Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Modulating the Nutrient Content by Potassium and/or GA_3 Application for Improving Canola Yield and Quality under Saline Soil Conditions

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In Loving Memory of Late Professor Doctor ""Mohamed Refaat Hussein Mahran""

Abstract
One of the crucial climate variables affecting agricultural plant responses is salinity (an abiotic stress). Since salt deposition affects wide areas, soil salinity has become a prevalent issue. The current field experiment was conducted to find out the effect of adding potassium (20, 40, and 60 Kg K2O.fed-1) to the soil alone or together with foliar application of gibberellic acid (50 and 100 ppm) after 30 and 60 days of sowing during the two growing seasons of 2021 and 2022 on growth, some physiological parameters, yield and the quality of canola seeds grown in saline soil. The addition of potassium alone or in the presence of foliar spray with GA3 improved all the tested parameters of canola plant (Photosynthetic pigments, relative water content, tissue water content and all yield parameters). Also, the macro- and micro-elements (N, P, K, Zn, Fe and Mn) and quality indicators (oil, carbohydrates, protein and total antioxidants) in the yielded seeds were increased. The most pronounced treatment was 40 kg K2O.fed-1 + 100 mg l-1 of GA3. The result of correlation analysis revealed that seed yield has a strong positive correlation (r=1) with seeds nutrition parameters content (Oil yield, protein, carbohydrate, N, P, K, Fe, Zn and Mn). In conclusion, the addition of potassium to the soil with GA_3 spraying increased canola output and growth, as well as the nutritional content of its seeds.
Keywords: Canola; Potassium; Gibberellic acid; Nutrient contents; yield; Saline soil.

1. Introduction

Canola (*Brassica napus*, L.) is a valuable source of oil and protein for use by both humans and animals. Canola has become one of the major oilseed crops in the world in the last forty years. Canola oil is currently, by volume, the third largest vegetable oil, behind soybean and palm oil [1]. The average seed oil content is approximately 42%, and the protein content is 21% [2]. Many developing nations are particularly concerned about the consequences of climate change because of their increased susceptibility to these effects and their limited capacity to lessen their negative effects on sustainable food production [3]. In many developing nations, the primary climatic variables contributing to diminishing agricultural productivity are major abiotic pressures like salt and drought [4].

In semi-arid regions of the world, salinity is one of the main obstacles to agriculture [5]. It takes time for the plants' deadly concentration of salt to build up, and it also interferes with how well the plants work. Salt degradation affects more than 800 million hectares of land globally, or more than 6% of the world's total land area [6]. Since salt deposition affects wide areas, soil salinity has become a prevalent issue. A thorough study of salinity is necessary to identify the best alleviation strategy and to comprehend the mechanisms that lead to salt buildup [7]. Salinity inhibits a plant's capacity to absorb water, which inhibits development and alters metabolism [8]. Additionally, they mentioned that the toxicity and high osmotic potential of Na and Cl ions restrict the absorption of nutrients and water by plant roots.

Potassium is necessary for the development and improved yield and its quality. As reviewed and discussed by Hussain et al.[9], potassium is known to play a role in plant osmo-regulation and stress alleviation under saline conditions. They added that under such soil conditions, K interacts with Na in the supply between soil' solution and plant interchange phases and in the absorption and translocation within the plants. About 2.6% of K is created in the earth's crust, plants cannot access it

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Receive Date: 23 December 2023, Revise Date: 14 January 2024, Accept Date: 24 January 2024
DOI: 10.21608/ejchem.2024.257477.9034

because much of it is linked to oxygen atoms is in a dehydrated state **[10].** Hussain et al.[9] indicated that crops stress tolerance can be motivated by optimizing potassium nutrition, since earlier studies proved that under low saline conditions there is no need to add K, while at high salinity level the K fertilizers application could be beneficial in mitigating the deleterious effects of salinity. It is an activator of dozens of key enzymes, such as protein synthesis, sugar transport, nitrogen and carbon metabolism, and photosynthesis [11]. It also activates and regulates ATPase in the plasma membrane to produce acid stimulation, which in turn causes cell wall loosening and hydrolase activation [12].

Phytohormones, which are active members, are involved in plant regulation and the stimulation of plant resistance to stress**.** They help crops to increase their tolerance and ability to withstand harsh environments by adaptation to severe abiotic stress situations **[13].** However, the trend of salinity to reduce growth and the progressive efficiency of exogenous Phytohormones' application, e.g. GA3 on morphological, physiological characteristics and biochemical activities, can be more dynamic to salt tolerant and effectively detract salinity stress. Since Lambari et al. [14] found that GA3 partially ameliorate the deleterious effects of salinity through increasing and accumulation of both anti-oxidative enzyme activity and osmolytes. Gibberellic acid is a crucial plant hormone that regulates signal pathways, seed germination, and plant development, according to Cavusoglu and Sulusoglu **[15]**. Therefore, it is crucial to make balance for the use of mineral fertilizers like potassium when growth regulators like gibberellic acid are used in the presence of salt stress circumstances. Fu et al.[16] discovered that the application of GA3 treatments led to a significant decrease in the percentage of barren stalks in a light-insensitive maize plant and an improvement in seed setting rates. This was achieved through an increase in the net photosynthetic rate, transpiration rate, stomatal conductance, photosynthetic pigment contents, photochemical efficiency of PS II, effective quantum yield of PSII photochemistry and antioxidant enzyme activities.

So, this investigation aimed to find out the changes in growth, productivity, seed quality and nutrient content of salinity stressed canola plants with adding either potassium alone or in combination with GA3 foliar spraying.

2. Materials And Methods

2.1. Experimental design

For the two winter seasons of 2021 and 2022, a field experiment on canola (Brassica napus L.) was carried out on a private farm in Fayoum Governorate, Egypt, to investigate the effects of potassium and gibberillic acid (GA3) on the growth parameters, productivity and oil content of canola seeds grown in saline soil. The seeds were planted in the form of hills above the rows, with a gap of 60 cm between rows and 30 cm between hills. The plants were cultivated to produce a single plant per hill. Nitrate ammonium (33% N), a nitrogen fertilizer, was supplied in two equal doses at the rate of 80 Kg N.fed-1. One dose was administered following thinning, and the other was applied 20 days later. As calcium superphosphate, the necessary dosage of phosphorus fertilizer (15.50% P2O5) was administered at the rate 100 kg.fed-1 during the preparation of the experimental site.

According to Rebecca **[17]**, certain physical and chemical characteristics of a representative soil sample utilized in the experiment were ascertained prior to cultivation and are shown in Table (1).

Varying rates (20, 40, and 60 Kg K2O.fed-1; fed=feddan=4200 m2) of potassium fertilizer in the form of potassium sulfate (48% K2O) is added to the soil. Foliar application of gibberellic acid at the rates of 50 and 100 ppm done at 30 and 60 days

of sowing during the two growing seasons. experimental treatments were set up in a randomized block design with three replicates to form a factorial experiment for the following treatments:

T1: Control (N & P)
T2: (GA_3) 50 mg l^{-1}
T3: (GA_3) 100 mg l^{-1}
T4: 20 kg $K_2O.fed^{-1}$
T5: 40 kg K2O.fed-1
T6: 60 kg K2O.fed-1
T7: 20 kg K2O.fed-1+ (GA3) 50 mg l-1
T8: 40 kg K2O.fed-1 + (GA3) 50 mg l-1
T9: 60 kg K2O.fed-1 + (GA3) 50 mg l-1
T10:20 kg K2O.fed-1 + (GA3) 100 mg l-1
T11: 40 kg K2O.fed-1 + (GA3) 100 mg l-1
T12: 60 kg K2O.fed-1 + (GA3) 100 mg l-1

2.2. Physiological measurements:

Chlorophyll content: With the use of the Minolta-SPAD Chlorophyll Meter (Minolta Camera Co., Osaka, Japan), the amount of greenery present in the plants was assessed. A numerical SPAD value that is proportionate to the quantity of chlorophyll in the leaf is determined by the SPAD-502 chlorophyll meter, which measures the absorbance of chlorophyll in the red and near-infrared areas **[18].**

Table 1: Certain chemical and physical characteristics of the test soil location

pH	EC	OM	$CaCO_3$	Particle size distribution			Texture
(1:2.5)	dSm^{-1}	%	%	Sand %	Silt %	Clay %	Class
8.18	8.93	0.23	2.26	62.17	31.74	3.14	Sandy Loam
Available nutrients (mg/kg)				Available Micronutrients(ppm)			
N	P	K		Fe	Zn	Mn	Cu
59.34	5.68	193.5		7.12	1.97	4.77	0.96
Soluble cation (meq l^{-1})				Soluble anions (meq l^{-1})			
Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
71.64	1.35	8.34	7.96	2.06	5.38	34.08	47.77

Relative water content: Castillo **[19]** investigated the relative water content (RWC) of leaves. Ten fully developed leaves, two leaves per plant, from five plants in each plot were chosen at identical heights, and their fresh weight (FW) was noted. For a full day, the leaves were submerged in purified water with dim illumination, and their weight was recorded. Following the measurement of the turgid weight (TW), the leaves were dried for 48 hours at 75°C, and their dry weights (DW) were determined. The following formula was used to determine the RWC:

$$RWC = (FW-DW) / (TW-DW) \times 100$$

Tissue water content: Leaf tissue water content (TWC) was intended using the following formula:

$$TWC = (FW) / (FW+DW) \times 100$$

2.3. Yield and its components:

In order to evaluate the average plant height, number of branches, pods number per plant, 1000-seed weight, seed yield, straw production, biological yield, and harvest index, samples were gathered from randomly selected plants in each trial unit. The harvest index (HI) can be determined with the following equation

HI = seed yield (ton/fed)/ biological yield × 100

2.4. Chemical determinations:

2.4.1. Macro- and Micro-elements:

The chemical compositions of canola seeds were determined at the end of the experiments. The macro- and micro-elements were determined using the method of Cottenie **[20]**. Phosphorus was determined by the spectrophotometer method and Potassium & Sodium were measured by flame emission. Meanwhile, micronutrients (Fe, Mn and Zn) were determined by atomic absorption spectroscopy.

2.4.2. DPPH radical scavenging activity (DPPH%):

The antioxidant activity of samples was determined by the 2, 2'-Diphenyl-1- icrylhydrazyl (DPPH) radical scavenging activity according to the colorimetric method of Liyana-Pathiranan and Shahidi **[21].** Methanolic leaves extract(100µl)were added to 4 ml DPPH solution (0.1 mM DPPH in methanol solution and 450 µl of 50 mM Tris-HCl buffer; p H 7.4).All tubes placed in the dark at room temperature after shaking for 30 min. Absorbance of the final solutions were recorded at 517 nm using Spectrophotometer. The percentage inhibition of the DPPH radical by the samples was calculated according to the formula:

Inhibition % = (Absorbance of blank – Absorbance of sample / Absorbance of blank) × 100

2.4.3. Total carbohydrate:

The determination of total carbohydrates was carried out according to Albalasmeh et al. [22]. Put a known weight of dried seeds in a test tube, add 10 mL of sulphuric acid (1N), and bake the mixture overnight at 100 °C. After filtering the mixture complete into 100 mL of distilled water. A 1 mL aliquot of sugar solution was put into a test tube, and it was then treated with 5.0 mL of concentrated sulfuric acid and 1 mL of 5% aqueous phenol solution. The tubes were submerged in a water bath set at 23–30 °C for 20 minutes after being vigorously shaken for ten minutes. The generated color's optical density was determined at 490 nm using a Shimadzu spectrophotometer model UV 1201.

2.4.4. Oil content

Oil content was determined according to Das et al. [23]. To extract the oil, aliquot of powdered canola seeds was combined with a 1:1 ratio of isopropanol to chloroform and left overnight. The solvent evaporated at lower atmospheric pressures of CO2. After the lipid filtrate was collected in a 2:1 v/v (Chloroform: methanol solution), the total dissolved oils were refined by washing with a 1% aqueous saline solution. After the chloroform was eliminated, the complete pure oil batch was weighed.

2.4.5. Total protein:

The Macro-Kjeldahl technique, as detailed by, was used to extract and calculate the crude protein

%, The total values of total N were multiplied by a factor of 6.25 to determine the value of total crude protein**[24].**

2.5. Statistical analysis:

Following a test of the homogeneity of the error using Bartlett's test, combined analyses of the data from the two seasons were statistically assessed using MSTAT-C **[25]** computer software. The least significant difference (LSD) test was used to compare the means of the various treatments at P<0.05 according to **Snedecor** and Cochran **[26]** if F values were significant. Data were subjected to principal component analysis (PCA) and Pearson correlation coefficient according to Payne **[27]** using Genstat Pro software version 20th edition.

RESULTS AND DISCUSSION

3.1. Growth parameters:

Plant height and number of branches (Fig. 1) were used to assess potassium, GA_3, and their interactions with canola plant growth. The data showed that all treatments were superior to the control, and the greatest effect was recorded by the 60 kg K_2O fed^{-1} +100 GA_3 mgL^{-1} treatment. Plant height and number of branches significantly increased with increasing GA_3 concentration from 0 up to 100 mg L^{-1} and K_2O from 20 to 60 kg fed^{-1}. The present results are in accordance with those obtained by Aslam and Siddiqui **[28]** on canola plants. They reported that plant height and number of branches, increased significantly with the application of GA_3 at 10, 15, and 30 g/ ha, combined with K at 20, 35, and 60 g/m2. Application of GA_3 and K fertilizer is required to boost canola's vegetative and reproductive growth **[29].**

Because exogenous GA_3 treatment may partially mitigate the saline harmful effects by raising antioxidative contents and the accumulation of osmolytes, it alone improves the development parameters of seedlings growing under salinity stress **[30].** One of the plant hormones and growth regulators, gibberellic acid (GA), stimulates a variety of physiological and developmental processes in plants **[31].** When NaCl stress is reduced, GA_3 can break these saline-induced restrictions in seeds, and early α-amylase activation increases the rate of germination **[32].**

Also, **Davies [33]** reported that stem elongation, leaf growth, flower and fruit development, as well as other developmental techniques, are all successfully aided by the GA_3. It is well known that increasing the use of growth regulators in various agricultural methods is most beneficial for fostering and enhancing plant growth in a variety of plant species **[34]. Also**, K is acrucial nutrient that increase protein synthesis, enzymatic activity, stomatal regulation, ionic balance management, translocation of photosynthates, and photosynthesis **[35]**. Exogenous GA_3 addition has the potential to reverse the effects of salt stress on plant growth by inducing various physiological processes, including an increase in leaf area, cell division and/or elongation and photosynthetic rate **[36].**

Chlorophyll content, RWC and TWC:

As shown in Table (2), the application of potassium and GA_3 alone or in combination increased chlorophyll, RWC, and TWC content significantly, except for GA_3 at a rate of 50 mg/L, where the increase was insignificant. The negative effects of salinity were mitigated by treatment with potassium or GA_3, but the combined application of these two treatments increased the concentrations of chlorophyll, RWC, and TWC in plants more effectively than each treatment alone.

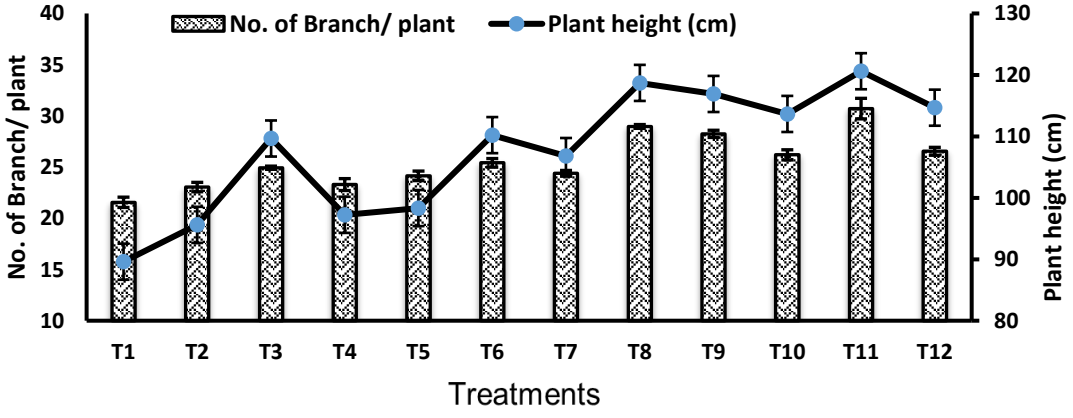

Figure (1): Effect of potassium and gibberellic acid on growth parameters of canola under saline soil conditions

The data also showed that the highest values of chlorophyll, RWC, and TWC content (46.92, 45.16, 87.81, and 78.12) were obtained by spraying GA_3 at 50 and 100 mg l^{-1} in combination with potassium at the rate of 40 kg fed^{-1}. These findings corroborated those of **[37],** who found that applying GA_3 reduced the amount of Na+ that stressed maize plants accumulated. According to **[15],** in a different investigation, the administration of GA_3 mitigated the negative effects of NaCl salinity on relative water content, electrolyte leakage, and chlorophyll content. In this regard, Nasri et al. **[38]** discovered that GA_3 increased plant shoot height, biomass, and relative water contents in both shoots and roots, therefore mitigating the negative effects of salinity. The mechanism is that GA_3 can induce seed embryos to come out of dormancy, which in turn can enhance plant metabolic processes, restore damaged cell integrity, and increase seed viability. According to Nimir et al. **[39]**, GA_3 reduced the amount of Na+ and lowered the number of other ions. Certain physiological functions, including photosynthesis, compound actuation, and the inhibition of excessive sodium absorption in saline environments, depend on potassium **[40].**

Zhang et al. **[41] found that** the chlorophyll content in the leaves of *Brassica oleracea* seedlings increased due to the addition of potassium (0.7-7.0 $g.kg^{-1}$) to the soil. Sulandjari et al. **[42]** on the medicinal plant (*Pereskia bleo*) found that potassium increased the plant's growth and chlorophyll content. They added that potassium availability is necessary to sustain photosynthesis, stomata function, and water availability in the plant body **[43].** Also, protect chloroplasts from oxidative damage **[44]**.

3.2. Yield and yield attributes:

The yield parameters (No. of pods /plant, 1000 seed weight, seed yield, straw yield and biological yield) and oil yield (g/m^2)of canola as affected by different concentrations of GA_3, potassium, and their interaction are presented in Table (3) and Fig. (2). It can be noticed that all treatments significantly increased seed yield and its attributes. Potassium at 60 kg/fed + 100 $mg.L^{-1}$ of GA_3 gave the heaviest seed yield (1.375 ton fed^{-1}) as compared with the untreated plants, which gave 0.907 tons/fed. The same trend was recorded on straw yield since the application of potassium at 60 $Kg.fed^{-1}$ + GA_3 at 100 $mg.L^{-1}$ significantly ($P<0.05$) increased its yield to reach 1.05 $ton.fed^{-1}$. On the other hand, the lightest straw yield was recorded by untreated plants (0.58 ton fed^{-1}). Application of potassium at 60 $Kg.fed^{-1}$ + spraying 100 mg L^{-1} GA_3 significantly increased biological yield which gave the heaviest weight (2.423 g) as compared with the other treatments. The highest values of harvest index (61.02, 60.79, and 60.5) were recorded with potassium at 40 $kg.fed^{-1}$ + GA_3 at 100 $mg.L^{-1}$, then potassium at 40 $kg.fed^{-1}$ + GA_3 at 50 $mg.L^{-1}$, and potassium at 60 $kg.fed^{-1}$ + GA_3 at 50 $mg.L^{-1}$, respectively.

This substantial increase might be explained by potassium's involvement in stomata movement, osmo-regulatory adaptation, and photosynthetic processes in plants that respond to salt soils. According to Pettigrew **[45],** potassium fertilizer increased maize, wheat, soybean, and cotton production's yield and quality. According to Reyhaneh et al.**[46]**, applying potassium to rice reduced the stress situation and increased the yield components and dry matter yield (Grain, straw, total biological yield, harvest index, 100 grains weigh, root dry weigh).

Table (2): Effect of potassium and gibberellic acid on chlorophyll, relative water content (RWC), and tissue water content (TWC) of canola under saline soil conditions

Treatments	Chlorophyll		RWC	TWC
	Booting	Ear emergence		
Control (N & P)	43.62	32.06	80.35	60.80
GA_3 (50 mg/L)	43.86	32.83	81.92	61.09
GA_3 (100 mg/L)	45.15	39.67	83.60	67.94
K_2O (20 $Kg.fed^{-1}$)	44.12	34.83	82.58	66.42
K_2O (40 $Kg.fed^{-1}$)	44.51	37.36	82.74	67.37
K_2O (60 $Kg.fed^{-1}$)	45.23	42.00	83.84	68.04
20 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	44.92	37.71	82.75	67.37
40 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	46.87	44.46	87.62	76.31
60 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	46.58	43.45	86.64	72.70
20 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	45.67	42.01	85.06	69.94
40 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	46.92	45.16	87.81	78.12
60 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	46.18	43.14	85.65	70.03
LSD at 0.05	0.98	1.12	1.09	1.13

(GA_3): Gibberellic acid

Gibberellic acid (GA_3) regulates signal pathways, germination of seeds, plant development, and plant production **[16].** Ali **[47]** demonstrated that applying GA_3 by spraying resulted in a noteworthy rise in the plant's wet and dry weight, number of pods per plant, and seed output per unit area. Also, Gadade et al.**[48]** found GA_3 treatment increased the morpho-physiological parameters (Plant height, number of branches per plant, yield per plant, and plot)**.**

3.3. Nutrient content:

Macro- and Micro-nutrients:

Data in Table (4) showed the effect of spraying GA_3 and applying potassium, as well as their interaction, on the levels of N, P, and K in the seeds of canola. Application of GA_3 and potassium individually had no significant increase in NPK content in the tested seeds.

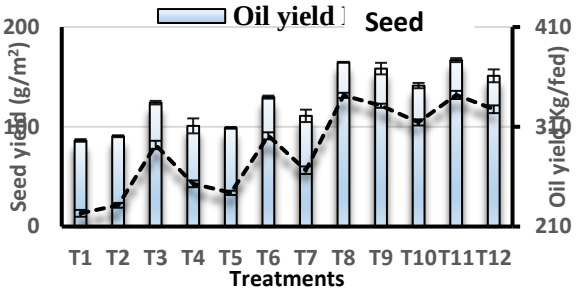

Figure (2): Effect of potassium and gibberellic acid on seed yield (g/m^2) and Oil production (Kg/fed.) of Canola under saline soil conditions.

Table 3: Effect of potassium and gibberellic acid on yield production and harvest index of canola under saline soil conditions

Treatments	No. of pods/plant	1000-seed wt. (g)	seed yield ($ton.fed^{-1}$)	Straw yield ($ton.fed^{-1}$)	Biological yield (g)	Harvest Index
Control (N & P)	283.2	3.21	0.907	0.58	1.487	56.74
GA (50 mg/L)	291.5	3.38	0.935	0.60	1.538	57.54
GA (100 mg/L)	304.7	3.44	1.185	0.79	1.973	59.42
K_2O (20 $Kg.fed^{-1}$)	316.5	3.51	1.098	0.72	1.813	58.61
K_2O (40 $Kg.fed^{-1}$)	317.0	3.53	0.965	0.64	1.603	58.62
K_2O (60 $Kg.fed^{-1}$)	320.0	3.56	1.219	0.83	2.049	59.51
20 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	332.3	3.59	0.998	0.68	1.679	59.40
40 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	343.3	3.66	1.370	1.01	2.381	60.79
60 Kg $K_2O.fed^{-1}$ + 50 $mg.L^{-1}$ GA_3	352.8	3.69	1.269	0.87	2.136	60.53
20 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	357.1	3.72	1.285	0.91	2.191	60.08
40 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	371.0	3.80	1.351	0.95	2.306	61.02
60 Kg $K_2O.fed^{-1}$ + 100 $mg.L^{-1}$ GA_3	383.8	3.92	1.375	1.05	2.423	60.19
LSD at 0.05	3.19	0.12	**0.026**	**0.038**	**0.041**	

(GA_3): Gibberellic acid

Table 4: Effect of potassium and gibberellic acid on macro- and micro- nutrients content of canola seeds under saline soil conditions

Treatments	Macronutrient (%)			Micronutrient (ppm)		
	N	P	K	Fe	Zn	Mn
Control (N & P)	1.93	0.12	0.44	181.0	32.8	20.7
GA_3 (50 mg/L)	2.06	0.12	0.51	184.3	36.0	21.6
GA_3 (100 mg/L)	2.51	0.15	0.55	212.0	39.8	26.1
K_2O (20 $Kg.fed^{-1}$)	2.24	0.13	0.53	189.0	36.5	22.6
K_2O (40 $Kg.fed^{-1}$)	2.34	0.14	0.54	202.5	37.0	23.2
K_2O (60 $Kg.fed^{-1}$)	2.73	0.16	0.57	219.2	40.6	27.5
20 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	2.51	0.14	0.55	204.6	38.3	25.4
40 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	3.16	0.19	0.72	248.5	44.2	31.6
60 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	3.08	0.19	0.64	238.6	43.8	30.1
20 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	2.82	0.17	0.58	229.4	41.9	28.5
40 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	3.25	0.21	0.79	255.9	45.8	32.4
60 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	2.94	0.17	0.61	229.4	43.3	29.7
LSD at 0.05	0.883	0.025	0.079	1.76	1.08	0.89

(GA_3): Gibberellic acid

Meanwhile, the association of both materials at different treatments greatly increased the N, P, and K content (%) as compared with the control. Potassium at 40 kg.fed^{-1} + GA_3 at 100 mg.L^{-1} gave the highest N, P, and K values (3.25, 0.21, and 0.79%, respectively) as compared with the untreated plants, which gave 1.93, 0.12, and 0.44, respectively, followed by potassium at 40 Kg.fed^{-1} + GA_3 at 50 mg.L^{-1} which produced 3.16, 0.19, and 0.72% as compared with the control plants.

Micronutrients in seeds showed a similar response to the tested treatments since they followed the same trend as macronutrients in general. The most significant (P<0.05) increase in Fe, Zn, and Mn in the tested seeds was recorded when 40 Kg of K +100 mg.L^{-1} GA_3 were applied. The gradual increase in these microelements due to individual application of either GA_3 or K led to a similar trend in the seeds of plants treated with different combinations of both materials. In these concerns, Gull and Kausar **[49]** discovered that adding 200 mM K_2SO_4 to saline soils enhanced the absorption of vital nutrients such as potassium, calcium, magnesium, and phosphorus. These findings were consistent with those of [50], who demonstrated that the application of GA_3 enhanced the absorption of nutrients, dry weights, plant height, leaf area, and yield of wheat grown in salty soil. Furthermore, exogenous GA_3 increased proline content during salt stress [51], maintaining membrane permeability and macro- and micronutrient concentrations. In plants, GA has an impact on several physiological and biochemical processes, particularly in environments when growth is challenged [52, 53]. One of the three macro elements nutrient required for plant development at varying salinity levels is the potassium to sodium ratio. The obtained data (Fig. 3) revealed that the Na content of seeds was significantly decreased by treatment with GA_3 and potassium at all rates, except GA_3 at the rate of 50 mg.L^{-1}without significant reduction as compared to the control. Also, the competence of the combined potassium and GA_3-treated plants was better in reducing sodium absorption, especially at the rate of 40 Kg K_2O.fed^{-1} + (GA_3) 100 mg.L^{-1} followed by 40 Kg K_2O.fed^{-1} + (GA_3) 50 mg.L^{-1} then 60 Kg K_2O.fed^{-1} + (GA_3) 50 mg.L^{-1}.

On the other hand, treated plants with GA_3 at 50 or 100 mg.L^{-1} or potassium at 20 or 40 or 60 Kg fed^{-1} individually significantly increased K content in seeds, except when the rate 50 mg.L^{-1} was applied. The cytosolic K+/Na+ ratio, which governs plant salt tolerance, is what defines salt resistance rather than the absolute quantity of sodium **[54].** Also, Hussain et al. **[55]** found that potassium treatment had a substantial effect on sodium.

The most sensitive metric to salinity in this study was the K/Na ratio, and the concentrations of N, P, and K in the seeds showed a similar tendency. Compared to their individual administrations of the tested materials plants received combined K and GA_3 showed higher concentrations of N, P, and K as well as higher K/Na ratio in saline soil. It was discovered that the untreated plants had a noticeably low K/Na ratio, whereas every treatment raised it in comparison to the control. When potassium was applied in conjunction with GA_3, salinity's negative effects were lessened, and the K/Na ratio rose especially at the rate of 40 Kg K_2O fed^{-1} + (GA_3) 100 mg l^{-1} followed by 40 Kg K_2O fed^{-1} + (GA_3) 50 mg l^{-1} which recorded the maximum K/Na ratio compared to the untreated plants. The outcomes seen here are in line with those of **[50]** on wheat (*Triticum aestivum* L.), **[56]** in maize (*Zea mays* L.), **[57]** in rice (*Oriza sativa* L.) and **[58]** in linseed (*Linum usitatissimum* L.).

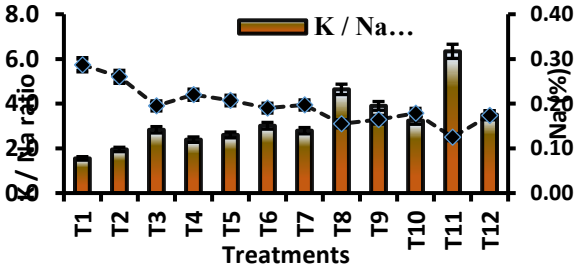

Figure (3): Effect of potassium and gibberellic acid on Na (%) and the K/Na ratio of canola seeds under saline soil conditions

3.4. Seed quality:

In the present study, data in Table (5) shows the effect of GA_3 (50 & 100 mg/L) or K_2O (20, 40 & 60 mg l^{-1}) and their interaction on oil, carbohydrates, protein contents and total antioxidants in seeds yield of Canola plants. Treatment of canola plants with different concentrations of GA_3 or K_2O increased the contents of all the above tested seed quality parameters. A marked increase in was observed in response to 100 mg l^{-1} GA_3 +40 K_2O (kg.fed^{-1}) followed by 50 mg/L GA_3+40 K_2O (kg.fed^{-1}). The % of increases are 26.24, 33.33, 68.57 and 24.11 in response to 100 mg l^{-1} GA_3 +40 K_2O (kg.fed^{-1}) compared to control plant. Khrmashow et al. **[59]** found that spraying okra plants with 25, 50, 75 and 100 ppm GA_3 increased the oil and protein content of the Syrian okra seeds. Kaur et al. **[60]** found an increase in reducing sugars, bound fructose and starch in the chickpea seedling when treated with GA_3 under water stress. Ahmad et al. **[61]** found that in stressed plants with 300 mm NaCl, the percentage of DPPH inhibition in shoots of *Pisum sativum* decreased due to GA_3 supplementation as compared with controls. According to research by Dar et al. [62] potassium at 150 kg ha^{-1} increases 1000-achene weight, biological and achene yields, oil and protein contents, and N and P absorption in sunflower plants.

Table 5: Effect of potassium and gibberellic acid on phytochemical composition (%) of Canola seeds under saline soil conditions

Treatments	Phytochemical composition (%)			
	Oil Content	Carbohydrates	Protein content	Antioxidant activity
Control	38.65	19.26	12.06	22.11
GA_3 (50 mg/L)	39.15	19.74	12.88	22.64
GA_3 (100 mg/L)	42.57	22.47	15.71	25.16
K_2O (20 Kg fed^{-1})	39.92	20.36	14.00	23.81
K_2O (40 Kg fed^{-1})	40.59	21.55	14.65	24.06
K_2O (60 Kg fed^{-1})	43.11	22.86	17.04	25.49
20 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	41.65	21.98	15.67	24.57
40 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	48.22	25.24	19.78	27.13
60 Kg $K_2O.fed^{-1}$ + 50 mg L^{-1} GA_3	47.82	24.73	19.23	26.89
20 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	44.95	23.54	17.65	26.08
40 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	48.79	25.68	20.33	27.44
60 Kg $K_2O.fed^{-1}$ + 100 mg L^{-1} GA_3	46.13	24.16	18.38	26.47
LSD at 0.05	0.654	0.263	0.327	0.044

(GA_3): Gibberellic acid.

3.5. Principal Component Analysis (PCA) and Pearson Correlations:

Principle components (PCs) are linear combinations of the original variables that are used in principle component analysis (PCA) and dimensionality reduction to transform data into a new coordinate system where the variance of the data is maximized. In this study, the first PC (PC1) explains the highest (93.44%) total variance, and the second PC (PC2) explains the lowest significant amount of variance (3.57%). Both PC1 and PC2 together explain more than 97.01% of the total variance (Fig. 4). Principle component analysis shows the relationship between the treatments and the biochemical and yield components. After doing a PCA-bi plot, two sets of variables were seen; the first set included a high amount of GA_3 combined with 20 and 60 kg $K_2O.fed^{-1}$ (20 kg $K_2O.fed^{-1}$+100 $mg.L^{-1}$ GA_3 and 60 kg $K_2O.fed^{-1}$+100 $mg.L^{-1}$ GA_3) correlated with No. of pods/p and shoot length.

Table 6: Heat-map for the correlation coefficients among tested parameters of Canola plants under saline soil conditions.

Variables	Plant height	No of Pods/plant	seed yield g/m^2	Oil production (Kg/fed)	Protein content	Carbohydrates5	N%	P%	K%	Fe %	Zn%	Mn%
Plant height	**1**	**0.906**	**0.795**	**0.830**	**0.888**	**0.834**	**0.888**	**0.832**	**0.747**	**0.852**	**0.851**	**0.852**
No of Pods/plant	**0.906**	**1**	**0.782**	**0.792**	**0.830**	**0.819**	**0.830**	**0.784**	**0.750**	**0.794**	**0.835**	**0.860**
Seed yield g/m^2	**0.795**	**0.782**	**1**	**0.953**	**0.930**	**0.858**	**0.930**	**0.933**	**0.818**	**0.919**	**0.911**	**0.914**
Oil production (Kg/fed)	**0.830**	**0.792**	**0.953**	**1**	**0.979**	**0.911**	**0.979**	**0.978**	**0.874**	**0.975**	**0.948**	**0.961**
Protein content	**0.888**	**0.830**	**0.930**	**0.979**	**1**	**0.939**	**1.000**	**0.986**	**0.904**	**0.988**	**0.961**	**0.978**
Carbohydrates5	**0.834**	**0.819**	**0.858**	**0.911**	**0.939**	**1**	**0.939**	**0.922**	**0.894**	**0.931**	**0.965**	**0.951**
N%	**0.888**	**0.830**	**0.930**	**0.979**	**1.000**	**0.939**	**1**	**0.986**	**0.904**	**0.988**	**0.961**	**0.978**
P%	**0.832**	**0.784**	**0.933**	**0.978**	**0.986**	**0.922**	**0.986**	**1**	**0.904**	**0.981**	**0.944**	**0.965**
K%	**0.747**	**0.750**	**0.818**	**0.874**	**0.904**	**0.894**	**0.904**	**0.904**	**1**	**0.914**	**0.902**	**0.904**
Fe %	**0.852**	**0.794**	**0.919**	**0.975**	**0.988**	**0.931**	**0.988**	**0.981**	**0.914**	**1**	**0.948**	**0.971**
Zn%	**0.851**	**0.835**	**0.911**	**0.948**	**0.961**	**0.965**	**0.961**	**0.944**	**0.902**	**0.948**	**1**	**0.962**
Mn%	**0.852**	**0.860**	**0.914**	**0.961**	**0.978**	**0.951**	**0.978**	**0.965**	**0.904**	**0.971**	**0.962**	**1**

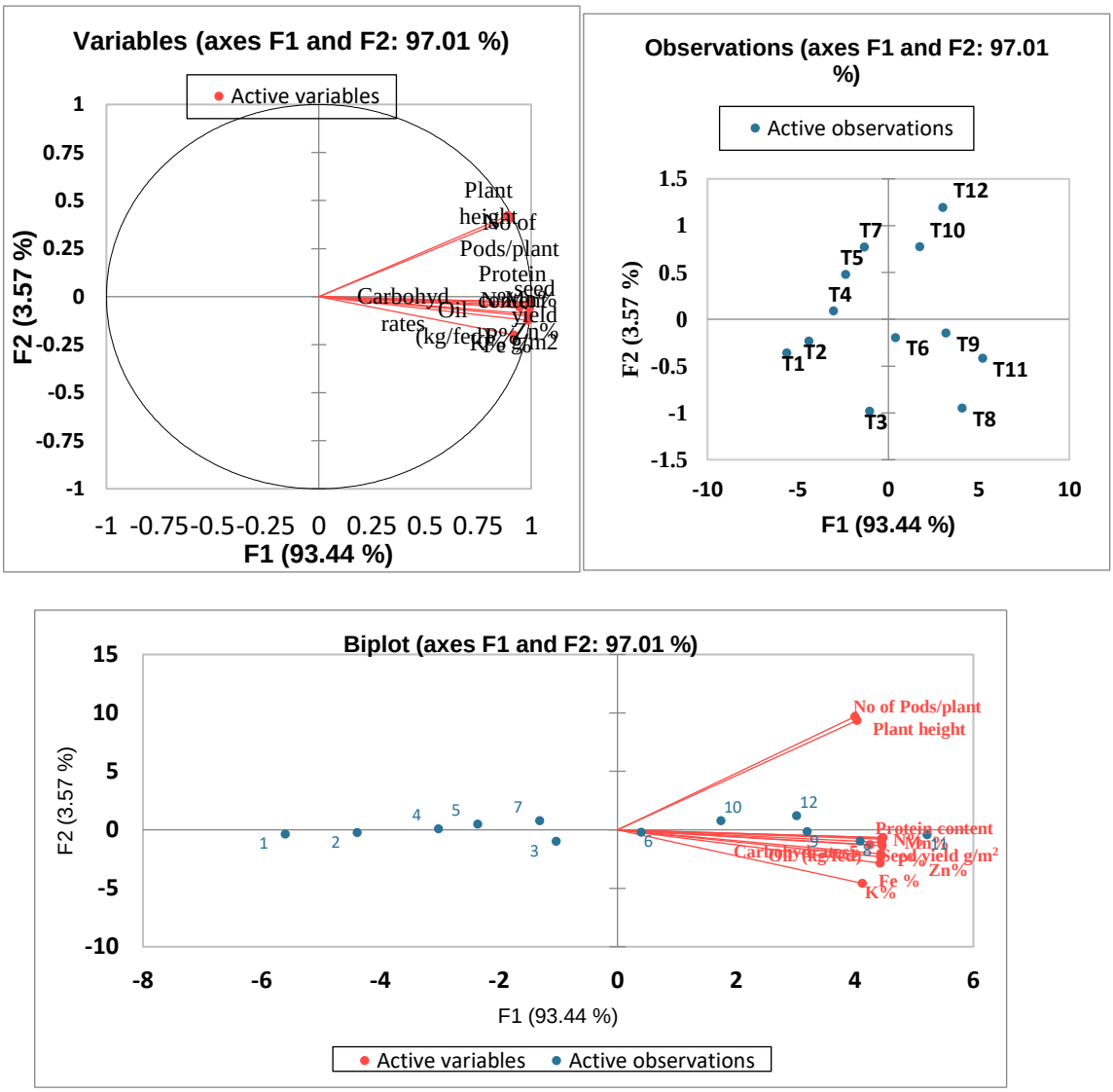

Figure 4: Principle component analysis charts of the tested parameters of canola.

The second group correlates with a high level of potassium alone or combined with a lower level of GA_3 (60 kg K_2O.fed^{-1}, 40 kg K_2O.fed^{-1}+50 mg l^{-1} GA_3, 60 Kg K_2O.fed^{-1} + 50 mg l^{-1} GA_3, and 40 kg K_2O.fed^{-1} + 100 mg l^{-1} GA_3). The most important variables are the seed yield, oil yield, protein, carbohydrate, N, P, K, Fe, Zn, and Mn**.** Data in Table (6) represents the correlation coefficients between seed yield and nutritional value of canola seeds. The result of correlation analysis revealed that seed yield has a strong positive correlation with seeds nutrition parameters content (Oil yield, protein, carbohydrate, N, P, K, Fe, Zn and Mn). It is worth mentioning that this strong positive correlation almost r=1.

4. Conclusion:

The current findings showed that the negative impacts of salt soil conditions on canola plant development and production may be diminished by spraying GA3 in combination with K-fertilization. This treatment found to enhance canola plant growth and productivity, particularly at the rate of 40 kg K2O.fed-1 + 50 mg.L-1 of GA3. The application of potassium and GA3 either separately or in combination, reflected that salt tolerance is linked to both a high K/Na ratio and a rise in the concentrations of N, P and K. The stimulatory effects of the two studied compounds can be explained by their impacts on cell elongation or division as well as the incorporation of K in various physiological and biochemical processes in the plant, e.g. protein synthesis and ionic balance regulation.

Conflict of interest

There are no conflicts to declare

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