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Research Article

Effects of Selenium Application on Plant Growth and Some Quality Parameters in Peanut (*Arachis hypogaea*)

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Abstract

Background and Objective: Selenium (Se) is an essential plant micronutrient and has been repetedly shown to enhance crop growth and crop tolerance to abiotic stresses when applied in trace amounts. However, physiological responses of different plants vary significantly to the Se fertilizer application. The aim of this study was to investigate the effect of Se application on yield and quality parameters of peanut under field conditions. **Materials and Methods:** A pot experiment was conducted where Se fertilizer was applied (i) To soil at 5 different doses, (ii) As folier fertilizer or (iii) Via seed soaking at 4 different doses. Two years field experiments were conducted under East Mediterranean conditions of Turkey. **Results:** The yields were significantly increased by all types of Se applications. The highest yield (6130 kg ha^{-1}) was obtained from foliar applications made 40 days after flowering. Increasing doses of Se increased 100 grain weight but oil, protein and nitrogen content of grains were not affected. **Conclusion:** Two years experiment clearly showed that external Se supply to peanut (all methods tested) increased yield formation in East Mediterranean conditions of Turkey. Here, particularly foliar application (3% sodium selenite) of Se 40 after flowering seems to be most effective way for its application.

Key words: Selenium, yield, quality, application types, peanut

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Over the last years Se is shown to affect many physiological processes in plants, including the growth. Selenium is known as the "double-edged sword element" for its dual toxic and beneficial activity depending on the dosage, thus some data show its positive effects on plant species at low concentrations and negative at higher [1,2].

However, the response of various crop types to different Se application doses and to application method are still not fully understood[3].

Field experiment, basal application of Se fertilizer enhanced alfalfa forage yield and crop Se content[4]. In another multiyear field trial in Australia, Se foliar application (40 g Se ha^{-1}) as potassium selenate (K_2SeO_4), increased seed Se concentration from 201-2772 μg kg^{-1}, but had no effect on seed yield[5]. Authors determined the effects of different levels of Se on the herbage yield of alfalfa at different growth stages and reported that application of Se increased the herbage yield, dry matter, plant height and leaf/steam ratio. Here, treatment with the application of 0.45 kg ha^{-1} Se doses had the highest herbage yield[6].

In the field experiment, black peanut was fertilized with different Se level (Na_2SeO_3) and researchers reported that increase in Se dose firstly increased the yield of black peanut and then decreased in higher Se applied treatments. When Se amount was higher than 2 mg kg^{-1}, Se content of black peanut exceeded the threshold value for humans (0.3 mg kg^{-1}). When the Se fertilization was 1.9 mg kg^{-1}, the yield of black peanut reached the highest[1] 4354.17 kg ha^{-1} and the Se content of black peanut[7] was 0.28 mg kg^{-1}.

Yield of peanut and the content of Se increased with increasing liquid Se amount applied. The peanut yield was maximium when liquid Se fertilizer amount was 6 000 mL ha^{-1}. In this experiment, the content of Se reached highest in flower stage when spraying with liquid Se fertilizer. According to some serearchers sodium selenate was much more effectively taken by plants than sodium selenite and there was a strong and linear relationship between total Se content and Se rate for chickpea[2,8].

In the present study, a pot experiment was carried out with five levels of Se fertilizer (0, 5, 10, 20 and 40 g ha^{-1}) and with three replications during the 2 years. This study was carried out to determine the effect of Se application on peanut's yield and quality along with oil, nitrogen and protein content in Easthern Mediterranean region of Turkey.

MATERIALS AND METHODS

The experiment was carried out in Cukurova region of Adana in Turkey. The Mediterranean climate with an average rainfall of 600 mm is dominating in the study area. Soils have thermic temperature with xeric moisture[9]. Wheat, corn, cotton, soybean, peanut, sunflower and rapeseed are the cultivated crops in the region. Soil was taken from 0-30 cm, air dried and passed through 2 mm sieve. Oil contents of depth grain were analyzed according to Soxhelet method[10]. Protein contents of grain were analyzed according to Kjeldahl method[11].

First and second years dose experiment was established according to the split plot design that was splited in the randomized blocks. In the experiment, the main plot types were split plot applications. Variance analysis was used to interpret the data.

Soil applications of Se: In soil application of Se, a 20:20 fertilizer with added Se has been applied with the following doses:

- Conventional, non-Se containing 20.20.0 fertilizer applications
- 5 ppm Se containing 20.20.0 fertilizer applications
- 10 ppm Se containing 20.20.0 fertilizer applications
- 20 ppm Se containing 20.20.0 fertilizer applications
- 30 ppm Se containing 20.20.0 fertilizer applications

Seed soaking applications of Se: Peanut seeds were soaked with Se containing solutions during 20 min prior to planting to investigate the effects of Se on crop growth. Sodium selenate was used for the preparation of Se containing solutions. After soaking with Se, seeds were dryed on clean papers under laboratory conditions and then sown in soil under field conditions. The dosages used for preperation of Se containing solutions are given:

- 0 pure water
- 50 μM Se containing solution
- 250 μM Se containing solution
- 1000 μM Se containing solution

Timings for foliar application of Se: On leave application of Se: 3% sodium selenite solution has been applied in the following conditions:

- Control (No Se applied)
- Before flowering
- 20 days after flowering
- 40 days after flowering
- 60 days after flowering

Variance analysis was used to interpret the data.

RESULTS AND DISCUSSION

Effects of Se applications on yields: Yield data was presented in Table 1. In the first year, lowest yield was obtained from control parcels (3907 kg ha^{-1}) where no Se was applied, while highest yield (5124 kg ha^{-1}) was obtained from 30 ppm Se applied parcels (Fig. 1). Increasing doses of soil applied Se was resulted with increasing yields statistically significant for the first year.

In the second year when Se applied directly to soil, lowest yield was obtained from control parcels (4179 kg ha^{-1}) where no Se was applied. However, highest yield (4873 kg ha^{-1}) was obtained from 10 ppm Se treatment. Increasing doses of soil applied Se for the second year increased yield slightly but the effect was not statistically significant. However, when data pooled over 2 years, average yield was significantly higher when Se applied at higher doses (Table 1).

Table 1: Crop yields and 100 seed weight of Se application experiment plots

		Crop yields (kg ha^{-1})			100 seed weight (g)			Oil content (%)		
Applications	Doses (kg ha^{-1})	First year	Second year	Average	First year	Second year	Average	First year	Second year	Average
Soil applications of Se	0 (Control parcel)	3907.00^{b}	4179.00	4043.00^{b}	111.30^{b}	111.00^{b}	111.20^{b}	45.40	50.10	47.80
	5	4644.00^{ab}	4807.00	4725.00^{ab}	120.00^{ab}	117.70^{a}	118.90^{a}	45.90	49.00	47.40
	10	4162.00^{ab}	4873.00	4518.00^{ab}	124.30^{a}	112.30^{ab}	118.30^{a}	44.30	49.70	47.00
	20	5106.00^{a}	459.30	4849.00^{a}	124.70^{a}	109.90^{b}	117.30^{a}	45.10	49.20	47.20
	30	5124.00^{a}	4660.00	4892.00^{a}	120.00^{ab}	110.80^{b}	115.40^{ab}	43.40	48.80	46.10
	Average	4588.60	4622.40	4605.40	120.07	112.33	116.20	44.83	49.33	47.08
	CV (%)	13.38	14.25	13.82	4.82	3.15	4.13	5.08	2.34	3.84
	LSD (%)	115.63	NS	77.57	10.90	6.67	5.87	NS*	NS	NS
Foliar application of Se	Control parcel	3780.00^{c}	492.001^{c}	4351.00^{d}	126.50^{a}	111.70^{cd}	119.10^{bc}	44.60	48.60	46.60
	Before flowering	4997.00^{a}	4770.00^{c}	4884.00^{c}	122.00^{bc}	110.20^{d}	116.10^{d}	44.90	49.10	47.00
	20 days after flowering	4251.00^{b}	4879.00^{c}	4565.00^{d}	119.50^{c}	120.80^{a}	120.10^{ab}	46.00	47.70	46.90
	40 days after flowering	4657.00^{a}	6130.00^{a}	5394.00^{a}	122.50^{b}	113.10^{c}	117.80^{cd}	46.30	48.00	47.10
	60 days after flowering	4823.00^{a}	5433.00^{b}	5128.00^{b}	126.50^{a}	116.20^{b}	121.30^{a}	43.40	48.80	46.10
	Average	4501.70	5226.60	4864.10	123.40	114.40	118.90	45.03	48.45	46.74
	CV (%)	4.33	3.61	3.94	1.27	1.31	1.29	5.09	2.51	3.92
	LSD (%)	36.67	35.54	23.48	2.95	2.81	1.87	NS	NS	NS
Seed soaking applications of Se	0 (Control parcel)	4612.00^{c}	5065.00^{b}	4839.00^{c}	113.00^{ab}	107.60^{b}	110.30^{c}	46.40	48.80^{a}	47.60
	50 mM	5190.00^{ab}	4976.00^{b}	5083.00^{b}	121.30^{a}	117.60^{a}	119.40^{a}	45.90	47.60^{b}	46.80
	250 mM	5313.00^{a}	5710.00^{a}	5511.00^{a}	116.00^{ab}	117.80^{a}	116.90^{ab}	45.60	48.80^{a}	47.20
	1000 mM	4987.00^{b}	4967.00^{b}	4977.00^{bc}	109.70^{b}	115.50^{a}	112.60^{bc}	45.90	48.20^{ab}	47.10
	Average	5025.40	5179.50	5102.40	115.00	114.60	114.80	45.95	48.36	47.15
	CV (%)	2.64	3.09	2.88	4.30	2.18	3.41	2.05	1.16	1.64
	LSD (%)	26.51	12.55	18.48	9.88	4.99	4.93	NS	1.12	NS

*NS: Not significant

Fig. 1: Parcel of 30 kg ha^{-1} dose of soil applications of selenium

Fig. 2(a-b): Control parcel of (a) Foliar application of selenium and (b) Seed soaked selenium

In the first year under foliar applied Se conditions, lowest yield was obtained from control parcels (3780 kg ha^{-1}) where no Se was applied (Fig. 2a), while highest yield (4997 kg ha^{-1}) was obtained from pre-anthesis stage Se applied treatment. In the first year, different foliar Se application time had statistically significant effects on yields. According to some resarcher foliar application of sodium selenide, independently of the doses, affected the characteristics height of the first pod insertion, height of the plant and number of seeds in the pods and decreased the productivity in 21% due to toxicity[3,12].

Foliar applied Se treatments effected yield in the second year and highest yield (6130 kg ha^{-1}) was obtained from post-anthesis (40 days after anthesis) stage in Se applied parcels. In the second year, different foliar Se application times had statistically significant effects on yields. Hu *et al.*[13] conducted a field experiment to investigate the effects of foliar Se application on the herbage yield and quality of alfalfa in China. The Se fertilizer was foliarly applied at four doses (0, 50, 100 and 200 mg kg^{-1}). The results showed that Se application could significantly increase herbage yield of alfalfa and the highest herbage yield occurred in the Se 50 treatment and was raised herbage yield by 1121 kg ha^{-2}, compared to non-Se applied treatment. In another field study, foliar application of Se on yield of soybean was studied. Foliar spraying Se fertilization was applied once at flowering stage with 300-1200 mL ha^{-1}. Soybean grain yield was increased with increasing of Se fertilizer levels[14].

In the present experiment, seed soaked Se treatment affected yield formation of peanut. Lowest yield was obtained from control parcels (4612 kg ha^{-1}) where no Se was applied (Fig. 2b), while highest yield (5313 kg ha^{-1}) was obtained from 250 mM Se applied parcels. Increasing doses of seed soaked Se was resulted with statistically significant yield increases for the first year.

In the second year under seed soaked Se conditions, lowest yield was obtained from 50 mM Se applied parcels, while highest yield (5710 kg ha^{-1}) was obtained from 250 mM Se applied parcels (Fig. 3). Increasing doses of seed soaked Se was resulted with statistically significant yield increases in the second year. For both years in seed soaking Se treatments, highest yields were obtained from 250 mM Se doses (Table 1).

Fig. 3: Parcel of 250 mM dose of seed soaking applications of selenium

Researchers studied that foliar Se application on the herbage yield and quality of alfalfa in China. The results indicated that Se application could significantly increase herbage yield of alfalfa[4,13]. Researchers claimed that foliar application of Se increased soybean grain yield[14,15]. Some researchers studied the effect of field application of two Se forms on lentil grain yield. The experiment was conducted in USA in 2012 and 2013 with five lentil genotypes and three Se treatments (control, 30 g ha^{-1} of selenite and 30 g ha^{-1} of selenate) applied at seeding and at 50% flowering. Application of selenite and selenate increased the lentil grain yield by 10 and 4%, respectively, compared to control[16]. The Se concentration of spring cereals increased on average 15-fold compared with the non-Se fertilized control treatment[17]. The different plant responses to the same Se dose may be partly explained by the form in which Se is supplied to the roots[1].

Effects of Se applications on 100 grain weights: One hundred grain weight datas were presented in Table 1. In the first year, in soil applied Se treatments, lowest 100 grain weight was obtained from control parcels (111.3 g), while highest 100 grain weight (124.7 g) was obtained from 20 ppm Se applied parcels. Increasing doses of soil applied Se was increased 100 grain weight statistically significant for the first year. In the second year under soil applied Se conditions, lowest 100 grain weight was obtained from control parcels (111 g), while highest 100 grain weight (117.7 g) was obtained from 5 ppm Se applied parcels. Increasing doses of soil applied Se was increased 100 grain weight statistically significant for the second year (Table 1).

In the first year under foliar applied Se conditions, lowest 100 grain weight (119.5 g) was obtained from parcels where Se was applied 20 days after anthesis, while highest 100 grain weight (126.5 g) was obtained both from post-anthesis (60 days after anthesis) stage and control parcels. In the first year, different foliar Se application times had statistically significant effects on 100 grain weight.

In the second year, under foliar applied Se conditions, lowest 100 grain weight (110.2 g) was obtained from parcels where Se was applied at pre-anthesis stage, while highest 100 grain weight (120.8 g) was obtained from post-anthesis (20 days after anthesis) stage Se applications. For both years, different foliar Se application times had statistically significant effects on 100 grain weights. Some researchers observed that foliar Se application on the quality and kernel weight of wheat (*Triticum* spp.) in Turkey. Here, in the first year under seed soaked Se conditions, lowest 100 grain weight (109.7 g) was obtained from 1000 mM Se applied parcels, while highest 100 grain weight (121.3 g) was obtained from 50 mM Se applied parcels.

Second year in the seed soaked Se treatments, lowest 100 grain weight (110.3 g) was obtained from control parcels, while highest 100 grain weight (119.4 g) was obtained from 50 mM Se applied parcels. For both years, different foliar Se application times had statistically significant effects on 100 grain weights. In a study where alfalfa and clover was grown in nutrient solutions and Se added at 0, 0.025, 0.25, 2.5 or 25.0 μg atoms L^{-1}, significant genotype and location differences were observed for seed yield. About 40 g ha^{-1} foliar Se application during reproductive stage was found most effective[18].

Effects of Se applications on oil contents of grain peanut: Oil contens of grain peanut data were presented in Table 1. In the first year under soil applied Se conditions, oil content was between 43.4-45.9%, while in the second year was between 48.8-50.1%. Overall data, Se application did not affect peanut oil content at both years.

Table 2: Nitrogen content and protein content of peanut grain of Se application plots

		Protein content (%)			Nitrogen content (%)		
Applications	Doses (kg ha^{-1})	First year	Second year	Average	First year	Second year	Average
Soil applications of Se	0 (Control parcel)	34.10^{a}	27.40	30.73^{a}	5.45^{a}	4.4^{a}	4.915^{a}
	5	30.70^{ab}	28.10	29.38^{ab}	4.87^{ab}	4.5^{ab}	4.678^{ab}
	10	29.10^{b}	28.10	28.63^{b}	4.66^{b}	4.5^{b}	4.583^{b}
	20	29.60^{b}	27.40	28.50^{b}	4.72^{b}	4.4^{b}	4.557^{b}
	30	28.90^{b}	27.90	28.37^{b}	4.62^{b}	4.5^{b}	4.537^{b}
	Average	30.47	27.78	29.12	4.86	4.44	4.65
	CV (%)	6.88	1.91	5.25	6.92	1.90	5.27
	LSD (%)	3.95	NS	1.87	0.63	0.16	0.30
Foliar application of Se	Control parcel	29.90^{b}	27.80	28.81^{b}	5.15^{a}	4.40	4.793
	Before flowering	29.50^{b}	28.10	28.76^{b}	4.73^{ab}	4.50	4.612
	20 days after flowering	29.30^{b}	27.90	28.58^{b}	4.69^{b}	4.50	4.575
	40 days after flowering	29.30^{b}	27.70	28.52^{b}	4.70^{b}	4.40	4.554
	60 days after flowering	33.20^{a}	27.60	30.36^{a}	4.65^{b}	4.40	4.529
	Average	30.21	27.80	29.00	4.78	4.44	4.61
	CV (%)	4.22	2.02	3.39	6.22	1.84	4.73
	LSD (%)	2.40	NS	1.20	0.56	NS	NS
Seed soaking applications of Se	0 (Control parcel)	34.30^{a}	28.30	31.32^{a}	5.49^{a}	4.50	4.997
	50 mM	32.60^{b}	28.40	30.50^{b}	5.21^{b}	4.60	4.88
	250 mM	34.10^{a}	27.90	31.03^{ab}	5.46^{a}	4.50	4.967
	1000 mM	33.50^{ab}	27.50	30.50^{b}	5.37^{ab}	4.40	4.88
	Average	33.64	28.03	30.84	5.38	4.48	4.93
	CV (%)	1.81	2.34	2.05	1.75	2.57	2.13
	LSD (%)	1.22	NS	0.80	0.19	NS	NS

*NS: Not significant

Effects of Se applications on protein contents of grain: Protein contens of grain peanut datas were presented in Table 2. In the first year under soil applied Se conditions, lowest grain protein content (28.9%) was obtained from 30 ppm Se applied parcels, while highest grain protein content (34.1%) was obtained from control parcels. Increasing doses of soil applied Se decreased protein content of grains significantly for the first year. In the second year under soil applied Se conditions, lowest grain protein content (27.4%) was obtained from control parcels, while highest grain protein content (28.1%) was obtained from 5 and 10 ppm Se applied parcels. Different doses of soil applied Se had no effect on protein content of grains statistically for the first year. But differences between averages of 2 years were significantly higher when Se applied to the soil.

In the first year under foliar applied Se conditions, lowest grain protein content (27.3%) was obtained from control parcels, while highest grain protein content (33.2%) was obtained from post-anthesis stage (60 days after anthesis) Se applied parcels. Different foliar application times of Se had statistically significant effects on protein content of grains for the first year.

In the second year under foliar applied Se conditions, lowest grain protein content (27.6%) was obtained from post-anthesis stage (60 days after anthesis) Se applied parcels, while highest grain protein content (28.1%) was obtained from pre-anthesis stage Se applied parcels. Different foliar application times of Se had no significant effects on protein content of grains for the second year. But differences between averages of 2 years were statistically significant.

In the first year under seed soaked Se conditions lowest grain protein content (32.6%) was obtained from 50 mM Se applied parcels, while highest grain protein content (34.3%) was obtained from control parcels where pure water was applied. Increasing doses of Se had decreasing effect on grain protein contents of seeds. Different doses of Se had statistically significant effects on protein content of grains.

In the second year under seed soaked Se conditions lowest grain protein content (27.5%) was obtained from 1000 mM Se applied parcels, while highest grain protein content (28.4%) was obtained from 50 mM Se applied parcels. Increasing doses of Se had decreasing effect on grain protein contents of seeds for second year similar to first year. Averages of 2 years grain protein was significantly higher in Se treatments (Table 2).

Effects of Se applications on nitrogen contents of grain: Nitrogen contens of grain peanut datas were presented in Table 2. In the first year under soil applied Se treatment, lowest grain nitrogen content (4.62%) was obtained from 30 ppm Se applied parcels, while highest grain protein content (5.45%) was obtained from control parcels. Increasing doses of soil applied Se was resulted with decreasing nitrogen content of grains statistically significant for the first year.

In the second year under soil applied Se conditions, lowest grain nitrogen content (4.4%) was obtained from 20 ppm Se applied parcels, while highest grain nitrogen content (4.8%) was obtained from control parcels. Increasing doses of soil applied Se was resulted with decreasing nitrogen content of grains statistically significant for the second year as in first year. High doses of soil applied Se significantly decreased grain nitrogen content for both years.

In the first year under foliar applied Se conditions, lowest grain nitrogen content (4.65%) was obtained from post-anthesis stage (60 days after anthesis), while highest grain protein content (5.15%) was obtained from control parcels. Different foliar application times of Se had statistically significant effects on nitrogen content of grains for the first year. In the second year under foliar applied Se conditions, grain nitrogen content was ranged between 4.4-4.5% with no significant differences.

In the first year, lowest grain nitrogen content (5.21%) was obtained from 50 mM Se applied parcels in seed soaked Se treatment, while highest grain protein content (5.49%) was obtained from control parcels. In the second year under seed soaked Se conditions grain nitrogen content was ranged between 4.4-4.6%. Different doses of Se had no statistically significant effect on seed nitrogen contents in the second year (Table 2).

CONCLUSION

As a result, all three Se application methods increased peanut yield significantly. This yield increase may be attributed to the increase in photosynthesis and antioxidant activity, however, none of these parameters were measured in the present study. However, similar yield increase due to Se fertilizer applications via increased photosynthesis and other biyological activities were reported by few researchers. All three application types of Se application in both years increased 100 grain weights significantly. However, Se application has minor affect on grain oil, grain protein and grain nitrogen content.

Overall, present study clearly showed that peanut plant requires external Se application for higher yield, however, quality paramters of grain is not affected by external Se supply. Foliar application about 40 days after anthesis stage seems to be the most effective and economic way of applying Se fertilizer.

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