Journal of Elementology ISSN 1644-2296

Ahmad A., Saima S., Parveen M., Ali E., Arif M., Yasin G., Akmal F. 2023.
Foliar application of nutrient for augmentation of rhizospheric heavy metal stress – growth and productivity of canola (Brassica napus L.*) measured with indices*.
J. Elem., 28(1): 145-159, DOI: 10.5601/jelem.2023.28.1.2334

RECEIVED: 12 September 2022
ACCEPTED: 19 January 2023

ORIGINAL PAPER

FOLIAR APPLICATION OF NUTRIENT FOR AUGMENTATION OF RHIZOSPHERIC HEAVY METAL STRESS – GROWTH AND PRODUCTIVITY OF CANOLA (*BRASSICA NAPUS* L.) MEASURED WITH INDICES

Aqsa Ahmad[1], Shahzadi Saima[1], Maqsoda Parveen[2], Ezin Ali[1], Muhammad Arif[1], Ghulam Yasin[1], Farah Akmal[1]

[1] Institute of Botany
[2] Department of Statistics
Bahauddin Zakariya University, Multan. Pakistan

Abstract

The experiment was conducted on three cultivars of canola (*Brassica napus* L.): Exceed, Cyclone and Legend, with the objective of investigating the alleviation of the rhizospheric lead toxicity by exogenous potassium. Seeds were germinated in pots and when plants were twenty-day-old, lead @15.0 and 30.0 mg kg^{-1} soil was added to pots. Plants were foliar sprayed twice with KCl solution. Plants were arranged in a completely randomized design. Various growth and production parameters were evaluated at physiological maturity. The fresh and dry weight of stems increased by 17.6% and 25.6%, correspondingly, when the plants were treated with KCl as compared to the control, but decreased by 20.4%, and 13.9%, respectively, in plants treated with 15.0 mg kg^{-1} of lead. These reductions in weight were higher under 30.0 mg kg^{-1} of lead applications. Roots (fresh and dry weight) of plants under the dual combination of lead and potassium decreased but this reduction was lower than in plants treated with lead only, which confirmed that potassium alleviated the toxic effect of the lead metal. The seeds (number and total yield) also decreased due to lead toxicity. The seeds (number and total yield) of plants under the dual combination of lead and potassium decreased, but this reduction was lower than in plants treated with lead only, which proved that potassium alleviated the toxic effect of lead.

Keywords: canola, growth, heavy metal, nutrient element, productivity

Ghulam Yasin, PhD, Institute of Botany, Bahauddin Zakariya University, Multan, Pakistan, e-mail: yasingmn_bzu@yahoo.com

INTRODUCTION

Canola, a source of edible oil for human consumption, is cultivated in many countries of the world. The name canola is a combination of two words: “CAN” (Canada) and “OLA” (oil), and originally was a symbol for the name of the Canadian Association for Rapeseed. It is now a term used for varieties of edible rapeseed in Australasia and North America. Rapeseed-mustard is important for increasing productivity of soils by promoting plant nutrient use efficiency (Ansari 2021). Rapeseed is now cultivated in China, Europe and Canada, and is used for livestock feed, industrial byproducts and edible oils. As reported by Song et al (2020), the hybridization of *B. oleracea* L. and *B. rapa* L. genomes resulted in rapeseed with a genome of 2 n=38 (AACC). Canola oil is reported to reduce heart disease risk, hypercholesterolemia and diabetes, etc. Canola meal is used as an absorbent, emulsifier, gelling agent, texturizer, etc., in a number of food products.

Changing environmental conditions create a number of abiotic stresses on plants, like shortage of water, salinity stress, temperatures stress, and nutritional deficiencies or metal toxicities. These stress agents can drastically influence plant growth and productivity (Verma et al. 2020).

The world population is rising gradually, and it is predicted to reach 9.8 billion by year 2050, which will necessitate an increase in crop production by 50%. This can be achieved by increasing the agricultural land area or by developing stress-tolerant crops. However, recent climate change events and growing urbanization make the latter option highly improbable (Srinivasan et al. 2013). Several environmental stresses can affect germination during the primary and critical stages of plant growth and development.

Heavy metals are the most dangerous ecological toxins and their increasingly frequent hazardous concentrations necessitate further investigations. Crops yields are badly affected by excessive quantities of toxic metals in the environment, from irrigation water contaminating arable lands and from motor vehicles. Lead is present in the environment in various forms. It occurs in the bound state or as a free metal ion in soil, where it interferes with the soil microorganisms (Vega et al. 2006). Plants can detoxify Pb by using three main pathways, i.e. an inducible method that involves decontamination and excretion into extracellular areas, a passive methodology where plants develop physical barriers to Pb uptake, and activation of an antioxidant defense system to satisfy Pb induced free radicals (Ashraf et al. 2015).

Due to harmful effects of heavy metal, plants develop detectable symptoms, such as chlorosis, root browning, stunted growth, decline and death (Ozturk et al. 2008). Toxicity of heavy metal denatures or inactivates many vital proteins and enzymes. Their reaction disrupts the integrity of membranes, resulting in the modification of basic plant metabolic reactions, such as respiration, homeostasis and photosynthesis (Hossain et al. 2012).

Furthermore, it promotes the production of reactive oxygen species (Krumova, Cosa 2016).

Potassium contributes to the stress tolerance in plants by adjusting the osmotic balance and through the ionic homeostatic mechanism. Many scholars support the concept that potassium improves the antioxidant defense in plants. Under a number of environmental adversities, potassium protects plants from oxidative stress. In addition, this element is contained in phytohormones and has some signaling association with other molecules (Tiwari et al. 2020). The particular molecular mechanisms of these defenses are still under investigation, even though immense progress has been made in identifying stress tolerance induced by potassium in plants. In this respect, latest information on the biological functions of potassium (K^+), its translocation, uptake, and role in tolerance to stresses has been revised (Hasanuzzaman et al. 2018). Keeping in view the above facts about lead, potassium and canola, this experiment was devised with the objective to examine the effects of lead stress on plant growth parameters and the ability of potassium foliar spray to reduce lead stress.

MATERIAL AND METHODS

The experiment was made to verify the effect of potassium chloride in augmenting the toxic effects of lead (Pb) on three cultivars of canola (*Brassica napus* L.): Exceed, Cyclone and Legend. It was carried in the Institute of Botany, Bahauddin Zakariya University, Multan.

Sixty plastic pots measuring 65 cm in diameter were used for plant growth. The soil for this experiment was collected from the Botanical Garden of Bahauddin Zakariya University, Multan. Analysis of the soil selected for the experiment was carried out in the laboratory of the Department of Botany, Bahauddin Zakariya University Multan. The soil was sandy loam in texture, with pH of 8.3, 1.4% organic matter and 5.0 ds/m EC. Each pot contained 5 kg of soil. Canola cultivars used in the research, i.e. Exceed, Cyclone, Legend, were bought from the Ayub Agriculture Research Institute, Faisalabad. Almost 90% of plant seeds germinated after 9 days since planting. The plants from each pot were thinned after 15 days, leaving 3 plants per pot. Manual weeding was performed to keep the plants free from weeds. The insecticide Thiodon was used to control the pests when necessary.

The plant pots were arranged in a completely randomized design (CRD) by cultivars and treatments. This was done to ensure the exposure of plants to all variants of environmental resources equally by cultivars and treatments. Lead used as a $PbCl_2$ solution was applied after 28 days of germination. Potassium was supplied as potassium chloride (KCl). The following treatments were established:

For all the cultivars, control plants (T_1) were grown without any treatment. The T_2, plants were sprayed only with potassium chloride. The T_3 pots were polluted with 15 mg kg^{-1} Pb. The T_4 pots were polluted with 15.0 mg kg^{-1} of lead and sprayed with potassium chloride. The T_5 pots received 30.0 mg kg^{-1} of lead only. The T_6 pots were polluted with 30.0 mg kg^{-1} of lead and sprayed with potassium chloride.

After eighteen days since the application of the treatments, data concerning growth parameters were taken. The analyzed growth parameters were stem (fresh and dry weight), root (fresh and dry weight) and length of plants. Other productivity parameters taken at the maturity of the crop were the number of siliques, 1000 seed weight, and the total yield. Stem, root and leaf fresh weight was measured by placing these plant organs on an electric measuring balance. The stem and root of each plant were put into a Kraft paper bag and placed in an oven at 60°C to achieve constant dry weight.

By applying a two-factorial analysis of variance with a completely randomized design (CRD), the data were evaluated statistically at ($P<0.05$). In addition, the Duncan's new multiple range test was made at 5% probability (Duncan 1955). For the interpretation of data, means and standard deviations were calculated.

RESULTS

Stem fresh weight (g)

Data in Table 1 summarize the response of three canola cultivars to different Pb metal concentrations (15.0 and 30.0 mg kg^{-1}) and the effect of KCl. They prove that the stem weight (fresh) differed highly significantly among the cultivars, and that there were highly significant differences among treatments. Also, non-significant differences were observed for cultivars and treatments.

Comparison of the 3 cultivars showed that V_1 (Exceed) has less stem weight (fresh) than V_3 (Legend) by 12.4%. The stem weight (fresh) of V_2 (Cyclone) was 38.04% higher than that of V_1 (Exceed). Low (15.0 mg kg^{-1}) and high (30.0 mg kg^{-1}) doses of lead decreased the stem weight (fresh) by 20.4% and 30.3%. An increase in the stem weight (fresh) was observed as 17.6% in the three cultivars under the application of KCl. The exogenous treatments with KCl compensated the reduction caused by the low and high concentrations of lead by 13.5% and 24.5%, respectively.

In the interactions of cultivars and treatments, the stem weight (fresh) in V_1 (Exceed) increased by 15% owing to potassium chloride relative to the control plant. In V_2 (Cyclone), the stem weight (fresh) increased following the application of potassium chloride by 18.9% compared to the untreated plants,

Table 1

Role of topically applied potassium chloride in alleviating lead stress effect on stem fresh weight in canola (*Brassica napus* L.), mean values (±SE)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean
V_1 (Exceed)	22±3.46	25.3±3.21	16.33±3.51	18±3	14±3	15±3	18.4±4.92 (a)
%age Difference		15	-25.9	-18.1	36.3	-31	
V_2 (Cyclone)	28±5.29	33.3±5.68	23±5.29	25±5.29	20.66±4.93	22.66±6.11	25.44±6.28 (b)
%age Difference		18.9	-17.8	-10.7	-26.4	-19.2	38.04
V_3 (Legend)	23.33±4.50	27.66±3.51	19±5	20.33±4.50	16.33±4.50	17.66±5.03	20.72±5.46 (b)
%age Difference		18.4	-18.4	-12.3	-30	-13.5	12.5
Mean LSD (3.03)	24.4±4.74 (a)	28.7±5.14 (b)	19.4±4.97 (bc)	21.1±4.88 (c)	17±4.69 (c)	18.4±4.69 (c)	21.5±6.22
%age Difference		17.6	-20.4	-13.5	-30.3	-24.5	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

in V_3 (Legend). The stem weight (fresh) decreased by 25.9% and 36.3% in V_1 (Exceed) under the influence of 15.0 mg kg^{-1} and 30.0 mg kg^{-1} lead, respectively, but decreased as 17.8% and 26.4% in V_2 (Cyclone) due to the above doses of lead. At the same level of stress, the decrease in the stem weight (fresh) in V_3 (Legend) was observed to be 18.4% and 30%. The stem weight (fresh) increased when potassium chloride was applied regardless of the applied dose of lead. It was noticed that potassium chloride compensated the stress effects of lead as 18.1% and 31% in V_1 (Exceed). In V_2 (Cyclone), KCl compensated the stress effects of lead by 10.7% and 19.2%, while 12.3% and 13.5% compensation was noticed in V_3 (Legend) when plants were supplied with lead in two concentrations along with KCl spray.

Stem dry weight (g)

In the Table 2, results for the dry weight of the stem differed very highly significantly by KCl and Pb treatments. Stem weight (dry) differed very highly significantly among cultivars. But adversity of Pb and the beneficial effect of potassium chloride was non-significant for both cultivars for different treatments.

Comparison among the cultivars showed that stem weight (dry) was slightly more expressed in V_2 (Cyclone) than in V_1 (Exceed) (9.09%). In V_3 (Legend), stem weight (dry) was less by 2.3%. The treatments with potassium

Table 2

Role of topically applied potassium chloride in alleviating lead stress effect on stem dry weight in canola (*Brassica napus* L.), mean values (±SE)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD 0.24)
V_1 (Exceed)	4.13±0.50	5.3±0.17	3.7±0.1	4.06±0.15	2.83±0.35	3.1±0.36	3.85±0.86 (a)
%age Difference		28.3	-10.4	-1.69	-31.4	-24.9	
V_2 (Cyclone)	4.5±0.26	5.4±0.30	3.83±0.11	4.16±0.05	3.56±0.15	3.66±0.11	4.2±0.68 (a)
%age Difference		20	-14.8	-7.5	-20.8	-18.6	9.09
V_3 (Legend)	4.33±0.15	5.56±0.15	3.8±0.36	4.16±0.25	3.4±036	3.46±0.15	4.1±0.78 [b]
%age Difference		28.4	-11.6	-3.92	-21.4	-20.09	-2.3
Mean LSD (0.17)	4.33±0.33 (a)	5.44±0.22 (b)	3.77±0.20 (b)	4.13±0.15 (c)	3.26±0.42 (d)	3.41±0.32 (d)	4.05±0.77
%age Difference		25.6	-13.9	-3.95	-22.6	-20.9	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

chloride resulted in an increase in the stem weight (dry) by 25.6%. Both concentrations of lead caused the reduction in stem weight (dry) by 13.9% and 22.6%, respectively. Potassium chloride treatments given to plants along with either concentration of Pb had a positive effect on stem weight (dry). It reduced the stress effect of low and high dose of Pb by 3.9% and 20.9%, respectively.

Interactions among cultivars and treatments showed that stem weight (dry) in V_1 (Exceed) was positively affected by the application of potassium chloride spray by increasing by 28.3% relative to the control plants. At the same level of potassium chloride treatments, stem weight (dry) in V_2 (Cyclone) increased by 20%, while in V_3 (Legend) it increased by 28.4%. Stem weight (dry) decreased by 10.4% and 31.4% in V_1 (Exceed) under the effect of 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead, respectively, and in V_2 (Cyclone) it decreased by 14.8% and 20.8%. In V_3 (Legend), a decrease in stem weight (dry) was observed to be 11.6% and 21.4%. When spraying with potassium chloride was applied, it compensated the stress effects of Pb by 1.6% and 24.9% in V_1 (Exceed), by 7.5% and 18.6% in V_2 (Cyclone), and by 3.9% and 20.09% in V_3 (Legend).

Root fresh weight (g)

Root weight (fresh) data revealed highly significant differences between the treatments (Table 3) and cultivars. Collaboratively, the treatments of various cultivars differed non-significantly.

Table 3

Role of topically applied potassium chloride in alleviating lead stress effect on root fresh weight in canola (*Brassica napus* L.)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD 1.41)
V_1 (Exceed)	16.03±1.11	21±2.13	11.5±1.79	14.2±2.26	9.06±2.06	10.03±2.17	13.6±4.48 (a)
%age Difference		31	-28.2	-11.4	-43.4	-37.4	
V_2 (Cyclone)	19.4±0.85	24.6±1.10	14.5±1.1	16.9±1.15	12.8±0.86	13.2±1.45	16.9±4.34 (a)
%age Difference		26.8	-25.2	-12.8	-34	-31.9	24.2
V_3 (Legend)	19.03±1.48	23.2±1.38	14.9±1.58	17.3±1	12.1±0.76	13.6±0.90	16.7±3.92 (b)
%age Difference		21.9	-21.7	9.09	-36.4	-28.5	22.7
Mean LSD (0.99)	18.15±1.89 (a)	22.9±2.10 (b)	13.6±2.08 (c)	16.1±1.99 (d)	11.3±2.07 (de)	3.41±2.20 (e)	15.7±4.43
%age Difference		23.7	-27.07	-11.04	-37.5	-81.16	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

A comparison of the three cultivars showed that root weight (fresh) was slightly more expressed in V_2 (Cyclone) and V_3 (Legend), at 24.2% and 22.7%, than in V_1 (Exceed). A greater increase in fresh weight was observed (23.7%) under the application of potassium chloride. The lower lead dose decreased the root weight (fresh) by 27.7% and the high lead dose application decreased the root weight (fresh) by 37.5%. Potassium chloride treatments provided to plants along with both concentrations of Pb had a positive effect on root weight (fresh). It reduced the stress effect of the low and high dose of Pb by 11.04% and 81.1%, respectively.

A comparison between cultivars and treatments showed that root weight (fresh) in V_1 (Exceed) increased as a result of the application of potassium chloride by 31%. In V_2 (Cyclone), the root weight (fresh) increased owing to the application of potassium chloride by 26.8%, while in V_3 (Legend) it increased by 21.9%. Root weight (fresh) decreased by 28.2% and 43.4% in V_1 (Exceed) due to the application of 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead, respectively, and the decrease in V_2 (Cyclone) was 25.2 and 34%, respectively, while in V_3 (Legend), the reduction of root weight (fresh) caused by 15.0 mg kg^{-1} and 30.0 mg kg^{-1} Pb was 21.7% and 36.4%, respectively. When potassium chloride was supplied in the presence of both concentrations of lead stress, it compensated the stress effects of Pb by 11.4 and 37.4% in V_1 (Exceed), by 12.8 and 31.9% in V_2 (Cyclone), and by 9.09% and 28.5% in V_3 (Legend).

Root dry weight (g)

Root weight (dry) differed very highly significantly among the cultivars. It was noted that root weight (dry) differed also highly significantly for the treatments. Differences of the interaction of treatments and cultivars were non-significant.

Table 4

Role of topically applied potassium chloride in alleviating lead stress effect on root dry weight in canola (*Brassica napus* L.)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD 0.16)
V_1 (Exceed)	3.63±0.05	4.53±0.30	2.76±0.05	3.23±0.15	2.46±0.05	2.63±0.05	3.21±0.73 (a)
%age Difference		25	-25	-11.1	-32.2	-27.5	
V_2 (Cyclone)	3.46±0.15	4.26±0.11	2.93±0.15	3.2±0.1	2.53±0.15	2.73±0.15	3.18±0.59 (b)
%age Difference		23.1	-15.3	-7.51	-26.8	-21.09	-0.93
V_3 (Legend)	3.53±0.15	4.3±0.20	3.06±0.25	3.5±0.26	2.63±0.15	2.9±0.2	3.33±0.60 [b]
%age Difference		21.8	-13.7	-0.84	-25.4	-17.8	4.71
Mean LSD (0.11)	3.54±0.13 (a)	4.3±0.22 (b)	2.92±0.19 (c)	3.31±0.21 (d)	2.54±0.13 (e)	2.75±0.17 (f)	3.24±0.64
%age Difference		22.8	-17.5	-6.49	-28.5	-22.3	

T_1 – control,T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb,T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

When the three cultivars were compared, it emerged that root weight (dry) was slightly more expressed in V_3 (Legend) than in V_1 (Exceed) and V_2 (Cyclone) by 4.71%. V_1 (Exceed) has more root weight (dry) by 0.93% compared to V_2 (Cyclone). An increase in root weight (dry) was expressed as 22.8% under the application of potassium chloride. Application of the low lead dose decreased the root weight (dry) by 17.5% and the high lead dose decreased the dry weight by 28.5%. The application of KCl lessened the effect of lead and decreased the stem length by 6.49% instead of 17.5% due to the application of 15.0 mg kg^{-1} of lead, while the 30.0 mg kg^{-1} of lead dose decreased root weight (dry) by 22.3% instead of 28.5%.

A comparison between the treatments and cultivars demonstrated that the application of potassium chloride increased the root weight (dry) by 25% in V_1 (Exceed), in V_2 (Cyclone) by 23.1%, and in V_3 (Legend) by 21.8% (Table 4). Root weights (dry) were reduced by 25% and 32.6% in V_1 (Exceed) exposed to 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead, respectively. In V_2 (Cyclone), root weight (dry) decreased by 15.3 and 26.8% under the effect of these two doses of lead, respectively, while in V_3 (Legend), the reduction of root weight (dry) due to 15.0 mg kg^{-1} and 30.0 mg kg^{-1} Pb was 13.7% and 25.4%, respectively, relative to the control. When potassium chloride was supplied along with 15.0 mg kg^{-1} and 30.0 mg kg^{-1} doses of lead, it compensated the stress effects of Pb by 11.1 and 27.5% in V_1 (Exceed), by 7.5% and 21.9% in V_2 (Cyclone), and by 0.84% and 17.8% in V_3 (Legend).

Number of siliques

The ANOVA showed that the number of siliques differed very highly significantly among the cultivars and treatments (Table 5), while differences between the interactions of treatments and cultivars were non-significant.

A comparison of the three cultivars revealed that the number of siliques was slightly more expressed in V_1 (Exceed) than in V_2 (Cyclone) as 10.07%. In V_3 (Legend), the number of siliques was higher by 16% than in V_1 (Exceed). Both concentrations of lead decreased the number of siliques

Table 5

Role of topically applied potassium chloride in alleviating lead stress effect on the number of siliques in canola (*Brassica napus* L.)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD=9.57)
V_1 (Exceed)	108.3±10.4	141.6±7.63	75±5	97.3±11.6	58±6.5	66±3.55	91.05±30.09 (a)
%age Difference		30	-30.7	-10.1	-46	-39	
V_2 (Cyclone)	96±6.55	129±3.60	70±4.35	82.6±7.50	50.3±6.65	63.3±6.02	81.88±26.7 (b)
%age Difference		34.3	-27	-13.9	-47.6	-34	-10.07
V_3 (Legend)	124±14.9	149±11.5	92±12.4	111±16.3	78±15.71	85.3±13.50	106.5±27.8 (c)
%age Difference		20.1	-25.8	-10.4	-37	-31.2	16
Mean LSD (6.77)	109.4±15.5 (a)	139±11.3 (b)	79±12.2 (c)	97±16.3 (d)	62.11±15.3 (de)	71.5±12.88 (e)	93.16±29.57
%age Difference		27	-27.7	-11.3	-43.2	-34	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl by 27.7% and 43.2%, respectively. There was an observed increase in the number of siliques as 27% under the application of potassium chloride. Both concentrations of lead were compensated by potassium chloride, reducing the stress effect by 11.3% and 34%, respectively.

An analysis of the interactions between the cultivars and treatments showed that the number of siliques in V_1 (Exceed) increased owing to the application of potassium chloride by 30%. In V_2 (Cyclone), the number of siliques increased following the application of potassium chloride by 34.3%, and by 20.1% in V3 (Legend). The number of siliques decreased by 30.7% and 46% in V_1 (Exceed) under the effect of 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead, respectively. The number of siliques decreased by 27% and 47.6% in V_2 (Cyclone) by supplying 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead. In V_1 (Exceed), the decrease in the number of siliques was 25.8% and 37%. When potassium chloride was applied, it compensated the stress effects of Pb by 10.1% and 39% in V_1 (Exceed), 13.9% and 34% in V_2 (Cyclone), and 10.4% and 31.2% in V_3 (Legend) – Table 1.

Weight of 1,000 seeds (g)

The data from the different treatments concerning the weight of seeds show that the treatments differed very highly significantly while differences between the cultivars were non-significant. When combined results for the cultivars and treatments were considered, the differences were non-significant (Table 6).

Table 6

Role of topically applied potassium chloride in alleviating lead stress on the weight of 1,000 seeds in canola (*Brassica napus* L.)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD 0.01)
V_1 (Exceed)	48±2	58±4	34±1	44±2	30±2	34±2	41.6±10
%age Difference		20.8	-29.1	-8.33	-37.5	-29.1	
V_2 (Cyclone)	50±2	60±2	36±1	42±1	28±2	32±1	42±10
%age Difference		20	-28	-16	-44	-36	0.96
V_3 (Legend)	48±1	58±2	36±1	44±2	30±2	28±2	41±10
%age Difference		20.8	-25	-8.33	-37.5	-41.6	-1.44
Mean LSD (0.007)	48±1.6 (a)	58±2 (b)	36±1.2 (c)	42±1.6 (d)	28±2 (e)	32±2 (f)	41.6±10
%age Difference		20.8	-25	-12.5	-41.6	-33.3	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

When the three cultivars were compared, the weights of 1,000 seeds of the Cyclone cultivar increased by 0.96% than that of the Exceed cultivar. The weight of 1,000 seeds of the Legend cultivar decreased by 1.44% than that of the Exceed cultivar. An increase in the weight of 1,000 seeds was observed in the three cultivars under the application of potassium chloride as 20.8%. The low (15.0 mg kg^{-1}) and high (30.0 mg kg^{-1}) doses of lead reduced the weight of seeds by 25% and 41.6%. Both levels of lead stress were compensated by potassium chloride up to 12.5% and 33.3%.

The interactions between the cultivars and treatments revealed that the seed weight in cv. Exceed increased by 20.8% owing to the exogenous application of potassium chloride. In cv. Cyclone, the seed weight increased by 20% due to the application of potassium chloride, while in cv. Legend the stem length increased by 20.8%. Decreased The root length in cv. Exceed was observed to decrease by 29.1% and 37.5% when 15.0 mg kg^{-1} and 30.0 mg kg^{-1} of lead were applied, respectively. The seed weight decreased by 28% and 44% in cv. Cyclone and by 25% and 37.5% in cv. Legend in response to these doses of lead. When exogenous potassium chloride was applied, it compensated the stress effects of Pb by 8.3% and 29.1% in cv. Exceed, by 16% and 36% in cv. Cyclone, and by 8.3% and 41.6% in cv. Legend.

Total yield (g)

The ANOVA results (Table 7) revealed that total yield differed highly significantly among the cultivars and the treatments. There were also non-significant differences among the treatments and cultivars evaluations.

Table 7

Role of topically applied potassium chloride in alleviating lead stress effect on total yield in canola (*Brassica napus* L.)

Specification	T_1	T_2	T_3	T_4	T_5	T_6	Mean (LSD 0.98)
V_1 (Exceed)	12.8±1.43	26.51±2.49	4.94±0.36	8.71±1.25	2.43±0.35	3.88±0.30	9.88±8.49 (a)
%age Difference		107.03	-61.4	-31.9	-81.01	-69.6	
V_2 (Cyclone)	11.7±0.54	25.8±1.20	4.61±0.27	7.39±0.49	1.98±0.39	3.71±0.20	9.21±8.30 [b]
%age Difference		120.5	-60.5	-36.8	-83.07	-68.2	-6.78
V_3 (Legend)	16.6±1.94	27.7±4.28	6.39±0.86	10.6±1.15	3.49±0.69	4.17±0.88	11.5±8.94 (b)
%age Difference		66.8	-76.9	-36.1	-78.9	-74.8	16.3
Mean LSD (1.38)	13.7±2.54 (a)	26.7±2.69 (b)	5.31±0.95 (c)	8.93±1.68 (d)	2.63±0.80 (e)	3.92±0.52 (e)	10.2±8.48
%age Difference		94.8	-61.2	-34.8	-80.8	-71.3	

T_1 – control, T_2 – 0 mg kg^{-1} Pb + KCl, T_3 – 15.0 mg kg^{-1} Pb, T_4 – 15.0 mg kg^{-1} Pb + KCl, T_5 – 30.0 mg kg^{-1} Pb, T_6 – 30.0 mg kg^{-1} Pb + KCl

An analysis of the three cultivars showed that total yield was 6.78% higher in V_1 (Exceed) than in V_2 (Cyclone). In cv. Legend, total yield 16.3% higher than in cv. Exceed. Both concentrations of lead reduced the total yield by 61.2% and 80.8%. Under the application of potassium chloride, an increase of 94.8% in total yield was observed. The application of KCl compensated for the stress effect of the low concentration of lead, as the total yield decreased by 34.8% instead of 61.2%, and that of the high concentration, where the decrease in total yield was 71.3% instead of 94.8%.

The interactions between the cultivars and treatments showed that the total yield in V_1 (Exceed) increased by 107.03% owing to the application of potassium chloride. In V_2 (Cyclone), the total yield increase by the application of potassium chloride was 120.5%, and in V3 (Legend) – 66.8%. Total yield decreased by 61.4% and 81.04% in V_1 (Exceed) by supplying 15.0 mg kg^{-1} and 30.0 mg kg^{-1} lead, respectively. In V_2 (Cyclone) total yield decreased in response to 15.0 mg kg^{-1} and 30.0 mg kg^{-1} lead (60.5% and 83.07%). While in V3 (Legend), a decrease in total yield was observed at 76.9% and 78.9%. When potassium chloride was applied, it compensated for the stress effects of lead by 31.9% and 69.6% in V_1 (Exceed), 36.8% and 68.2% in V_2 (Cyclone), and 36.1% and 74.8% in V3 (Legend) – Table 7.

DISCUSSION

The findings from this study illustrate the response of three canola (*Brassica napus* L.) cultivars: Exceed, Cyclone, and Legend, to metal stress (lead), and their development when supplied potassium chloride. Under the metal stress (lead) and potassium chloride treatments, the growth parameters of the three cultivars were compared with the control (without any treatment) plants and with each other. Plants growing in a metal stressed environment showed reduction in growth due their affected physiological and biochemical metabolism (Asati et al. 2016).

The most crucial component for crop growth and high, good quality yield is nitrogen fertilizer, which increases the photosynthetic rate, produces more metabolites, stimulates meristematic activity, and transports nutrients to seeds. Increased nitrogen levels result in higher seed yield and yield characteristics (Noreen et al. 2016). In our study, the plant growth and yield also increased after the application of nitrogen fertilizer.

Our results showed that heavy metal stress (Pb) decreased the growth (stem and root length) of canola cultivars. Similar findings were observed in another experiment, caried out by Varma and Jangra (2021), where plants developing on soil contaminated with heavy metals showed decreased growth because of variations in their biochemical and physiological activities. Various negative consequences of plant exposure to metal stress were explored in their review, in addition to methods of creating plant resistance to metal stress. Industrial waste and sewage disposal are sources of Fe, Cr, Ni, Co, Cd, Mn, Cu, Pb, Zn, and Hg in soils (Varma, Jangra 2021). Plants absorb lead from the soil and retain the majority of this element in the roots. However, there is evidence that aerial parts may also accumulate some lead. Lead reduced the stem and root extension and leaf growth (Juwarkar, Shende 1988). Inhibition of root extensions depends on the absorption of lead and ionic structure and the pH of a medium. Root growth inhibition dependent on concentrations of lead has been noticed in *Sesamum indicum* L. (Kumar, Singh 1993). In many plant species, a high lead level in soil stimulates irregular morphology (Asati et al. 2016).

Results of the experiments conducted by Hasanuzzaman and co-workers demonstrated that under stress and in physiological situations, potassium is essential for plant survival. It is a biological component, which demonstrates regulatory activities in physiological and biochemical processes that support plant growth and development. The role of K^+ in a proper plant growth and development is investigated in this study. It boosts the plant's tolerance to stresses (Hasanuzzaman et al. 2018). In our study, it has been demonstrated that potassium enhanced the growth of canola plants and alleviated the toxic effects of heavy metal (lead). Potassium has an important function in plant development and physiological characteristics under normal circumstances. Several investigations have also shown that K^+ is an important protective role against abiotic stress.

This study also showed a decrease in growth parameters of canola plants under the two levels of lead in soil. The effect of lead toxicity on the roots was stronger than on stems in all canola cultivars. In soil, lead (Pb) is universally the most toxic component. It produces harmful effects on the growth, morphology, and photosynthetic processes of plants. Lead has also been reported to prevent seed germination (Mrozek, Funicelli 1982). Similar studies by other researchers have revealed that the stem and root biomass decreased due to lead toxicity (Ashraf et al. 2015). Declines in yield parameters were recorded. Effects of metal stress on crop yield have been reported by other scholars (Khan et al. 2009).

CONCLUSION

Exceed, Cyclone, and Legend were the three canola (*Brassica napus* L.) cultivars used in the experiment, which was carried out in the Bahauddin Zakariya University's research laboratory and botanical garden in Multan, Pakistan. When compared to control plants, plants treated with 15 mg kg^{-1} and 30 mg kg^{-1} of lead had lower fresh weight, dry weight, the number of siliques, and yield. The goal was to learn more about how potassium supplements applied topically can reduce the effects of rhizospheric lead toxicity. When the plants were treated with KCl, the weight of the stems, both fresh and dry, rose. The study revealed that the application of potassium significantly alleviated the effects of the heavy metal.

Conflict of interest

Authors have no conflict of interest and there was no funding body for research and manuscript.

Authors' contribution

Ghulam Yasin designed and conducted the experiment. Aqsa Ahmad and Farah Akmal participated in data collection. Shahzadi Saima, Ezin Ali and Muhammad Arif participated in manuscript drafting and proofreading. Maqsoda Parveen analysed the data statistically.

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