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RESEARCH PAPER

Foliar application effect of gibberellic acid on growth, yield components and some qualitative characteristics of linseed (*Linium usitatissimum* L.)

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A B S T R A C T:
Understanding the effects of spraying five levels of gibberellic acid (0,125,250 375 and 500) mg L^{-1} on growth, yield and quality of two flax cultivars (Syrian local and Poland), using factorial randomized complete block design (RCBD) by three replications which was applied as experimental design, at Grdarasha experimental field of the College of Agricultural Engineering Science, Salahaddin University, Erbil, with GPS reading of (Latitude 36. 10116 N and Longitude 44.00925 E), and elevation of 415 meters above sea level. The statistical analysis indicated to significant effect of both factors and their interactions on most of the studied traits, foliar application of gibberellic acid caused significant increase in seed yield (*Mg* ha^{-1}), biological yield (*Mg* $ha^{-1)}$, HI %, oil % and oil yield (*Mg* ha^{-1}) which were the highest values about (1.69, 7.01, 24.28, 46.10 and 0.78), respectively recorded by applying 500 mg L^{-1} of GA3. The highest values of all growth and seed yield characteristics; plant height, fruit length, no. of branch, stem width, no. of capsules $plant^{-1}$, seed yield and HI by (51.48 cm, 31.08 cm ,7.30 branches plant $^{-1}$, 2.58 mm, 29.98 capsules $plant^{-1}$, 1.34(*Mg* ha^{-1}) and 20.61%) respectively were obtained from Poland cultivar.
The highest values (22.16, 18.63, 0.44, 5.58 and 7.25) % for oleic, linoleic, linolenic, palmitic and stearic acid respectively which were recorded from the interaction treatment of GA3 (375 mg L^{-1}) x Syrian Cultivar. Strong positive correlation was found between seed yield to each of (plant height (cm), fruiting stem (cm), number of branch $plant^{-1}$, stem width (mm), number of capsule $plant^{-1}$, number seed $capsule^{-1}$, seed index (g), harvest index %, oil yield (*Mg* ha^{-1}) with the correlation coefficient(r) values of (0.87**,0.86**,0.89**.0.81**,0.79**,0.77**,0.98** ,0.96**and 0.99**.

KEY WORDS: Flax, Gibberellic acid, Growth, Yield, Fatty acids profile
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1.INTRODUCTION:

An important aspect of agriculture is the cultivation of plants for food, fiber, biofuel, medicine and other products to sustain and enhance human life. Flax (*Linum usitatissimum* L.) which also known as linseed, is one of the predominant industrial fiber and oil seed crops which grown in temperate climates and is confined mainly to low elevations, but it can be grown successfully up to 770 meters above sea level.

Vaisey-Genser and Diane, (2003) stated that flax is one of the most versatile and useful crops that has been grown for thousands of years. Every part of the flax plant is used commercially, either directly or indirectly or after processing.

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Linseed has long been used as cash crop and is mainly grown as oleaginous and natural textile fiber (linen) crop, that is continuously being utilized for various industrial purposes and also as a food supplement (Chauhan et al., 2009). Flax contains a mixture of fatty acids, it is rich in polyunsaturated, particularly alpha –linolenic acid, the essential omega -3 and linoleic acid, the essential omega -6 these fatty acids which are essential in human nutrition (Shabaz, 2013).

Due to commercial importance of linseed, breeders have tried to increase its seed yield using various techniques. In recent years, growth hormones have attracted much attention to enhance yield and its related traits of linseed (Rastogi *et al*.,2013). In flax culture, it has been tried to raise seed and oil productivity by the application of plant growth regulators (PGR), may maintain internal hormonal balance, for example, efficient sink–source relationship, thus enhancing crop productivity (Singh et al., 1987). Considerable evidence indicates that plant hormones play a decisive role in flax production, and numerous reports indicated to concerning the foliar feeding of gibberellic acid to different plants. Their use has great effect on stem growth, flowering, root formation, and fruit development, with successful results in most crops. Growth regulators have an important role in the biosynthesis of fiber in different crop, affecting both quality and elongation. (Grindal *et al*., 1998)

Gibberellin play vital role in regulating developmental processes within plant bodies (Gou *et al.,* 2010). (Bora and Sarma,2006) illustrated that gibberellin helps in cell growth of stem, leaves and other aerial parts by causing cell elongation, and increase in intermodal length, they mentioned that a higher concentration of gibberellins increases plant growth. Saini *et al.*, (2021) indicated that gibberellic acid is a phytohormone which is necessary in small quantity at low concentration to enhance plant growth activities and development to increases dry weight and yield in Indian mustard.

Mckenzie and Deyholos, (2011) reported that treatment of GA_3 causes stem elongation, expansion and proliferation and cell wall thickening in bast fiber of linseed, gibberellin helps in cell growth of stem, leaves and other aerial parts by causing cell elongation, and increase in intermodal length. The present study aimed to evaluate the optimal concentration of GA_3 in order to increase seed yield oil and fatty acids content in flax**.**

2. MATERIALS AND METHODS:

The experiment was conducted at Grdarasha Field, College of Agricultural Engineering Sciences, Salahaddin University- Erbil.to test the role of gibberellic acid on growth characteristics, yield and quality of two flax cultivars Syrian (local) and Thorshansity 72 (Poland cultivar) using randomized complete block design (RCBD) with three replicates. A representative number of soil samples was taken from the upper 30 cm of the experimental field then mixed to make a representative composite sample. Table 2.1 shows some physical and chemical properties of the soil.

Although, the experiment had been done under rain fed conditions and irrigated according to crop requirements. Therefore, most of the precipitation was between November and May, Fig. 2.1 shows the metrological data at field location (*).

Phosphorus and potassium fertilizer were applied before planting, in the form of triple super phosphate and potassium sulfate at the rate of 50 and 35kg ha^{-1} respectively, while nitrogen fertilizer as a form of urea was applied with the rate of 100 kg ha^{-1} which divided into two doses half of it was added prior to planting while the second dose was applied in the early spring at the growth stage of the stem elongation.

The field was subdivided into three blocks' each block consists of 10 experimental units. The plot's dimensions were (1*1.5 m) which contains five rows, the distances between them were 20 cm. Seeds at rate of 100 kg ha^{-1} were sown on 11^{th} November manually at 2.0 cm depth by drilling method then simultaneously irrigated and supplemental irrigation was used to avoid drought stress and weed control was done whenever needed.

The first factor comprised five levels of gibberellic acid (0, 125, 250, 375 and 500) mg L^{-1}, containing 0.2 % Tween-80 (wetting agent) , the untreated or control treatment was sprayed with distilled water. Growth regulator application was applied three times with interval of 20 days at 50% of flowering all foliar spray was done at early hours of the day to reduce evaporation in the morning. The second factor was used two flax cultivars (Syrian local cultivar) and Thorshansity 72 (Poland cultivar) as plant material.

2.1. Plant Sampling:

Random representative samples of ten plants were taken at full maturity stage from each experimental unit to estimate the following characteristics: 1. Stem length (cm). 2. Fruiting zone length (cm). 3. Stem diameter (mm). 4. Fruiting branches $plant^{-1}$ 5. Capsules $plant^{-1}$. 6. Seeds $capsule^{-1}$. 7. Seed index (g).

Plants were harvested from the whole plot to determine:

1. Biological yield (*M*g ha^{-1}), the plants of each plot weighted then converted to *M*g ha^{-1}.
2. Seed yield (*M*g ha^{-1}). The seeds of each plot were separated and weighted to record seed

production from one plot then converted to ($Mg\ ha^{-1}$).

3. Percentage of harvest index %

It was calculated by using the following formula mentioned by (Hunt and Lloyd 1987):

$$HI = \frac{seed\ yield}{biological\ yield} \times 100.$$

The oil was determined by soxhlet extraction apparatus using hexane according to the methods 2 described by (Association of Official Analytical Chemists,1995). Oil yield was determined by multiplying seed yield ($Mg\ ha^{-1}$) by oil percentage. Oil yield ($Mg\ ha^{-1}$) = Oil % × Seed Yield ($Mg\ ha^{-1}$).

2.2. Fatty acid composition:

The fatty acid compounds were analyzed using a gas chromatography device (GC-2010) of the Japanese-origin Shimadzu model, where the ionized flame detector (FID) was used and a capillary column type (SE-30) with lengths (30 m * 0.25 mm) was used according to the following conditions, with the following information:

1. Injection area temperature 280 ^oC
2. Detector temperature 310 ^oC
3. Separator column temperature 120-290 (10 ^0C / Min.)
4. Gas flow rate100 Kpa. (Honggen *et al*., 2015).

2.3. Statistical analysis:

The data were statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design (RCBD) using SPSS program version (26). The difference among means of treatments and interaction treatments were tested using Duncan's multiple range test at level of significant 5% (Cochran and Cox, 1957). the statistical charts and spider charts or radar plot were drawn using Excel computer software package. Simple correlation coefficient was calculated among all studied traits (Al-Rawi and Khalaf-allah, 1980).

3. RESULTS:

3.1. Effect of flax cultivars on some growth characteristics and yield components.

According to the data in table 3.1 most of growth and yield components characteristics were significantly influenced by flax cultivars except seed capsule^{-1} and seed index. The maximum plant height (51.48cm), fruit length (31.08 cm), no. of branch (7.30) branch plant^{-1} and stem width (2.58 mm) which were noted with (Thorshansity 72 Poland cultivar). The Poland cultivars surpassed local Syrian cultivar (6.87,15.24, 14.96, 8.86 and 19.30) % for the mentioned traits respectively.

3.2. Effect of gibberellic acid spraying on some growth characteristics and yield components.

The results in table 3.2 revealed that the foliar application of G_4 affect significantly on growth characteristic in flax, the highest value (53.89, 32.32, 8.35 and 2.77) were recorded for plant height (cm), fruit length (cm), no. of branch plant^{-1} and stem width (mm) with spraying 500 mg L^{-1} GA_3 (G_4) respectively, while their lowest values (45.38, 26.04, 5.63 and 2.06) were recorded from control treatment (G_0) respectively.

There is also significant effect of gibberellic acid on yield component of flax cultivars as shown in table (3.2) which caused superior of spraying 500 mg L^{-1} GA_3) on control (GA_0) for number of capsule plant^{-1} and seed index (g)with the values (52.32 and 14.65) % respectively.

3.3. Interaction effect of flax cultivars and gibberellic acid spraying on some growth characteristics and yield components

Table 3.3 clarified that interaction of flax cultivars and levels of gibberellic acid spraying affected significantly on all studied vegetative parameters, whereas the highest plant height, fruit length and number of branch per plant and stem width were (57.82cm and 37.00cm, 8.97branch plant^{-1}and 2.94 mm) observed for Poland cultivars treated with GA_4 compared with interaction between local cultivars with control (GA_0) which recorded the lowest values (44.03cm and 25.03 cm, 5.27branch plant^{-1} and 2.04 mm).

Ultimately the table showed that the interaction treatment (Poland cultivar x G_4) affected significantly on studied yield component which recorded the highest (36.23, 7.03 and 7.25) and lowest values (20.70, 5.42 and 6.04) for No. of capsule Plant^{-1}, Seed capsule^{-1} and Seed index (g) respectively.

3.4. Effect of flax cultivars on yield and quality:

Table 3.4 refers that the yield indices parameters were affected significantly by flax cultivars, Poland surprised local cultivar (11.67 and 17.50) % in seed yield and harvest index with values of

(1.34 and 1.20) *M*g ha^{-1} and 20.61 and 17.54) respectively. While local cultivars recorded significantly highest value (6.83 *M*g ha^{-1}) in biological yield and (44.75 %) in oil content compared with Poland cultivars (6.47 *M*g ha^{-1} and 42.30). Which obtained for obtained for Poland cultivar**.**

3.5. Effect of Gibberellic acid spraying on yield and quality of flax cultivars:

Table 3.5 showed that spraying of gibberellic acid cased significant increase in seed yield and flax quality, the highest values (1.69, 7.01, 24.28, 46.10 and 0.78) were recorded for seed yield, Biological yield (*M*g ha^{-1}), harvest index, oil (%) and oil yield (*M*g ha^{-1}) were recorded from G_4 respectively. while their lowest values (1.05,6.47,16.24,41.07and0.43) were obtained from control treatment for the mentioned parameters respectively.

3.6. Interaction effect of flax cultivars and Gibberellic acid spraying on yield and quality

Table 3.6 explains the yield traits of the studied flax cultivars in response to gibberellic acid foliar application. The interaction between Poland cultivar and G_4, produced highest value of (seed yield *M*g ha^{-1}, HI % and oil yield *M*g ha^{-1}) with values of 2.00, 29.07 and 0.90) respectively, while the interaction treatment of local cultivar and G_4 recorded highest values (7.13 *M*g ha^{-1} and 47.07 %) for biological yield and oil content. Furthermore, the lowest values for all parameters in table3.6 was recorded for the interaction between Poland and control treatment with values (0.99, 15.26 ,40.07 and 0.40) except biological yield (6.45 *M*g ha^{-1}) was obtained for (local*control).

3.7. Effect of flax cultivars and gibberellic acid spraying on fatty acids composition

Table 3.7 refers to the effects of gibberellic acid spraying on flax cultivars fatty acids content, the highest value for the un-saturated fatty acid (oleic, linoleic and linolenic acid) and saturated fatty acid palmitic and stearic acid were recorded for the interaction treatments (C_1G_3) with values (22.16, 18.63, 0.44, 5.58 and 7.25) % respectively, while their lowest values (19.18, 14.88 ,0.18, 4.85 and 4.96) were recorded for the interaction treatment (C_2G_0).

Fig 3.1 explains radar shape for the effect of interaction treatments on fatty acids content, the treatments which were located near the inner circle or the first circle refers to the lowest fatty acid values and the interaction treatments which located near outer circle means the highest value or the best interaction treatments and so on for the location for other interaction treatments for the radar shapes. The shifting of treatment combinations towards the outer circle means or refers to the best interaction treatments and via versa.

3.8. Correlation coefficient analysis:

According to the presented data in table 3.8 which shows the significant correlation between most of the studied traits. The seed yield has strong positive correlation with each of (plant height cm, fruiting stem cm, no. branch plant^{-1}, stem width mm, no. capsule plant^{-1}, no. seed capsule^{-1}, seed index g, HI %, oil yield *M*g ha^{-1} with the correlation coefficient values (r) of 0.87**,0.86**,0.89**.0.81**,0.79**,0.77**,0.98** ,0.96**and 0.99** respectively and similar correlations were recorded between most of other traits (table 3.8). In the same table which shows that oleic acid correlated significantly with biological yield, linolenic, palmitic and stearic acid with the correlation coefficient (r) values of 0.71* and oil % 0.84**, 0.94**,0.93** and 0.97** respectively.

While linoleic acid positively correlated with linolenic, palmitic and stearic acid with correlation coefficient (r) of 0.68* 0.95** ,0.93**, 0.96** respectively. Linolenic acid correlated positively with biological yield, oil %, oleic and linoleic with correlation coefficient values (r) of (0.75*, 0.93**, 0.94** and 0.95**) respectively.

Palmitic acid correlated positively with biological yield, oil, oil yield, oleic, linoleic, linolenic r = 0.73*,0.94**,0.65*,0.93,0.93 ,0.98. While steric acid correlated significantly with oil %, oleic, linoleic and linolenic and palmitic acid with (r values) 0.80**,0.97**,0.96**0.91,0.86**.

4.DISCUTIION:

As explained in table (3.1) the difference between cultivars in growth and yield components which may be due to the reasons mentioned by Muhamad and Mahmood, (2019) they stated that there was genetic variation between the two cultivars in the mentioned characteristics and the

Poland cultivars surprised local cultivars. While the role of spraying GA_3 on some growth characteristics (table 3.2) may be due to the role of gibberellin which play vital role in regulating developmental processes within plant bodies and may be promotes stem elongation by increasing the physiological levels of auxin, either by increasing auxin production or decreasing the destruction of auxin (Ullah *et al.,* 2017), these results were in concord with those found by (Silva *et al*., 2005) and (Rastogi *et al*., 2013).

The increases in yield component values may be due to the role of foliar sprayed of GA_3 in enhance the number of seeds per silique, seed size and weight as mentioned by Saini *et al*., (2021), Copur, *et al.* (2019), Kaya (2015) and Rastogi *et al*., (2013). The significant effect of interaction between cultivars and GA_3 spraying as shown in table (3.3) is harmony with Ayala-Silva *et al*., (2005), they stated that gibberellic acid increased stem height with 250 mg L^{-1} having a greater effect than 125 mg L^{-1} for both cultivars and the application of GA_3 at 125 mg L^{-1} resulted in 10% increase in stem height for 'Opaline' and 16% for 'Hermes'. The higher concentration, 250 mg L^{-1}, resulted in an increase of 14 % for 'Opaline' and 19% for 'Hermes'. For stem diameter, the increase in the seed index may be as a result of the carbohydrate sink capacity enlarged by growth stimulating photosynthetic activity and carbohydrate production These results were in harmony with the finding of Bora and Sarma (2006) They stated that GA_3 application produced maximum no. pod per plant, seed index and seed yield for both studied varieties.

The differences between cultivars in their effect on seed yield and quality (table 3.4) may be due to the reasons mentioned before by (Sarkess and Mahmood, 2019) in seed yield parameters.

The influence of GA_3 on yield and quality of flax cultivars as recorded in table (3.5) were similar to those obtained by Sinini *et al*., (2021) and Copur *et al.,* (2019). These results are in good line with the findings of Rastogi *et al.,* (2013) they stated that the application of growth hormones increased seed yield under field conditions they obtained that the dose of 600 mg L^{-1} of GA_3, was supra optimal for the enhancement of seed yield. Siddiqui *et al.,* (2014) reported that plant growth regulators (PGRs) have a significant role in enhancing yield in linseed. Saini *et al.,* (2021) confirm that seed yield per plant was influences by foliar sprayed of various concentration of GA_3. Faizanullah and Noshen, (2010) found that the growth regulators increased the seed oil content in flax plant. Baydar, (2000) reported that oil synthesis increases with increasing dose of GA_3 in safflower.

As explained in table. 3.6 the significant interaction effect of flax cultivars and GA_3 spraying on yield and quality similar to those obtained by Arslan and Culpan, (2017) they clarified that the interactions between doses of GA_3 and cultivar affect significantly, the highest oil content (41.05 and 41.99 %). were obtained in Balcı cultivar by applications 200 and 300 ppm GA_3 respectively The interaction between cultivars and spraying with GA_3 to a certain level caused increase in fatty acids concentration, the highest values were recorded from interaction treatment of C_1G_3 this may be due to creating the best growth condition for forming fatty acids by the mentioned interaction, or may be due to the dilution effect in additional to the reason before that were affected on yield and yield components.

5.CONCLUSION:

The most outstanding conclusions that can be drawn from this study are:

The application of different levels of gibberellic acid caused a significant increase in the most important studied characteristics such as plant height, fruit length, no. branch $plant^{-1}$ stem width, number of capsule $plant^{-1}$, seeds $capsul^{-1}$ seed index, seed yield, biological yield, harvest index, oil and oil yield. The cultivars also significantly affected most of the studied characteristics, Poland cultivar surprised Syrian cultivars in most of growth characteristics, yield and yield component except biological yield and oil content Syrian cultivars is surprised.

Additionally, gibberellic acids caused increase in the concentration of some saturated and unsaturated fatty acids such as oleic, linoleic, linolenic, palmitic and steric acid, the lowest value was recorded for control treatment for both of flax cultivars.

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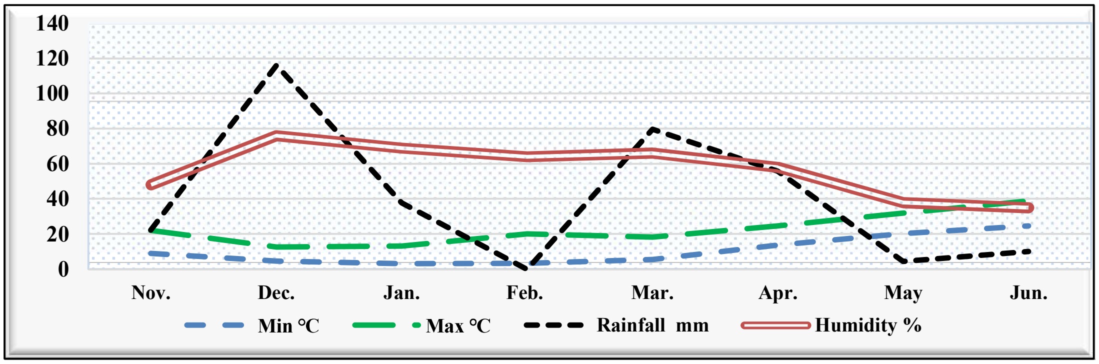
Table 2.1. Some physical and chemical properties of the soil. *

pH	EC dS m^{-1}	HCO_3^-	Ca^{+2}	Mg^{2+}	Na^+	SO_4^{2-}	HCO_3^-	Cl^-	CO_3^{2-}	K^+	P
										Available	
		$mmol^{-1}$								*Mg* kg^{-1}soil	
7.55	0.70	2.40	4.50	2.10	0.50	1.15	4.80	2.01	0.00	119	2.99
Sand	Silt	Clay	Texture name			Moisture at field capacity		Moisture at Wilting point			
%			Clay loam			%					
32.9	33.0	34.1				25.50		15.78			

*The soil properties tests were conducted at the Directorate of Agriculture Research Center/Erbil.



*The metrological data were conducted at the Directorate of Agriculture Research Center/Erbil.

Fig 2.1. Metrological data recorded at the experimental location.

Table 3.1. Effect of flax cultivars on some growth characteristics and yield components.

Cultivars	Plant height cm	Fruit length cm	No branch $Plant^{-1}$	Stem width (mm)	No. of Capsule $Plant^{-1}$	Seed $capsule^{-1}$	Seed index (g)
Local	48.17^b	26.97^b	6.35^b	2.37^b	25.13^b	5.69^a	6.19^a
Poland	51.48^a	31.08^a	7.30^a	2.58^a	29.98^a	6.27^a	6.37^a

Table 3.2. Effect of gibberellic acid spraying on some growth characteristics and yield components.

Gibberellic acid	Plant height (cm)	Fruit length (cm)	No branch $Plant^{-1}$	Stem width (mm)	No of capsule $Plant^{-1}$	Seed $capsule^{-1}$	Seed index (g)
G_0	45.38^b	26.04^c	5.63^b	2.06^c	22.86^b	6.12^{ab}	5.94^b
G_1	48.37^{ab}	27.03^{bc}	6.35^b	2.39^b	23.02^b	4.95^b	6.10^b
G_2	49.25^{ab}	28.30^{abc}	6.72^b	2.49^{ab}	26.54^b	6.25^{ab}	6.15^b
G_3	52.23^b	31.43^{ab}	7.06^{ab}	2.66^{ab}	30.55^{ab}	6.00^{ab}	6.41^{ab}
G_4	53.89^a	32.32^a	8.35^a	2.77^a	34.82^a	6.59^a	6.81^a

Table 3.3. Interaction effect of flax cultivars and gibberellic acid spraying on some growth characteristics and yield components

Cultivars	Gibberellic acid	Plant height (cm)	Fruit length (cm)	No branch Plant^{-1}	Stem width (mm)	No of capsules Plant^{-1}	Seed capsule^{-1}	Seed index (g)
Local	G_0	44.03^{c}	25.03^{c}	5.27^{c}	2.04^{c}	20.70^{b}	5.42^{ab}	6.04^{b}
	G_1	48.03^{bc}	26.53^{c}	6.07^{bc}	2.32^{bcd}	20.77^{b}	4.96^{b}	6.08^{b}
	G_2	49.08^{abc}	26.73^{bc}	6.30^{bc}	2.38^{bcd}	24.13^{ab}	5.69^{ab}	6.14^{b}
	G_3	49.77^{abc}	28.90^{bc}	6.37^{bc}	2.49^{a-d}	26.67^{ab}	6.22^{ab}	6.35^{b}
	G_4	49.97^{abc}	27.^{63bc}	7.73^{ab}	2.60^{abc}	33.40^{ab}	6.15^{ab}	6.36^{b}
Poland	G_0	46.73^{bc}	27.05^{bc}	6.00^{bc}	2.07^{bc}	25.02^{ab}	6.82^{ab}	5.84^{b}
	G_1	48.70^{abc}	27.53^{bc}	6.63^{bc}	2.47^{a-d}	25.27^{ab}	4.95^{b}	6.11^{b}
	G_2	49.43^{abc}	29.87^{bc}	7.13^{abc}	2.61^{abc}	28.95^{ab}	6.80^{ab}	6.16^{b}
	G_3	54.70^{ab}	33.97^{ab}	7.75^{ab}	2.83^{ab}	34.43^{a}	5.77^{ab}	6.48^{b}
	G_4	57.82^{a}	37.00^{a}	8.97^{a}	2.94^{a}	36.23^{a}	7.03^{a}	7.25^{a}

Table 3.4. Effect of flax cultivars on yield and quality.

Cultivars	Seed yield *Mg* ha^{-1}	Biological *Mg* ha^{-1}	HI %	Oil %	Oil yield *Mg* ha^{-1}
Local	1.20^{b}	6.83^{a}	17.54^{b}	44.75^{a}	0.54^{a}
Poland	1.34^{a}	6.47^{b}	20.61^{a}	42.30^{b}	0.58^{a}

Table 3.5. Effect of Gibberellic acid spraying on yield and quality.

Gibberellic acid	Seed yield	Biological yield	HI	Oil	Oil yield
	Mg ha^{-1}		%		*Mg* ha^{-1}
G_0	1.05^{b}	6.47^{ab}	16.24^{b}	41.07^{e}	0.43^{c}
G_1	1.12^{b}	6.18^{b}	18.19^{b}	42.53^{d}	0.48^{bc}
G_2	1.20^{b}	6.75^{ab}	17.71^{b}	43.50^{c}	0.52^{bc}
G_3	1.29^{b}	6.85^{b}	18.98^{b}	44.42^{b}	0.57^{b}
G_4	1.69^{a}	7.01^{a}	24.28^{a}	46.10^{a}	0.78^{a}

Table 3.6. Interaction effect of flax cultivars and Gibberellic acid spraying on yield and quality

Cultivars	Gibberellic acid	Seed yield	Biological yield	HI	Oil	Oil yield
		Mg ha^{-1}		%		*Mg* ha^{-1}
Local	G_0	1.11^{ab}	6.45^{a}	17.21^{b}	42.07^{ef}	0.47^{cd}
	G_1	1.13^{ab}	6.73^{a}	16.71^{b}	43.90^{cd}	0.49^{cd}
	G_2	1.14^{ab}	6.82^{a}	16.66^{b}	45.07^{bc}	0.52^{bcd}
	G_3	1.22^{ab}	7.00^{a}	17.63^{b}	45.63^{b}	0.56^{bc}
	G_4	1.38^{b}	7.13^{a}	19.49^{b}	47.07^{a}	0.65^{b}
Poland	G_0	0.99^{b}	6.49^{a}	15.26^{b}	40.07^{g}	0.40^{d}
	G_1	1.11^{ab}	5.62^{b}	19.68^{b}	41.17f^{g}	0.46^{cd}
	G_2	1.25^{ab}	6.6^{a}	18.75^{b}	41.93^{ef}	0.53^{bcd}
	G_3	1.36^{ab}	6.69^{a}	20.32^{b}	43.20^{de}	0.59^{bc}
	G_4	2.00^{a}	6.89^{a}	29.07^{a}	45.13^{bc}	0.90^{a}

Table 3.7. Interaction effect of flax cultivars and gibberellic acid spraying on fatty acids.

Treatments	Oleic	Linoleic	Linolenic	Palmitic	Steric
			%		
C_1G_0	19.71	15.24	0.21	5.01	5.33
C_1G_1	19.95	15.83	0.27	5.18	5.52
C_1G_2	20.47	16.34	0.32	5.33	5.96

C_1G_3	22.16	18.63	0.44	5.58	7.25
C_1G_4	20.98	17.00	0.41	5.46	6.44
C_2G_0	19.18	14.88	0.18	4.85	4.96
C_2G_1	19.26	15.08	0.21	5.00	5.17
C_2G_2	19.67	15.49	0.26	5.15	5.28
C_2G_3	20.15	15.97	0.30	5.23	5.38
C_2G_4	20.41	16.48	0.34	5.41	5.52

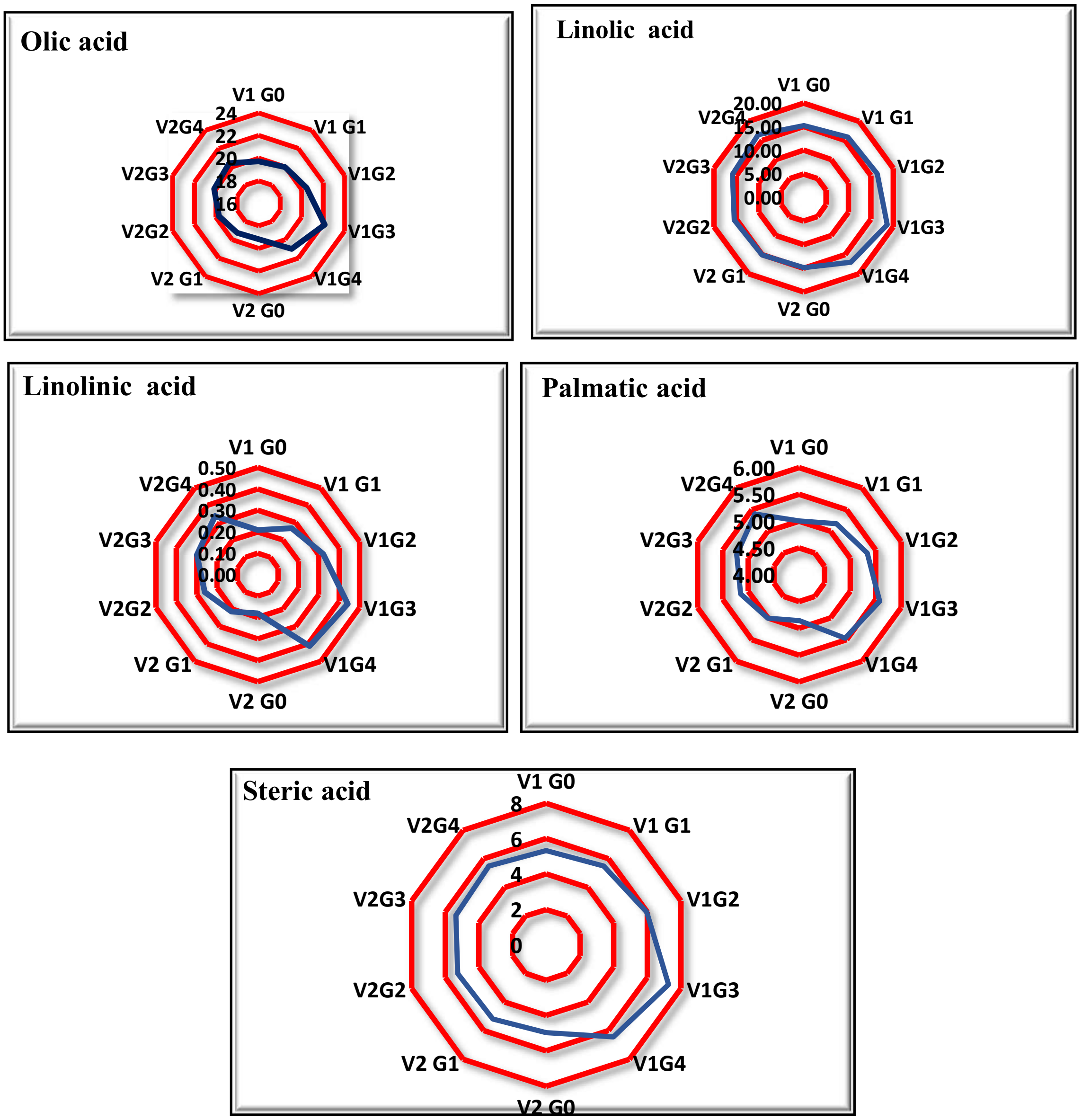


Fig 3.1. Radar shape shows the interaction effect of flax cultivars and gibberellic acid.

Table 3.8. Correlation coefficient analysis among the traits of flax cultivar

Plant length cm	**0.87****															
Fruit length cm	**0.86****	**0.96****														
No. branch	**0.89****	**0.93****	**0.88****													
Stem width mm	**0.81****	**0.94****	**0.88****	**0.94****												
No capsule plant^{-1}	**0.79****	**0.87****	**0.85****	**0.95****	**0.88****											
No seed capsul^{-1}	**0.77****	**0.87****	**0.86****	**0.89****	**0.96****	**0.84****										
Seed index g	**0.98****	**0.90****	**0.88****	**0.87****	**0.83****	**0.78****	**0.78****									
Bio yield *M*g ha^{-1}	**0.39**	**0.32**	**0.25**	**0.33**	**0.29**	**0.38**	**0.21**	**0.38**								
HI %	**0.96****	**0.85****	**0.86****	**0.87****	**0.80****	**0.75***	**0.78****	**0.95****	**0.13**							
Oil %	**0.49**	**0.42**	**0.22**	**0.43**	**0.47**	**0.40**	**0.32**	**0.53**	**0.76***	**0.32**						
Oil yield *M*g ha^{-1}	**0.99****	**0.85****	**0.81****	**0.87****	**0.80****	**0.79****	**0.74***	**0.98****	**0.49**	**0.92****	**0.62**					
Oleic acid %	**0.29**	**0.29**	**0.17**	**0.22**	**0.34**	**0.28**	**0.24**	**0.39**	**0.71***	**0.13**	**0.84****	**0.41**				
Linoleic acid %	**0.31**	**0.33**	**0.21**	**0.26**	**0.37**	**0.31**	**0.29**	**0.41**	**0.68***	**0.16**	**0.82**	**0.33**	**0.21**			
Linolenic acid %	**0.45**	**0.46**	**0.30**	**0.45**	**0.53**	**0.48**	**0.43**	**0.52**	**0.75***	**0.29**	**0.93****	**0.57**	**0.94****	**0.95****		
Palmitic acid %	**0.53**	**0.53**	**0.38**	**0.49**	**0.59**	**0.48**	**0.50**	**0.60**	**0.73***	**0.38**	**0.94***	**0.65***	**0.93****	**0.93****	**0.98****	
Stearic acid %	**0.10**	**0.10**	**-.04**	**0.07**	**0.18**	**0.13**	**0.10**	**0.20**	**0.62**	**-0.04**	**0.80****	**0.24**	**0.97****	**0.96****	**0.91****	**0.86****

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