Fertilization of Peanut with Selenium

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ABSTRACT

Selenium (Se) is identified as an antioxidant and anti-carcinogenic and increasing Se the peanut (*Arachis hypogaea* L.) plant could benefit human and animal health. In 2006, Se was applied to soil at two locations and four concentrations to determine Se concentration in the peanut plant. Selenium (Sodium Selenite) was applied at rates of 0.5, 1.0, 5.0 and 10 mg Se/kg soil. Prior to harvest, plant samples were collected, washed, partitioned, dried, and ground to pass through a 2 mm sieve and analyzed for Se. Composite soil samples were taken prior to peanut digging, air dried, and analyzed for Se. In general, the higher the concentration of Se applied to the soil the higher the concentration of Se in peanut leaf, stem, root, peg, kernel, and hull. There was no difference in Se concentration between sites for leaf, stem, root, or pegs. There was a difference of Se with hulls and kernels between sites possibly attributed to soil series. Pooled data over both sites showed the untreated areas had an average 0.495 mg Se/kg kernel. The 0.5Se and 1Se treatment had an average Se concentration of 3.97 mg Se/kg kernel which could decrease the quantity of peanuts a person would need to consume from 760 to 14 g/day to get the needed requirement of Se. The treatments 5Se and 10Se averaged 16.1 mg Se/kg kernel. Adding Se to the soil can increase Se in the peanut kernel and plant which could be beneficial to human and/or animal health. However, application of high grade Se to peanut land at 0.5 mg Se/kg would cost about $526/ha which may not be economical for the grower.

Key Words: Selenium, Sodium selenite, peanut pods, leaves, stems, roots, soil samples.

Peanut kernels are a great source of protein and contain a variety of vitamins, minerals, and beneficial unsaturated fats. Consumer demand for peanut requires growers to produce the best quality peanut possible to maintain these high standards. Highest peanut yield and grades come from land rotated with peanut 1 out of 3 or more years and when previous crops are grass-type species such as corn, grain sorghum, or small grains (Henning *et al.*, 1982). Sturkie and Buchanan (1973) showed that peanut responded better to residual fertilizer than with direct fertility applications.

Selenium (Se) concentration in the soil depends on the parent material from which soil is derived. The U.S. Southeast, where a major portion of peanut is grown, is one of three major areas of the United States where Se concentrations are inherently low (<5 mg/kg; Kubota *et al.*, 1967). These low Se soil concentrations do not necessarily reduce plant growth or reduce yield, conversely, high concentrations of Se have been documented to harm animals when eating vegetation growing on high Se soils (>10 mg/kg, Kubota *et al.*, 1967) and humans who eat both animals and vegetation grown on these soils (Miller and Donahue, 1990).

Selenium is considered an antioxidant and anti-carcinogenic. Low Se in the human diet may contribute to development of a form of heart disease, hypothyroidism, and weakened immune system (Coombs, 2000; Zimmerman and Kohrl, 2002). Beck *et al.*, (2003) documented that Se deficiency was not the cause of the above illnesses but rather, it can make the body more susceptible to an illness caused by other nutritional, biochemical, or infectious stresses. Coombs *et al.* (2001) studied the effect of Se supplements on the recurrence of different types of skin cancers at seven clinics in the U.S. during 1983 to early 1990's. They showed that taking a Se supplement of 200 μg did not affect recurrence of skin cancer, but significantly reduced the occurrence of death from total cancers. They showed that incidence of prostate cancer, colorectal cancer, and lung cancer was notably lower in the group given the Se supplement.

Selenium deficiency in the U.S. is rare but has been seen in other countries, most notably China, where soil concentrations of Se are typically low (Ellis and Salt, 2003). Dietary Reference Intakes developed by the Institute of Medicine (Institute of Medicine, 2000) recommend that adults need about 55 μg Se/day. Selenosis, Se toxicity, occurs when blood levels of Se are greater than 100 μg/dL with symptoms of hair loss, white blotchy mails, fatigue, gastrointestinal upsets, irritability, and possible nerve damage (Goldhaber, 2003).

The content of Se in plant residue used for food is highly dependent on the Se concentration found

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in the soil where the plant is grown. Peanuts raised in the U.S. have about 72 µg Se/kg of raw peanut (USDA, 2007). With peanuts being shipped around the world from the U.S., increasing the level of Se concentration could be beneficial to the dietary needs of developing countries or in areas where nutritional supplements may be less available. The objectives of this research were to determine if adding Se to the soil could increase Se concentration in the peanut plant and if Se concentrations were increased, what would be the cost Se fertilization.

Materials and Methods

This project was conducted at two sites in 2006. Site 1 was installed 3 km north of Sasser, GA on Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) with 2 to 5% slope. A subsurface drip irrigation (SDI) system had been installed at this site in the spring of 2000. The SDI system had drip laterals buried at 0.3 m deep and spaced at 0.91m with emitters spaced at 0.3 m. Water flow rate was 5.6 L/min per 100 m or 1.0 L/hr/emitter.

Site 2 was conducted at the USDA-ARS Multicrop Irrigation Research Farm in Shellman, GA. A subsurface drip irrigation system was installed in 2001 on a Greenville fine sandy clay loam soil (fine, kaolinitic, thermic Rhodic Kandiudults). Thin-wall drip tubing (Typhoon 630, 15 mil, Netafim, USA) with emitters spaced at 0.46 m was installed 0.30 m below the soil surface. Drip tubing was spaced 0.91 m apart and had a flow rate of 5.12 L/min per 100 m or 1.4 L/hr/emitter.

The experiment was a randomized complete block design with three replications of five treatments consisting of an untreated control and four Se concentrations replicated three times. Se rates were 0.5, 1.0, 5.0, and 10 mg Se/kg soil (assuming 2,240,000 kg/ha soil at 15 cm soil depth) applied after planting but prior to peanut emergence. The Se source was Sodium selenite (Na_2Se0_3) dissolved in four liters of water and applied on the soil surface. After partial soil drying, the soil surface was raked to incorporate the Se about 2.0 to 3.0 cm soil depth and then re-watered with another four liters of water. Water was applied such that runoff did not occur. Individual plots were 1.83 m wide by 3 m long for a total of 15 plots.

Land preparation was the same at both sites with disk harrowing two times followed by an experimental bedder (USDA-ARS-National Peanut Research Laboratory, Dawson, GA) used to make 1.83 m beds. Peanut rows were planted in a single row orientation at 0.91-m apart using a commercial vacuum type planter (Monosem planter, ATI Inc, Lenexa, KS). Seeds, Georgia Green, were planted at rates recommended for reducing the risk of Tomato Spotted Wilt Virus, 20 seeds/m (Brown *et al.*, 2004). Pest management practices, i.e., disease, insect, and weed control, followed University of Georgia Agricultural Extension Service recommendations for peanut production (Prostko, 2004). Decisions to apply pest management practices were determined by field scouting. Irrigation water was applied daily based on replacement of crop water use for peanut described by Stansell *et al.* (1976) except when precipitation amounts exceeded estimated daily water use.

A composite soil sample (0 to 10 cm) was taken just prior to peanut harvest in each replication and at both sites. However, soil samples at Site 2 were contaminated during drying and were not analyzed. Unfortunately soil sample could not be retaken at Site 2 due to loss of plot identity and contamination following a tillage operation. Peanuts in each replication were hand dug to reduce the possibility of cross contamination to adjacent plots from both soils and plant material. Five random plant samples were taken in each replication just after peanut digging. Plant samples were washed with water, and partitioned into leaves, stems, pegs, pods, and roots. Partitioned plant parts were dried at 60 C and sent to a commercial laboratory for mineral nutrition analysis including Se (Waters Agricultural Laboratories, Inc. Camilla, GA). Yield rows were harvested with a stationary plot combine (Kingaroy Engineering Works, Ltd., Kingaroy, Australia). Pod yield was determined after being mechanically dried, weighed, and adjusted to 7% moisture (wet basis). Harvested peanuts were cleaned to remove foreign material and total yield was calculated. Peanuts were shelled and a 200 g subsample of kernels and hulls were collected and analyzed for Se concentration.

Plant tissue and soil data were analyzed using a general analysis of variance procedure (Statistix8, 2003). Tukey's pairwise least significant difference range test was used to show differences among means ($P \leq 0.05$) when *ANOVA F*-test showed significance.

Results and Discussion

Site 1 received 421 mm of precipitation during the growing season (01 May to 30 Sep). During this same period, 434 mm of water was applied to the peanuts, for a total of 855 mm of water. Site 2 had 394 mm of precipitation with 446 mm of irrigation

Table 1. ANOVA probability values of differences in Se concentration of leaf, stem, root, peg, hull, and kernel by site and Se application for peanut grown at two GA sites in 2006.

Source	df	Leaf	Stem	Root	Peg	Hull	Kernel
Site	1	0.209	0.858	0.773	0.159	0.010	0.000
Se treatment	4	0.001	0.000	0.012	0.000	0.000	0.000

for a total of 840 mm of total water. Overall, both Sites 1 and 2 had nearly the same precipitation and irrigation totals for the year.

Table 1 shows the ANOVA probability values for site and plant part analyzed for Se. There was no difference between sites for leaf, stem, root, or peg Se concentration, but there was a difference between sites for hull and kernel Se as indicated by interaction effects of these variables (Table 2). There were differences in Se concentration within the plant by Se soil treatment. Mean separation tests showed that the untreated, 0.5Se, and 1Se had lower concentrations of Se in both kernel and hulls compared with the treatments 5Se and 10 Se (Table 2) at both sites. This could be attributed to the soil series where Site 1 was loamy sand and Site 2 was a sandy clay loam. Further analysis of the high Se concentrations (5Se and 10Se) indicates that Site 1 had higher accumulations of Se in the hulls and kernel than Site 2 (Table 2). The average cation exchange capacity (CEC) for Site 1 was 50 mmol (+)/kg. The soil samples for Site 2 were contaminated and not analyzed but literature values of CEC for a clay loam is 150 to 300 mmol (+)/kg (Miller and Donahue, 1990). This indicates that Se may be more tightly held to the soil complex (Site 2) and not taken up by the roots or absorbed through the hull and directly into the kernel like calcium (Wiersum, 1951; Sumner *et al.*, 1988). More research is necessary to document this hypothesis.

Table 2 shows that plant samples taken prior to harvest at both sites showed no difference in Se concentration in kernels or hulls when comparing the untreated with the Se0.5 and Se1 treatments. There was a difference in Se concentrations when comparing the higher concentration levels with the untreated (5Se and 10Se). Therefore, this research shows it would take at least 5 mg Se/kg of soil to increase Se levels either the peanut kernel or hull. If we look strictly at the Se treatments of 0.5Se and 1Se compared with the untreated areas, we see that any addition of Se numerically increased the concentration of Se especially in the kernel but not necessarily in the hull. Data pooled over both sites show that the untreated peanuts had 0.495 mg Se/kg kernel. The 0.5Se and 1Se treatments showed an average Se concentration in the kernel of 3.97 mg Se/kg. Average Se values for the untreated or lowest Se treatments were greater than reported by the USDA (2007) for normal raw peanuts. It is unclear why peanut kernels from this research had a higher value of Se compared with that reported by the USDA (2007). At the 72 μg Se/kg of raw peanut a person would need to consume over 760 g of peanuts/day to get the same daily recommended allowance of Se. However, with an average kernel concentration of 3.97 mg Se/kg (average of 0.5 and 1Se treatment) a person would only need to consume only 14 g peanuts/day to get the total daily recommended allowance of Se recommended by the Dietary Reference Intakes developed by the Institute of Medicine (Institute of Medicine, 2000).

Selenium concentrations did not increase in the hull at the untreated, 0.5Se or 1Se rates but did increase at higher application rates (5Se and 10Se). This could indicate that for Se to move into the kernel it must go through the hull similar to that process described for calcium (Wiersum, 1951; Sumner *et al.*, 1988).

Data were pooled over both sites for selected plant parts since there were no differences in site

Table 2. Mean Se concentration values for the interaction of Se treatment by location for kernel and hull plant parts at two sites in GA during the 2006 growing season.

	Site 1	Site 2	Site 1	Site 2
Treatment	Kernel		Hull	
		Se mg/kg		
Untreated	0.77 B[†]	0.22 c	0.26 C	0.57 c
Se0.5	2.93 B	0.76 c	2.26 C	0.44 c
Se1	12.10 AB	1.37 c	1.30 C	1.10 c
Se5	23.62 A	7.50 b	12.57 AB	5.66 b
Se10	21.55 A	11.64 a	19.96 A	9.96 a

[†]Means in the same column followed with the same letter (upper or lower case) within a plant part is not different at $P \leq 0.05$.

Table 3. Mean Se concentration values of leaf, stem, root, and peg plant parts for various Se treatments for two sites in GA during 2006. Mean soil Se concentration collected from Site 1 only taken prior to harvest.

Treatment	Plant Part				
	Leaf	Stem	Root	Peg	Soil
			Se mg/kg		
Untreated	0.51b	0.07b	0.33b	0.33b	0.75b
Se0.5	0.72b	0.75b	1.50b	2.15b	1.25b
Se1	0.70b	0.56b	1.50b	1.82b	0.80b
Se5	3.50a	3.36ab	7.40ab	13.29a	6.30a
Se10	4.91a	7.09a	23.10a	19.68a	15.60a

[†]Means followed with the same letter within each column (plant part) are not different at P≤ 0.05.

probability values (Table 1). Mean separation values for leaf, stem, root, and pegs are shown in Table 3. In general, Se values were greater in the high Se treatments compared with the lower Se or untreated areas. This indicates that peanut plants may uptake Se and transport it throughout the plant. There does tend to be higher concentrations of Se in the below ground plant part compared with the above ground plant parts. For instance, pegs and roots have an average of 21 mg Se/kg at the 10Se treatment while leaf and stems show an average 6.0 mg Se/kg or a 3 fold increase in Se for the underground plant parts compared to above ground plant parts. This would suggest that Se is mobile but not highly mobile in the plant. There could also be a relationship between concentration point-of-uptake, i.e., soil-plant interface, and mobility of Se. This hypothesis could be tested by applying Se foliarly and monitoring Se movement in the plant compared with soil applied Se.

Pod yield was lower for Site 1 compared with Site 2 (Table 4). There was no yield difference between Se treatments compared with the untreated at either site and there was not a significant site by treatment interaction. Yield results from this and other studies previously discussed show that Se did not affect yield at the rates and methods employed with these soils. Se toxicity with respect to plants may only occur with phytotoxicity when Se is applied directly to plants (foliar applications as discussed previously) above certain levels, which may result in reduced plant growth or possibly kill the plant. Other studies suggested the use of Se as a seed coat. Previous studies have shown that Se can negatively affect seed germination and elongation of young roots in several crop species (Carlson *et al.* 1989, Levine, 1925, Spencer and Siegel, 1978). In the study by Carlson *et al.* (1989) the length of the young roots of sorghum, which is related to corn, were reduced by concentrations of Se of 16 to 32 mg/liter of solution. In another study, Se reduced yield of sorghum by up to 95% (Carlson *et al.* 1991) where sodium selenate was more deleterious to sorghum than sodium selenite. Wheat and barley may be more resistant to Se than sorghum (Carlson *et al.* 1989).

Table 4. Pod yield for various Se treatments compared with untreated areas at Sites 1 and 2.

Treatment	Site 1	Site 2
	kg/ha	
Untreated	3256ab[†]	4622A
Se0.5	3296ab	4530A
Se1	2873b	4550A
Se5	3462ab	3711A
Se10	3598ab	4171A

[†]Means followed with the same letter (lower or upper case) in each column are not different at P≤ 0.05.

Selenium is difficult to apply as a fertilizer because the rates required are extremely low. Application of Se as a dry fertilizer by itself has not been widely adopted for the following reasons: 1) blending Se with other fertilizers requires the use of prilled Se fertilizer, presently, powdered Se does not have the physical characteristics required for proper handling and blending; 2) conventional farm equipment cannot be regulated accurately enough to apply the Se with the high degree of accuracy that is required; 3) the danger of inhaling air-borne Se produced through handling powdered/prilled fertilizer or the absorption of the Se through the skin when workers handle the fertilizer, and 4) expense. Mixing with other fertilizers such as nitrogen may be feasible (spray on liquid then dry) as researchers in New York state added sodium selenite to fertilizers at levels of 2.24 and 4.48 kg/ha and found that crop Se increased over 0.1 mg Se/kg over a four year study (Cary and Allaway, 1973). Soluble Se may be applied foliarly with pesticide sprayers but the effectiveness may be short-lived. In New Zealand, farmers are using a new slow-release Se product called ''Selcote Ultra'' on low Se enriched pastures. This prilled product can be blended with other fertilizers to facilitate application (http://www.nufarm.co.nz/NZ/Home).

There is not a demand for Se fertilizer in low Se test soil areas as much as there is a demand to reduce the toxic effects of Se to plants, animals and eventually humans. Fertilizer grade Se in the US is not readily available to the local grower. Without a Se fertilizer grade source, growers would need to rely on foliar or reagent grade sources. Even with safe handling procedures, the cost of purchasing pure Se (Sodium Selenite or Selenate) may be cost prohibitive with the amounts that need to be applied to increase the amount of Se in the plant. Data shown in Table 2 indicate it takes application rates of 0.5 to 1.0 mg Se/kg soil to increase the level of kernel Se concentration above normal ranges in the soil tested. Application of 0.5 mg Se/ kg of soil would require 1.12 kg sodium selenite/ha. The cost of reagent grade selenite is about $470/kg for a total cost of over $526/ha. This cost may be prohibitive when using reagent grade Se, therefore, a less expensive Se source would need to be found that could be used as a fertilizer without restrictions for the crop to be used for animal or human consumption. Since peanut plant growth and yield was unaffected by Se fertilization, there is no financial benefit to the grower to add expensive Se to crop as a fertilizer under current market regulations.

Literature Cited

Beck, M.A., O. Levander, and J. Handy. 2003. Selenium deficiency and viral infection. J. of Nutr. 133:1463s-67s.

Brown, S., J. Todd, A. Culbreth, J. Baldwin, J. Beasley, B. Kemerait, E. Prostrko, and N. Smith. 2004. Minimizing spotted wilt of peanut. Extension-Bulletin 1165. Ga. Agric. Exp. Stn. Athens, GA.

Carlson, C.L., Adriano, D.C., and Dixon, P.M.. 1991. Effects of soil applied selenium to growth and selenium content of a forage species. Env. Quality 20:363-368.

Carlson, C.L., Kaplan, D.I., and Adriano, D.C.. 1989. Effect of selenium on germination and radical elongation of selected agronomic species. Environmental and Experimental Botany 27:493-698.

Cary, E.E. and W.H. Allay. 1973. Selenium content of field crops grown on selenite-treated soils. Agron. J. 65:922-924.

Coombs, G.F., L.C. Clark, Jr., and B.W. Turnbull. 2001. An analysis of cancer prevention by selenium. BioFactors 14:153-159.

Coombs, G.F. 2000. Food system-based approaches to improving micronutrient nutrition: the case for selenium. BioFactors 12:39-43.

Ellis, D.R. and D.E. Salt. 2003. Plants, selenium and human health. Curr Opin Plant Biol 6:273-279.

Goldhaber, S.B. 2003. Trace element risk assessment: essentiality vs. toxicity. Regulatory Toxicology and Pharmacology 38:232-242.

Henning, R.J., A.H. Allison, and L.D. Tripp. 1982. Cultural practices. pp. 123-138. *In* H.E. Pattee and C.T. young (eds.) 1982. Peanut science and technology. Amer. Peanut Res. and Ed. Soc. Yoakum, TX 77995.

Institute of Medicine, Food and Nutrition Board. 2000, Dietary Reference Intakes: Vitamin c, vitamin e, selenium, and carotenoids. National Academy Press, Washington, DC.

Kubota, J., W.R. Allaway, D.L. Carter, E.E. Cary, and V.A. Lazar. 1967. Selenium in crops in the United States in relation to selenium-responsive diseases of livestock. J. Agric. Food Chem. 15:448.

Levine, V.E. 1925. Effect of selenium compounds upon growth and germination in plants Am J. Bot 12:82-90.

Miller, R.W. and R.L. Donahue. 1990. Soils: an introduction to soils and plant growth. Prentice Hall, Englewood Cliffs, NJ 07632.

Prostko, E. (ed.) 2004. Peanut Update-2004. Extension publication No. CSS-04-0109. Ga. Agric. Exp. Stn. Athens, GA.

Spencer, N.E. and S.M. Siegel. 1978. Effect of sulk and selenium–Hg–toxicity in turnip seed germinates Water Air Soil Pollut. 9:423-427.

Stansell, J.R., J.L. Shepherd, J.E. Pallas, R.R. Bruce, N.A. Minton, D.K. Bell, and L.W. Morgan. 1976. Peanut response to soil water variables in the southeast. Peanut Sci. 3:44-48.

Sturkie, D.G. and G.A. Buchanan. 1973. Cultural practices, pp. 299-326. *In* Peanuts: Culture and uses. APREA, Stillwater, OK.

Sumner, M.E., C.S. Kvien, H. Smal, and A.S. Csinos. 1988. On the calcium nutrition of peanut (*Arachis hypogaea* L.). I. Operational model. J. Fert. 5:97-102.

U.S. Department of Agriculture, Agricultural Research Service. 2007. USDA National Nutrient Database for Standard Reference, Release 20. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

Wiersum, L.K. 1951. Water transport in the xylem as related to calcium uptake by groundnuts (*Arachis hypogaea*). Plant Soil 3:160-169.

Zimmerman, M.B. and J. Kohrle. 2002. The impact of iron and selenium deficiencies on iodine and thyroid metabolism: biochemistry and relevance to public health. Thyroid 12:867-878.