat chloride treatments in soybean is important and it reduces the arachidic acid ratio. The arachidic acid ratios found in the experiment are similar to the ratios reported by Mohamed et al. (2020) but are different from the ratios reported by Abd et al. (2005) and Osman and Salem (2011). It is thought that the difference in arachidic acid ratios in the trial findings is due to different cultivars and species used, different plant growth doses and treatments, and ecological conditions.

Lignoceric acid

The study found that the interactions of different PGR treatments, lignoceric acid ratios, year, treatments and year × treatment were significant (Table 2). Lignoceric acid was found in trace amounts in peanuts and the highest was obtained from control (1.37%) treatment, while the lowest was obtained from SWFB60 (0.43%) treatment (Table 4). Abd et al. (2005) stated that the dose is important and the lignoceric ratio increases in soybean by mepiquat chloride treatments. In our trial findings, lignoceric acid ratios in all treatments were found to be lower than the control group. It can be said that this situation that occurred in the experiment is inversely proportional to the content of PGR used in the lignoceric acid ratio in peanuts.

Oleic/Linoleic (O/L) ratio

In the treatment of different PGR, the interaction of oleic/linoleic (O/L) acid ratio and treatment × year interaction was found significant (Table 2). The O/L ratio is important in peanuts, and as the oleic acid ratio increases, it is inversely proportional to the linoleic acid ratio (Lopez et al., 2001; Andersen and Gorbet, 2002). The lowest O/L ratio was found in the control treatment with 1.91%, while the highest was obtained from the GA_3FB10 treatment with 3.04%. All treatments were higher than the control group (Table 4). A high O/L ratio is desired by both chillers and consumers in terms of health, nutrition and fat shelf life in peanuts (Lopez et al., 2001).

Iodine Value (IV)

Iodine value is an indicator of the unsaturated fatty acid content in oil components (Bakal and Arioglu, 2019). In the experiment, treatments of different PGR to peanuts were found to be significant for iodine value (Table 2). The iodine value treatments ranged from 84.77% (GA_3FB10) to 93.35% (SWFB60) (Table 4). Although the iodine value is seen as an indicator of quality in peanuts, it is desired to be low (Al-Bachir, 2015; Sahin et al., 2022). Sawan et al. (2007) reported that mepiquat chloride treatments in cotton seeds increased the iodine value. In comparison with the findings of this researcher, the iodine value increased in mepiquat chloride treatments. In the GA_3 treatments applied in the trial, it was seen that the dose and period were important and the treatment of GA_3FB10 (84.77%) was important in order to find the most effective iodine value. For conventional U.S. peanut varieties, the O/L ratio is around 1.5 to 2.5. Varieties are considered to be high oleic when this ratio is greater than 9.0. High oleic peanuts have been found to have increased shelf life (up to 10 times) and improved flavor when compared to normal O/L ratios (Sahin et al., 2022).

Oil Yield

Oil yield was affected significantly ($p < 0.01$) by year, treatments, and year × treatment interaction (Table 2). All PGRs had an important contribution on oil yield regardless of its type compared to non-treated (control) group. The highest oil yield was found to be GA_3FB20 (337.08 kg da^{-1}) while the lowest was found to be control (125.31 kg da^{-1}) (Table 4). Saini and Jain (2017) reported that PGR increased the oil yield by from 30% to 50% compared to control because PGR had market effect on biosynthetic pathways. Similarly, it was reported that PGR treatments to sunflower increased the oil yield by 40-68% (Osman and Salem, 2011). Hasan and Ismail (2018) stated increasing PGR doses affected pod yield and oil content positively, thereby, oil yield also reached the higher value. The present study showed a similar trend with previous studies.

CONCLUSION

The present study evaluated the effects of the plant growth regulators such as gibberellic acid, mepiquat-chloride and seaweed applied in different growth stages on oil content and fatty acid compositions of peanut. The results showed that plant growth regulators regardless of contents had positive effects over control. The highest oil content was observed in mepiquat-chloride and seaweed applied at full bloom. Even if gibberellic acid applied at full bloom had average value of oil content, it was reached the maximum oil yield. Besides, it also came to forefront with the highest oleic/linoleic acid ratio and the lowest iodine value. As a result, gibberellic acid especially applied at full bloom may be recommended for optimum selection.

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LITERATURE CITED

Abd, E.D., A.A. Ramadan, H.A.M. Mostafa, A.L. Wanas and M.S. Gad. 2005. Interaction effects of benzyladenine and/or pix on soybean plants: 1. Some morphological and physiological responses. Journal of Plant Production. 30(10):5959-5972.

Al-Bachir, M. 2015. Quality characteristics of oil extracted from gamma irradiated peanut (*Arachis hypogea* L.). Radiation Physics and Chemistry. 106(1):56-60. doi: 10.1016/j.radphyschem.2014.06.026

Andersen, P.C. and D.W. Gorbet. 2002. Influence of year and planting date on fatty acid chemistry of high oleic acid and normal peanut genotypes. Journal of Agricultural and Food Chemistry. 50(5):1298-1305. doi: 10.1021/jf0113171

Arioglu, H.H. 2014. The oil seed crops growing and breeding. Adana: Cukurova University, Faculty of Agriculture Publishing.

Arioglu, H.H., C. Kurt, H. Bakal, B. Onat, L. Gulluoglu and N.S. Sinan. 2013. The effects of pix applied at different growing stages on some agronomical characteristics of peanut. Turkish Journal of Field Crops 18(2):260-267.

Bakal, H. and H.H. Arioglu. 2019. The determination of fatty acids composition and oil quality factors of some peanut varieties having different market types at different harvesting times in main and double crop growing seasons in Mediterranean region. Turkish Journal of Field Crops 24(2):221-229. doi: 10.17557/tjfc.655078

Baydar, H. 2002. Effects of gibberellic acid treatment for pollen sterility induction on the physiological activity and endogenous hormone levels of the seed in safflower. Turkish Journal of Biology 26(4):235-239.

Bibi, M., M. Hussain, M.S. Qureshi and S. Kousar. 2003. Morpho-chemical and physiological response of sunflower (*Helianthus annuus* L.) to gibberellic acid and nitrogen. Pakistan Journal of Life and Social Sciences. 1(1):51-53.

Erdemli, H. and M.D. Kaya. 2015. The effects of gibberellic acid doses on yield and germination under abiotic stress conditions in sunflower (*Helianthus annuus* L.). Biotech Studies 24(1):38-46. doi: 10.21566/tbmaed.71738

FAOSTAT. 2023. Food and agriculture data, http://www.fao.org/faostat/en/#data/QC, (Accessed August 24, 2023)

Fornes, F., M. Sanchez-Perales, J.L. Guardiola. 2002. Effect of a seaweed extract on the productivity of'de Nules' clementine mandarin and navelina orange. Botanica Marina. 45(5):486-489. doi: 10.1515/BOT.2002.051

Hasan, M. and B.S. Ismail. 2018. Effect of gibberellic acid on the growth and yield of groundnut (*Arachis hypogaea* L.). Sains Malaysiana. 47(2):221-225. doi: 10.17576/jsm-2018-4702-02

Hashem, H.A., W.H. Abd-Allah and R.M. Khater. 2022. Effect of some safe agricultural treatments on growth and productivity of *Nigella sativa* L. plants under south sinai conditions. Egyptian Journal of Desert Research. 72(2):315-334. doi: 10.21608/EJDR.2022.169183.1116

Heydari, M., H.R.T. Moghadam, F. Ghooshchi, S.A.M. Modarres-Sanavy and P. Kasraie. 2021. Foliar application of humic acid and some exo-and endophytic growth hormones on yield, yield components and fatty acid composition in safflower (*Carthamus tinctorius* L.) under drought stress. Journal of Agricultural Sciences. 27(4):500-508. doi: 10.15832/ankutbd.748132

Khan, M.N., Z. Khan, T. Luo, J. Liu, M. Rizwan, J. Zhang and L. Hu. 2020. Seed priming with gibberellic acid and melatonin in rapeseed: Consequences for improving yield and seed quality under drought and non-stress conditions. Industrial Crops and Products. 156:112850. doi: 10.1016/j.indcrop.2020.112850.

Khrmashow, D.Z., M. Bouras and F. Sahuni. 2022. Effect of spraying with ga_3 on the quality and oil content of Syrian Okra seeds *Abelmoschus esculentus* (L.). American Journal of Plant Sciences 13(1):83-90. doi: 10.4236/ajps.2022.131006

Kim, S.K., H.D. Lee and H.J. Choi. 2011. Effects of mepiquat chloride and trinexapac-ethyl on oil composition, seed yield and endogenous gibberellins in flax. Korean Journal of Plant Resources. 24(6):696-701.

Lopez, Y., O.D. Smith, S.A. Senseman and W.L. Rooney. 2001. Genetic factors influencing high oleic acid content in Spanish market-type peanut cultivars. Crop Science 41(1):51-56. doi: 10.2135/cropsci2001.41151x.

Maliki, A.A.A.M.A. 2022. Effect of gibberellic acid and water stress in growth, yield characteristics and oil percentage on sunflower. Natural Volatiles & Essential Oils. 9(1):1837-1847.

Mohamed, N.H., E.A. Hassan, E.H. Hamad and M.R. Khater Rania. 2020. Response of black cumin (*Nigella sativa* L.) plants to the addition of natural fertilizers and the inoculation by bacteria mix and seaweed liquid extract. Archives of Agriculture Sciences Journal. 3(2):1-15. doi: 10.21608/AASJ.2020.103899

Nasiroleslami, E., H. Mozafari, M. Sadeghi-Shoae, D. Habibi and B. Sani. 2021. Changes in yield, protein, minerals, and fatty acid profile of wheat (*Triticum aestivum* L.) under fertilizer management involving application of nitrogen, humic acid, and seaweed extract. Journal of Soil Science and Plant Nutrition. 21(4):2642-2651. doi: 10.1007/s42729-021-00552-7

Onemli, F. 2012. Impact of climate change on oil fatty acid composition of peanut (*Arachis hypogaea* L.) in three market classes. Chilean Journal of Agricultural Research. 72(4):483-488. doi: 10.4067/S0718-58392012000400004

Osman, H.E. and O. Salem. 2011. Effect of seaweed extracts as foliar spray on sunflower yield and oil content. Egyptian Journal of Phycology. 12(1):57-70. doi: 10.21608/EGYJS.2011.114938

Sahin, C.B., M. Yilmaz and N. Isler. 2022. Determination of oil quality and fatty acid compositions of some peanut (*Arachis hypogaea* L.) genotypes grown in Mediterranean region. Turkish Journal of Field Crops 27(1):142-148. doi: 10.17557/tjfc.1095649

Saini, C. and N.K. Jain. 2017. Influence of sulphur and plant growth regulators on yield, quality and nutrient uptake in summer peanut (*Arachis hypogaea*). Annals of Agricultural Research 38(2):170-175.

Sawan, Z.M., S.A. Hafez, A.E. Basyony and A.R. Alkassas. 2007. Nitrogen, potassium and plant growth retardant effects on oil content and quality of cotton seed. Grasas Y Aceites. 58(3):243-251. doi: 10.3989/gya.2007.v58.i3.179

Schmidt, R.E., E.H. Ervin and X. Zhang. 2003. Questions and answers about biostimulants. Golf Course Manage. 71(6):91-94.

Shaki, F., H. Ebrahimzadeh-Maboud and V. Niknam. 2019. Effects of salicylic acid on hormonal cross talk, fatty acids profile, and ions homeostasis from salt-stressed safflower. Journal of Plant Interactions. 14(1):340-346 doi: 10.1080/17429145.2019.1635660

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2. ed. New York: McGraw-Hill Publ. Company.

Turan, M. and C. Kose. 2004. Seaweed extracts improve copper uptake of grapevine. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science. 54(4):213-220. doi: 10.1080/09064710410030311

Yol, E. and B. Uzun. 2018. Influences of genotype and location interactions on oil, fatty acids and agronomical properties of groundnuts. Grasas Y Aceites. 69(4): e276. doi: 10.3989/gya.0109181.