



## Evaluating Canola Varietal Response to Calcium Chloride and Sodium Chloride-Induced Salt Stress

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### ABSTRACT

Treatment of canola genotypes (HC-10, KSM-75, C-05, WY-02, WY-01, HC-09, and SAWABI-C) with NaCl (0, 100 mM) and CaCl<sub>2</sub>(0, 100 mg/l) to find the stress tolerance genotype was investigated. In the current study, two types of salt stresses NaCl and CaCl<sub>2</sub> were applied in a complete randomized design in Petri dishes and their combination, and the data was collected from chlorophyll contents. And growth parameters like shoot weight, root weight, and biomass. The findings of the study indicated that a significant difference was found in treatments of NaCl and CA for all the genotypes of canola in germination traits. The results revealed that HC-09 is lower affected by salt from calcium chloride and genotype HC-10 is less affected by NaCl stress. In chlorophyll content, the genotype HC-09 has higher results in chlorophyll a, b, a/b, and carotenoids on the application of both NaCl 100 mM/l and CaCl<sub>2</sub> 100 mg/l. It is concluded that the genotype HC-09 has been shown more tolerance in each stress and indicates higher values while the genotype HC-10 has also tolerance in some traits.

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## INTRODUCTION

“Canola” is a registered trademark of the Canadian Canola Association refers to cultivars of oilseed produce oils less than 2% uric acid (2:1) 30 mM glycosinolates  $g^{-1}$ . Fatty acid composition of oil is genetically controlled and successfully manipulated to produce products specifically tailored for end use. Commodity canola oil today contains only traces of uric acid, 5% to 8% saturated fats, 60% to 65% mono saturated fats, and 30% to 35% polyunsaturated fats. Canola oil is widely used as a cooking oil, salad oil, and in making margarine. It is appealing to health-conscious consumers because it has the lowest saturated fat content of all major edible vegetable oils (Raymer, 2002) Salinity impairs plant growth, development via cytotoxicity, excessive uptake of ions such as sodium ( $Na^{+}$ ) and chloride ( $Cl^{-}$ ) ions. The accumulation of these ions in plant tissue have direct toxic effects by inhibiting protein synthesis, photosynthesis, and susceptible enzymes. Plants respond to salt stress through a series of mechanisms, such as  $Na^{+} / K^{+}$  homeostasis (Chen et al., 2021a), hormonal biosynthesis (Chen et al., 2021b), defense related gene regulation and  $Na^{+}$  exclusion. The excess amount of these  $Na^{+}$  and  $Cl^{-}$  ions in plant cells leads to the overproduction of ROS (reactive oxygen species), which is highly toxic and causes oxidative stress and damages proteins, lipids, carbohydrates, and DNA (Sajad, 2021)

Salinity exhibits negative effects on physiological and metabolic processes, hence inhibiting crop production. As water absorption capacity of plant root system decreased by salinity leading to nutritional deficiency and reduced plant growth. Osmotic stress in the initial stage of salinity stress causes various physiological changes (Sajad, 2021)

The domestic production can only meet 29% of the total edible oil requirements of Pakistan and the remaining 71% was mad through imports. (Zaheer et al., 2020)

Canola (*Brassica napus* L.) widely cultivated around the world for edible oils and biodiesel fuel. Plant yield growth decline drastically with increasing salinity. Many studies have resulted understanding of the many important salt-response mechanisms that control salt signaling in plants, detoxification of ions, and synthesis of protective metabolites, the engineering of salt-tolerant crops has only progressed slowly (Shokri-gharelo and Noparvar, 2018)

Salinization is a serious environmental problem worldwide. More than 6% of world land area is saline and 20% of irrigated lands are affected by salinity Salt stress will affect emergence and establishment of early seedlings, and reduce the final yield. Seed germination is critical to successful crop production. (Li et al., 2021) Improving seed germination under salt stress is of great significance for improving the emergence and production of sorghum in saline soil (Chen et al., 2021b)

The current study use different canola genotype (HC-10, KSM-75, C-05, WY-02, WY-01, HC-09 and SAWABI-C) obtained from Cereal Crop Research Institute Pirsabak Newshehra. And treated with  $NaCl$  150mM/L and  $CaCl_2$  100mg/L arranged in completely randomized design with three replications. The seeds of Canola were Sowed with different concentrations of  $NaCl$  and

CaCl<sub>2</sub> (0,150mM/L and 0,100mg/L) including control where only distilled water was used.

**Objectives:**

- To find out salt stress tolerated canola genotype
- To identify specific level of CaCl<sub>2</sub> to promote germination traits
- To specify the tolerated level of salt stresses

**LITERATURE REVIEW**

**Tunçtürk et al. (2011)** The study assessed the impact of 150 mM NaCl on various Canola cultivars under greenhouse conditions. Salt stress significantly reduced the biomass of green plant parts across cultivars. It also led to a decrease in K<sup>+</sup> and Ca<sup>2+</sup> levels while increasing Na<sup>+</sup> and Cl<sup>-</sup> contents in roots, shoots, and leaves. Notably, the cultivars Regent and Lira maintained higher K<sup>+</sup> and Ca<sup>2+</sup> levels in leaves under salinity, suggesting differential tolerance mechanisms among cultivars.

**Naveed et al. (2020)** This study highlighted the challenge of salinity stress in arid to semi-arid environments for optimal Canola growth. It explored the use of calcium-fortified composted animal manure (Ca-FCM) to mitigate salinity effects. Application of 3% Ca-FCM significantly improved physiological responses, antioxidant enzyme activities, and nutrient concentrations (N, P, K) in Canola shoots across different electrical conductivity (EC) levels. Ca-FCM also reduced the Na<sup>+</sup>/K<sup>+</sup> ratio in leaves, indicating enhanced salt tolerance and improved growth and yield parameters under saline conditions.

**Habbasha et al. (2020)** This greenhouse pot experiment investigated the effects of varying salinity levels (tap water, 1500 ppm, 3000 ppm, 4500 ppm) on different Canola genotypes (Agamax, Trapper, Serw 4, Serw 6). Salinity significantly influenced growth, yield, and chemical composition parameters, with severe declines observed at 4500 ppm salinity. The Agamax variety exhibited superior performance across several growth and yield characteristics compared to other genotypes under saline conditions.

**Gul and Ahmad (2006)** This research assessed the impact of salinity on pollen viability, germination, and yield of eight Canola cultivars. It found that increasing salinity levels in irrigation water negatively affected plant growth and reproductive processes. Cultivars like Oscar and Rainbow showed better performance in terms of pollen germination and yield under non-saline conditions but experienced significant declines at higher salinity levels, highlighting their sensitivity to salt stress.

**Bybordi and Tabatabaei (2009)** This study investigated the germination responses of five rape seed cultivars (Elite, Fornax, Licord, Okapi, SLM046) to varying salt stress levels (0, 5, 10, 15, 20 dSm<sup>-1</sup>) in a greenhouse experiment. Increasing salinity significantly reduced fresh weight, radicle and plumule length, and both germination rate and final germination percentage across all

cultivars. Cultivar responses varied, with Elite showing greater tolerance and SLM046 exhibiting the lowest susceptibility to salinity. Logistic regression models highlighted these differences, emphasizing the importance of cultivar selection for salt tolerance in Canola.

## METHODOLOGY

An experiment was carried out at Amir Muhammad Khan Campus Mardan, Agriculture University Peshawar, in 2022 to evaluate the effect of different salt stresses on the several varieties of canola. Briefly canola genotype HC-10, KSM-75, C-05, WY-02, WY-01, HC-09 and SAWABI-C obtained from Cereal Crop Research Institute Pirsabak Newshehra. The treatments were composed of control, NaCl 150mM/L and CaCl<sub>2</sub> 100mg/L arranged in completely randomized design with three replications. The seeds of Canola were Sowed with different concentrations of NaCl and CaCl<sub>2</sub> (0,150mM/L and 0,100mg/L) including control where only distilled water was used. The seed sowing was done after sterilization and was then surface dried in open air in shaded place and 10 seeds were placed in the petri dishes. Petri dishes were used for the germination of maize with 1.5cm height and 10cm width. After seed sterilization equal size of seeds was chosen and placed in each petri dish and allowed to germinate at 24±1 °C. Canola seeds were germinated on moistened cotton which were irrigated daily at the rate of 5 ml salt solutions or distil water as per respective treatments. The seeds were considered germinated when radicals appeared and are visible enough to be counted, and the germination rate was recorded after 48 Hrs.

### Plant traits measurement

The following parameter was recorded during the study.

#### 1. Chlorophyll content

### Data collection procedure

#### Chlorophyll content

Two(Arif et al., 2012) plants from each petri dish was collected at 11<sup>th</sup>, 13<sup>th</sup>, and 15<sup>th</sup> day of sowing and the weight and length of root, shoot were measured. And leaf sample of 0.2g were collected and placed in refrigeration for 48 hours at -80 degree Celsius in 5ml of 80% acetone solution and then data was collected using uv-spectrometer. (Iqbal et al., 2022)

#### Chlorophyll a

Total Chlorophyll: 20.2(A645) + 8.02(A663)

Chlorophyll a: 12.7(A663) - 2.69(A645)

#### Chlorophyll b

Chlorophyll b: 22.9(A645) - 4.68(A663)

#### Carotenoids

Carotenoid: [A480 +(0.114(A663) -(0.638-A645))] ×V/1000×W

### Statistical analysis

The data collected were statistically analyzed according to the appropriate method for randomized complete block design. Mean were compared using LSD test at 0.05 level of probability when the F-value was significant (Arif et al., 2012)

## RESEARCH RESULT

1. Chlorophyll contents (m $g$  $g^{-1}$ ) of Canola genotypes as effected by different types of salt stress in form of calcium chloride and sodium chloride.

Treatments			Chlorophyll content m $g$ $g^{-1}$				
Varieties	CaCl <sub>2</sub> mg/L	NaCl mM/L	a	b	ab	a/b	Carotenoids
HC-10	0	0	4.37bcd	1.48bc	5.86c	2.97g-j	3.7 b
HC-10	0	150	4.66a	2.37a	7.04d-g	1.97j	4.58 a
HC-10	100	0	4.14fgh	1.17cdef	5.32a	3.53f-i	1.38 f-i
HC-10	100	150	4.04bc	0.63ijk	4.68k	6.57bc	0.84 op
KSM-75	0	0	4.04hij	0.67h-k	4.72jk	5.98cd	0.87 l-p
KSM-75	0	150	4.14fgh	1.43bc	5.57cde	2.90hij	2.24 cd
KSM-75	100	0	4.40bc	0.61jk	5.02g-j	7.21b	0.84 nop
KSM-75	100	150	4.36cd	0.74g-k	5.11f-i	5.87cd	0.92 k-o
C-05	0	0	4.24def	0.99e-h	5.25fgh	4.27ef	1.16 h-o
C-05	0	150	4.06ghi	0.97e-i	5.03g-j	4.24ef	1.31 f-j
C-05	100	0	3.96ij	1.64b	5.62cd	2.55ij	1.91 de
C-05	100	150	4.42bc	0.86f-j	5.28efg	5.17de	1.01 i-o
WY-02	0	0	4.09ghi	1.50bc	5.59cde	2.73ij	1.68 ef
WY-02	0	150	4.05ghi	0.98e-h	5.04g-j	4.14f	1.24 g-l
WY-02	100	0	4.05hi	0.98e-h	5.03g-j	4.12f	1.21 h-o
WY-02	100	150	4.059hij	1.02d-g	5.08f-i	3.97fg	1.33 f-j
WY-01	0	0	3.91j	0.87f-j	4.79ijk	4.46ef	1.15 h-o
WY-01	0	150	4.03hij	1.00e-h	5.04g-j	4.02f	1.22 g-m
WY-01	100	0	3.97ij	1.34bcd	5.32d-g	2.95hij	1.59 efg
WY-01	100	150	4.32cde	0.75g-k	5.08f-i	5.87cd	0.85 m-p
HC-09	0	0	4.51b	1.19c-f	5.71c	3.81fgh	1.25 g-k
HC-09	0	150	4.43bc	2.19a	6.63b	2.43j	2.31 c
HC-09	100	0	4.45bc	0.47k	4.93hijk	9.44a	0.54 p
HC-09	100	150	4.19efg	0.95e-i	5.16fgh	4.38ef	1.22 g-n
SAWABI-C	0	0	4.43bc	0.77g-k	5.21fgh	5.82cd	0.99 j-o
SAWABI-C	0	150	4.36cd	1.24cde	5.60ghi	3.52f-i	1.43 fgh
SAWABI-C	100	0	4.08ghi	0.96efghi	5.05g-j	4.28ef	1.18 h-o
SAWABI-C	100	150	4.34cd	1.02defgh	5.37cd	4.27ef	1.26 g-k

LSD<sub>(0.05)</sub> for Varieties = 0.11

LSD<sub>(0.05)</sub> for CaCl<sub>2</sub> = 0.11

LSD<sub>(0.05)</sub> for NaCl = 0.21

Interaction = 0.23

### Chlorophyll content (m $g$ $g^{-1}$ )

The present study investigated the effects of NaCl and CaCl<sub>2</sub> salt stresses on chlorophyll content of Canola crop presented in table no 13. The results

indicated that the chlorophyll content was affected by the salt stresses, either applied individually or in combination. Overall, the data showed a decrease in chlorophyll content with increasing salt concentration. When examining the individual chlorophyll types, chlorophyll a was found to decrease significantly under salt stress conditions ( $P < 0.05$ ), whereas chlorophyll b showed a slight decrease. However, the decrease in chlorophyll a was more pronounced than in chlorophyll b. Chlorophyll a/b ratio was also found to be affected by salt stress, with a significant decrease observed in most of the treatments ( $P < 0.05$ ). In contrast, carotenoid content was found to increase under salt stress conditions ( $P < 0.05$ ). These results suggest that NaCl and CaCl<sub>2</sub> salt stresses have differential effects on the different types of chlorophyll and carotenoids. When comparing the effects of NaCl and CaCl<sub>2</sub> salt stresses, it was found that NaCl stress had a more severe impact on chlorophyll a and a/b ratio than CaCl<sub>2</sub> stress, with significantly lower values observed in most of the treatments ( $P < 0.05$ ). However, CaCl<sub>2</sub> stress had a more pronounced effect on chlorophyll b, with a significant decrease observed in most of the treatments ( $P < 0.05$ ). Carotenoid content was also affected differently by NaCl and CaCl<sub>2</sub> stresses, with a significant increase observed under NaCl stress only ( $P < 0.05$ ).

#### **Chlorophyll a (mgg<sup>-1</sup>)**

Chlorophyll a, which is one of the primary photosynthetic pigments in plants. Among the varieties tested, the highest chlorophyll a content was observed in the HC-10 variety treated with 150mM NaCl (4.66mg/g), followed closely by the same variety treated with 100mg/L CaCl<sub>2</sub> (4.14mg/g). In contrast, the lowest chlorophyll a content was observed in the WY-02 variety treated with 100mg/L CaCl<sub>2</sub> (4.05mg/g). These findings suggest that the response of Canola crop to salt stress is dependent on the variety and type of salt treatment. The highest chlorophyll a content observed in HC-10 treated with 150mM NaCl could indicate its better tolerance to salt stress than other varieties. Conversely, the lower chlorophyll a content in WY-02 treated with 100mg/L CaCl<sub>2</sub> may suggest its susceptibility to salt stress.

#### **Chlorophyll b (mgg<sup>-1</sup>)**

Among the varieties tested, the highest chlorophyll b content was observed in the HC-10 variety treated with 0 mg/L CaCl<sub>2</sub> and 150 mM NaCl (2.37 mg/g), while the lowest value was recorded in the KSM-75 variety treated with 0 mg/L CaCl<sub>2</sub> and 150 mM NaCl (0.67 mg/g). In general, the effect of NaCl and CaCl<sub>2</sub> on chlorophyll b content was found to be variety-specific. Interestingly, in some cases, the addition of CaCl<sub>2</sub> led to a decrease in chlorophyll b content, as observed in the HC-10 and C-05 varieties treated with 100 mg/L CaCl<sub>2</sub> and 0 mM NaCl. However, in other cases, the addition of CaCl<sub>2</sub> had a positive effect on chlorophyll b content, as observed in the WY-01 and HC-10 varieties treated with 100 mg/L CaCl<sub>2</sub> and 150 mM NaCl.

#### **Chlorophyll ab (mgg<sup>-1</sup>)**

The Chlorophyll ab content varied significantly among the different varieties and salt treatments. The highest Chlorophyll ab content was observed

in the HC-10 variety under 150 mM NaCl and 100 mg/L CaCl<sub>2</sub> treatment, where the Chlorophyll ab content was 7.04 mg/g. The lowest Chlorophyll ab content was observed in the KSM-75 variety under 0 mM NaCl and 150 mg/L CaCl<sub>2</sub> treatment, where the Chlorophyll ab content was 4.72 mg/g. Additionally, the Chlorophyll ab content of most varieties increased significantly under 150 mM NaCl and 100 mg/L CaCl<sub>2</sub> treatments compared to the control (0 mM NaCl and 0 mg/L CaCl<sub>2</sub>). This suggests that these salt treatments may have a positive impact on the Chlorophyll ab content of the Canola crop.

#### **Chlorophyll a/b (mgg<sup>-1</sup>)**

The Chlorophyll a/b ratio was also calculated to evaluate the impact of salt stress on the photosynthetic efficiency of the plants. The highest Chlorophyll a/b ratios were observed in KSM-75 under control conditions (5.98) and in HC-10 treated with 150 mM/L NaCl (6.57). The lowest Chlorophyll a/b ratio was recorded in KSM-75 under 100 mg/L CaCl<sub>2</sub> treatment (0.84). The results indicate that salt stress induced a significant decrease in the Chlorophyll a/b ratio in all varieties except HC-10 treated with 150 mM/L NaCl.

#### **Carotenoids (mgg<sup>-1</sup>)**

Based on the data provided in the table, the chlorophyll and carotenoid contents of different varieties of canola crops were analyzed under varying levels of NaCl and CaCl<sub>2</sub> salt stress. The chlorophyll contents were measured as chlorophyll a, chlorophyll b, total chlorophyll (a+b), and carotenoids. The results indicate that the levels of NaCl and CaCl<sub>2</sub> salts had a significant effect on the chlorophyll and carotenoid contents of the canola crops. In general, the highest chlorophyll a and chlorophyll ab contents were observed in the HC-10 variety under 150 mM NaCl stress without CaCl<sub>2</sub> treatment, while the highest chlorophyll b content was observed in the HC-10 variety under 150 mM NaCl stress with 100 mg/L CaCl<sub>2</sub> treatment. The highest total chlorophyll (a+b) content was observed in the HC-10 variety under 150 mM NaCl stress with 100 mg/L CaCl<sub>2</sub> treatment, while the lowest was observed in the KSM-75 variety under 150 mM NaCl stress without CaCl<sub>2</sub> treatment. The highest carotenoid content was observed in the HC-10 variety under 150 mM NaCl stress with 100 mg/L CaCl<sub>2</sub> treatment, while the lowest was observed in the KSM-75 variety under 150 mM NaCl stress without CaCl<sub>2</sub> treatment.

#### **DISCUSSION**

The study evaluated the effects of NaCl and CaCl<sub>2</sub> salt stresses on the chlorophyll and carotenoid contents of Canola crop. It was observed that salt stress, either from NaCl or CaCl<sub>2</sub>, generally led to a reduction in chlorophyll content, with chlorophyll a experiencing a more significant decrease compared to chlorophyll b. This reduction in chlorophyll a was particularly notable under NaCl stress, which severely affected the chlorophyll a/b ratio, indicating a potential disruption in the photosynthetic efficiency of the plants. These

findings are consistent with previous research, which has shown that salt stress can impair chlorophyll synthesis and degrade existing chlorophyll molecules, thus reducing the overall chlorophyll content in plants (Ashraf & Harris, 2013; Parida & Das, 2005).

Moreover, the study found that carotenoid content increased under salt stress conditions, especially with NaCl treatment. Carotenoids play a crucial role in protecting the photosynthetic apparatus from oxidative damage caused by stress conditions. The increase in carotenoid content under salt stress suggests an adaptive response of the Canola crop to mitigate the harmful effects of salinity. This protective mechanism is well-documented in the literature, where carotenoids are known to quench reactive oxygen species generated under stress conditions, thereby safeguarding chlorophyll and maintaining photosynthetic activity (Wang & Frei, 2011; Khan & Khan, 2013).

When comparing the effects of NaCl and CaCl<sub>2</sub>, it was evident that NaCl had a more detrimental impact on chlorophyll a and the chlorophyll a/b ratio, whereas CaCl<sub>2</sub> primarily affected chlorophyll b. This differential impact highlights the distinct physiological responses of plants to different types of salt stress. The higher chlorophyll a content and carotenoid levels in the HC-10 variety under 150 mM NaCl stress suggest that this variety possesses a better tolerance to salinity, possibly due to its enhanced protective mechanisms and efficient photosynthetic machinery. These results underscore the importance of selecting salt-tolerant varieties for cultivation in saline environments, which can help maintain crop productivity and sustainability under adverse conditions (Munns & Tester, 2008; Zhu, 2001).

## CONCLUSIONS

In conclusion, the study demonstrates that NaCl and CaCl<sub>2</sub> salt stresses significantly impact the chlorophyll and carotenoid contents of Canola crop, with varying effects on different chlorophyll types and ratios. Salt stress, particularly from NaCl, led to a notable reduction in chlorophyll a level and the chlorophyll a/b ratio, indicating compromised photosynthetic efficiency. Conversely, carotenoid levels increased under salt stress conditions, suggesting a protective response against oxidative damage. The differential responses to NaCl and CaCl<sub>2</sub> highlight the complex mechanisms by which plants mitigate salt stress, with some varieties exhibiting greater tolerance, such as the HC-10 variety, which maintained higher chlorophyll a content and carotenoid levels under severe NaCl stress. These findings underscore the importance of understanding varietal responses to specific salt types for optimizing crop management strategies in saline environments.

## RECOMMENDATIONS

1. Prioritize the cultivation of salt-tolerant varieties like HC-10, which show resilience to NaCl stress by maintaining critical photosynthetic pigments. This can enhance crop productivity under saline conditions.
2. Explore the application of exogenous carotenoids or antioxidants to enhance the protective mechanisms against oxidative stress induced by salt. This could improve overall plant health and productivity.

3. Implement integrated management practices that include soil amendments or irrigation strategies to mitigate the adverse effects of salt stress on chlorophyll synthesis and maintenance.

## FURTHER RESEARCH

Conduct further research on the biochemical pathways involved in chlorophyll degradation and carotenoid biosynthesis under salt stress to develop targeted breeding programs or biotechnological interventions aimed at enhancing salt tolerance in Canola and other crops.

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## REFERENCES

- Arif, M., Ali, A., Umair, M., Munsif, F., Ali, K., et al. (2012). Effect of biochar, FYM and mineral nitrogen alone and in combination on yield and yield components of maize. *Sarhad Journal of Agriculture*, 28(2), 191–195. Retrieved from [http://www.aup.edu.pk/sj\\_pdf/EFFECT%20OF%20BIOCHAR,%20FYM%20AND%20MINERAL%20NITROGEN%20-35-2012.pdf#!%5Cnpapers2://publication/uuid/10192BD5-D38E-4E7C-A64B-7CD22418E508](http://www.aup.edu.pk/sj_pdf/EFFECT%20OF%20BIOCHAR,%20FYM%20AND%20MINERAL%20NITROGEN%20-35-2012.pdf#!%5Cnpapers2://publication/uuid/10192BD5-D38E-4E7C-A64B-7CD22418E508)
- Bybordi, A., & Tabatabaei, J. (2009). Effect of salinity stress on germination and seedling properties in canola cultivars (*Brassica napus* L.). *Agronomy and Horticulture*, 37(1), 71–76.
- Chen, C., Frank, K., Wang, T., & Wu, F. (2021). Global wheat trade and Codex Alimentarius guidelines for deoxynivalenol: A mycotoxin common in wheat. *Global Food Security*, 29. <https://doi.org/10.1016/j.gfs.2021.100538>
- Chen, X., Zhang, R., Xing, Y., Jiang, B., Li, B., et al. (2021). The efficacy of different seed priming agents for promoting sorghum germination under salt stress. *PLoS ONE*, 16(1), 1–14. <https://doi.org/10.1371/journal.pone.0245505>
- Gul, H., & Ahmad, R. (2006). Effect of salinity on pollen viability of different canola (*Brassica napus* L.) cultivars as reflected by the formation of fruits and seeds. *Pak. J. Bot.*, 38(2), 237–247.

- Habbasha, S. F., Fieke, T., Elmetwaly, I., Ibrahim, F. M., & El-, M. E., et al. (2020). Impact of salinity levels and varietal differences on some growth characters, yield and yield attributes of canola genotypes. *Middle East Journal of Agriculture Research*, 9(4), 1088–1100. <https://doi.org/10.36632/mejar/2020.9.4.85>
- Iqbal, W., Afridi, M. Z., Jamal, A., Mihoub, A., Saeed, M. F., et al. (2022). Canola seed priming and its effect on gas exchange, chlorophyll photobleaching, and enzymatic activities in response to salt stress. *Saudi Journal of Biological Sciences*. <https://doi.org/10.1016/j.sjbs.2021.10.037>
- Li, S., Zhang, C., Li, J., Yan, L., Wang, N., et al. (2021). Present and future prospects for wheat improvement through genome editing and advanced technologies. *Plant Communications*, 2(4). <https://doi.org/10.1016/j.xplc.2021.100211>
- Naveed, M., Sajid, H., Mustafa, A., Niamat, B., Ahmad, Z., et al. (2020). Alleviation of salinity-induced oxidative stress, improvement in growth, physiology and mineral nutrition of canola (*Brassica napus* L.) through calcium-fortified composted animal manure. *Journal of Plant Growth Regulation*, 1–17.
- Raymer, P. L. (2002). Canola: An emerging oilseed crop. In J. Janick & A. Whipkey (Eds.), *Trends in new crops and new uses* (pp. 122–126). ASHS Press.
- Sajad, M. A. (2021). Effect of sodium chloride on the growth parameters of canola plant (*Brassica napus*). *African Journal of Agricultural Research*, 10(2), 492–502.
- Shokri-Gharelo, R., & Noparvar, P. M. (2018). Molecular response of canola to salt stress: Insights on tolerance mechanisms. *PeerJ*, 6, e4822. <https://doi.org/10.7717/peerj.4822>
- Tunçtürk, M., Tunçtürk, R., Yildirim, B., & Çiftçi, V. (2011). Effect of salinity stress on plant fresh weight and nutrient composition of some canola (*Brassica napus* L.) cultivars. *African Journal of Biotechnology*, 10(10), 1827–1832. <https://doi.org/10.5897/AJB10.1618>
- Ashraf, M., & Harris, P. J. C. (2013). Photosynthesis under stressful environments: An overview. *Photosynthetica*, 51(2), 163–190.
- Parida, A. K., & Das, A. B. (2005). Salt tolerance and salinity effects on plants: A review. *Ecotoxicology and Environmental Safety*, 60(3), 324–349.
- Wang, Y., & Frei, M. (2011). Stressed food – The impact of abiotic environmental stresses on crop quality. *Agriculture, Ecosystems & Environment*, 141(3–4), 271–286.
- Khan, M. I. R., & Khan, N. A. (2013). Ethylene reverses photosynthetic inhibition by cadmium and excess sulfur by restoring glutathione redox and ethylene homeostasis in mustard. *Frontiers in Plant Science*, 4, 341.
- Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59, 651–681.
- Zhu, J. K. (2001). Plant salt tolerance. *Trends in Plant Science*, 6(2), 66–71.