Enhancement the quality and productivity of Canola (*Brassica napus* L.) using some bio stimulant applications under saline soil conditions

ABSTRACT

Salinity is one of the most serious and significant challenges facing the agricultural sector. It directly damages soil irrecoverably and negatively affects the quality and productivity of many crops. Priming is a process of seeds treatment with a rapid soaking with drying the seeds before setting, using for regulating the germination process by managing and regulating the temperature and seed moisture content. Priming involves advancing the seed to enable fast and uniform emergence. Once, field's condition (temperature and moisture) is appropriate, germination occurs in a much shorter time. Several benefits to seed priming, and they include: faster speed of emergence, enables seed to germinate and emerge even under adverse agro-climatic conditions, improves uniformity to optimize harvesting efficiency, increases vigor for fast and strong plant development and increases yield potential. Hence, how to use priming is still a challenge that remains to be solved. This experiment was carried out in two winter seasons 2021/2022 and 2022/2023 at Tag El-Ezz Research Station ARC in Egypt, using canola (*Brassica napus* L.) var. Serw 4 with adding two potassium humate treatments (zero as control and 2 kg.fed^{-1}) as main plots, two selenium applying methods (priming and foliar) as sub main plot and four rates of selenium application (zero as control, 1.5, 3.0 and 4.5 ppm) as sub sub-plots and their interactions on canola plant growth, yield and yield components. Some chemical composition and oil percentages in canola seeds were analyzed. After harvest, soil's available N, P and K were determined. Results could be summarized as follow:

Humate applied at 2 kg. fed^{-1} increased chlorophyl (a+b) by 3.84%, yield by 8.65% and oil content by 1.76% comparing with the control. Humate application alleviates adverse effect of salinity stress and maximize oil yield comparing with without humate application. Priming is more effective than foliar application. Selenium application at 1.5 ppm is the superior rate followed by 3.0 ppm, control and 4.5 ppm at the least. The interactions between humate and Canola seed priming in 1.5 ppm selenium mitigate the harmful effect of soil salinity on Canola and increased yield, productivity and quality.

Keywords: Canola, Salinity, Humate, Selenium, Priming, Foliar.

INTRODUCTION

Due to health concerns regarding saturated fat and unsaturated in the human diet, canola is becoming an increasingly important source of edible vegetable oil after soybean and palm because of its low saturated fat content **(Bell et al. 2023**). It was recently launched in Egypt in order to solve the 1.25-million-ton oil deficits (**El Gafary et al.,2022**). Canola mature seeds contain 40–45% oil, with a high percentage of unsaturated fatty acids (almost 94%) (**Abd-Elfttah et al., 2022**). Canola oil is considered a vital functional food as it contains different antioxidant substances i.e., vitamin E, carotenoids and phenolic compounds (**Secchi et al., 2023**). Antioxidant component of canola plays a significant role in the prevention and treatment of various diseases, including as cancer and atherosclerosis, and neurological diseases (**Ghazalah et al., 2021**). This increased demand, and the need for crop diversification, will undoubtedly promote increased acreage of canola in Egypt, where some soils are or have the potential to become saline.

Canola (*Brassica napus* L.) is one of family *Brassicaceae* and is closely salty resistant plant (**El Habasha *et al*., 2020),** where canola var. Serw 4 cultivation is good in saline soils 8 dsm^{-1} (**Al-Thabet, 2003).** This is approved by the data indicating that canola seeds germinate at the available salt conditions in soil lethal for true plant, and the productivity does not decline under mild soil salinity. There is a point of view that a salt tolerance of canola plants depends on their ability to accumulate toxic ions in the vacuole, which minimizes negative effects of these ions on cell metabolism, (**Shaaban et al., 2023).**

Potassium humate is the potassium salt of humic acid. It is a high-quality plant stimulant and soil conditioner and can be applied in landscape and garden as well as for all agricultural and horticultural plants. It also could stimulate seed germination. With high concentration of humic acid, it could be stored and transported easily. Its solubility is excellent, could be formulated by different fertilizers and pesticides.

Humic substances application has potential significant effects on crop agronomic performance and soil quality parameters. Humic substances chemical and molecular structure, solubility and other factors such as application rate, soil and crop type also affected effects on crop performance (**Bhatt and Singh,2022**). Humic substances are classified as humic acid, fulvic acid and humin based on their solubility in water, acidic or alkaline solutions. Due to the non-degrading nature of the humin fraction in humic substances, researchers have focused on the humic and fulvic acids fractions because they are capable of improving soil fertility and health within short time frames **(Ampong *et al*., 2022).**

Humic acid is beneficial to crops as it has a positively effect on various developmental and physiological processes in different crops such as germination, root development, cell enlargement, photosynthetic activity, mitochondria respiration, nutrient uptake and abiotic stress resistance (**Hemati *et al*., 2022**). It works as anti-stress substance where it increases plant tolerance to salinity via stimulation of antioxidant enzymes activities (**Sible *et al*., 2021**). Several researches indicated the effective role of humic acid application on canola growth, yield, productivity and quality (**Rajpar *et al*., 2011, Ahmad *et al*., 2016 and Hemati *et al*., 2022)**.

Selenium (Se) is an essential micronutrient for the growth, health, and development of humans and animals, and its importance to plants is still under study and debate. The biological functions of selenium include promoting growth and development, enhancing the body's antioxidant capacity, preventing oxidative stress, boosting immunity **(Samynathan et al. 2023**) . In general, sources of selenium will first convert into selenides to function in organisms and then convert into proteins containing selenocysteine, namely selenoproteins that will be absorbed and utilized by plants organs. Excessive selenium levels have some toxic effects **(Saito, 2021).**

Recently, Selenium is classified as inorganic plant bio stimulant where it has an effective role in plant growth and development (**Lanza and Reis, 2021**) as well as its role in increasing plant tolerance to several stresses via activation of antioxidant enzymes, inhibition of lipid peroxidation and scavenging ROS radicals (**El-Badri *et al*., 2022**). The effect of selenium on the plant, whether beneficial or harmful, depends on the type of plant and the concentration of selenium **(Kamran *et al*., 2020**). Bio stimulant role of selenium depend on its concentration in plant where low and moderate concentrations are needed for growth, homeostatic function and development but high concentration led to toxicity (**Ahmad *et al*., 2021**).

This study targets to maximize oil yield and productivity of canola seeds under saline soil conditions by using some bio-stimulant applications as humate and selenium.

MATERIALS AND METHODS:

Experiments were conducted to investigate the effect of humate and selenium on growth, yield productivity and quality of canola plants under saline conditions.

1) Experimental Site.

The field experiment of the present study was carried out at Tag El-Ezz Research Station, Agriculture Research Center (ARC) , (31°31' 47.64" N latitude and

30°56' 12.88" E longitude) El-Dakahlia Governorate, Egypt during the two consecutive winter seasons in 2021/2022 and 2022/2023.

2) Soil Sampling and Analysis.

Random disturbed soil samples from the surface of the soil (at the depth 0-30 cm) were collected before planting. The characteristics of initial soil are presented in Table 1, where all soil analyses were done according to **Page *et al*., (1982) and Klute (1986).**

Table 1. The average of physical, chemical, and nutritional properties of the experimental field during two seasons 2021/2022 and 2022/2023 before planting.

Particle size distribution (%)				Textural Class	EC dSm^{-1}*	pH**	SSP ***	SAR****	ESP*****
C. sand	F. sand	Silt	Clay				(%)		
5.02	12.14	36.82	46.02	Clay	10.00	8.18	33.1	6.77	8.02

Soluble ions (mmol L^{-1})								Available elements mg kg^{-1}		
Soluble cations				Soluble anions						
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	N	P	K
25.59	22.21	33.10	19.10	0.00	10.00	49.82	40.18	44.61	9.63	203.25

* Soil Electrical Conductivity (EC) and soluble ions were determined in saturated soil paste extract.

** Soil pH was determined in soil suspension (1: 2.5).

SSP*** : Soluble Sodium Percentage SAR**** : Sodium Adsorption Ratio.

ESP***** : Exchangeable Sodium Percentage.

3) Experiment description.

Two field experiments were carried out using a split split-plot design with three replicates. Experiments were subjected to forty-eight plots resulting from the combinations of two potassium humate treatments (zero as control, 2 kg fed^{-1}) as the main plots, selenium applied by two methods (priming and foliar) as the sub-plots and four rates of selenium applying (without spraying as control, 1.5, 3.0 and 4.5 ppm) as the sub sub-plots. Sixteenth treatments were repeated three times every season on canola (*Brassica napus* L.) var. Serw 4. Plot area was 14 m^2 (4.0m ×3.5m). Seeds of canola were sown at the tenth day of November every season at rate of 4 kg fed^{-1}. Potassium humate were soil applied twice (the first before sowing and the second after 20 days from sowing) at the above mentioned. Mono calcium phosphate (15% P_2O_5) was applied during the soil preparation at a rate of 200 kg fed^{-1}. Ammonium sulfate (20.5%N) was applied at rate of 30 kg N fed^{-1} for canola plant after 25 and 45 days from sowing. Potassium sulfate (48% K_2O) was applied at rate of 50 kg fed^{-1} with the second dose of N fertilizer.

Plots of foliar section were sprayed twice with selenium as potassium selenate (K_2SeO_4) after 30 and 60 days from sowing. On the other hand, plots in primed section, seeds were incubated in 50 mL of K_2SeO_4 solution at three concentrations which are 1.5, 3.0 and 4.5 mg l^{-1} (referred as “Se primed”) for 6 h on an orbital shaker with 150 rpm at 28°C, and then air dried on sterile filter paper for about 24 h at 30°C. All other cultural practices and irrigation were done as recommended according to the Ministry of Agriculture and Soil Reclamation (MASR). Potassium humate was purchased from the agriculture commercial market and was analyzed according to **Buurman et al., (1996)** as shown in Table 2.

Table 2. Average values of physical and chemical analysis of used humate

Potassium humate	HA*	FA**	Solubility	Moisture	pH	Total macro element		
						N	P	K
	%					%		
	62.0	2.76	100	5.80	8.32	0.34	1.32	10.95

*Humic Acid. ** Fulvic Acid.

4) Data recorded.

A: Vegetative growth chemical composition

1. **Chlorophyll content**: The fresh leaves of five plants were randomly selected from each plot at the maximum vegetative growth stage i.e., 70 days after sowing, in order to determine chlorophyll a, b, and a+b in mg g^{-1} FW by reading the absorbance on a spectrophotometer at 664 and 647 nm, and photosynthetic pigment concentrations were computed using the following equation described by **Nayek *et al.*, (2014)**:

Chl. a = 12.7 (OD) 664 - 2.79 (OD) 647

Chl. b = 20.7 (OD) 647 - 4.62 (OD) 664

Where OD denotes the optical density for absorbance.

2. **Micronutrients (Fe, Zn and Mn) content in leaves:** The samples of leaves were dried at 70^0c to determine Fe, Zn and Mn as described by **Walinga *et al.*, (2013).**

3. **Antioxidant enzymes**:

a- Enzyme extraction: After 500 mg of the leaf sample was frozen in liquid nitrogen and coarsely pulverized with a pestle in a cooled motor, 10 mL of phosphate buffer (pH 7.0) was added to the frozen powder. Following a 10-minute centrifugation at 15000 × g at 4 °C, the homogenate was utilized as an enzyme source for catalase (CAT; EC 1.11.1.6) and peroxidase (POD; EC 1.11.1.7).

b- Catalase (CAT) and peroxidase (POD) enzymes activities were determined spectrophotometrically according to **Alici and Arabaci, (2016)**

Proline Assay: Proline content of leaves was determined according to the method of **Ábrahám et al. (2010).** A spectrophotometer was used to test its absorbance at 520 nm. The proline content was estimated using a standard curve in mg.g^{-1} FW

B: Yield and yield parameters

1. At harvesting (after 170 days from planting) grain yield (ton fed^{-1}) and some yield parameters i.e., Plant height (cm), Number of racemes (branches) per plant, Number siliquae per plant and 1000 seed weight (g) were determined in each plot.
2. N, P, K and Se in mature seeds were determined according to **Walinga *et al.*, (2013)**
3. Nutrients uptake was calculated according to following equation:

$$\text{Nutrients uptake in mature seeds (kg fed}^{-1}) = \frac{\text{Nutrient concentration x seeds yield kg fed}^{-1}}{100}$$

4. Protein concentration (%) was estimated by multiplication N% x 6.25 **A.O.A.C. (1990)**.
5. Oil percentage (%) was determined by soxhelt apparatus using petroleum ether as a solvent as described by **A.O.A.C. (1995).**
6. Carbohydrates and vitamin E were determined according to **A.O.A.C (2007).**

C: Residues nutrients in soil after canola harvesting

According to **Reeuwijk (2002),** soil samples were randomly taken from each experimental sub sub-plot at a depth of 0–20 cm in order to assess the amount of N, P, and K that was available (mg kg^{-1}).

D) Statistical analyses

For analysis, data from identical tests conducted over a two-year period were merged. Using the LSD test, significant differences between treatment means were established at P 0.05. In accordance with **Gomez and Gomez (1984)**, the CoSTATE computer program was used to statistically analysis the data for the current study.

RESULTS AND DISCUSSION

Canola has been classified as a salt-tolerant crop, and yields significantly decreased when soil salinity levels exceeded 8.0 dSm^{-1}. This study aimed to maximize resistance of canola to salinity by treating with soil humate and selenium as a priming and foliar application.

1) **Effect of potassium humate and selenium applications on growth performance and productivity**

The average data tabulated in Table 3 showed the effect of potassium humate treatments, selenium application at different methods and rates as well as their interactions on chlorophyll and micronutrients i. e. Fe, Zn and Mn content of canola leaves under the saline soil conditions. Additionally, impact of studied treatments on antioxidant enzymes activities and proline content in foliage of canola under salinity stress was presented in Table 4. While, Tables from 5 to 7 demonstrated the effect of potassium humate and selenium application on yield and yield attributes (Table 5), nutrients (N, P, K and Se) uptake by mature seeds (Table 6) and yield quality as protein, oil, carbohydrates and vitamin E content in mature seeds of canola under salinity stress (Table 7).

a) Effect of potassium humate application:

Data showed that humate application has a positive impact on chlorophyll and micronutrients content on canola leaves comparing with control (without humate application). The highest values were (0.694,0.388, 1.080 ,68.46, 29.01 and 40.18) for chl a, chl b, chl a+b, Fe, Zn and Mn, respectively with relative increments 3.84%, for chl a+b, 2.20% for Fe, 5.33% for Zn and 1.97% for Mn comparing with control. Also, it increases activity of catalase enzyme by 9.52 %, activity peroxidase enzyme by 11.91% as well as increases proline content by 8.12 % comparing with control treatment as shown in Tables (3 &4).

Regarding to yield, yield attributes, nutrients content and quality of mature seeds data showed that application of potassium humate recorded the highest values of plant height (140.30 cm), No. of racemes (branches) plant $^{-1}$ (5.67), No. of siliquae plant $^{-1}$(128.56), 1000 seed weight (2.57 gm) and seeds yield (1.13 ton.fed^{-1}). Humate increased yield by 8.65 % comparing with control (without addition of potassium humate). Additionally, humate application increased values of nutrients content in mature seeds of canola by 14.55%, 12.64%, 13.75% and 12.73 % for N, P, K and Se, respectively. Also, potassium humate application improved protein, oil, carbohydrates and vitamin E contents of canola seeds where protein increased by 5.81%, oil increased by 1.76%, carbohydrates increased by 2.96% and vitamin E increased by 2.83% as compared to control.

These results may be attributed to salinity has a negatively effect on the studied vegetative growth parameters where it decreased chlorophyll content in various ways including stomatal closure, activation of the chlorophyllase enzyme that degrades chlorophyll and causes alteration in protein complexes of chlorophyll, the same results were founded by **Gul *et al*., (2023**). On the other hand, salt stress causes oxidative stress through an excessive production of ROS (**Hasanuzzaman *et al*., 2020)**, exposes the plant to osmotic pressure that limits the availability of water inside the cell, causing cells dehydration, reducing the turgor pressure and has a deleterious effect on nitrate reductase enzyme activity which is responsible for proline biosynthesis (**Hozayn *et al*., 2021**)

While, humate application significantly improves the reduction in chlorophyll content as it promotes the uptake of nutrients like Fe and Mn which needed by enzymes involved in the formation of chlorophyll and the photosynthesis process (**Ampong *et al*., 2022**). In addition to, the positive impact of humate application on releasing nutrients from soil minerals, increasing availability of trace minerals and therefore increasing their absorption by plant (**Mosa *et al*., 2020**). These elements are responsible for stimulation synthesis and activation of antioxidant enzymes and increasing proline accumulation, these results are in harmony with that recorded by **Sible *et al*., (2021).** All these indirect effects of humic application led to ROS scavenging and enhancement the defense system of plant against salinity stress (**Mourad *et al*., 2020**).

Regarding to yield, yield component and mature seed quality, salinity has a deleterious effect on nutrient content i.e.; N, P, K and Se uptake in mature seeds of canola and it was suggested as a result of combination of different factors occur under salinity conditions as water stress, accumulation of toxic ions and ions imbalance. Reduction in N content in mature canola seeds may be due to the interference between Cl^- and NO_3^-, while P content reduced as a result of low P and Ca minerals solubility that cause reduction in phosphorus availability in soil, as well as the interference between Na^+ and K^+ ions as result of salinity in root zone negatively affected on K concentration. All these effects reduce yield productivity and seeds content of protein, carbohydrate, oil and vitamin E. These results are in accordance with that concluded by **Naveed *et al*., (2020**) and **Hussain *et al*., (2023**)

Application of potassium humate significantly effects on yield, yield parameters and causes increments in mature seeds quality under salinity stress, these results may be attributed to the vital role of humic acid as growth regulator - it has cytokinin- auxin like properties - in stimulating the developmental processes of plant as cell division, enlargement and differentiation. (**Rashid *et al*., 2020).** Also, it has a bio stimulant role in stimulating germination, growth and increasing yield as well as increasing plant tolerance to a biotic stress as salinity leading to highest yield productivity with enhancement quality (**Eyni *et al*., 2023**).

b) Effect of selenium application methods

It’s clear that both techniques (foliar application and seed priming) of selenium applications were recorded a significant effect on chlorophyll and micronutrients content in leaves of canola. The superior was observed with Se seed priming technique with relative increments 1.62 ,2.40, 1.90,   1.03, 2.18 and   0.858   % for chla, chlb, chla+b, Fe, Zn and Mn, respectively. Also, seed priming increased canola tolerance against salinity via increasing antioxidant activities and proline content where it recorded the highest values of them with relative increments 4.64 for CAT activity, 6.06 for POD activity and 3.98 % for proline content comparing with foliar application, respectively.

On the other hand, selenium applications can alleviate the negative effect of salinity stress on canola yield, yield attributes, nutrients content and quality of mature seeds under salinity conditions as shown in Tables (5 & 6 and 7). The most effective method was seed priming where the values of 1000 seed weight and yield increased by 3.29% and 3.73%, respectively comparing with foliar application method. Also, the highest values of N (35.48) with increments 6.32%, of P (3.89) with increments 5.42 %, of K (30.48) with increments 6.12 % and of Se (43.44) with increments 5.74% in mature canola seeds were found in selenium seed priming technique (Table 6). Seed priming method recorded the highest values of protein (19.53), oil (42.98), carbohydrates (15.20) concentrations and vitamin E content (18.71) of canola seeds with relative increments 2.68%,0.963 %, 1.74% and 1.57%, respectively.

It’s clear that, the used techniques i.e. seed priming and foliar application were recorded a significant effect in all studied parameters but the superior was seed priming technique. Under various environmental conditions, priming increases seed efficiency, uniformity, crop stand, and yield while also assisting in breaking dormancy (**Johnson and Puthur, 2021).** Seed priming technique is more effective as a result of its ability in increasing plant tolerance against stress via two steps, first one: preparing seed for several vital activities related to germination and the second: enhancing seed response to stress by activating enzymes, accumulating germination and osmotic adjustment (**Hussain *et al.*, 2023)**. Also, seed priming technique under salinity stress speeds up antioxidant enzyme activity and shortens the time it takes for seeds to germinate, hence reducing or eliminating the negative effects of reactive oxygen species and increased stimulation of the plant's defenses (**Khan *et al*., 2022**)

When seeds are primed, a physiological state occurs that promotes germination and enhances uniform seedling emergence through regulating hormones, metabolic activity, dormancy, and membrane permeability (**Molnár *et al.*, 2022**). In addition to nutrient in seed priming technique is stored inside seed then it is excreted during the germination stages as demand of plant thus led to increments in yield and yield component (**Iqbal *et al*., 2022).**

c) Effect of selenium rates

Selenium applications at different rates has a differential effect according to selenium concentration. Se concentration and plant sensitivity affect selenium's phytotoxicity in plants. In this research, selenium at 1.5 ppm concentration is more effective than other concentrations and gave the highest values of all studied parameters followed by 3.0 ppm, where the lowest one was 4.5 ppm. Selenium application at 1.5 ppm increased the values of chl a+b by 15.68%, Fe by 4.87%, Zn by 13.09 and Mn by 6.21% in canola leaves under salinity. While, the values of previous parameters decreased gradually by increasing selenium concentration and selenium at 4.5 ppm decreased values of chl a+b, Fe, Zn and Mn by 8.52, 8.06 ,22.32 and 4.30%, respectively comparing with control.

On the other hand, data presented in Table (4) showed that selenium application at 1.5 ppm was the superior where the value of CAT activity was 3.11, of POD activity was 2.64 and the value of proline was 0.507.

Regarding to yield, nutrients content and quality of canola's seeds, selenium application at 1.5 ppm was the superior followed by application of selenium at 3.0 ppm concentration, then control (without spraying) and application of selenium at 4.5 ppm concentration at least.

Selenium application at 1.5 ppm increased 1000 grain weight by 43.11%, yield by 41.99%, N content in mature seeds by 74.56%, P content in mature seeds by 66.97%, K content in mature seeds by 73.05% and Se content in mature seeds by 67.72% comparing with control. Quality of mature seeds increased at 1.5 ppm concentration where the relative increments were 22.01, 7.33%, 12.41% and 9.74 % for protein, oil, carbohydrates and vitamin E, respectively comparing with control.

This result may be due to the oxidative and toxic effect of high selenium concentrations in plant leading to cell damaging thus led to inhibition in canola growth (**Samynathan *et al*., 2023).** Higher amount of Se has an inhibitory effect on porphobilinogen synthetase enzyme that responsible for chlorophyll biosynthesis, encourage ROS production, accelerates lipid peroxidation, damages plasma membranes which causes cell dehydration and reduction in nutrients uptake (**Kamran *et al*., 2020).** While, the using of selenium at low concentration enhance plant tolerance against oxidative stress and act as protectant in plant (**Khan *et al*., 2023**)

Application of Se at a concentration of 1.5 ppm results in improvements in canola growth, yield productivity, and quality. This is because Se plays a crucial role in preserving the fluidity and shape of chlorophyll and enhancing the activity of enzymes required for photosynthesis, process (**El-Badri *et al.*, 2022**).). Bio stimulant effect of selenium appeared clearly in reducing the negative effects of salinity on plants through several physiological processes such as: promoting osmoprotectants accumulation as proline, maintaining gas exchange and enhancing antioxidant enzymes (CAT and POD) activity **(Khan et al., 2022).** On the other hand, selenium is considerably improving the transport of iron, zinc and manganese elements to plant shoots, that are essential elements for antioxidant enzymes and increase their activity (**Ahmad et al., 2021).** Also**,** selenium enhances plant defense mechanisms at low concentrations by stimulating enzymatic and non-enzymatic activity, which can aid in the removal of ROS and the prevention of oxidative stress in plants (**Lanza and Reis, 2021**) and by increasing proline concentration in plant via enhancing the activity of the nitrate reductase enzyme and increases the absorption of nitrogen (**Hemmati et al., 2019**). These results are in harmony with that concluded by **Sible et al., (2021)** and Franzoni **et al., (2022**).

d)Effect of interaction

Generally, the interaction of potassium humate application and canola seed priming in selenium at 1.5 ppm concentration alleviate the deleterious effect of salinity on canola, enhance chlorophyll content, plant tolerance to salinity, promoting growth and yield productivity. This implies that the soil application of humate in conjunction with seed priming in 1.5 ppm selenium had a synergistic impact, reducing the negative effects of salinity and enhancing the availability and uptake of nutrients by the plants, hence maximizing plant growth, yield productivity and quality (oil yield) .

Table 3. The average effect of potassium humate treatments, techniques and rates of selenium application and their interactions on chlorophyll and micronutrients content of canola after 70 days from sowing.

Treatment			Chlorophyll content (mg. gFW^{-1})			Micronutrients content (mg kg^{-1})		
			Chl a	**Chl b**	**Chl a+b**	**Fe**	**Zn**	**Mn**
Main: Humate application								
Without humate			0.669	0.371	1.040	66.98	27.54	39.40
With humate			0.694	0.388	1.080	68.46	29.01	40.18
F test			***	***	**	***	***	***
****LSD at 0.05 %**			0.001	0.012	0.012	0.004	0.012	0.040
Sub main: Methods of Se application								
Foliar application			0.676	0.375	1.05	67.37	27.97	39.62
Seed priming			0.687	0.384	1.07	68.07	28.58	39.96
F test			***	***	***	***	***	**
LSD at 0.05 %			0.002	0.004	0.004	0.040	0.017	0.024
Sub sub main: Selenium rates								
***Cont**			0.662	0.360	1.02	67.73	27.95	39.25
1.5 ppm Se			0.748	0.439	1.18	71.03	31.61	41.69
3.0 ppm Se			0.703	0.401	1.10	69.87	29.84	40.65
4.5 ppm Se			0.614	0.318	0.933	62.27	23.71	37.56
F test			***	***	***	***	***	***
LSD at 0.05 %			0.009	0.003	0.012	0.040	0.017	0.057
Interaction								
Without Humate	**Foliar application**	**Cont**	0.647	0.342	0.989	67.12	26.70	38.46
		1.5 ppm Se	0.733	0.428	1.161	70.72	30.94	41.32
		3.0 ppm Se	0.682	0.388	1.07	69.23	29.18	40.27
		4.5 ppm Se	0.593	0.306	0.899	58.72	21.85	36.76
	Seed Priming	**Cont**	0.658	0.359	1.017	67.36	27.78	39.26
		1.5 ppm Se	0.742	0.436	1.178	70.95	31.36	41.59
		3.0 ppm Se	0.690	0.395	1.085	69.61	29.52	40.45
		4.5 ppm Se	0.608	0.314	0.922	62.14	23.03	37.14
With Humate	**Foliar application**	**Cont**	0.664	0.367	1.031	68.02	28.59	39.52
		1.5 ppm Se	0.756	0.442	1.198	71.11	31.90	41.86
		3.0 ppm Se	0.715	0.408	1.123	70.16	30.25	40.72
		4.5 ppm Se	0.623	0.320	0.943	63.90	24.38	38.04
	Seed Priming	**Cont**	0.679	0.374	1.053	68.42	28.74	39.76
		1.5 ppm Se	0.761	0.451	1.212	71.32	32.26	42.00
		3.0 ppm Se	0.726	0.415	1.141	70.49	30.42	41.18
		4.5 ppm Se	0.634	0.334	0.968	64.32	25.60	38.33
F test			**	**	**	***	***	***
LSD at 0.05%			0.019	0.007	0.023	0.076	0.035	0.113

***Cont: control treatment with zero concentration** ****LSD: Least significant difference**

Table 4. The average effect of potassium humate treatments, techniques and rates of selenium application as well as their interactions on antioxidant enzymes activities and proline content.

Treatment			Unit.min^{-1}.g^{-1}protein		(mg. gFWt^{-1})
			CAT	POD	Proline
Main: Humate application					
Without humate			2.31	1.93	0.394
With humate			2.53	2.16	0.426
F test			***	***	***
**LSD at 0.05 %			0.062	0.020	0.012
Sub main: Methods of Se application					
Foliar application			2.37	1.98	0.402
Seed priming			2.48	2.10	0.418
F test			***	***	***
LSD at 0.05 %			0.002	0.010	0.004
Sub sub main: Selenium rates					
*Cont			2.25	1.78	0.370
1.5 ppm Se			3.11	2.64	0.507
3.0 ppm Se			2.64	2.34	0.434
4.5 ppm Se			1.69	1.40	0.329
F test			***	***	***
LSD at 0.05 %			0.050	0.019	0.003
Interaction					
Without humate	Foliar application	Cont	2.07	1.63	0.357
		1.5 ppm Se	2.99	2.06	0.482
		3.0 ppm Se	2.53	2.50	0.394
		4.5 ppm Se	1.50	1.27	0.313
	Seed Priming	Cont	2.18	1.72	0.364
		1.5 ppm Se	3.05	2.76	0.497
		3.0 ppm Se	2.60	2.18	0.426
		4.5 ppm Se	1.62	1.32	0.321
With humate	Foliar application	Cont	2.30	1.80	0.372
		1.5 ppm Se	3.16	2.86	0.518
		3.0 ppm Se	2.69	2.27	0.448
		4.5 ppm Se	1.76	1.49	0.337
	Seed Priming	Cont	2.48	1.98	0.388
		1.5 ppm Se	3.24	2.91	0.532
		3.0 ppm Se	2.75	2.43	0.469
		4.5 ppm Se	1.89	1.54	0.348
F test			***	***	***
LSD at 0.05%			0.091	0.040	0.008

*Cont: control treatment with zero concentration **LSD: Least significant difference

Table 5. The average effect of potassium humate treatments, techniques and rates of selenium application as well as their interactions on yield and yield component of canola under salinity stress.

Treatment			Plant height (cm)	No. of		1000 seed weight (g)	Yield (Ton.fed^{-1})
				racemes . plant^{-1}	siliquae . plant^{-1}		
Main: Humate application							
Without humate			134.09	5.19	126.06	2.37	1.04
With humate			140.30	5.67	128.56	2.57	1.13
F test			***	***	**	***	***
**LSD at 0.05 %			5.13	0.062	0.646	0.003	0.003
Sub main: Methods of Se application							
Foliar application			135.68	5.31	126.64	2.43	1.07
Seed priming			138.72	5.55	127.99	2.51	1.11
F test			**	***	**	***	***
LSD at 0.05 %			1.18	0.028	0.552	0.018	0.002
Sub sub main: Selenium rates							
*Cont			133.69	5.28	125.36	2.25	0.993
1.5 ppm Se			153.78	6.37	137.75	3.22	1.41
3.0 ppm Se			144.74	5.75	133.58	2.52	1.11
4.5 ppm Se			116.58	4.33	112.57	1.90	0.842
F test			***	***	***	***	***
LSD at 0.05 %			1.58	0.038	0.959	0.031	0.004
Interaction							
Without humate	Foliar application	Cont	128.52	5.14	124.33	2.16	0.956
		1.5 ppm Se	151.03	6.24	136.60	3.04	1.345
		3.0 ppm Se	141.16	5.53	130.25	2.40	1.062
		4.5 ppm Se	110.32	3.37	110.12	1.72	0.762
	Seed priming	Cont	130.38	5.22	124.96	2.21	0.979
		1.5 ppm Se	153.13	6.32	137.33	3.18	1.407
		3.0 ppm Se	143.36	5.60	133.62	2.47	1.093
		4.5 ppm Se	114.87	4.12	111.32	1.78	0.789
With humate	Foliar application	Cont	135.27	5.36	125.13	2.28	1.009
		1.5 ppm Se	155.30	6.40	138.33	3.26	1.442
		3.0 ppm Se	145.33	5.69	135.12	2.53	1.120
		4.5 ppm Se	118.51	4.80	113.25	2.02	0.895
	Seed priming	Cont	140.60	5.40	127.36	2.32	1.027
		1.5 ppm Se	155.66	6.52	138.42	3.38	1.484
		3.0 ppm Se	149.12	6.19	135.33	2.66	1.177
		4.5 ppm Se	122.63	5.03	115.60	2.08	0.921
F test			**	***	**	***	***
LSD at 0.05%			3.16	0.076	1.91	0.063	0.009

*Cont: control treatment with zero concentration **LSD: Least significant difference

Table 6: The average effect of different potassium humate treatments, different techniques and rates of selenium application as well as their interactions on nutrients uptake by mature Canola seeds under salinity stress.

Treatment			Nutrients uptake (kg. fed^{-1})			(g fed^{-1})
			N	P	K	Se
Main : Humate application						
Without humate			32.09	3.56	27.70	39.73
With humate			36.76	4.01	31.51	44.79
F test			***	***	***	***
**LSD at 0.05 %			0.604	0.005	0.245	0.674
Sub main: Methods of Se application						
Foliar application			33.37	3.69	28.72	41.08
Seed priming			35.48	3.89	30.48	43.44
F test			***	***	***	**
LSD at 0.05 %			0.185	0.027	0.639	0.655
Sub sub main : Selenium rates						
*Cont			28.90	3.27	24.93	31.51
1.5 ppm Se			50.45	5.46	43.52	52.85
3.0 ppm Se			35.77	4.02	31.18	46.88
4.5 ppm Se			22.57	2.40	18.78	37.80
F test			***	***	***	***
LSD at 0.05 %			0.557	0.058	0.980	0.448
Interaction						
Without humate	Foliar application	Cont	26.79	2.96	22.86	28.89
		1.5 ppm Se	45.07	5.07	39.56	48.70
		3.0 ppm Se	33.05	3.74	28.69	42.83
		4.5 ppm Se	19.67	2.09	16.31	33.56
	Seed Priming	Cont	28.29	3.18	23.99	30.84
		1.5 ppm Se	48.12	5.34	42.49	52.06
		3.0 ppm Se	34.89	3.92	30.40	45.72
		4.5 ppm Se	20.83	2.20	17.28	35.27
With humate	Foliar application	Cont	29.79	3.40	25.85	32.51
		1.5 ppm Se	51.93	5.61	44.86	54.09
		3.0 ppm Se	36.30	4.05	31.59	47.61
		4.5 ppm Se	24.34	2.58	20.04	40.46
	Seed Priming	Cont	30.72	3.55	27.03	33.81
		1.5 ppm Se	56.69	5.84	47.18	56.54
		3.0 ppm Se	38.86	4.35	34.04	51.35
		4.5 ppm Se	25.43	2.72	21.47	41.93
F test			***	***	***	**
LSD at 0.05%			1.11	0.116	1.961	0.897

*Cont: control treatment with zero concentration **LSD: Least significant difference

Table 7: The average effect of potassium humate treatments, techniques and rates of selenium application as well as their interactions on quality of mature canola seeds under salinity stress.

Treatment			%			mg.100g^{-1}
			Protein	Oil	Carbohydrates	Vitamin E
Main : Humate application						
Without humate			18.73	42.40	14.85	18.31
With humate			19.82	43.15	15.29	18.83
F test			***	***	***	***
**LSD at 0.05 %			0.217	0.031	0.031	0.035
Sub main: Methods of Se application						
Foliar application			19.02	42.57	14.94	18.42
Seed priming			19.53	42.98	15.20	18.71
F test			***	***	***	***
LSD at 0.05 %			0.028	0.020	0.044	0.073
Sub sub main : Selenium rates						
*Cont			18.17	41.99	14.66	18.26
1.5 ppm Se			22.17	45.07	16.48	20.04
3.0 ppm Se			20.06	43.49	15.53	18.93
4.5 ppm Se			16.71	40.54	13.60	17.04
F test			***	***	***	***
LSD at 0.05 %			0.236	0.043	0.040	0.034
Interaction						
Without humate	Foliar Application	Cont	17.5	41.50	14.45	18.00
		1.5 ppm Se	20.93	44.35	16.33	19.62
		3.0 ppm Se	19.43	42.92	15.20	18.51
		4.5 ppm Se	16.12	40.03	12.96	16.31
	Seed Priming	Cont	18.06	41.82	14.60	18.28
		1.5 ppm Se	21.37	44.92	16.45	19.97
		3.0 ppm Se	19.93	43.30	15.42	18.86
		4.5 ppm Se	16.50	40.36	13.40	16.94
With Humate	Foliar Application	Cont	18.43	42.10	14.72	18.34
		1.5 ppm Se	22.50	45.30	16.52	20.22
		3.0 ppm Se	20.25	43.75	15.63	19.17
		4.5 ppm Se	17.00	40.62	13.71	17.24
	Seed Priming	Cont	18.68	42.56	14.89	18.42
		1.5 ppm Se	23.87	45.73	16.62	20.36
		3.0 ppm Se	20.62	44.00	15.90	19.21
		4.5 ppm Se	17.25	41.16	14.36	17.68
F test			***	***	***	***
LSD at 0.05%			0.473	0.087	0.080	0.068

*Cont: control treatment with zero concentration **LSD: Least significant difference

2) Effect of potassium humate and selenium applications on available nutrients in soil after harvesting

Available nutrients i. e. nitrogen, phosphorus and potassium (mg kg^{-1}) status in the soil after canola harvesting were shown in Figs. 1, 2 and 3, respectively. It's clear that available N, P and K of the soil increased with addition of humate application comparing with untreated.

Regarding to different techniques priming was the superior where it recorded the highest values of N, P and K status in soil post harvesting. The highest rate of Se application i.e., 4.5 ppm recorded the highest values of N (47.04), of P (10.89) and of K (209.01) comparing with other treatments.

The interaction of humate application and seed priming in 4.5 ppm , Se recorded the highest values of the available N, P and K nutrients values.

This result may be due to the beneficial role of potassium humate in soil fertility, enhancement soil properties, increasing nutrient availability in soil leading to increasing nutrient uptake and thus increase nutrient content in mature seeds. Also, it acts on P acquisition by plant by keeping P in solution that led to increasing P uptake by plant (**Bhatt and Singh, 2022**). Addition of potassium humate maintains a high potassium content and in parallel reduces the content of sodium in cytosol of the plant cell sap, which adjust cell osmosis and increases plant resistance to salinity (**Ouni et al., 2014**). The interaction of humate application and seed priming in 4.5 ppm Se recorded the highest values of the available N, P and K nutrients values where humic acid contributes to soil fertility through improving nutrient availability in the soil and maintaining P in the soil solution, which increases P availability. On the other hand, high concentration of selenium reduce nutrients uptake by plant so selenium application at 4.5 ppm resulted in the highest remaining N, P and K in soil

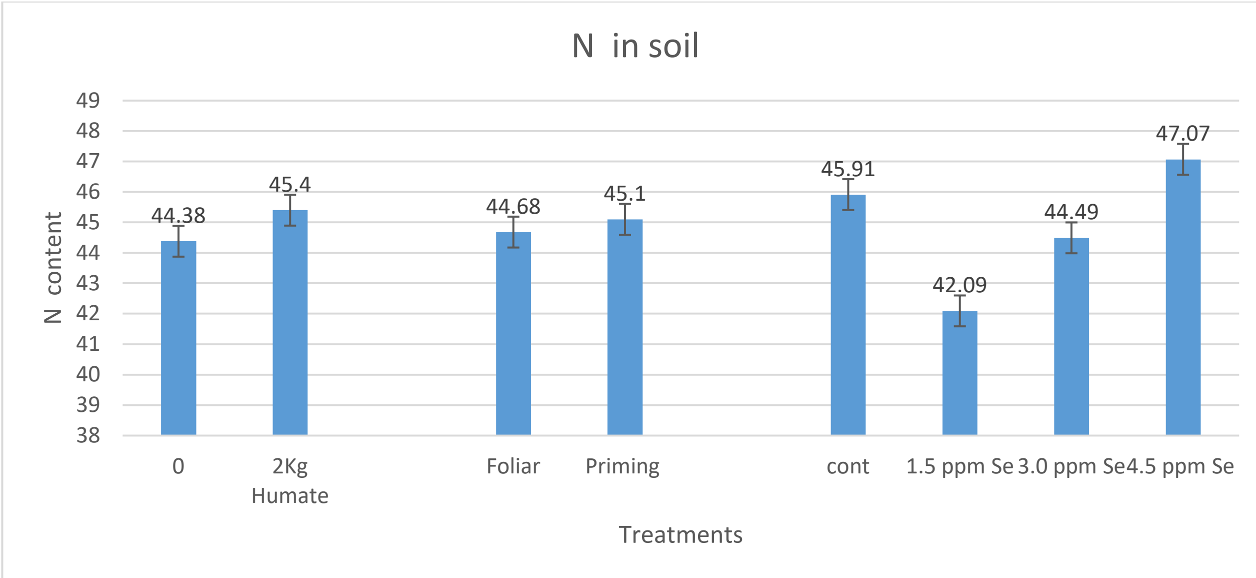

Fig. 1: **The individual average effect of potassium humate treatments, techniques and rates of selenium application and N status on soil after harvesting**

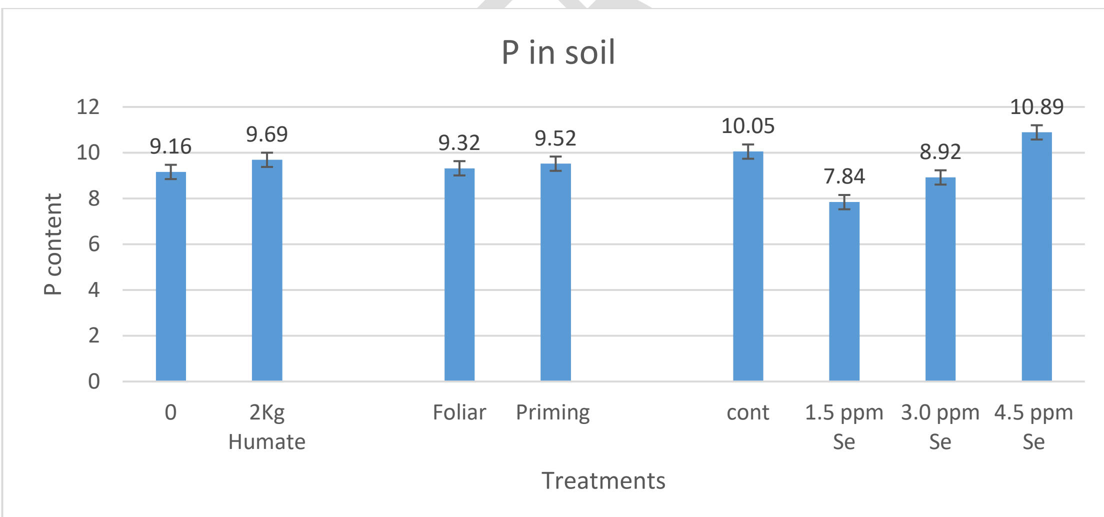

Fig. 2: **The individual average effect of potassium humate treatments, techniques and rates of selenium application and P status on soil after harvesting**

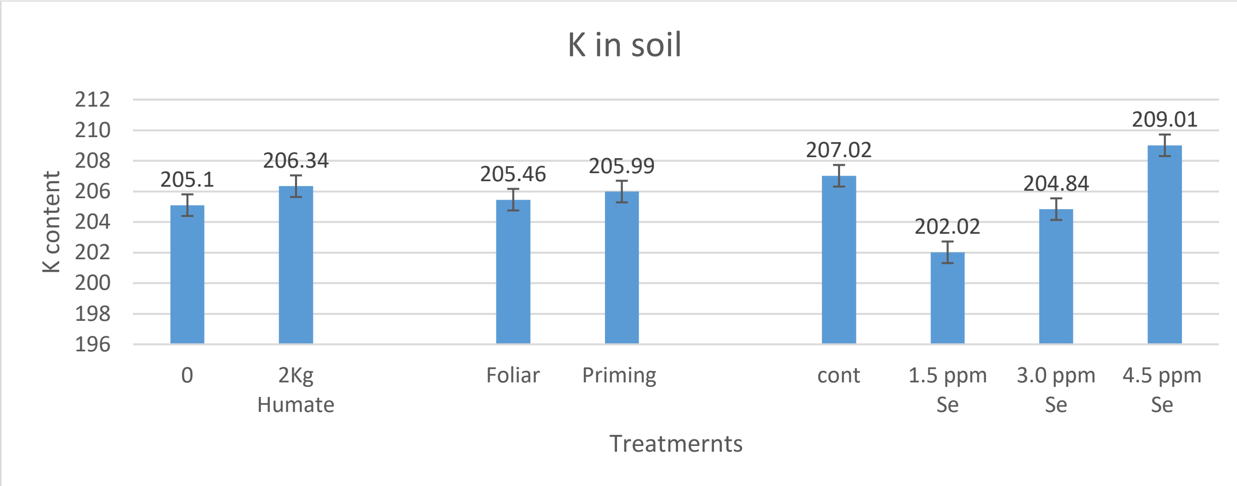

Fig. 3: **The individual average effect of potassium humate treatments, techniques and rates of selenium application and K status on soil after harvesting**

CONCLUSION

Plant bio-stimulants contributed to improving crop productivity under stress conditions while preserving the environment. Canola plant's growth, yield, and productivity were negatively impacted in the current experiment by salt stress. However, the use of soil humate application in combination with seed priming in a selenium solution at a low concentration of 1.5 ppm reduced the negative effects of salt stress and enhanced the plant resistance by increasing the activity of antioxidant enzymes and the accumulation of proline which led to improving the growth, quality and productivity of the Canola plant under these conditions of saline soils.

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