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Effects of Different Rates of Selenium Fertilizer and Cow Manure on Selenium Uptake in *Festuca arundinacea*

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ABSTRACT

One of the crucial elements for livestock and human nutrition is selenium and its deficiency or toxicity can harm human and livestock health. The present study is designed with the aim of studying the effect of different levels of selenium fertilizer (Selcote-Ultra) and cow manure on the uptake of selenium in tall fescue. For this purpose, a pot experiment with complete randomized block design in the form of a factorial experiment was carried out on a single soil sample with the cultivation of *Festuca arundinacea* (Tall fescue), five levels of selenium fertilizer (0, 5, 10, 20 and 40 $g.ha^{-1}$), and two levels of cow manure (Zero and 100 tons per hectare) with three replications during the 2014-2015. The result of means comparison showed that the uptake of selenium during three harvests was affected by different levels of selenium fertilizer and cow manure. With increasing selenium rates, selenium uptake in the plant aerial parts in all three harvests raised significantly ($p<0.05$). Selenium uptake for the cattle in all treatments except for the control treatment in all three harvests was in the optimal range, therefore the treatment of 5 $g.ha^{-1}$ selenium could be used as a suitable treatment for providing cattle and human demands with selenium, because its application is more economical in comparison to treatments of 10, 20, and 40 $g.ha^{-1}$. With increasing cow manure application, selenium uptake in tall fescue in all three harvests revealed a significant decrease ($p<0.05$) which is due to dilution effect and the organic material role in selenium absorption.

Keywords*:* *Nutrition, Selcote ultra, Tall fescue.*

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INTRODUCTION

Selenium (Se), an essential trace element for humans and animals, involving multiple biological functions, such as enhancing immunization, anti oxidation, and detoxification of heavy metals (Mao *et al*., 2016). It is present in several seleno-proteins that contribute to preventing oxidative cellular degradation (Zeng and Combs, 2008). This element is incorporated into the primary structure of these proteins as the amino acid seleno-cysteine (Se Cys). In the 1970s, it was discovered that Se was a constituent of the anti-oxidant enzyme glutathione peroxidase (GPX). Se deficiency in humans causes ailments such as Keshan disease, a heart disorder, and Kaschin-Beck disease, a degenerative disorder that affects bone. However, at elevated doses Se can cause toxic effects (Tan *et al*., 2002; Hartikainen, 2005). Furthermore, the essential or toxic effect of this element in humans depends on its chemical form (Reilly, 2006). Several means of administering selenium to deficient ruminants are available (Surai, 2006). Agronomic biofortification is defined as increasing the bioavailable concentrations of essential elements in edible portions of crop plants through the use of fertilizers. The potential for using selenium-containing fertilizers to increase forage selenium concentrations and, thus, dietary selenium intake has been demonstrated in Finland, New Zealand, and Australia where it has proven to be both effective and safe (Whelan *et al.,* 1994; Broadley *et al*., 2006). Plant species also differ in their ability to incorporate selenium from soil. Most forage plants are categorized as non-selenium accumulator plants (Hall, 2013). Selenium content in all soils varies from 500 $mg.kg^{-1}$ in an organic material rich soil to less than 0.1 $mg.kg^{-1}$ in soils poor in organic material (Wells, 1997). One of the strategies to eliminate difficulties that induced by selenium deficiency is applying selenium fertilizers. Selenium at high doses is toxic as it induces adverse cardio-metabolic effects, associated with an increased risk of type-2 diabetes and hyperlipidemia (Lee and Jeong, 2012). The intake of selenium in human body is largely derived from plants (White, 2015). Therefore, when stressing the fortification of crop selenium nutrition, particular attention should be paid to how to take effective agronomic measures to balance the selenium concentration in crops grown in high-Se areas. The major source of Se in most human diets is provided by plants. The availability of Se to the plant is determined by soil properties and conditions. Thus Se can occur as inorganic (Selenite and selenate) or organic forms. Selenate, which is more soluble than selenite, can pass directly into plant roots; in contrast the uptake mechanism for selenite is unclear (Lin, 2009). Selenate competes with sulphate transport in the root plasma membrane and it is much more abundant in leaves than selenite (Reilly, 2006). Inorganic Se absorbed by plants is metabolized in a variety of ways to organic Se compounds, the distinct molecular structures of which depend on the plant species (Gammelgaard and Jackson, 2011). Soils differ greatly in Se content, and in some geographical zone slow concentrations lead to a decrease in plant Se uptake (Moreno-Rodriguez *et al*., 2005; Hawkesford and Zhao, 2007). In some countries, inorganic Se compounds are commonly used as additives in fertilizers to improve the nutritional quality of local food stuffs. This practice of Se fertilization has been applied mainly in Finland and New Zealand (Eurola *et al*., 2001). A number of studies have addressed the effects of distinct forms of

Se and cultivation conditions on edible plants. These studies mainly used selenite and selenate as sodium salts or barium salts (Rayman *et al*., 2008; Broadley *et al*., 2010). Selcote ultra is a slow release selenium granular fertilizer containing 1% of selenium that was used mainly for compensating selenium deficiency in forage crops. The selenium fertilizer composition included 90% sodium and barium selenate and 10% sodium and barium selenite. Results by Gupta *et al*. (1982) showed that through applying 2.24 kg selenium in each hectare of the soil in the form of selenate, the remaining effect of selenium lasted for 4-5 farming years for timothy and 2 years for barley, respectively. Utilizing high concentrations of selenium can lead to decrease in different products performance in given regions of the world. For instance, amounts exceeding 2.5 ppm selenium in soil, reduced wheat and sun flower growth in the soil with a pH of 7.9 in Harilna, India (Singh and Singh, 1978). *Festuca arundinacea* (Tall fescue) is a forage crop that is utilized for the cattle ration. This plant has different potentials for selenium uptake. Gizel-Nelson (1981) grew some farming plants and vegetables in order to measure their difference in selenium uptake in a selenium-rich soil. The results revealed that there was up to 10 times difference in selenium uptake. Funes-Collado *et al*. (2013) grew cabbage, lettuce, chard and parsley, in peat enriched in Se by means of the additive selcote ultra and Na_2SeO_3 and Na_2SeO_4. The concentration ranges were between 0.1 mg $Se.kg^{-1}$ and 30 mg $Se.kg^{-1}$ for plants grown in selcote ultra media, and between 0.4 mg $Se.kg^{-1}$ and 1606 mg $Se.kg^{-1}$ for those grown in peat enriched with Se sodium salts. Se fertilizer can be used to increase Se content of grape, especially for European and American species, with significant effect of increasing grape nutrition quality and an effective means of lowering heavy metals (Zhu *et al*., 2017). The current study is designed with the aim of studying the effect of different levels of selenium fertilizer and cow manure on the uptake of selenium in tall fescue in order to achieve optimum concentration of selenium in this plant.

MATERIALS AND METHODS

Field and Treatment Information

In order to investigate different levels of selenium fertilizer and cow manure on selenium uptake a pot experiment with complete randomized block design in the form of a factorial experiment was carried out on a single soil sample with the cultivation of *Festuca arundinacea* (Tall fescue), five levels of selenium fertilizer (0, 5, 10, 20 and 40 $g.ha^{-1}$), two levels of cow manure (Zero and 100 tons per hectare) with three replications during the 2015-2016. The soil sample was taken from four points of the farm in depth of zero to 30 cm, and the compound sample was provided after mixing the samples. Average selenium concentration in this soil was 0.4 $mg.kg^{-1}$ that was classified as selenium deficient soils. Some of the physical and chemical characteristics of the taken soil sample and cow manure were measured according to standard methods (Carter and Gregorich, 2006). Their results are shown in tables 1 and 2.

Table 1. Physical and chemical properties of studied soil

Index	Soil texture	pH	ECe ($ds.m^{-1}$)	O.C ($g.kg^{-1}$)	$CaCO_3$ (%)	SO_4 ($meq.L^{-1}$)
Soil Sample	Silty Clay	6.08	2.4	1.6	32.75	0.04

Table 2. Some characteristics of cow manure sample

Index	pH	EC (dS m^{-1})	O.C (g kg^{-1})	N_t (g.kg^{-1})	P (%)	K (%)
Cow manure	8.60	17	24.9	1.3	0.09	0.40

Farm Management

After being air-dried the taken soil samples was passed through a 2 mm-sieve. 360 kg of the soil was divided into two equal parts and half of it was loaded with cattle manure equivalent to 100 tons per hectare and it was thoroughly mixed with soil. The prepared soils were moved to 30 pots with capacity of 6 kilograms. After having pots prepared, selcote ultra treatments were placed in center and depth of 10 cm of each pot. Afterwards seeds of tall fescue equivalent to 40 kg per hectare was planted in depth of 3 cm and was irrigated immediately. The pots were transferred to the green house. Next irrigations were daily up to appearance of sprouts, then and during the growing phase they were irrigated every 4 days. Urea fertilizer was added to the pots during two steps; 22 ppm at the time of germination and 33 ppm when the vegetation was complete. Also 55 ppm of ammonium phosphate was added to all samples.

Traits Measure

Generally plants were harvested in three turns. The first harvest was when the plant approached the height of approximately 20 cm. Next harvests were done when the plant reached the height of 20 cm. In each harvest, the aerial parts of the plant was taken from 2 cm height from the soil surface. After getting prepared, the plant samples were moved to paper envelopes and they were dried and weighted in a ventilating oven for 72 hours at 65ºC. The samples were then powdered by Wiley mill and their selenium concentration was measured by Atomic Absorption Spectrometry (Kopsell *et al*., 1997).

Statistical Analysis

Data obtained from each treatment were transferred to excel sheets. The diagrams were plotted using this software. Statistical analysis on data was performed using SAS (Ver.8) software and Fisher LSD test at 5% probability level.

RESULTS AND DISCUSSION

The effect of selcote ultra fertilizer on selenium uptake

The mean comparison of selenium uptake under the effect of different selcote ultra levels in three harvests is shown in Fig. 1. As can be observed, with increasing the use of selcote ultra fertilizer, selenium uptake by tall fescue in three harvests displayed an ascending trend and it was significant ($P<0.05$). This is also clearly evident in other researcher works that through planting lettuce in a pot and applying 0.1 and 1 mg selenium per kilogram of soil, selenium uptake of control was 6.24 µg and in 0.1 and 1 mg per kilogram treatment it was 103 and 1150 µg out of each pot, respectively (Hartikainen *et al*., 2000). Application of selenite and selenate increased the lentil grain yield by 10% and 4%, respectively, compared to the control. Seed Se concentration was significantly higher in lentils treated with selenate (1.4 mg.kg^{-1}) compared to selenite (0.9 mg.kg^{-1}) and the control (0.6 mg.kg^{-1}) (Ekanayake *et al*., 2015). Through the first harvest to the third, there was a descending trend in plant selenium uptake (Fig. 1).

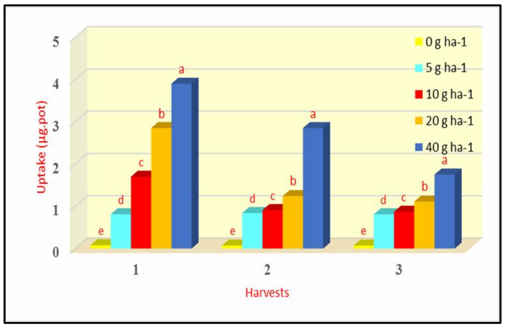

Fig. 1. Mean comparison of the different selenium fertilizer rates on selenium uptake at different harvest turns (Bars having the same letter are not different at p= 0.05).

It seems that, the reason for this decrease is due to reduction in fertilizer amount as a result of processes like uptake by the plant, leaching, absorption by microorganisms and their synthetic materials and finally evaporation of its organic forms. However, leaching in this case does not seem that much important since it is a slow releasing fertilizer.

The effect of selcote ultra fertilizer on the mean uptake of selenium

The mean comparison of selenium uptake by tall fescue under the effect of selcote ultra indicated in Table 3. As can be observed, with increasing application of selenium fertilizer, selenium uptake by the plant among control treatment and selenium fertilizer treated samples showed a significant increase ($p<0.05$).

Table 3. Effect of selenium fertilizer levels on selenium uptake in tall fescue (µg per pot)

The amount of selcote ultra ($g.ha^{-1}$)	Mean of uptake
0	0.12^{e}
5	0.67^{d}
10	1.50^{c}
20	1.77^{b}
40	2.04^{a}

(Class having the same letter are not different at P = 0.05).

The treatment of applying 40 g selenium per hectare had the highest uptake and after that were treatments of 20 and 10 g selenium per hectare. Recent studies demonstrate that the application of Se increases plant productivity in terms of biomass or grain yield. The application of Se resulted in increases of 43% for seed production in canola (*Brassica napus* L.), 14% for biomass yield in lettuce (*Lactuca sativa* L.), and 40% for tuber yield in potato (*Solanum tuberosum* L.) (Lyons *et al*., 2009). Application of Se increased the tolerance of wheat (*Triticum sp*. L.) and Brassica seedlings to ultraviolet radiation, cold, drought, and salinity stresses (Chu *et al*., 2010).

The effect of cow manure on selenium uptake in tall fescue at during three harvests

Mean comparison of selenium uptake in tall fescue under the effect of different levels of cow manure in three harvests is presented in Fig. 2. As can be seen, increasing cow manure usage, selenium uptake in tall fescue showed a significant decrease in each harvest ($p<0.05$). Selenium uptake in first harvest of the control treatment was 1.1 µg and in treatment of 100 mega grams per hectare was 0.6 µg (Fig. 2). In the second and third harvests also selenium uptake in the control treatments revealed a significant decrease in comparison to the treatment where cow manure was not used ($p<0.05$). The effect of the organic material in selenium uptake, increased action of microorganisms and selenium uptake by them or conversion of selenium mineral forms to evaporating organic forms can be mentioned as factors that cause decreased selenium uptake in treatments where cow manure was used. Soil organic manure (OM) is an important component that retains Se in soils.

The proportion of OM-bound Se can be affected by soil type in general or the composition and content of soil OM in specific (Johnson *et al*., 2000; Wang *et al*., 2016). Higher content of OM are usually found in peat soils. Tolu *et al*. (2014) reported that the influence of soil OM on Se mobility should be emphasized in these soils, while the mobility of Se is mainly controlled by Se adsorption onto oxy-hydroxides in volcanic soils, red earths, and other soils poor in OM. Results of Davis *et al*. (2006) showed that with increasing the organic material, selenium uptake decreased in plant. Floor *et al*. (2011) found that less Se was mobilized under acid conditions in OM-rich soils. When the amount of total Se in soil is low, the Se immobilization by soil OM becomes more prominent.

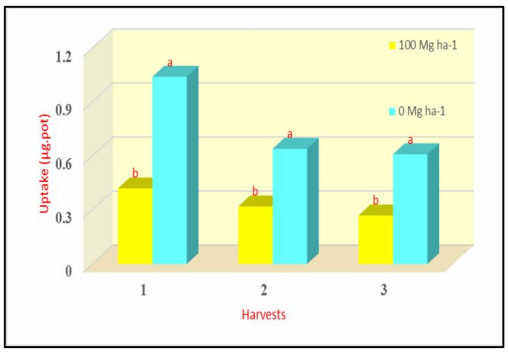

Fig. 2. Mean comparison of the different cow manure rates on selenium uptake in tall fescue at different harvest. (Bars within a manure class having the same letter are not different at p= 0.05)

CONCLUSION

Applying selenium fertilizer led to significantly selenium uptake rise in tall fescue ($p<0.05$). In next harvests, uptake in the studied plant showed a significant decrease. It seems that the reason for this decrease is decreased amounts of fertilizer as a result of processes like uptake by the plant, leaching, uptake by microorganisms and their synthetic materials and finally evaporation of the fertilizer organic forms. Applying 40 g ha^{-1} selenium in the form of selcote ultra led to increase selenium uptake in plant, but the obtained uptake did not approach the toxicity threshold for herd of cattle, hence its uptake up to the afore mentioned limit is recommended in this soil. Due to the impact of cow manure in decreasing plant selenium uptake, use of selenium fertilizers is recommended in the soil with organic fertilizers to supply selenium for animals and humans.

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