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The effect of selenium on salinity stress and selenate – sulfate comparision in kale

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ABSTRACT

Increased salinity is a threat to arid and semiarid zone agriculture worldwide. Kale consumption has increased as its nutritional and antioxidant benefits become more widely known. Compared with other vegetables, it is relatively salt tolerant. However, there is limited information on its salt tolerance, nutrient uptake under saline conditions, and physiological response. We examined the yield response, physiological parameters, and mineral nutrient content of kale grown under variable conditions of salt and Se addition in a greenhouse study. The experiment consisted of four salinity levels, four Se levels, and combined salinity treatments for a total of 16 treatments each with four replications. Salinity decreased yield when irrigated at 6 and 9 dS m^{-1} but not at 3 dS m^{-1}. Selenium addition increased yield at all salinity levels but did not increase salt tolerance. Addition of 0.25 mg Se per kg of soil, corresponding to leaf Se concentrations of 1 mg kg^{-1}, was sufficient to increase yield by an average of 11% relative to control. Kale yield loss began between 3 and 6 dS m^{-1} irrigation water salinity and 50% yield loss occurred at EC 6.

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Kale; salinity; selenium; yield

Introduction

Salinity is one of the biggest abiotic plant stress conditions and a common problem worldwide content in experiment where that reduces yield in agricultural production. Kale (Brassica *oleracea L.*) is very similar to cabbage, the vegetable is open leaved and the oldest variety of Brassica. It has very high nutritional value and antioxidant activity. Kale consumption has increased substancially in recent years as its nutritional value has been highlighted in sudies and the popular press; however, additional study is needed on both nutritional quality and response to salinity. Kale is reported to have optimal yield when irrigated with waters with electrical conductivities of the saturation extract in the 2.3 ± 5.5 dS m^{-1} range (Shannon and Grieve 1999). There are very few studies on kale and cabbage response to salt stress (Salachna, Piechocki, and Byczyńska 2017). Several studies have indicated that Se, even at low concentrations, protects plants from salt stress (Terry et al. 2000; Kong, Wang, and Bi 2005).

Selenium is an important micro-element for human and animal nutrition, but is toxic to humans and animals when taken in high doses. Through its antioxidant content and biotic and abiotic stress tolerance, studies on Se have shown that it significantly increases and improves other physiologic parameters (Mora et al. 2015). Selenium provides a benefical contribution to plant growth and development and product quality due to its antioxidative effects.

The chemistry and transport of selenate and sulfate in soils is similar, with selenate slightly more mobile than selenite. Sulfate also competes with selenate for sorption sites because both

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may only form outer-sphere complexes with soil minerals (Mora et al. 2015). Selenium uptake by plants is mostly as selenate, the predominant form in oxidized soil environments. Both selenate and sulfate use the same pathways for plant transport and assimilation. (Cabannes et al. 2011), As they use the same pathway, selenate uptake can be strongly decreased under conditions of high sulfate concentration (Suarez, Grieve, and Poss 2003) . Selenate also competitively inhibits sulfate uptake from nutrient solutions, but this inhibition is unlikely to be significant in soil-grown plants because the concentration of selenate in soil solution is generally several orders of magnitude lower than that of sulfate.

Recent studies have identified a number of selenate-resistant mutants of *Arabidopsis thaliana*; the phenotype is caused by a mutation in the high-affinity sulfate transporter Sultr1;2 resulting in decreased uptake of both sulfate and selenate (Shibagaki et al. 2002; El Kassis et al. 2007). Sultr1;2 is localized in the root tip, root cortex, and lateral roots, and its expression is enhanced by S deficiency. Sulfate supply influences selenate uptake not only through a direct competition for membrane transporters, but also through regulation of the expression of sulfate transporter genes. Sulfur-deficient plants up-regulate the expression of sulfate transporter genes, leading to a strong increase in the capacity for selenate uptake (Li, McGrath, and Zhao 2008; Shinmachi et al. 2010).

Nutrient uptake is affected by the membranes selectivity and nutrient interactions. Therefore, some nutrient uptake can be decreased or increased by plant. Thus, it can affect plant yield.

The objectives of this study were to determine the effects of selenium on kale response to salt stress, the effect of salinity on yield as well as selenate and sulfate uptake, nutrient contents, and physiological parameters.

Materials and methods

Plant material, growth conditions and treatments

This study was carried out in the USDA Salinity Laboratory, Riverside, CA, USA (lat. 33E58’24′, long. 117E58’12′) in 2015. Kale was used as the test plant, with seeds planted in plastic viols. Experimental treatments were started after kale plants had 4–5 leaves. Kale was grown in containers with 4 kg of soil in glass greenhouse. Greenhouse temperature was maximum 25 °C. Electrical conductivities (ECs) of the irrigation waters were 0.65, 3, 6, and 9 dS^{-1}. In order to obtain target EC values, $CaCl_2$, $MgCl_2$, and $NaCl_2$ were added to tap water using the model reported by Suarez and Taber (2007) (EXTRACT CHEM). The control salinity was 0.65 dS m^{-1} in all experiments. In this study additional SO_4 beyond adequate levels in the irrigation water (0.73 mmole $L^{-1}$was not given as salt applications not to decrease selenate uptake and to compare selenate and sulfate uptake). Selenium was given as $NaSeO_4$ (sodium selanate). A total of 64 pots were used in the study. The pots were irrigated with Hoagland’s modified solution every day. The irrigation water for the 16 treatments was stored in individual tanks. Treatments began after four true leaves were fully expanded. The experimental design consisted of control and four concentrations of Se 0, 0.25, 1, and 2 mg L^{-1} as sodium selenate, with each Se level tested at the four salinity levels. Each treatment was replicated four times. After 60 days of treatment, leaf samples were harvested. Initial properties of the soil used in this experiment were pH 7.27 and soil extract EC, 1.27 dS m^{-1}.

Two days before the harvest plant photosynthetic rate (Pn), stomatal conductance (gs), transpiration rate (Tr), and concentration of intercellular CO_2 (Ci) were measured with portable LICOR 6400 photosynthesis system at 10.00–11.00 am. SPAD values as relative chlorophyll values were measured using a leaf chlorophyll meter (SPAD-502, Minolta, Osaka, Japan). The average chlorophyll content of three leaves of each pot was used for estimating the chlorophyll content.

Plant tissues digested with nitric acid (HNO_3) using a microwave-digestion system (CEMMars 5, manufactured by CEM Corp., Matthews, NC, USA). Plant ion concentration (total S, Se, Ca, Na, K, Fe, Cu, Zn of the leaf tissue) determined by inductively coupled plasma optical emission

Table 1. Kale yield as related to Se and salt applications.

		Se doses (mg L^{-1})				
	Salt level (dS^{-1})	Control (0.19)	0.25	1	2	Mean
Wet weight(g)	Control	105*Ba**	108*Ba*	126*Aa*	105*Ba*	111
	3	104Ba	104*Ba*	*99Bb*	*122Aa*	107
	6	50*Bb*	75*Ab*	54*Bc*	54*Bc*	58
	9	35*Ac*	39*Ac*	40*Ad*	41*Ad*	39
	Mean	73	81	80	81	
Dry weight(g)	Control	*13Ba**	13*ABa*	15*Aa*	12*Bb*	13
	3	12*Ba*	11*Bb*	11*Bb*	14*Aa*	12
	6	6*Bb*	10*Ab*	7*Bc*	7*Bc*	8
	9	5*Ab*	6*Ac*	6*Ac*	6*Ac*	6
	Mean	9	10	10	10	

*Italic letters shows the difference between selenium × salinity interaction.

spectrometry (ICP-OES), and chloride was determined on nitric acetic acid extracts by coulometric-amperometric titration.

Fresh weights were measured after cutting plants at the soil surface. Plants were washed first with tap and then with deionized water and dried in an oven at ±65 °C until weight was stable. Dry weight of plants measured on an analytical balance.

The experiment and statistical model was randomized complete block design. The obtained data were analyzed by variance analysis technique. There are four levels of salinity (EC) factor (0.65, 3, 6, and 9 dS m^{-1}) and four levels of Se factor (control, 0.25, 1, and 2 mg L^{-1}). The number of observations in subgroups is three. In the study, Tukey multiple comparison test was used to determine the differences between the factor averages.

Results and discussion

As seen in Table 1 selenium × salinity interactions were significant, and kale fresh and dry weights started to decrease with increasing salinity above EC 3 dS m^{-1} under control Se conditions (Figures 1, 2). Control and 3 dS m^{-1} salt treatment were similar for both wet weight and dry weights. At EC 6 dS $^{-1}$, yield was 50% of control due to salt stress. Salt tolerance is expressed in terms of relative yield, that is yield under salt treatment divided by yield under control, often expressed as EC level at which yield loss of 50 occurs (Malcolm and Smith 1971; Shannon and Grieve 1999). The yield losses due to salinity also occurred for the elevated Se treatments (Table 1). Again the 50% yield loss occurred around EC 6 dS m^{-1}. Thus, Se application did not result in increased salt tolerance. This is in contrast to the earlier report that Se supplementation increases salt tolerance (Terry et al. 2000; Kong, Wang, and Bi 2005).

The yields under Se application across all salinities were somewhat greater in the treatments with added Se. Under low salinity, dry and wet weight of kale plants increased with increasing Se application, suggesting Se application was beneficial. Across all salinity levels, application of 0.25 mg L^{-1}Se was sufficient. Selenate addition thus increased yields somewhat across all salinity levels but did not increase salt tolerance.

The leaf ion data in Table 2 indicate that kale leaf selenium concentrations increased with Se applications as expected. The selenium × salinity interaction was significant on Se concentration. The response was highly nonlinear, however, with an increase of Se from control (0.19 mg kg^{-1}) to first Se treatment, resulting in a tenfold increase in leaf Se, across all salinity levels (Table 2). Control plants are below the sufficient rate, and it is considered essential for plant growth. With subsequent additions of Se, twofold Se additions in applications resulted in fourfold increases in leaf Se. Earlier, Grace, Craighead, and Watt (2000) found that the concentrations of leaf Se doubled with Se fertilizer of kale plants. Researchers applied 5 g Se ha^{-1} and found, while control had 0.14 mg kg^{-1} Se applied leaves had 0.34 mg kg^{-1} Se.

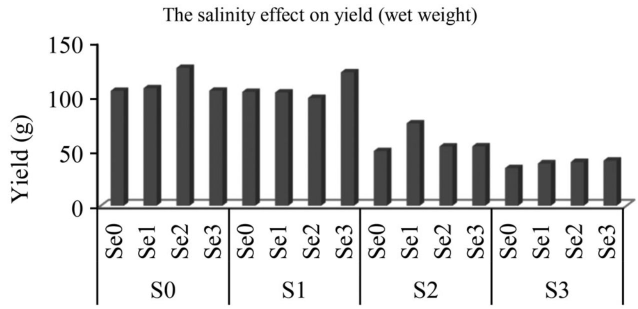

Figure 1. The salinity effect on yield.

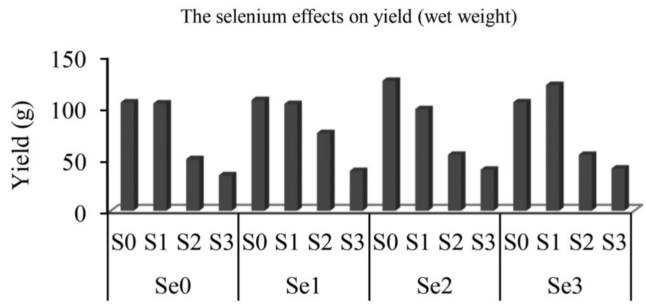

Figure 2. The selenium effect on yield.

The leaf Se concentrations decreased significantly with salt applications, even though the sulfate concentrations were constant for all treatments. The control contained 0.19 mg kg^{-1} Se, and with the salt applications the Se concentrations decreased to 0.03, 0.07, and 0.07 mg kg^{-1}, respectively for the EC 3, 6, and 9 dS m^{-1} salinity treatments.

The leaf S concentrations decreased significantly with increasing salinity for all Se levels (Table 2). Selenium × salinity interaction was significant, the leaf S concentrations showed a slight, generally nonsignificant increase with Se applications, in contrast to the expected response of reduced S uptake with increased Se application. Although S was constant for all treatments, the increase with the Se application can be explained by physiological mechanism. Among the other elements examined only S concentrations decreased with salt applications since SO_4 was never given as a salt. While the control of leaves S concentration was 4.8, the salt applications leaves S concentration were 3.8, 2.3, and 2.0 mg kg^{-1}, respectively.

Se uptake and accumulation depends on different plant species, and plants can be classified as Se accumulators and non-accumulators. The accumulation of Se by agricultural plants is dependent on the plant species, soil properties, and the chemical form of Se. Brassicacea species are able to uptake more Se due to more ability to accumulate *S. Brassicaceae* species such as Indian mustard (*Brassica juncea* L.), broccoli (*Brassica oleracea botrytis* L.), and canola (*Brassica napus spp. oleifera* L.) have been classified as primary accumulators. The critical Se concentration in plant tissues, which decreased the yield in Indian mustard was 105 µg g^{-1} DW, in maize (*Zea mays* L.) 77 µg g^{-1} DW, in rice (*Oryza sativa* L.) 42 µg g^{-1} DW, and in wheat 19 µg g^{-1} DW, a levels attained by Se addition as selenite of 5 µg g^{-1} soil for Indian mustard and maize, 4 µg g^{-1} soil for wheat, and 10 µg g^{-1} soil for rice (Rani, Dhillon, and Dhillon 2005). Zayed and Terry (1992) examined black mustard (*Brassica nigra* L.) and broccoli (*Brassica oleracea botrytis* L.), which are varieties of Brassica that accumulate relatively large amounts of Se and may contain, and tolerate, several hundred *µ*g Se g^{-1} shoot dry weight. Some plants of Se concentrations in shoots were *Astragalus pectinalus* 4 mg kg^{-1}, *Stanleya pinnata* 330 mg kg^{-1}, *Gutierrezia fremontii* 70 mgkg^{-1},

Table 2. The effects of Se and salt applications on Se, S, B, Fe, Zn, Cu, Cl concentrations in kale leaves.

		Selenium doses (mg L^{-1})				
Nutrients mg L^{-1}	Salt level (dS^{-1})	Control	0.25	1	2	Mean
Se	Control	0.19 *Da******	2*Ca*	11.7*Ba*	21.6*Aa*	8.9
	3	0.03*Ca*	0.8*Cab*	4.1*Bb*	12.1*Ab*	4.3
	6	0.07*Ca*	0.7*Cab*	3.9*Bb*	10.9*Abc*	3.9
	9	0.07*Ca*	0.6*Cb*	3.4*Bb*	10.5*Ac*	3.6
	Mean	0.09	1.0	5.8	13.8	
S	Control	4.8*Aa*	5.3*Aa*	5.5*Aa*	5.3*Aa*	5.2
	3	3.8*Abab*	4.1*ABb*	3.0*Bb*	4.4*Aa*	3.8
	6	2.9*Ab*	2.1*Ac*	2.3*Ab*	2.1*Ab*	2.3
	9	1.5*Abc*	1.4*Bc*	2.4*Ab*	2.6*Ab*	2.0
	Mean	3.2	3.2	3.3	3.6	
B	Control	21.2	33.3	27.8	28.2	27.6A*
	3	5	7.4	3.7	7.4	5.9B
	6	2.5	2.2	2.3	2.1	2.3B
	9	1.4	2.0	22	2.2	2.0B
	Mean	7.5	11.2	9.0	10.0	
Zn	Control	18.17	18.84	18.46	18.54	18.50A
	3	17.51	17.43	17.96	18.03	17.73B
	6	17.70	17.44	17.25	17.12	17.38BC
	9	16.64	17.23	17.48	17.06	17.10C
	Mean	17.50	17.73	17.78	1768	
Cu	Control	2.12	2.573	2.633	2.405	2.439A
	3	0.95	1.17	0.71	1.19	1.01B
	6	0.57	0.50	0.59	0.50	0.54C
	9	0.38	0.42	0.47	0.50	0.44C
	Mean	1.01	1.17	1.10	1155	
Cl	Control	169	175	134	137	154
	3	609	774	747	618	687
	6	844	815	737	684	770
	9	988	972	941	777	919
	Mean	652a**	684a	639ab	554b	
Fe	Control	29*Ad*	24*Ac*	21*Ad*	24*Ac*	24
	3	21*Ac*	18*Ab*	16*Ac*	15*Ab*	17
	6	35*Ab*	35*Aa*	29*Ab*	33*Aa*	33
	9	43*Aba*	42*Ba*	50*Aa*	35*Ba*	42
	Mean	25	24	24	22	

*Capital letters shows the difference between salt applications;
**Lower case letters shows the difference between selenium applications;
***Italic letters shows the difference between selenium × salt interaction.

Zea mays 10 mg kg^{-1}, *Helianthus annuus* 2 mg kg^{-1}(Shrift 1969). Our leaf Se concentrations were thus well below any potentially toxic level. The bioavailability of selenate ions in soils is higher than selenite ions and is generally decreased with increasing amounts of clay, organic matter, iron oxide, sulfate ions concentration, and lower soil pH value. Genetic differences in the Se uptake were observed for many plants.

Sulfur-rich plants like the Brassica spp. (mustard, cabbage, broccoli, and cauliflower) and other Cruciferae are good concentrators of Se. In a study by Slekovec and Goessler (2005), the highest Se concentration was determined in onion and radish leaves (37.4 and 37.1 mg kg^{-1}) followed by leaves of garlic (19.6 mg kg^{-1}) and cabbage (11.9 mg kg^{-1}). White et al. (2007) compared selenate and sulfate uptake by 39 plant species grown in hydroponic culture under the same conditions. They found that, among the 37 species of Se non-accumulators, there was a very close positive relationship between leaf S and leaf Se concentration, indicating that selenate and sulfate accumulation is strongly linked. In general, Brassicaceae species are able to accumulate more Se because they have a greater ability to accumulate S. Kale selenium uptake can be contrasted any other Brassica species, and no differences were found on uptake and transport of Se over S (Suarez, Grieve, and Poss 2003). Sulfate assimilation and uptake is coordinated by plants nutrient concentrations of the plant (Smith et al. 1997; Buchner, Takahashi, and Hawkesford 2004). Root sulfate

Table 3. The effects of selenium and salt applications on Ca, K, PO_4 concentrations.

		Selenium doses (mg L^{-1})				
Nutrients (%)	Salt level (dS^{-1})	Control	0.25	1	2	Mean
Ca	Control	2.46	2.56	2.48	2.41	2.48A*
	3	1.85	2.14	1.77	1.98	1.94B
	6	1.46	1.28	1.64	1.66	1.51C
	9	1.60	2.08	1.88	1.92	1.87B
	Mean	1.84	2.019	1.94	1.99	
K	Control	2.62*Ba***	2.68*Ba*	3.15*Aa*	2.63*Bb*	2.77
	3	2.60*Ba*	2.59*Ba*	2.46*Bb*	3.05*Aa*	2.67
	6	1.24*Bb*	1.88*Ab*	1.35*Bc*	1.35*Bc*	1.45
	9	0.86*Bc*	0.96*Bc*	0.99*Bd*	1.0*Ad*	1.02
	Mean	1.83	2.03	1.99	2.01	
Na	Control	0.32*Ba*	0.33*Ba*	0.37*Aa*	0.29*Bb*	0.33
	3	0.35*Ba*	0.28*Bb*	0.27*Bb*	0.35*Aa*	0.30
	6	0.15*Bb*	0.25*Ab*	0.17*Bc*	0.17*Bc*	0.19
	9	0.12*Ab*	0.13*Ac*	0.15*Ac*	0.15*Ac*	0.14
	Mean	0.22	0.25	0.24	0.24	

*Capital letters shows the difference between salt applications;
**Italic letters shows the difference between selenium × salt interaction.

availability decreased in enhanced expression of sulfate transporter genes, which enhances the capacity for sulfate uptake and consequently enhances the uptake of Se in some studies (Hawkesford 2003; Shinmachi et al. 2010).

While B leaf concentrations increased with Se applications, B concentrations significantly decreased with salt applications from 27.6 mg kg^{-1} (control) to 5.9, 2.3, and 2.0 mg kg^{-1}, respectively, as shown in Table 2. Also, leaf B concentrations increased with increased Se doses. In another study, Badawy et al. (2017) reported that Se and B individually or in combined applications, under either with saline or without saline conditions, significantly increased in canola plants under physiological parameters. As shown in Table 2, Cu concentrations decreased with salt applications, similar to B.

Selenium × salt interaction was important on Fe concentration. Kale Fe concentrations were affected by Se doses and salt levels compared with control conditions, and Fe concentrations increased with salt levels. In contrast to the salinity effect, we see that application of Se decreased Fe leaf concentrations. Salinity stress reduced all nutrients except iron, indicating that salinity has a different effect on iron uptake as compared with other microelements. In a study by Li, Yang, and Zhang (2016) on iron availability and salinity on physiological responses of barley tolerance to saline stress, they determined that barley had a big capacity to acquire Fe, thus equipping it with tolerance to Fe deficiency in saline growth medium. Acidification, reduction, and chelation are strategies of Fe acquisition by plants (Abadia, Vazquez, and Rellan-Alvarez 2011). In our study, SPAD index value increased with salt and selenium applications (Table 4). SPAD values can be related to chlorophyll content (Ling, Huang, and Jarvis 2011). Among physiological parameters only SPAD increased under saline conditions, it can be related to Fe increase (Table 2). Terry and Low (1982) have reported that leaf chlorophyll content is related to the leaf content of chloroplast Fe and to the leaf content of chloroplast lamellar Fe. Our results are in agreement with Ors and Suarez (2017) with spinach.

Kale Cl concentrations increased with salt applications (Table 3) as expected since NaCl was the added salt, and selenium applications decreased Cl concentrations. With salt applications Na concentrations decreased. However, our findings on Na reduction are in contrast to the other studies (Bsoul et al., 2017) but Hassan et al. (2020) reported that Se application decreased Na concentration in black gram under salt stress conditions.

As seen in Table 3, Selenium × salinity interaction was important for Ca and K concentrations, and Ca and K concentrations decreased with salt applications compared with control. In response to salt stress, the potassium concentrations of the plant are an indicator for the tolerance of the

Table 4. The effects of selenium and salt applications on Pn, gs, Ci, Ti, SPAD.

Nutrients	Salt level (dS^{-1})	Selenium doses ($mg\ L^{-1}$) Control	0.25	1	2	Mean
Pn	Control	20	22	22	21	21
	3	15	16	12	18	15
	6	12	8	9	8	9
	9	6	6	10	11	8
	Mean	13	13	13	15	
gs	Control	0.8	1.3	1.1	1.1	1.1A*
	3	0.2	0.3	0.2	0.3	0.23B
	6	0.1	0.1	0.1	0.1	0.08B
	9	0.1	0.1	0.1	0.1	0.07B
	Mean	0.3	0.4	0.4	0.4	
Ci	Control	296	308	298	290	298A
	3	222	257	213	239	233B
	6	175	155	197	199	182C
	9	193	250	226	230	225B
	Mean	222	242	234	240	
Tr	Control	8.5	10.3	10.5	9.6	9.7A
	3	3.8	4.7	2.8	4.8	4.0B
	6	2.3	1.6	2.4	2.0	2.0C
	9	1.5	1.7	1.9	2.0	1.8C
	Mean	4.0	4.6	4.4	4.6	
SPAD	Control	44.8*Ab***	44.3*Ab*	45.3*Ab*	43.0*Ab*	44.4B
	3	47.1*Ab*	47.3*Ab*	47.6*Ab*	47.8*Ab*	47.5B
	6	54.9*Aa*	56.6*Aa*	57.9*Aa*	53.1*Aa*	55.7A
	9	54.9*Aa*	55.0*Aa*	57.9*Aa*	56.8Aa	56.2A
	Mean	50.4	50.8	52.2	50.2	

*Capital letters shows the difference between salt applications;
**Italic letters shows the difference between selenium × salt interaction.

plant (Astaneh et al. 2018). Without Se applications K concentrations decreased with salinity. With Se applications K concentrations also decreased with increasing salinity but the K leaf concentrations were greater at all salinity levels when Se was applied (Table 3) than in the treatments increased. Calcium and magnesium concentrations showed similar increase, with selenium applications kale leaf concentrations did not decrease.

As seen in Table 4, plant photosynthetic rate (Pn), stomatal conductance (gs), transpiration rate (Tr), and concentration of intercellular CO_2 (Ci) decreased with salt applications. Photosynthetic rate decreased from 21 to 15, 9, and 8 respectively with salt applications. Salinity stress decreases the photosynthetic activity of plants and is related to stomatal limitations, such as stomatal closure and nonstomatal limitations, including chlorophyll reduction (Jiang et al. 2012) chloroplast harm (Shu et al. 2013; Zhao et al. 2015), and the reduction of membrane and proteins of enzymes in the photosynthesis (Mittal, Kumari, and Sharma 2012; Astaneh et al. 2018).

With Se applications the photosynthetic values also decreased with salinity, but the values were greater than in the no Se treatments (at similar salinity, Table 4); thus, Se affected physiological parameters positively. Among Se doses, there are no significant differences. When the control photosynthetic rate was 12, the other values were 12, 12, and 13, respectively. Stomatal conductance also increased from 0.3 to 0.4. While the control of concentration of intercellular CO_2 was 222, with the other Se applications the values increased to 242, 234, and 240. In an earlier study, researchers indicated that salt stress had a positive physiological effect on some growth parameters of garlic and application of Se made plants more tolerant to salt stress-induced oxidative damage by enhancing their antioxidant defense systems (Astaneh et al. 2018). Except for SPAD values, decreased physiological differences such as stomatal conductance, plant photosynthetic rate transpiration rate, and concentration of intercellular CO_2 under salinity stress have been reported on different plants (Yousif et al. 2010; Ors and Suarez 2017).

Conclusion

This study has showed that selenium affected positively plants physiological parameters and yield under both control salt stress conditions. We can say that Se applications are beneficial even in the regions, which have salinity problems. In general, the dose of 0.25 mg L^{-1} Se application was appropriate to improve kale yield even under saline conditions. Among the Se doses, 0.25 mg L^{-1} Se (corresponding to leaf Se concentrations of 0.7 mg kg^{-1}) was sufficient for improved kale yield, nutrient concentrations, and physiological properties. For human, excessive Se doses can be toxic and unhealthy. The critical selenium level has been established as 5 mg kg^{-1} dry matter for livestock (Anonymous 1980). Further studies can be undertaken to better evaluate Se needs for other crops.

It has been revealed that with salinity, increasing iron uptake, other than other nutrients, may be a new study subject.

Disclosure statement

No potential conflict of interest was reported by the authors.

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