Effect of Gypsum Application Rate, Soil Type, and Soil Calcium on Yield, Grade and Seed Quality of Runner Type Peanut Cultivars

J.A. Arnold III[1], J.P. Beasley Jr., G.H. Harris, T.L. Grey*, and M. Cabrera

ABSTRACT

Calcium (Ca) availability in the 0 to 8 cm soil depth often limits peanut yield and influences grade in the southeastern United States. Field experiments were conducted in 2012 and 2013 at the University of Georgia's Coastal Plain Experiment Station, Tifton, GA (CPES) and the Southwest Georgia Research and Education Center, Plains, GA (SWREC) to determine large-seeded (Georgia-06G) and medium-seed sized (Georgia Greener) runner-type cultivar response to gypsum application rates of 0, 560, 1120, 1650 kg/ha. Peanut pod yield and grade (TSMK) were significantly different between locations with 7610 and 6540 kg/ha at CPES and SWREC, respectively. However, there were no differences between peanut cultivars or gypsum rates. Standard germination, seed vigor (cold germination), and seed Ca content analysis were also conducted on subsamples from each plot. Average peanut seed germination was 97% across all samples. No differences were observed for standard germination or vigor testing. Differences in locations were observed for yield, TSMK, percent jumbo, percent medium kernels, and seed Ca content. Peanut cultivar and gypsum application rate had effects on seed Ca concentration. Seed Ca concentration levels were 825 and 787 mg/kg for Georgia Greener and Georgia-06G, respectively. Seed Ca content increased as field gypsum application rate increased at both locations.

Key Words: Soil calcium (Ca), gypsum, pod yield, grade, seed quality, seed vigor

Introduction

Calcium (Ca) is the most common limiting nutrient in peanut production in the Coastal Plain of the Southeastern United States. Calcium (Ca) requirements for vegetative growth in peanut (*Arachis hypogaea* L.) are not much different from other leguminous crops such as pigeon pea (*Cajanus cajan*), cow pea (*Vigna unguiculata*), or soybean (*Glycine max*) (Bell *et al*., 1989). Thus, the highest Ca requirement is for peanut pod and seed production. In a study using hydroponic nutrient solutions of 0 to 2500 µm of Ca, Zharare *et al*. (2009) noted that pod formation would not initiate in solutions without Ca. They also reported that increasing amounts of Ca were required for pod set, proper seed set, and morphological development for maturing pods and seed. (Zharare et al, 2009). Similar results were also reported by Smal *et al*. (1989). Calcium deficiency symptoms in peanut include blackened plumules, unfilled pods or "pops", and increased incidence of pod rot (Csinos and Gaines, 1986). These symptoms can reduce peanut yield and grade (percent total sound mature kernels, TSMK). Additionally, seed from peanut grown in Ca-deficient soils have exhibited low seed Ca concentration which has been linked to reduced germination rates and seedling vigor (Adams *et al*., 1993; Howe *et al*., 2012).

Peanut has a unique fruiting phenology in which the blooms are borne in the axils of leaves but the fruiting body forms on the end of the gynophore that expands and matures below the soil surface. Calcium moves through the plant in the xylem from roots to shoots along the transpiration stream (Skelton and Shear, 1971), and has very limited movement in phloem tissue. The developing fruit is below the soil surface, thus it is unable to transpire and receive Ca from the shoot. Since adequate Ca cannot be received from the plant, it must be absorbed by the pod directly from soil solution (Sumner *et al*., 1988). After the gynophore "pegs" into the soil surface, early stages of pod expansion and seed growth begin (Boote, 1982). It is during these early stages of fruit development that Ca uptake is the greatest.

Early research reported that 92% of Ca uptake by the pod occurred in the 20 to 80 day period following the gynophore entering the soil, and that 69% of uptake occurred between days 20 to day 30 (Mizuno, 1959). Other research has shown that withholding Ca from the pegging zone (0-8 cm soil depth) during the first 30 days after initial pegging severely reduces seed size and dry weight as compared to withholding Ca at other periods of

[1]First, third, fourth, and fifth authors: Former Graduate Student, Professor, Professor, and Professor, Crop and Soil Sciences Department, University of Georgia, Tifton, GA 31793; Second Author Professor and Head, Department of Crop, Soil, and Environmental Sciences, Auburn University, Auburn, AL

*Corresponding author's e-mail: *tgrey@uga.edu

growth (Smal et al, 1989). Soil Ca level needed to produce optimum yield is dependent on seed size. Larger seeded cultivars require higher levels of Ca in the pod zone than smaller seeded cultivars (Gaines *et al*., 1989; Walker and Keisling, 1978). These studies involved peanut response to gypsum application and noted that larger seeded cultivars, considered Virginia market types, have a positive yield response to gypsum application in soils with Ca levels up to 1559 kg/ha at the 0 to 8 cm depth. However, runner-type cultivars only responded to gypsum application when residual soil Ca levels were below 225 kg/ha. Studies conducted in Alabama indicated that peanut yield response to gypsum application only occurred when soil Ca levels were less than 125 mg/kg (Adams *et al*., 1993). The greater Ca requirement of large seeded cultivars has been attributed to a decreasing surface to volume ratio of the pod as size increases. As pods expand, more Ca must pass through a unit area of the pod surface this developing seed coat in order to obtain the optimum seed Ca level (Kvien *et al*., 1988). Although large seeded Virginia type cultivars require greater soil Ca than those with a smaller seed size for improved yields, seed Ca concentration required by Virginia market type cultivars and runner-type cultivars are similar. Virginia cultivars have been shown to have a critical seed Ca concentration for optimum germination of 420 mg/kg (Cox *et al*., 1976), while runner market type cultivars, which produce smaller seed, have been shown to require between 386 and 414 mg/kg (Adams *et al*., 1993). The authors suggested the differences in critical Ca levels were varietal and not linked to seed size.

As with all plants, adequate water is required for sustained growth and development of peanut. Drought conditions during the growing season can decrease number of pods produced, size of pods produced, reduce yield and grade, and cause poor seed germination of peanuts (Pallas et al., 1977). Sporadic rain fall patterns coupled with the sandy soils of the Coastal Plain region that dry out quickly can create episodic droughts in the southeast. Water use in peanut is highest during the peak pod fill (R4 to R7) with up to 0.6 cm taken up per day. The peanut plant is most susceptible to drought during this time period (Stansell et al., 1976). Supplemental irrigation has been shown to increase yield, grade, and seed quality of peanut (Lamb et al., 1997). As producers recognize the benefits of irrigation, use of irrigation in commercial production in Georgia has increased from 70,875 ha in 1970 to 587,250 ha in 2000. Most of this irrigated area is used for peanut and other row crop production (Lamb et al., 2010). Water required by the growing peanut is not only for vegetative growth but for pod growth and expansion. The developing fruit absorbs most of it water directly from the soil (Skelton and Shear, 1971). Not only is pod set and pod expansion decreased by drought, pod and seed uptake of Ca can also be reduced (Pallas et al., 1977). Soil solution Ca available via diffusion is also reduced with low soil moisture. As previously stated, seed Ca concentration is related to seed germination, and has been shown to be a major contributor to reduced germination of seeds. Pallas et al (1977) suggested that lower seed Ca was a major factor in reduced germination of peanuts grown in droughty conditions. To insure optimum germination, UGA cooperative extension also recommends peanuts grown for seed should be irrigated.

As new peanut cultivars have been released and become popular with and adopted by producers, research has been conducted in the Southeast to evaluate their Ca requirements. As cultivar differences in fertility requirements have been noted by other researchers, it is important to evaluate the fertility requirements of newly released peanut cultivars in different locations across the region. The objective of this study was to determine the response of large-seeded (Georgia-06G) and medium-seed sized (Georgia Greener) runner-type peanut cultivars to gypsum application rates. The variables evaluated in this study include physiological aspects of yield, seed calcium concentration, and seed vigor.

Materials and Methods

Experiments were conducted in 2012 and 2013 at the University of Georgia's Coastal Plain Experiment Station (CPES) in Tifton, Georgia (31.42°N, 83.52°W) and Southwest Georgia Research and Education Center (SWREC) in Plains, Georgia (32.04°N, 84.37°W). Soil series at the locations were Tifton loamy sand (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults) and Greenville sandy clay loam (Clayey, Kaolinitic, thermic Rhodic Kandiudults), respectively. Additionally, all experiments were grown under irrigated conditions.

Experiments were organized at both locations in split-plot designs with peanut cultivar as the main factor and gypsum rate as the sub-factor. One large-seeded (Georgia-06G) (Branch, 2007a) and one medium-seeded (Georgia Greener) (Branch, 2007b) runner-type cultivar were grown in two row plots 1.83 m by 12.19 m, and four rates of gypsum (0, 560, 1121, and 1682 kg/ha) were applied. Agri-

Cal gypsum ($CaSO_4$) (Agri-B Technologies, Albany, GA) was used in all experiments. Each treatment was replicated four times. Gypsum ($CaSO_4$was applied at the R1 growth stage (30 to 45 DAP) as recommended by the University of Georgia Cooperative Extension Service. After seedling emergence, soil samples were taken in each two row plot. For the samples, six 5-cm^2 long cores were collected from the top 7.6 cm of soil (pegging or pod zone) of each plot. The probe used for this purpose is described by Walker *et al*, 1976. Soil samples were analyzed for Ca, K and Mg contents using the Mehlich 1 double acid extractant (Kissel and Sonon, 2008). Testing was performed by The University of Georgia Agricultural and Environmental Services Laboratory (Athens, GA 30602). Standard management practices for peanut production as outlined by the University of Georgia Extension (Beasley, 2013), which include herbicide and fungicide applications, were employed. No fertilization occurred in the study, other than the gypsum treatments that were applied, and both locations were irrigated. Also, treatments were not adjusted based on soil testing results. Weather data were obtained from the Georgia Automated Environmental Monitoring Network, using the weather stations located at the respective research centers. Plots were harvested at maturity, which was determined using the hull-scrape maturity profile method (Williams and Drexler, 1981). Plots were dug using a two-row KMC digger-shaker and harvested with a two-row peanut KMC peanut combine (Kelly Manufacturing Company Tifton, GA). The entire length of the 1.8 m by 12.2 m plot was harvested. Peanuts were dried to approximately 6% moisture using standard peanut drying equipment. Total pod yield from each plot was recorded and samples were taken for grade, shelling out-turn, standard germination, and seed Ca concentration analysis. Grading was conducted according to industry standards by the Georgia Federal-State Inspection Service in Tifton, Georgia. Peanuts were shelled using a rotary sheller and sorted using official sorting screens (GA FSIS, Albany, GA) to separate standard kernel sizes Jumbo, Medium, and No.1s (APSA, 2013). A Jumbo kernel is defined as a seed that will not pass through a screen with slots 0.83 by 1.9 cm. Medium kernels are defined as seeds that will pass through a screen with slots 0.83 by 1.9 cm, but will not pass through a screen with slots 0.71 by 1.9 cm. All whole kernels and splits passing through the screen with slots 0.71 by 1.9 cm were classed as splits and others kernels and were weighed together. Weights of each group were recorded as a percentage of the weight of the unshelled sample. Standard and vigor (cold germination) tests were performed according to official seed testing rules (AOSA, 2010) by the Georgia Department of Agriculture in Tifton, Georgia. Seed Ca analysis was performed by grinding whole kernels in a food processor followed by microwave digestion and analyzed using an inductively coupled plasma (ICP) spectrophotometer (Perkin Elmer – Optima 7300 DV(dual view) OES). This was also performed at the Georgia Department of Agriculture Laboratories in Tifton, GA.

Data for pod yield, TSMK, seed size, standard germination, vigor (cold germination), and seed Ca concentration were analyzed using the GLIMMIX procedure in SAS. Main effects of location, cultivar, and gypsum rate were tested as well as the two-way interaction between each main effect. To broaden inference, data were combined over years. Replication and years were considered random effects in the analysis.

Results and Discussion

Environmental Conditions

Average initial soil Ca concentrations at SWREC were 234 mg/kg in 2012 and 336 mg/kg in 2013. Average Ca to potassium (K) ratio was 3:1 in 2012 and 2013. At CPES the Ca levels were 287 mg/kg in 2012 and 391 mg/kg in 2013. Ca to K ratio was 9:1 in 2012 and 3:1 in 2013. Average temperatures, rainfall, and irrigation totals are shown in Table 1.

Yield and Grade

Yield was significantly different between locations, but no differences were observed between cultivars or gypsum rates. All results for yield and grade were pooled over years. Yield was greater at CPES (7610 kg/ha) than at SWREC (6540 kg/ha). Average pod yield was 7190 kg/ha for Georgia-06G and 6970 kg/ha for Georgia Greener. Average pod yield was 6900, 7050, 7140, and 7250 kg/ha for gypsum rates of 0, 560, 1120, and 1680 kg/ha, respectively (Table 4). Percent TSMK was significantly ($p < 0.0001$) higher at CPES (77.2) than at SWREC (75.2), but no differences were observed between cultivars or gypsum rates. The difference in yield and grade between locations is likely due to the difference in environmental conditions between CPES and SWREC.

Seed size characteristics

Location had a significant effect on percent jumbo and medium kernels; higher levels of jumbo kernels were observed at CPES and higher levels of medium kernels were observed at SWREC (Table 3). Since a large-seeded and a medium-seeded runner type

Table 1. Temperature, rainfall[a], and irrigation for the Southwest Georgia Research and Education Center Plains, GA and the Coastal Plain Experiment Station Tifton, GA in 2012 and 2013.

	Max temp		Min temp		Rainfall		Irrigation	
	Plains	Tifton	Plains	Tifton	Plains	Tifton	Plains	Tifton[d]
	C[b]				cm[c]			
2012								
May	30.4	29.6	16.7	17.9	2.9	8.8	2.5	
June	30.7	30.0	18.5	19.3	6.8	13.3	5.1	
July	33.5	32.7	21.5	22.2	10.2	16.9	7.6	
Aug	30.9	30.1	20.7	21.6	4.7	34.0	7.6	
Sept	29.5	29.4	17.7	19.2	10.1	9.8	0	
Oct	25.9	26.3	16.0	16.8	1.4	3.9	0	
Season	30.8	30.0	18.9	19.8	36.1	86.7	22.9	
2013								
May	29.4	29.5	16.4	17.9	2.3	3.6	0	1.3
June	30.2	30.6	20.1	21.4	13.3	33.8	0	0
July	30.0	30.5	21.0	21.8	19.7	14.7	0	0
Aug	30.5	31.3	20.8	21.8	15.0	22.1	0	4.1
Sept	29.2	29.2	18.5	19.8	5.5	7.9	2.5	7.6
Oct	27.0	27.9	15.0	16.6	0.9	1.0	0	0
Season	29.6	30.1	19.2	20.5	56.8	83.1	2.5	13.0

[a]Temperature and rainfall data obtained from www.georgiaweather.net
[b]Average of daily values for time period listed
[c]Sum of daily values for each time period
[d]Irrigation data unavailable for CPES in 2012.

cultivar were grown, a difference in seed size between cultivars was expected and was observed. Gypsum rate did not affect seed size parameters.

Seed Quality

Location, cultivar, and gypsum rate all had a significant effect on seed Ca concentration. Additionally, the interaction between location and rate was significant at $p<0.05$. Seed Ca concentration was 825 and 786 mg/kg for Georgia Greener and Georgia-06G, respectively. Seed Ca concentration increased with gypsum application rate at both locations. At CPES, seed Ca concentration was 735, 771, 790, and 890 mg/kg for 0, 560, 1120, and 1680 kg/ha of gypsum, respectively. The highest rate of gypsum was different from the non-treated check, but no other differences were observed. At SWREC, seed Ca concentration was 710, 790, 912, and 916 mg/kg for 0, 560, 1120, and 1680 kg/ha of gypsum, respectively. The two highest rates were significantly different from the 560 kg/ha rate of gypsum and the untreated control (Table 4). No differences were observed for germination or vigor tests. Average germination was 97%. Research has shown that applied gypsum can leach more readily through loamy sand soils than finer textured sandy clay loam soils such as those found at SWREC (Alva and Gascho, 1991). This would allow better nutrient retention over the loamy sand at CPES, and would allow for better uptake Ca, resulting in higher seed Ca concentration.

Table 2. Analysis of variance probability values determined for yield, TSMK[a], jumbo kernels, medium kernels, germination, and seed Ca by treatment of location, cultivar and gypsum rate at the Southwest Georgia Research and Education Center (Plains, GA) and the Coastal Plain Experiment Station (Tifton, GA), 2012 and 2013 combined.

			Kernels		Seed		
	Pod Yield	TSMK	Jumbo	Medium	Germination	Vigor	Ca
	P-values from GLIMMIX Procedure (α=0.05)						
Location	<.0001	<.0001	<.0001	<.0001	ns	ns	0.0216
Cultivar	ns	ns	<.0001	<.0001	ns	ns	0.0122
Gyp Rate	ns	ns	ns	ns	ns	ns	<.0001
Loc*Rate	ns	ns	ns	ns	ns	ns	0.0025
Loc*cult	ns	ns	ns	ns	ns	ns	ns
Cult*Rate	ns	ns	ns	ns	ns	ns	ns

[a]Abbreviations: TSMK, total sound mature kernels; ns= not significant at α=0.05

Table 3. Yield and quality parameters by location and peanut cultivar in Georgia, 2012 and 2013 combined.

Treatments	Yield	TSMK[a]	Kernels		Germination	Vigor	Seed Ca
			Jumbo	Medium			
	kg/ha	%					mg/kg
Location							
SWREC	6544 b[b]	75.2 b	30.6 b	20.4 a	97.2	95.5	832.2 a
CPES	7612 a	77.2 a	35.6 a	17.0 b	97.9	96.6	778.7b
Cultivar							
Georgia-06G	7187	76.2	35.9 a	17.7 b	97.6	95.7	786.1 b
Georgia Greener	6970	76.1	30.3 b	19.8 a	97.6	96.3	824.7 a

[a]Abbreviations: TSMK, total sound mature kernels.

[b]Means followed by the same letter within the same parameter are not significantly different at the $P<0.05$

The current Ca fertility recommendations for the state of Georgia suggest that gypsum be applied if the soil Ca levels in the pegging zone are less than 250 mg/kg, and that a gypsum rate of 1120 kg/ha should be applied regardless of the soil Ca level if peanuts are grown for seed (Harris, 2013). The results of this research indicate that these recommendations are adequate for the cultivars Georgia-06G and Georgia Greener grown on sandy clay loam and loamy sand soils, as peanut response to soil Ca levels and gypsum application was similar to that of runner cultivars previously evaluated in Georgia, Florida, and Alabama. Tillman *et al.* (2010) evaluated the response of four cultivars to gypsum application. That study indicated that gypsum application had no effect on pod yield, total sound mature kernel (TSMK), percent jumbo kernel, and weight of 100 seeds. Initial soil Ca levels reported in that study were all above 250 mg/kg. However, a significant difference in seed Ca concentration between cultivars was reported. Howe et al. (2012) reported that seed Ca concentration increased with gypsum application rates, but yield was not increased by gypsum rate when soil Ca levels already were sufficient (Howe *et al.*, 2012). This reaffirms findings by Adams and Hartzog (1991), as well as Tillman et al. (2010) that higher soil Ca levels are needed for high quality seed production than is required for optimum yield. Previous research has shown that germination rates are in part related to seed Ca concentration, and certain levels of Ca are required for optimum germination levels. Previous research by Cox *et al.* (1982) and Adams *et al.* (1993) found seed Ca concentration at maximum germination was 420 and 400 mg/kg, respectively for the cultivars they evaluated. More recent research by Howe et al (2012) reported seed Ca concentration at maximum germination was 600 mg/kg. Peanut seed Ca concentration for all treatments in this study was well above the previously reported levels and as a result, high germination rates were observed.

Conclusions

Proper soil fertility is an integral part of ensuring optimum yield and seed quality for peanut producers. Yield and germination rate of Georgia-06G and Georgia Greener were not affected by the gypsum applications rates used in this study as the soil Ca levels at the testing locations was at or above levels recommended by the UGA extension service. Thus, these recommendations are reaffirmed for runner-type peanut production in Georgia.

Table 4. Pod yield, TSMK[a], seed size, and seed Ca by gypsum rate for peanut grown at the Southwest Georgia Research and Education Center (SWREC) and the Coastal Plain Experiment Station (CPES) combined over 2012 and 2013.

Gypsum rate	Yield	TSMK[a]	Kernels		SWREC	CPES
			Jumbo	Medium	Seed Ca	
kg/ha	kg/ha	%			mg/kg	
0	6898	76.0	33.5	18.6	710 c[b]	735 b
560	7048	75.9	33.3	18.2	790 b	771 ab
1120	7141	76.3	32.9	18.9	912 a	790 ab
1680	7253	76.3	32.6	19.1	916 a	819 a

[a]Abbreviations: TSMK total sound mature kernels

[b]Means followed by the same letter within the same column are not significantly different at the $P<0.05$

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