

Effect of Planting Distances and Spraying with Plant Extracts on Seed Yield and Biochemical Compounds of Castor (*Ricinus communis* L.)

Salwa Alwan Khan¹, Ahmed Yassin Hassan²

1- Department of Field Crop Sciences, College of Agriculture, University of Diyala, Iraq

2- Department of Field Crop Sciences, College of Agriculture, University of Diyala, Iraq

Corresponding author's email: salwaalwan@uodiyala.edu.iq

Abstract:

A field experiment was conducted at the Agricultural Research Station, Department of Field Crop Sciences / College of Agriculture – University of Diyala / Iraq, to study the effect of planting distances and spraying with plant extracts on seed and oil yield of castor. The experiment was carried out using a Randomized Complete Block Design (RCBD) with a split-plot arrangement, including three planting distances between plants (45, 65, 85) cm and four levels of plant extracts (0, 50+50, 100+100, 150) ml L⁻¹. The results showed that the planting distance of 65 cm significantly outperformed in seed yield and biochemical compounds, while the 85 cm distance recorded the highest oil percentage, and the 45 cm distance gave the highest phenolic content. The fatty acid analysis results also indicated that the 85 cm planting distance increased ricinoleic, oleic, and linoleic acids. Regarding spraying with plant extracts, it improved most of the studied traits, with the (100+100) ml L⁻¹ treatment excelling, while the highest value of ricinoleic acid was recorded at the (50+50) ml L⁻¹ concentration, and the highest concentrations of oleic and linoleic acids were achieved at the (150) ml L⁻¹ concentration. For the interaction between planting distances and spraying with plant extracts, the treatment (65 cm + 100+100 ml L⁻¹) excelled in seed yield and oil yield, while the treatment (85 cm + 100+100 ml L⁻¹) recorded the highest oil percentage, and the treatment (45 cm + 100+100 ml L⁻¹) gave the highest phenolic content. The study recommends adopting a planting distance of 65 cm with spraying of plant extracts at a concentration of (100+100) ml L⁻¹ to obtain the highest seed and oil yield, while using the 85 cm planting distance to improve oil quality in terms of fatty acid composition.

Keywords: Castor (*Ricinus communis* L.), Plant spacing, Plant extracts, Seed yield, Oil yield, Fatty acids.

(Extracted from a Master's thesis for the first researcher)

Introduction:

Ricinus communis L. is a plant belonging to the Euphorbiaceae family, growing in tropical, subtropical, and temperate regions

and soils [19]. The plant is characterized by its ability to adapt to various environmental conditions, as it grows well at temperatures

ranging between 20–25°C, while temperatures below 12°C or above 38°C negatively affect its growth and productivity [22, 24]. Crop yield varies depending on prevailing environmental conditions and the nature of the cultivated variety [1]. In Pakistan, castor production reached about 2.3 thousand tons in 2016 on an area of 2.25 thousand hectares [25]. The importance of this crop stems from the economic and medicinal value of its seed-extracted oil, which is used in the manufacture of various pharmaceutical and cosmetic preparations and diverse industrial products, in addition to its use in some agricultural applications and biofuel production [2, 22]. Unsaturated fatty acids contribute to reducing the risk of chronic diseases such as cardiovascular disease, diabetes, and cancer [10]. Castor seeds also contain significant concentrations of bioactive compounds, which enhance their medicinal and industrial value [5]. Plant density is one of the agricultural factors affecting the growth and productivity of castor, as it contributes to regulating the utilization of available resources such as water, light, and nutrients [23]. High plant density may lead to increased competition

among plants, while selecting appropriate spacing helps improve vegetative traits, yield, and its components [16]. They also indicated that regulating plant density is an important means of improving resource use efficiency of water, light interception, and nutrient uptake, thereby enhancing crop productivity [17]. With the trend toward sustainable agriculture and reducing reliance on chemical fertilizers, interest has increased in using plant extracts as safe and environmentally friendly alternatives to stimulate growth and improve plant productivity. The importance of adopting modern techniques and natural environmental alternatives for maintaining agricultural production has been emphasized [11]. It has also been shown that plant extracts contain effective bioactive compounds, including phenolics and plant hormones, which contribute to activating physiological processes, improving nutrient absorption, and increasing plant tolerance to various environmental stresses [11].

Therefore, this study aimed to investigate the response of seed yield and oil yield of castor (*Ricinus communis* L.) to planting distances and spraying with plant extracts.

Materials and Methods:

Table (1): Some chemical and physical properties of the field soil(Analysis was conducted at the Laboratory of the Department of Soil and Water Resources Sciences, College of Agriculture, University of Diyala)

Unit	Result	Analysis Type
dS/m ⁻¹	8.7	Soil (EC)
	7.70	pH
mg/kg ⁻¹	26.25	Nitrogen(N)
mg/kg ⁻¹	3.1	Phosphorus(P)
mg/kg ⁻¹	290	Potassium(K)
%	27	Calcium Carbonate (CaCO ₃)

%	1.5	Organic Matter (O.M.)
%	Silt Clay loam Clay=29.2 Sand=30.8% Silt=40	Texture

2-1 Land Preparation and Agricultural Operations:

The field experiment was conducted at the Agricultural Research Station, Department of Field Crop Sciences / College of Agriculture, University of Diyala, Iraq, during the 2025 growing season. The land designated for the experiment was prepared by plowing, leveling, and smoothing, after which furrows were opened and the land was divided into experimental units. The total number of experimental units was (36) units, each containing (10) plants, with a distance of (1.25 m) left between replications. Phosphate fertilizer was added at a rate of (100 kg ha⁻¹) during land preparation and before planting. Castor seeds were soaked in water for (24) hours prior to planting, then sown on 19/3/2025 in

the upper third of the furrow, with three seeds per hill. Irrigation was carried out immediately after planting to ensure adequate moisture for germination. After seedling emergence, thinning was performed, leaving one plant per hill.

Nitrogen fertilizer was added at a rate of (100 kg ha⁻¹) in two split applications: the first batch was added, and the second batch was added (20) days after the first. Irrigation operations continued throughout the growing season according to plant requirements and prevailing weather conditions. Weeding was also carried out manually whenever necessary to remove weeds and reduce their competition with castor plants for water, nutrients, and light.

2-2 Experimental Treatments:

First Factor (A): Three planting distances were used: (45, 65, 85) cm, coded as (A1, A2, A3) respectively, with each experimental unit assigned one distance.

Second Factor (B): Four levels of spraying with plant extracts were used: (0, 50+50, 100+100, 150) ml L⁻¹, coded as (B0, B1, B2, B3).

The nettle extract and green tea extract were prepared separately by weighing (100 g) of nettle powder and soaking it in (1 L) of water, and similarly weighing (100 g) of green tea powder and soaking it in (1 L) of water for (24) hours. After that, the extracts

were filtered using a piece of gauze to obtain the aqueous extracts. Spraying was carried out in three applications, with the first application on 28/4/2025, and a (15)-day interval between each application. Castor plants were sprayed during the early morning hours or in the afternoon to avoid high temperatures.

The prepared extracts were used according to the following treatments:

1. B0: Control treatment (distilled water only).
2. B1: (50) ml L⁻¹ nettle extract + (50) ml L⁻¹ green tea extract, then the volume was

completed to (1 L) by adding (900 ml) of distilled water, and the solution was sprayed on the plants.

3. B2: (100) ml L⁻¹ nettle extract + (100) ml L⁻¹ green tea extract, then the volume was completed to (1 L) by adding (800 ml)

of distilled water, and the solution was sprayed on the plants.

4. B3: (150) ml L⁻¹ nettle extract, then the volume was completed to (1 L) by adding (850 ml) of distilled water, and the solution was sprayed on the plants.

2-3 Statistical Analysis:

The experiment was conducted according to a Randomized Complete Block Design (R.C.B.D.) with a split-plot arrangement, using two factors: planting distances and plant extracts (green tea and nettle). The

results were analyzed using the [20] program according to the design used in the study, and Duncan's multiple range test was adopted for mean comparisons at a probability level of 0.05 [9].

in Table (2), the chemical composition of green tea leaves As mentioned (*Camellia sinensis L.*) [4,15]

Table (3) Biochemical analyses of nettle leaves (*Urtica dioica*)[2]

The Components	The quantity
Nitrogen (N)	1.19g
Phosphorus (P)	1g
Potassium (K)	0.5g
Manganese (Mn)	0.7g
Zinc (Zn)	51mg
Iron (Fe)	60mg
Magnesium (Mg)	41mg
Coneshin	110mg
Thiamine	90mg
Vitamin A	88mg
Vitamin B	74.1mg
Vitamin C	120mg
Carbohydrates	11.0g
Fats	0.4g
Flavonoids	0.3g
Tannins	g 2.9

(μg)	Amino acids	%10	Crude protein
5.28	Glutamine	%1.98	Fats
2.66	Glycine	mg/L^{-1}	Vitamins
5.0	Arginine	1240	Vitamin A
2.75	Phenylalanine	420	Vitamin C
4.35	Aspartate	212	Vitamin E
1.18	Histidine	100.010	Biotin
1.86	Serine	mg/L^{-1}	Mineral salts
0.35	Methionine	0.030	Manganese
5.60	Lysine	0.750	Iron
2.18	Threonine	0.100	Zinc
2.91	Valine	51.210	Potassium
2.98	Leucine	27.500	Magnesium
1.98	Isoleucine	13.100	Sodium
		24.450	Calcium
		101.250	Phosphorus
		0.390	Cobalt

2-3 Studied Traits:

2-3-1 Seed Yield (kg ha^{-1}):

Seed yield (kg ha^{-1}) was estimated according to the following equation:

Seed yield (kg ha^{-1}) = Weight of seeds produced from the experimental unit (kg) / Area of the experimental unit (m^2) $\times 10000$

2-3-2 Seed Oil Percentage (%):

The fixed oil was extracted from the seeds using a Soxhlet apparatus with the organic solvent hexane. A sample of (15 g) of seeds was placed in a cellulose thimble after being placed in an oven at 105°C for one hour for drying and weight stabilization purposes, and to prepare them for extraction. The seeds were ground whole using a Roller Mill. Then, (250 ml) of hexane was added, and extraction was carried out using the apparatus at a temperature of 75°C inside the laboratory for six hours. After that, the oil was concentrated by evaporating the

hexane at room temperature (25°C or above) for a full day. The extracted oil was stored in closed, opaque glass jars away from light at 4°C for the purpose of fatty acid determination [13].

Oil weight was calculated by the difference between the weight of the glass jar containing the oil and its empty weight, then divided by the weight of the sample used and multiplied by 100.

Oil percentage (%) was calculated according to the following equation:

$$\text{Oil (\%)} = (W2 - W1) / W3 \times 100$$

2-3-3 Oil Yield (kg ha^{-1}):

Oil yield (kg ha^{-1}) was estimated based on seed yield and the laboratory-extracted oil percentage for each experimental unit according to the following equation:

$$\text{Oil yield (\%)} = \text{Seed yield (\%)} \times \text{Oil percentage (\%)} / 100$$

2-3-4 Total Phenol Content:

The total phenolic compounds content in the ethanol extract was determined using the Folin-Ciocalteu reagent. The reaction mixture consisted of (0.5 ml) of the extract, (1.5 ml) of Folin-Ciocalteu reagent (Merck, Germany), and (1.5 ml) of 20% sodium wavelength of 765 nm. Phenol content was estimated using a standard curve with gallic acid as the standard compound (Sigma-Aldrich, Germany) [14]. The quantity of

carbonate solution. The sample was then mixed using a vortex mixer after being diluted with distilled water to (10 ml). After two hours of reaction, the absorbance was measured using a spectrophotometer at a

phenolic compounds was expressed as micrograms of gallic acid equivalent per gram of dry seed weight ($\mu\text{g GAE g}^{-1}$).

2-3-5 Estimation of Fatty Acids Using Gas Chromatography-Mass Spectrometry (GC-MS):

The fatty acids in the oil were converted to fatty acid methyl esters (FAMES) for concentration determination according to the method of [6]. Using a GC-MS device in the laboratories of the College of Science – University of Samarra, a Japanese-made Shimadzu 12A-GC DA-Restek stabil wax device equipped with a capillary column of carboxyl TG WAX-MS was used for fatty acid analysis. The column dimensions were (length 30 m × diameter 0.25 mm × film thickness 0.25 µm). Hexane was used as the solvent with a split ratio of 1:10, and (1 µl) of the oil solution was injected into the device. Helium was used as the carrier gas with a constant column flow rate of (3

ml/min). The temperature program started at 140°C for 0 minutes, then increased at a rate of 5°C/min to 190°C, then raised from 190°C at 4°C/min, then further raised to 280°C. The injector and detector temperatures were raised to 270°C. The total injection time was 48.30 minutes, with a split injection type of 100, and the ion source temperature was 200°C.

The resulting mass spectra of each peak were compared with the mass spectra available in the device library to identify the fatty acids of the oil extracted from the plant samples (oleic acid, linoleic acid, and ricinoleic acid)

4. Results and Discussion

4-1 Seed Yield (kg ha⁻¹):

The results presented in Table (4) indicate that there was a significant effect among planting distances for castor plants, as the planting distance of 65 cm significantly outperformed the others, giving the highest mean seed yield (kg ha⁻¹), reaching 1340.94 kg ha⁻¹, while the 45 cm distance gave the lowest mean seed yield (kg ha⁻¹), amounting to 1276.39 kg ha⁻¹.

The superiority of the 65 cm planting distance in achieving the highest seed yield may be attributed to providing an appropriate balance between plant density and reduced competition intensity among plants for light, water, and nutrients, as well compared to the control (no spraying) treatment, which gave the lowest mean seed yield (kg ha⁻¹) at 1200.22 kg ha⁻¹.

The superiority of the aforementioned spraying treatment may be attributed to its positive effect in enhancing the plant's physiological activity by improving

as providing suitable shading that helped maintain soil and plant moisture content. This provided favorable conditions for the continuation of physiological processes, increased photosynthetic efficiency, and carbohydrate formation. This was positively reflected on yield components, especially increasing the number of capsules and seed filling, which consequently led to increased seed yield [7].

There were significant differences among the spraying treatments with plant extracts, as the (100+100) treatment gave the highest mean seed yield (kg ha⁻¹), reaching 1361.30 kg ha⁻¹, photosynthetic efficiency and increasing the formation and translocation of synthesized nutrients to the seeds, which contributed to increased seed yield. This is consistent with [8].

In addition, there was an interaction between the experimental treatments, as the

interaction treatment of 65 cm planting distance with foliar spraying of the (100+100) extract significantly outperformed, giving the highest mean seed yield (kg ha^{-1}) at $1444.37 \text{ kg ha}^{-1}$, while

the interaction treatment of 85 cm planting distance with no plant extract spraying gave the lowest mean seed yield (kg ha^{-1}) at $1170.13 \text{ kg ha}^{-1}$.

Table (1): Effect of planting spacings, spraying with plant extracts, and their interaction on seed yield (kg/ha^{-1})

Planting Spacing	Spraying Concentrations of Green Tea and Nettle (ml/L)				Spacing Mean
	B ₀	B ₁	B ₂	B ₃	
A ₁	1213.53 fe	1284.83 cd	1335.67 b	1271.53 cd	1276.39 B
A ₂	1217.00 e	1266.57 d	1444.37 a	1435.83 a	1340.94 A
A ₃	1170.13 g	1180.37 fg	1303.87 cb	1295.13 cd	1237.37 C
Spraying Mean	1200.22 D	1243.92 C	1361.30 A	1334.16 B	

4-2 Seed Oil Percentage (%):

Table (5) shows that there was a significant increase among planting distances for castor plants in seed oil percentage, as the 85 cm distance gave the highest mean seed oil percentage, reaching 43.22%, while the 45 cm distance gave the lowest mean seed oil percentage at 40.39%.

The superiority of the 85 cm planting distance in increasing seed oil percentage may be attributed to reduced competition intensity among plants for environmental resources, which led to improved photosynthetic efficiency and increased carbohydrate accumulation, which are

considered essential materials involved in oil synthesis and accumulation in seeds [8].

The data in Table (5) also indicated significant differences among spraying treatments with plant extracts, as the (100+100) treatment gave the highest mean seed oil percentage, reaching 42.44%, while the control (no spraying) treatment gave the lowest mean seed oil percentage at 40.78%.

The reason for the superiority of the (100+100) treatment in increasing seed oil percentage is that these plant extracts contribute to improving the plant's physiological activity. They activate

enzymes responsible for nutrient formation and increase photosynthetic efficiency due to their content of bioactive compounds such as nutrients and some growth regulators [7].

Furthermore, an interaction was found between the experimental treatments, as the interaction treatment of 85 cm planting

distance with foliar spraying of the (100+100) extract significantly outperformed, giving the highest mean seed oil percentage at 44.10%, while the interaction treatment of 45 cm planting distance with no plant extract spraying gave the lowest mean seed oil percentage at 39.66%.

Table (2): Effect of planting spacings, spraying with plant extracts, and their interaction on oil percentage in castor see (%):

Planting Spacing	Spraying Concentrations of Green Tea and Nettle (ml/L)				Spacing Mean
	B ₀	B ₁	B ₂	B ₃	
A ₁	39.66 g	40.90 e	40.90 e	40.10 f	40.39 C
A ₂	40.63 e	42.03 dc	42.33 c	41.76 d	41.69 B
A ₃	42.06 dc	43.43 b	44.10 a	43.30 b	43.22 A
Spraying Mean	40.78 D	42.12 B	42.44 A	41.72 C	

4-3 Oil Yield (kg ha⁻¹):

It is evident from Table (6) that there was a significant increase in oil yield (kg ha⁻¹) at the 65 cm planting distance, which gave the highest mean of 559.56 (kg ha⁻¹), compared to the lowest mean oil yield (kg ha⁻¹) at the 45 cm distance, which was 515.85 (kg ha⁻¹).

The superiority of the 65 cm planting distance in achieving the highest oil yield (kg ha⁻¹) may be attributed to its superiority in seed yield, in addition to achieving a high oil percentage, since oil yield is influenced

by both seed yield and seed oil percentage. This is attributed to this distance providing an appropriate balance between plant density and reduced competition intensity among plants for environmental resources, which was positively reflected on yield components and increased accumulation of carbohydrates and lipids in seeds, thus leading to higher oil yield. This is consistent with findings of [18].

There were also significant differences among foliar spraying treatments with plant

extracts, as the (100+100) treatment excelled, giving the highest mean oil yield (kg ha^{-1}) of 577.65 (kg ha^{-1}), while the control (no spraying) treatment gave the lowest mean oil yield (kg ha^{-1}) at 489.45 (kg ha^{-1}).

The reason for the superiority of the foliar spraying treatment with plant extracts (100+100) in giving the highest oil yield (kg ha^{-1}) is that these plant extracts contain macro- and micronutrients and bioactive compounds (such as amino acids and growth-promoting substances), which lead to increased photosynthetic activity and accumulation of carbohydrates, which represent the primary source for oil

formation, and subsequently fatty acids within seeds, which is positively reflected on increased oil yield. This is consistent with [11].

It is also noted from the table that there was a significant effect among interaction treatments, where the interaction treatment of 65 cm planting distance with foliar spraying of the (100+100) extract excelled, giving the highest mean oil yield (kg ha^{-1}) of 611.56 (kg ha^{-1}), while the interaction treatment of 45 cm planting distance with the control (no spraying) treatment gave the lowest mean oil yield (kg ha^{-1}) of 481.53 (kg ha^{-1}).

Table (3): Effect of planting spacings, spraying with plant extracts, and their interaction on oil yield (kg/ha^{-1}):

Planting Spacing	Spraying Concentrations of Green Tea and Nettle (ml/L)				Spacing Mean
	B ₀	B ₁	B ₂	B ₃	
A ₁	481.53 g	525.43 ef	546.36 cd	510.06 f	515.85 C
A ₂	494.53 g	532.43 ed	611.56 a	599.73 a	559.56 A
A ₃	492.30 g	512.63 f	575.03 b	560.93 cb	535.22 B
Spraying Mean	489.45 D	523.50 C	577.65 A	556.91 B	

4-4 Total Phenol Content ($\text{mg } 100 \text{ g}^{-1}$ seeds):

From Table (7), it is evident that there was a significant superiority among planting distance treatments for castor plants, as the 45 cm planting distance treatment excelled,

giving the highest total phenol content in seeds, reaching 211.64 ($\text{mg } 100 \text{ g}^{-1}$ seeds), compared to the lowest mean phenol content

at the 85 cm planting distance, which was 195.67 (mg 100 g⁻¹ seeds).

This may be attributed to competition among plants for light, water, and nutrients, and the occurrence of moderate physiological stress within the plant, which stimulates the plant to synthesize antioxidant compounds and increase stress tolerance [21], consistent with the findings of [21].

Meanwhile, the spraying treatments with plant extracts showed a significant effect, as the (100+100) extract spraying treatment excelled, giving the highest mean phenol content of 206.43 (mg 100 g⁻¹ seeds), compared to the control (no spraying) treatment, which was 192.99 (mg 100 g⁻¹ seeds).

This is attributed to the plant extracts containing bioactive compounds such as

amino acids, which help activate the metabolic pathways responsible for phenol formation.

There was also a significant interaction between the experimental treatments, where the highest values were given by the interaction treatment of 45 cm distance with (100+100) extract spraying, which gave the highest mean phenol content of 213.47 (mg 100 g⁻¹ seeds), while the lowest values were given by the interaction treatment of 85 cm distance with no plant extract spraying, which was 182.16 (mg 100 g⁻¹ seeds).

Table (4): Effect of planting spacings, spraying with plant extracts, and their interaction on phenol content in castor seeds (mg·100g⁻¹ seeds):

Planting Spacing	Spraying Concentrations of Green Tea and Nettle (ml/L)				Spraying Mean
	B ₀	B ₁	B ₂	B ₃	
A ₁	209.78 a	210.70 a	213.47 a	212.61 a	211.64 A
A ₂	187.05 d	209.49 a	204.45 b	200.10 cb	200.27 B
A ₃	182.16 d	198.83 c	201.37 cb	200.31 cb	195.67 B
Spraying Mean	192.99 B	206.34 A	206.43 A	204.34 A	

4-5 Effect of Planting Distances and Spraying with Plant Extracts on Oleic Acid Concentration in Oil:

The results shown in Figure (1) revealed differences in oleic acid concentration with varying planting distances, as the 85 cm distance gave the highest mean of 457.69 (mg 100 g⁻¹ seeds), while the 45 cm distance recorded the lowest value of 191.84 (mg 100 g⁻¹ seeds).

The results shown in Figure (2) showed a gradual increase in oleic acid concentration with increasing concentrations of spraying with plant extracts, as the (150) treatment recorded the highest value of 359.56 (mg 100 g⁻¹ seeds), while the control (no

spraying) treatment gave the lowest value of 232.21 (mg 100 g⁻¹ seeds).

The increase in oleic acid concentration at the 85 cm planting distance may be attributed to the effect of planting distance on the metabolic processes associated with fatty acid synthesis and modification of their composition within seeds, which contributed to increased oleic acid concentration in the oil. The superiority of spraying treatments with plant extracts is also attributed to their role in activating metabolic processes associated with the synthesis of enzymes contributing to oils and fatty acids.

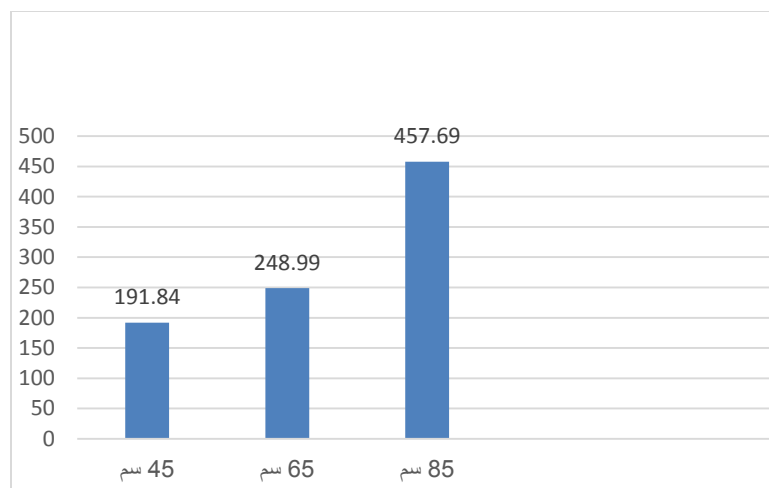


Figure (1) Effect of planting distances on oleic acid concentration in oil.

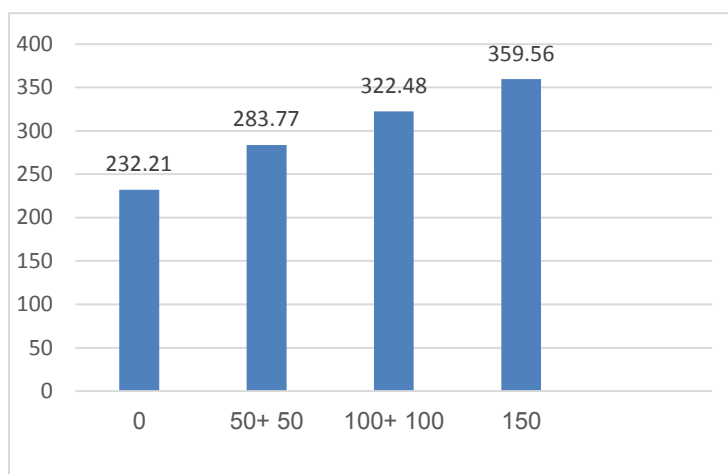


Figure (2) Effect of foliar spray with plant extracts on oleic acid content in oil.

The results shown in Figure (3) also demonstrated a clear effect of the interaction between planting distances and plant extract concentrations on oleic acid content in the oil. It was found that the 85 cm planting distance with spraying at the (100+100) concentration gave the highest content, reaching 528.18 ($\text{mg } 100 \text{ g}^{-1} \text{ seeds}$), compared to the interaction treatment of 45 cm distance with the control (no spraying), which gave the lowest value of 180.78 ($\text{mg } 100 \text{ g}^{-1} \text{ seeds}$).

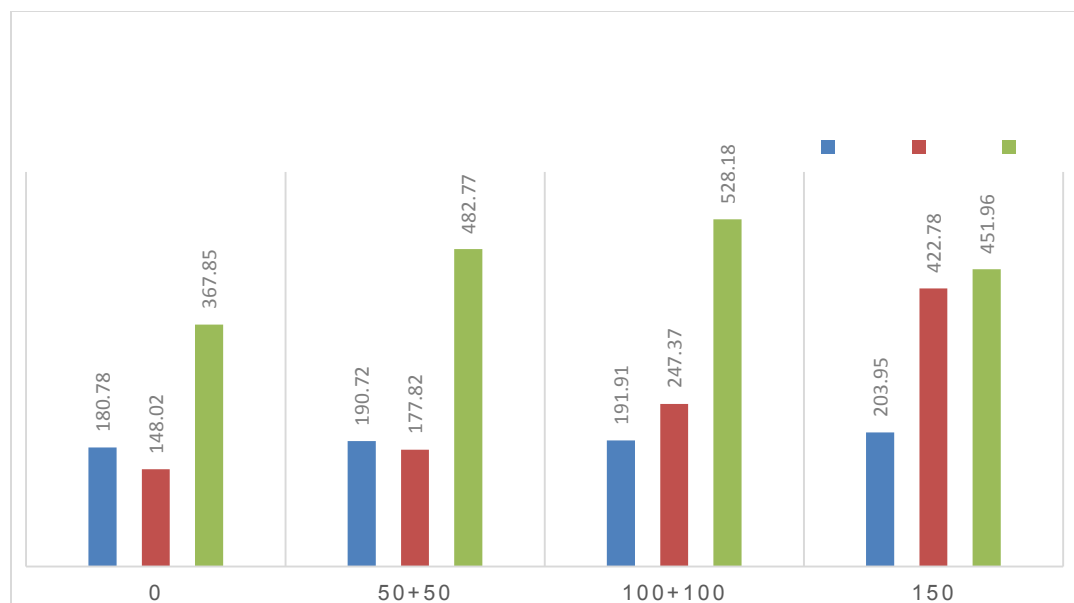


Figure (3) Interaction between planting distances and spray with concentrations of plant extracts on oleic acid concentration in oil.

4-7 Effect of Planting Distances and Spraying with Plant Extracts on Linoleic Acid Content in Oil:

Figure (4) shows a gradual increase in linoleic acid concentration with increasing planting distance between plants, as the 85 cm distance recorded the highest concentration of 11937.95 (mg 100 g⁻¹ seeds), while the 45 cm distance gave the lowest concentration of 4411.16 (mg 100 g⁻¹ seeds).

Figure (5) also shows that spraying with plant extracts led to differences in linoleic acid content, as the (150) treatment recorded the highest value of 10426.61 (mg 100 g⁻¹ seeds), compared to the control (no spraying) treatment, which gave the lowest value of 3544.15 (mg 100 g⁻¹ seeds).

The increase in linoleic acid content in oil at the 85 cm planting distance is attributed to the effect of planting distances on the metabolic processes associated with the synthesis of unsaturated fatty acids within seeds, which led to increased accumulation of linoleic acid in the oil. The superiority of spraying treatments with plant extracts is also attributed to their content of bioactive compounds and nutrients that contributed to improving the efficiency of metabolic processes and activating the enzymes responsible for the synthesis of unsaturated fatty acids, which was positively reflected on increasing linoleic acid content in the oil compared to the control (no spraying) treatment.

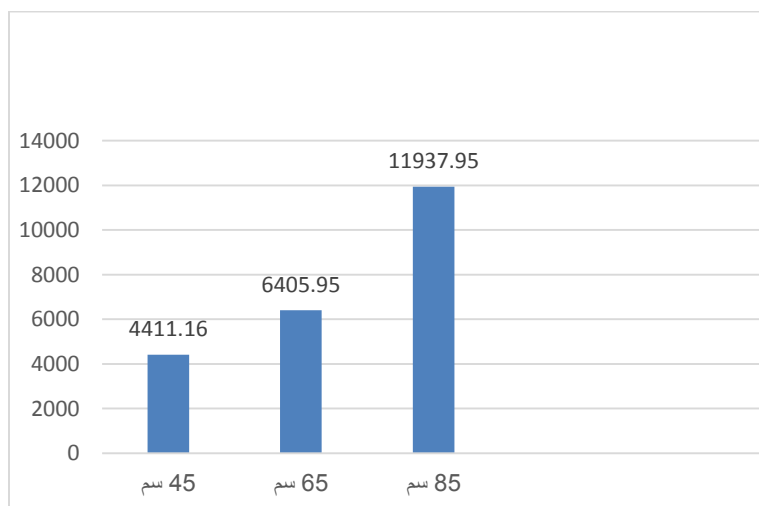


Figure (4) Effect of planting distances on linoleic acid content in oil.

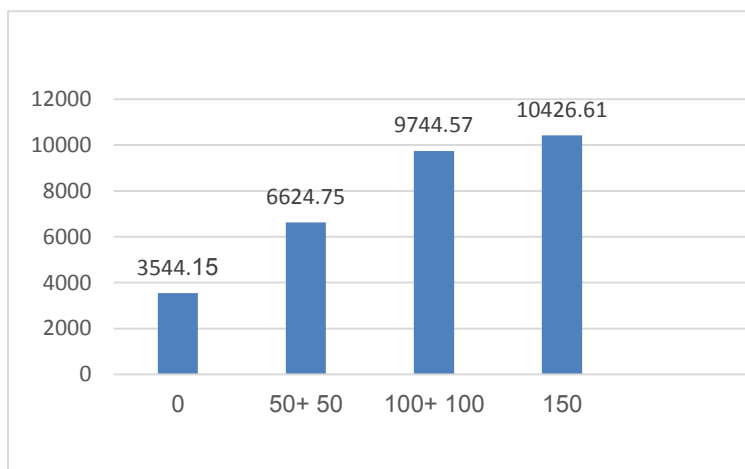


Figure (5): Effect of spraying with plant extracts on linoleic acid concentration in the oil.

The mean values in Figure (6) show an increase in the interaction means, with the treatment (85 cm + 100+100) giving the highest concentration of 16462.75 (mg 100

g^{-1} seeds), while the lowest values were recorded at (65 cm + no spraying), amounting to 1934.4 (mg 100 g^{-1} seeds).

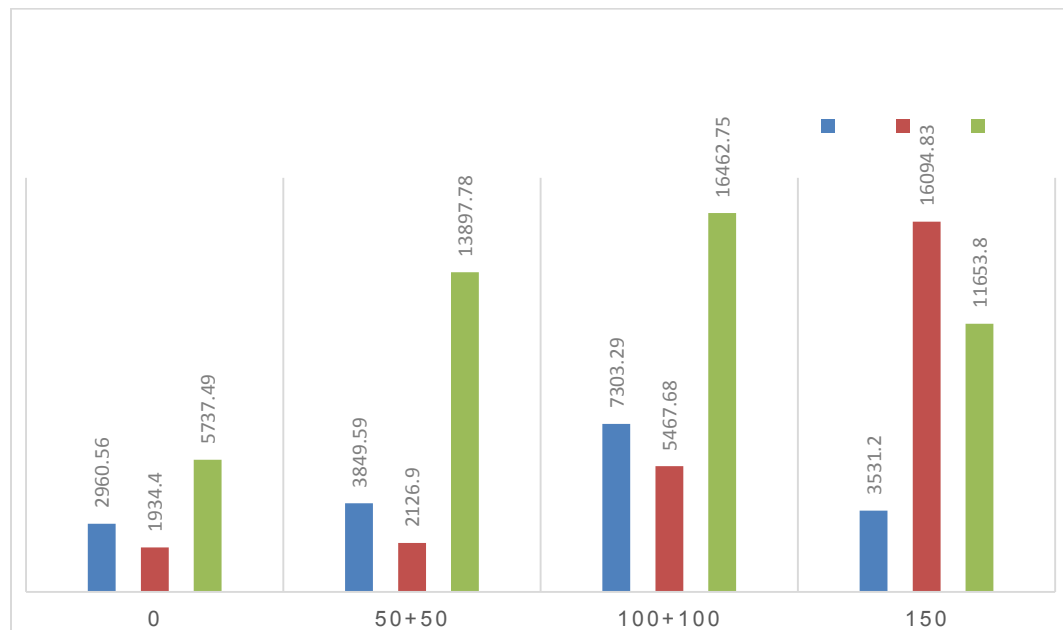


Figure (6): The interaction between planting spacings and spraying with plant extract concentrations on linoleic acid concentration in the oil.

4-9 Effect of Planting Distances and Spraying with Plant Extracts on Ricinoleic Acid Content in Oil:

Figure (7) shows a clear effect of planting distances on ricinoleic acid concentration in oil, as the 85 cm distance recorded the highest concentration of 49014.65 (mg 100 g^{-1} seeds), while the 45 cm distance gave the lowest concentration of 19691.66 (mg 100 g^{-1} seeds).

As is evident from Figure (8), the concentrations of spraying with plant extracts affected ricinoleic acid concentration, as the (50+50) treatment recorded the highest value of 40415.06 (mg 100 g^{-1} seeds) compared to the control

treatment, which gave the lowest value of 28996.07 (mg 100 g^{-1} seeds).

The increase in ricinoleic acid content at the 85 cm planting distance is attributed to its effect on improving the metabolic processes responsible for the synthesis and accumulation of fatty acids within seeds, which was positively reflected on increasing ricinoleic acid content in the oil. The superiority of spraying treatments with plant extracts is also attributed to their role in enhancing

the efficiency of physiological and metabolic processes, which contributed to

increasing the content of this acid in the oil.

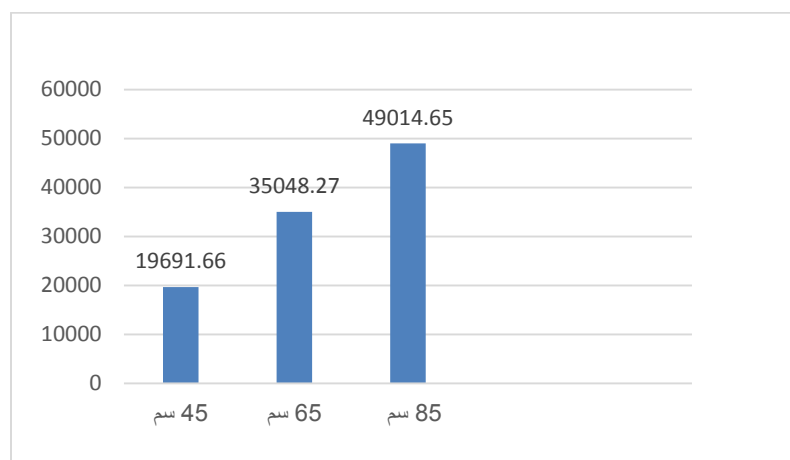


Figure (7): Effect of planting spacings on ricinoleic acid concentration in the oil.

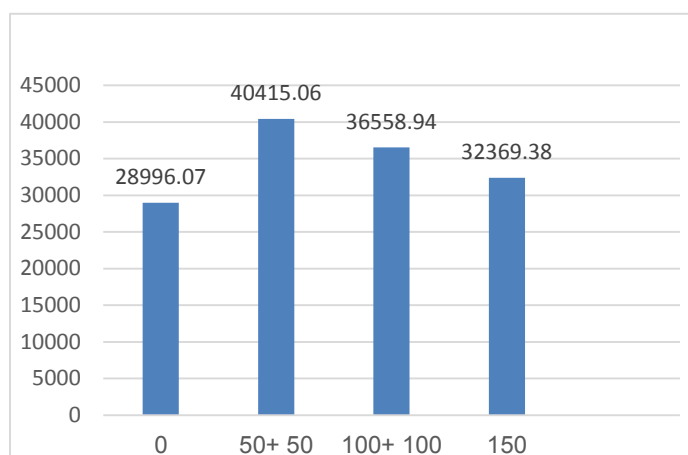
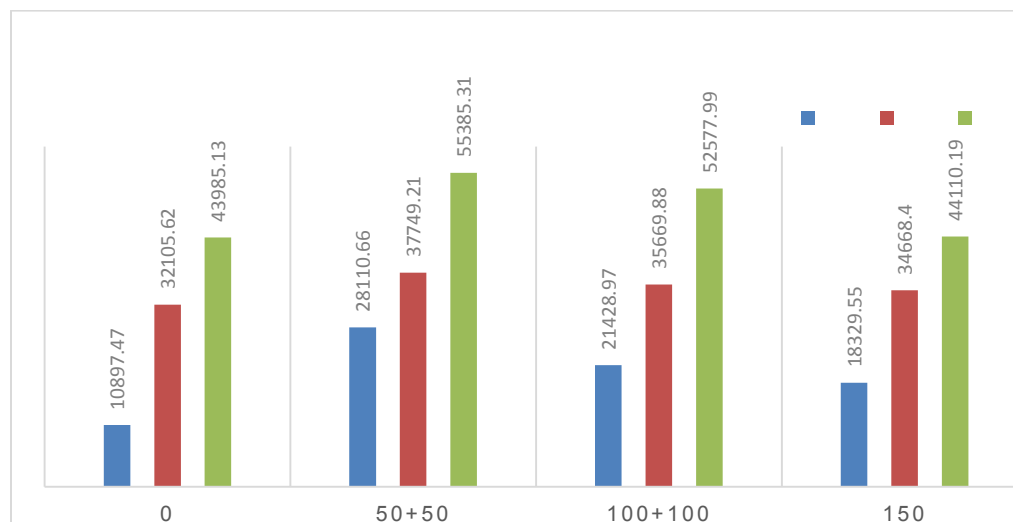


Figure (8): Effect of spraying with plant extracts on ricinoleic acid concentration in the oil.

Figure (9) shows that the interaction treatment of (85 cm + 50+50) gave the

highest concentration of 55385.31 (mg 100 g⁻¹ seeds), compared to (45 cm + no

spraying), which amounted to 10897.47 (mg 100 g⁻¹ seeds).



References :

- [1] Ahmed, M., E.A. Waraich, M. Skalicky, S. Hussain, U. Zulfiqar, M.Z. Anjum, H.R. Muhammad, B. Marian, R. Disna, L. Laura, A. Ibrahim and E. Ayman (2021). Adaptation strategies to improve the resistance of oilseed crops to heat stress under a changing climate: An overview. *Frontiers in Plant Science*, 12, 1–36.
- [2] Al-Khazraji, A.J., Abdul Redha, A.K. and Al-Majma'i, S.M. (2002). Chemical analysis of nettle plant and effect of its addition at different levels on blood proteins of broiler chickens. *Iraqi Journal of Agriculture*, 7(6).
- [3] Anjani, K. (2014). A re-evaluation of castor (*Ricinus communis L.*) as a crop plant. *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 9(1), 1–21.
- [4] Armstronga, L., do Carmob, M.A.V., Wuc, Y., Esmerinod, L.A., Azevedob, L., Zhangc, L., & Granatoe, D. (2020). Optimizing the extraction of bioactive compounds from pu-erh tea (*Camellia sinensis* var. *assamica*) and evaluation of antioxidant, cytotoxic, antimicrobial, antihemolytic, and inhibition of α -amylase and α -glucosidase activities. *Food Research International*, 137, 109430.
- [5] Bhuneshwari, R. and Surya Pratap, S. (2022). A review of the study of nutritional composition and health benefits of sweet corn (*Zea mays L.*) and coconut (*Cocos nucifera L.*) oils. *Annals of Phytomedicine*, 11(2), 130–136.
- [6] BS EN ISO 5508, (1995). Animal and Vegetable Fats and Oils. Analysis by Gas
- [7] Bulgari, R., Morgutti, S., Cocetta, G., Negrini, N., Farris, S., Calcante, A., & Ferrante, A. (2017). Evaluation of borage

extracts as potential biostimulant using a phenomic, agronomic, physiological, and biochemical approach. *Frontiers in Plant Science*, 8, 1–16.

[8] Caliskan, S., & Caliskan, M.E. (2018). Row and plant spacing effects on the yield and yield components of safflower in a Mediterranean-type environment. *Turkish Journal of Field Crops*, 23(2), 85–92.

[9] Duncan, D.B. (1955). Multiple range and multiple F tests. *Biometrics*, 11(1), 1–42.

[10] Ganesan, K., Sukalingam, K. and Xu, B. (2018). Impact of consumption and cooking manners of vegetable oils on cardiovascular diseases: A critical review. *Trends in Food Science & Technology*, 71, 132–154.

[11] Godlewska, K., Biesiada, A., Michalak, I., & Pacyga, P. (2020). The effect of botanical extracts obtained through ultrasound-assisted extraction on white head cabbage (*Brassica oleracea* L. var. *capitata* L.) seedlings grown under controlled conditions. *Sustainability*, 12(5), 1871.

[12] Goss, M.J., Tubelleh, A., & Goorahoo, D. (2013). A review of the use of organic amendments and the risk to human health. *Advances in Agronomy*, 120, 275–379.

[13] Khoddami, A., Ghazali, H.M., & Yassoralipour, A. (2011). Physicochemical characteristics of *Nigella sativa* L. oil as affected by different extraction methods. *Journal of the American Oil Chemists' Society*, 88(4), 533–540.

[14] Laouini, S.E., & Ouahrani, M.R. (2017). Phytochemical screening, in vitro antioxidant and antibacterial activity of

Rumex vesicarius L. extract. *Scientific Study and Research*, 18(4), 367–376.

[15] Lee, L.S., Kim, S.H., Kim, Y.B. and Kim, Y.C. (2015). Quantitative analysis of major constituents in green tea with different plucking periods and their antioxidant activity. *Molecules*, 19(7), 9173–9186.

[16] Lopes, G.E.M., Vieira, H.D., & Partelli, F.L. (2013). Response of castor bean plants to different row spacings and planting seasons. *American Journal of Plant Sciences*, 4, 10–15.

[17] Magalhaes, I.D., Soares, C.S., Costa, F.E., Almeida, A.E.S., Oliveira, A.B., & Vale, L.S. (2013). Viability of castor bean and sesame intercrop in Paraiba, Brazilian semiarid: Influence of different planting dates. *Revista Brasileira de Agroecologia*, 8(1), 57–65.

[18] Mai, W., Xue, X., & Azeem, A. (2023). Plant density differentially influences seed weight in different portions of the raceme of castor. *Polish Journal of Environmental Studies*, 32(4), 3247–3254.

[19] Ramadan, M.F. (2019). *Fruit Oils: Chemistry and Functionality*. Switzerland: Springer.

[20] SAS (2004). *Statistical Analysis System User's Guide for Personal Computer Release*. SAS Institute Inc., Cary, NC, USA.

[21] Selmar, D., & Kleinwächter, M. (2013). Stress enhances the synthesis of secondary plant products: The impact of stress-related over-reduction on the accumulation of natural products. *Plant and Cell Physiology*, 54(6), 817–826.

[22] Severino, L.S., Auld, D.L., Baldanzi, M., Cândido, M.J., Chen, G., Crosby, W., Tan, D., He, X., Lakshamma, P.,

Lavanya, C., Machado, O.L.T., Mielke, T., Milani, M., Miller, T.D., Morris, J.B., Morse, S.A., Navas, A.A., Soares, D.J., Sofiatti, V., Wang, M.L., Zanutto, M.D., & Zieler, H. (2012). A review on the challenges for increased production of castor. *Agronomy Journal*, 104(4), 853–880.

[23] Soratto, R.P., Schlick, G.D.S., & Giacomo, B.M.S. (2011). Low-height castor bean row spacing and plant population for mechanical harvest. *Pesquisa Agropecuária Brasileira*, 46(3), 245–253.

[24] Yin, X., Lu, J., Agyenim-Boateng, K.G., & Liu, S. (2019). Breeding for Climate Resilience in Castor: Current Status, Challenges, and Opportunities. In: *Genomic Designing of Climate-Smart Oilseed Crops* (pp. 441–498). Springer.

[25] Yousaf, M.M., Hussian, M., Shah, M.J., Ahmed,B., Zeshan, M., Raza, M.M., & Ali, K. (2018). Yield response of castor bean to NPK fertilizers under arid climatic conditions. *Pakistan Journal of Agricultural Research*, 31(2), 180–188.