Peanut (*Arachis hypogaea*) Response to Agricultural and Power Plant By-Product Calcium

W.J. Grichar[1]*, B.A. Besler[1], and H.A. Melouk[2]

ABSTRACT

Field studies were conducted at three locations in the south Texas peanut growing region to compare regular agricultural calcium with power plant by-product calcium applied at planting or peanut pegging to runner peanut at rates of 560 to 1680 kg/ha. Both calcium sources decreased *Rhizoctonia* and *Pythium* pod disease development up to 62% when compared with the non-treated control and resulted in a yield increase over the non-treated control of up to 25%. When *Rhizoctonia* or *Pythium* was not a problem, no increase in peanut yield over the non-treated control was noted with any calcium application. Peanut grade (Total Sound Mature Kernels + Sound Splits) was increased at one location with the use of both calcium sources. Calcium, magnesium, and potassium content of foliage, hull, and kernel tissue was variable and was not related to calcium source.

Key Words: Disease development, pod yield, grade, mineral content.

Peanuts require adequate calcium (Ca) in the top 8 cm of the soil during pegging and pod fill (Gascho *et al.*, 1993). Sandy soils of the south Texas peanut growing region are sometimes deficient in Ca for peanut production (Lemon *et al.*, 2001). Yields in these soils may be limited by Ca deficiency more often than by any other plant nutrient deficiency (Gaines *et al.*, 1989).

[1]Res. Scien. and Res. Assoc., respectively, Texas Agric. Exp. Sta., 3507 Hwy. 59E., Beeville, TX 78102.

[2]Res. Plant Path., USDA/ARS, Plant Sci. and Water Cons. Lab., Dept. Entomology & Plant Pathology, Oklahoma State Univ., Stillwater, OK 74078.

*Corresponding author (email: w-grichar@tamu.edu).

Peanut requires Ca for proper kernel development and a high quality seed (Gascho and Davis, 1995). Research in peanut has shown that Ca is transported upward in the plant from the root via uptake through the stem; however, little or no Ca is transported from the leaves downward through the pegs to the developing pod via the phloem (Wiersum, 1951; Mizuno, 1959). The Ca absorption problem for the developing fruit is compounded by little water movement upward from the gynophore to the plant tops to provide a gradient to carry needed Ca into the developing fruit via mass flow (Beringer and Taha, 1976; Wolt and Adams, 1979).

Calcium for seed development must be absorbed by the gynophore by passive uptake via diffusion (Sumner *et al.*, 1988). Therefore, a concentration of Ca is needed in the pod development zone of the soil to prevent Ca deficiency. Gascho and Davis (1995) reported that the development period critical for Ca absorption begins about 20 d following the entrance of the peg into the soil and may extend for an additional 60 d, whereas Mizuno (1959) found 92% Ca taken up by the pod during the first 20 d that the peg entered the soil and 69% of Ca was absorbed within 30 d after peg entered the soil. Smal *et al.* (1989) reported that withholding Ca from the pod zone during the first 30 d after initial pegging resulted in smaller seeds and less seed dry weight in comparison with treatments where Ca was withheld later.

Filonow *et al.* (1988) found neither a decrease in pod rot severity nor increase in peanut yields in Oklahoma from the use of up to 3360 kg/ha $CaSO_4$ soils naturally infested with *Pythium myriotylum* Drecho or *Rhizoctonia solani* Kuhn. This amount of applied Ca was several times that reported by Csinos *et al.* (1984) to reduce pod rot of cv. Early Bunch peanut in Georgia soils. Filonow *et al.* (1988) reported an uptake of Ca by peanut hulls in soils to which Ca was applied. However, there was no evidence of decreased pod rot with increasing Ca content in hulls. In fact, disease severity was often greatest in hulls having the greater concentration of Ca.

These studies were initiated to compare agricultural Ca with Ca obtained as a by-product of a coal-generated power plant. The two sources of Ca were applied at planting or pegging for disease and peanut yield response. Also, calcium, magnesium, and potassium content of the foliage, hull, and kernel were compared to determine if any differences in plant uptake between Ca sources were apparent.

Materials and Methods

Field studies were conducted during the 1998 and 1999 growing seasons at one location in Atascosa Co. and two locations in Wilson Co. to determine the effects of calcium upon peanut pod yield and quality. Agricultural calcium obtained from a local distributor (Hoe-Down, Standard Gypsum Corp., Fredericksburg, TX) was compared with calcium obtained as a by-product of a coal-generated power plant located near LaGrange, TX (Boral Material Technologies Inc., San Antonio, TX). Representative samples of agricultural calcium and by-product calcium were collected prior to study initiation and submitted to the Texas Agric. Ext. Serv. Soil Testing Lab. for chemical analysis.

Soil at the Atascosa Co. location was a Duval loamy fine sand (fine-loamy, mixed, hyperthermic Aridic Haphistalfs) with less than 1% organic matter and pH 7.2. Soil at the Wilson Co. location was a Miguel fine sandy loam (fine, mixed, hyperthermic Udic Paleustalfs) with 1.5% organic matter and pH 7.0. Initial Ca levels at the Wilson Co. location were intermediate (96 to 140 ppm) while Ca levels at Atascosa Co. were high (150 to 190 ppm).

The runner market type cultivar GK-7 was planted at all locations during late May or early June using a vacuum planter (Monosem pneumatic planter, A.T.I., Inc., Lenexa, KS) set to plant seed 5 cm deep at the rate of 90 kg/ha. Plot size was four rows, 3.9 m wide × 9.5 m long.

Calcium was hand applied to plots prior to planting after herbicides were applied or approximately 60 d after planting when peanut had begun to peg. The Ca for each plot was pre-weighed and spread over the peanut row (at plant) or spread over the top of the peanut plant into the pegging zone (peg).

The experimental design was a randomized complete block with four replications. Calcium treatments included by-product Ca at 560, 1120, 1680, and 2240 kg/ha total product applied at plant or 1120 and 1680 kg/ha total product applied at pegging. Agricultural Ca was applied at 1120, 1680, and 2240 kg/ha total product applied at plant or 1120 or 1680 kg/ha total product applied at peg. A non-treated control was included for comparison.

Soil samples and treatment response data were obtained from the middle two rows of each plot to prevent edge effects from adjacent plots. Yields were obtained by digging each plot separately, air-drying in the field for 5 to 8 d, and harvesting peanut pods with a combine. Weights were recorded after soil and foreign material were removed from plot samples. Peanut grades [total sound mature kernels (TSMK) and sound split kernels (SS)] were determined from a 200-g pod sample from each plot following procedures described by the Federal-State Inspection Serv. (USDA, 2001).

Disease incidence was determined immediately after digging. Infection sites (hits) were determined by discolored pods with visual confirmation of the fungus by mycelia or sclerotia production (Rodriguez-Kabana *et al.*, 1975). Maximum length for a target site was 30 cm if no healthy stems intervened. Differences between adjacent infection sites were based on the presence of apparently healthy intervening stems.

The location in Wilson Co. historically had moderate to heavy incidence of the soil-borne diseases Rhizoctonia

pod rot (*R. solani*) and pythium pod rot (*P. myriothylum*). The Atascosa Co. location was symptomatic for Rhizoctonia pod rot, southern blight (*Sclerotium rolfsii* Sacc.), and sclerotinia blight caused by *Sclerotium minor* Jagger.

Soil test samples from each experimental unit were obtained with a hydraulic tractor-mounted core sampler (Concord Environmental Equipment, Hawley, MN) prior to peanut planting and at the conclusion of each growing season. Soil cores were divided into increments of 0 to 15 cm, 15 to 30 cm, 30 to 46 cm, 46 to 61 cm, and 61 to 91 cm. Plant, shell, and kernel samples were taken from five plants per plot at peanut digging. Individual pods were washed and placed in paper bags and left on a bench in the greenhouse to dry. Dried pods were manually shelled and hulls and kernels separated. Dried tissue was ground to powder in a coffee mill. From these ground samples, subsamples of 2 g for leaves, kernels, and hulls were placed in coin envelopes and submitted for Ca analysis by the nitric acid digestion procedure (Servi-Tech Laboratories, Dodge City, KS). In the same way, a 200-g soil sample from each treatment, soil depth subsample, and replication were submitted to chemical analysis using the ammonium acetate extraction method (Servi-Tech Laboratories, Dodge City, KS).

Disease incidence, pod yield, peanut grade (TSMK + SS), and Ca, Mg, and K content of hull, kernel, and foliage tissue were subjected to analysis of variance and means compared using Fisher's protected LSD ($P \leq 0.05$). Since there was a treatment × location interaction for disease incidence, peanut pod yield, and grade (TSMK + SS), that data are presented separately for each location. There was a treatment × year interaction for Ca, Mg, and K content from hull, kernel, and foliage tissue; therefore, those data are presented separately by year. There was a treatment × location interaction for Mg content of kernel tissue in 1998, so data are presented separately by location.

Results and Discussion

Chemical Composition of Calcium Sources. Chemical analysis of the two Ca sources indicated that power plant by-product Ca source contained higher concentrations of B, Cl, Mg, K, and Na than the agricultural Ca source (Table 1). Concentrations of Ca and S were similar for the two calcium sources; thus, any differences in plant uptake likely would be attributed to variations in solubility. Moisture levels were higher in the by-product Ca compared to agricultural Ca.

Disease Development. There was a location × treatment interaction; therefore, disease data are presented separately by location. In 1998 at the Wilson County location, all Ca rates except by-product Ca at 560 kg/ha applied at plant decreased disease development up to 50% when compared with the non-treated control (Table 2).

Table 1. Chemical composition of by-product calcium and agricultural calcium.

Component	By-product Ca	Agricultural Ca
	Mg/kg	
Aluminum	< 0.05	< 0.05
Arsenic	< 0.01	< 0.01
Barium	0.09	0.06
Boron	0.25	0.12
Calcium	590	570
Cadmium	< 0.005	< 0.005
Chloride	40.0	< 1.0
Chromium	< 0.01	< 0.01
Copper	0.02	< 0.02
Iron	< 0.02	< 0.02
Lead	< 0.005	< 0.005
Magnesium	12.0	< 0.5
Manganese	< 0.01	0.01
Mercury	< 0.0002	< 0.0002
Molybdenum	< 0.02	< 0.02
Nickel	< 0.02	< 0.02
Phosphorus	< 1.0	< 1.0
Potassium	3.7	< 1.0
Selenium	< 0.01	< 0.01
Silver	< 0.01	< 0.01
Sodium	41.0	0.92
Sulfate	1580.0	1500.0
Vanadium	< 0.02	< 0.02
Zinc	0.06	0.1
Sulfur (%)	14.3	16.3
pH	7.3	8.0
Moisture (%)	20.0	1.0

Research from other studies has indicated a decrease in pythium disease development when Ca was applied. Garren (1964) first reported that high rates of Ca resulted in a reduction in diseased or rotted peanut pods. Walker and Csinos (1980) stated that under severe disease pressure with several cultivars, disease decreased for all cultivars as the rate of Ca increased.

At the Atascosa Co. location in 1998, no differences in disease incidence were noted between the non-treated control and any Ca treatment (Table 2). At this location, the primary disease was southern blight, and no response to southern blight using Ca has been reported in the literature. However, Gascho and Davis (1995) reported high levels of Ca may surpress the pathogen that causes southern blight or added Ca may increase resistance or productivity of the host plant.

In 1999, by-product Ca at 560 and 1680 kg/ha applied at plant or 1120 kg/ha applied at peg and agricultural Ca at 1120, 1680, and 2240 kg/ha applied at plant reduced Rhizoctoni and pythium pod rot when compared with the non-treated control (Table 2). Other studies have shown that high rates of Ca are required to ensure adequate Ca be present in the pegging zone for pod development (Jones *et al.*, 1976).

Table 2. Disease incidence at each location after peanuts were inverted.

Treatment	Rate	Application timing	Location[a] 1998 Wilson Co.	1998 Atascosa Co.	1999 Wilson Co.
	kg/ha		----- Hits/15.8 m row -----		
Untreated check	–	–	28.0	28.2	20.0
By-product Ca	560	Planting	25.0	30.4	8.0
	1120	Planting	18.0	29.6	14.0
	1680	Planting	16.0	21.8	9.6
	2240	Planting	14.0	24.4	12.0
	1120	Pegging	18.4	22.6	10.0
	1680	Pegging	10.6	26.6	15.0
Agricultural Ca	1120	Planting	18.6	28.8	8.6
	1680	Planting	19.0	34.0	10.0
	2240	Planting	16.6	37.2	10.6
	1120	Pegging	14.6	28.4	12.6
	1680	Pegging	16.0	31.2	12.0
$LSD_{(0.05)}$			6.4	11.2	9.0

[a]Disease incidence in Wilson Co. was Rhizoctonia and pythium pod rot. Disease incidence in Atascosa Co. was southern blight, Rhizoctonia pod and limb rot, and sclerotinia blight.

Peanut Yield. Since soil-borne diseases and disease incidence varied with each location, yield data are presented separately by location. No increase in peanut yield over the non-treated control was noted with Ca at either location in 1998 (Table 3). However, in 1999, by-product Ca at 2240 kg/ha or agricultural Ca at 1680 and 2240 kg/ha applied at plant increased peanut yield up to 22% over the non-treated control. On coarse textured soils low in residual Ca, peanut yields have been increased with Ca applications (Sullivan *et al.*, 1974; Walker and Csinos, 1980). Jordan *et al.* (2000) reported supplemental Ca increased pod yield of virginia- and runner-type peanut over the non-treated control at two of the five locations in the Virginia-Carolina region.

Peanut Grade (TSMK + SS). There was a location × treatment interaction; therefore, data are presented separately by location. Only in 1998 at the Atascosa Co. location was a grade increase with any Ca treatment noted over the non-treated control (Table 4). By-product Ca at 1680 kg/ha applied at plant or agricultural Ca at 1120 kg/ha applied at peg did not increase peanut grade over the non-treated control. At the Wilson Co. location, by-product Ca at 1680 kg/ha produced the highest grade while the agricultural Ca rate of 1120 kg/ha produced the lowest grade.

In 1999 at Wilson Co., all peanut grades except by-product Ca at 1120 kg/ha applied at plant or peg were at least 75% TSMK (Table 4). Other studies have also reported varying results. Jordan *et al.* (2000) reported that applying Ca at 340 or 680 kg/ha increased the percent extra large kernels (ELK) from 40% when Ca was not applied, to 46 and 51%, respectively. Walker and Keisling (1978) reported Ca increased percentage TSMK of five cultivars. Hallock and Allison (1980) reported similar results in Virginia using several different Ca sources.

Table 3. Peanut yield with by-product and agricultural calcium.

Treatment	Rate	Application timing	Location 1998 Wilson Co.	1998 Atascosa Co.	1999 Wilson Co.
	kg/ha		---------- kg/ha ----------		
Check	–		2654	4195	3325
By-product Ca	560	Planting	3227	4164	3768
	1120	Planting	3037	4100	3358
	1680	Planting	3016	3946	3783
	2240	Planting	3324	4053	3859
	1120	Pegging	2404	4160	3590
	1680	Pegging	3008	4363	3456
Agricultural Ca	1120	Planting	3213	4015	3804
	1680	Planting	3042	4011	4011
	2240	Planting	3222	3786	4044
	1120	Pegging	2890	4264	3582
	1680	Pegging	2913	4102	3619
$LSD_{(0.05)}$			721	415	514

Table 4. Percent peanut grade with by-product and agricultural calcium.[a]

Treatment	Rate	Application timing	Locations 1998 Wilson Co.	1998 Atascosa Co.	1999 Wilson Co.
	kg/ha		----- % SMK + SS -----		
Check	–		74.8	65.3	75.8
By-product Ca	560	Planting	73.6	72.4	76.5
	1120	Planting	73.5	73.3	74.8
	1680	Planting	73.5	68.9	77.3
	2240	Planting	75.1	73.3	76.0
	1120	Pegging	74.1	72.4	74.3
	1680	Pegging	75.5	72.1	76.5
Agricultural Ca	1120	Planting	74.5	73.4	77.3
	1680	Planting	75.4	73.1	75.0
	2240	Planting	74.1	70.8	76.5
	1120	Pegging	72.1	69.4	75.8
	1680	Pegging	74.3	71.6	75.8
$LSD_{(0.05)}$			2.9	4.9	2.4

[a]Grade = total sound mature kernel (SMK) and sound splits (SS).

Foliage Tissue Contents. There was no location × treatment interaction for any nutrient; therefore, data were combined over locations. However, there was a year × treatment interaction for all nutrients so data are presented separately by year. In 1998, only agricultural Ca at 1120 kg/ha applied at peg produced higher Ca content in leaf

tissue than the non-treated control. In 1999, no difference in foliage Ca content was noted between the non-treated control and any Ca treatment, although there were differences among Ca treatments. Agricultural Ca at 1120 kg/ha applied at peg had the highest Ca level, while agricultural Ca at 1680 or 2240 kg/ha applied at plant had the lowest Ca levels. Sullivan *et al.* (1974) noted an increase in leaf Ca content where Ca was applied to the virginia cultivar NC 5 at flowering at 670 and 1340 kg/ha.

In 1998, Mg content in foliage tissue was highest with by-product Ca applied at plant at 2240 kg/ha or applied at peg at 1120 kg/ha (Table 5). The lowest Mg content was with by-product Ca applied at plant at 560 kg/ha or agricultural Ca applied at peg at 1680 kg/ha. In 1999, the highest Mg level was by-product Ca applied at plant at 2240 kg/ha while the lowest was agricultural Ca at 1680 kg/ha applied at plant. Sullivan *et al.* (1974) reported that Mg content in leaf tissue from NC 5 was highest where no Ca had been applied, while lowest levels were found in leaf tissue from plots treated with Ca at 1346 kg/ha.

In 1998, K content of the foliage was significantly higher than the non-treated control with by-product Ca at 1120 or 2240 kg/ha applied at plant, 1120 kg/ha applied at peg, or agricultural Ca at 1120 kg/ha applied at plant or peg. In 1999, no differences in K content between the non-treated control and any Ca treatments were noted although there were differences between Ca treatments. Foliage tissue from by-product Ca at 1120 kg/ha applied at peg had a higher K content than tissue from plots which received agricultural Ca at 1680 and 2240 kg/ha applied at peg or 1120 kg/ha applied at plant (Table 5).

Hull Tissue Content. There was no location × treatment interaction for any nutrient; therefore, data were combined over locations. However, there was a year × treatment interaction for all nutrients, so data are presented separately by year. In 1998, all Ca treatments produced a higher Ca content than the non-treated control, while in 1999 only agricultural Ca at 1680 kg/ha applied at plant had a higher hull Ca content than the non-treated control (Table 6). Potassium content in hulls from Ca treated plots did not differ from those of the non-treated control in 1998 (Table 6). In contrast, during 1999 the K content in hull tissue from the non-treated control was higher than those from plots which received Ca. The lowest K concentrations were from hulls treated with agricultural Ca at 2240 kg/ha applied at planting or 1120 and 1680 kg/ha of agricultural Ca applied at pegging. Sullivan *et al.* (1974) reported a 10 to 30% decrease in K hull content, depending on Ca rate.

Hull Mg content was lower with both types of Ca than the non-treated control in both 1998 and 1999 (Table 6). In 1998, there was a 3 to 14% decrease in Mg content from the untreated check, while in 1999 the decrease from the non-treated control ranged from 20 to 41%.

Kernel Tissue Content. There was a location by treatment interaction for Mg in 1998; therefore, that data are presented separately by location. There was a year × treatment interaction for all nutrients so that data are presented separately by year. In 1998, all Ca rates, except by-product Ca at 560 kg/ha, resulted in increased Ca kernel content from 14 to 24% over the non-treated control (Table 7). Calcium content was highest with agricultural Ca applied at planting at 1680 kg/ha. In 1999, none of the Ca treatments resulted in an increase in Ca content over the non-treated control. Sullivan *et al.* (1974) reported that Ca content in seed increased as Ca rate increased. Hallock and Allison (1980) reported Ca seed content was generally higher for pegging time applications than when Ca was applied at planting. Dark plumule and watery hypocotyl abnormalities in kernels have been related to Ca deficiency (Cox and Reid, 1964;

Table 5. Calcium, magnesium, and potassium content of foliage tissue from agricultural and by-product calcium.

Treatment	Rate	Application timing	Ca		Mg		K	
			1998	1999	1998	1999	1998	1999
	kg/ha		ppm					
Check	–	–	1.83	2.37	0.58	0.89	2.18	1.63
By-product Ca	560	Planting	1.93	2.37	0.54	0.81	2.39	1.60
	1120	Planting	1.98	2.39	0.58	0.93	2.49	1.59
	1680	Planting	1.93	2.32	0.57	0.91	2.33	1.68
	2240	Planting	2.07	2.37	0.65	0.94	2.45	1.57
	1120	Pegging	2.11	2.26	0.65	0.80	2.51	1.82
	1680	Pegging	1.98	2.43	0.62	0.81	2.42	1.66
Agricultural Ca	1120	Planting	1.94	2.50	0.59	0.86	3.18	1.51
	1680	Planting	1.90	2.14	0.56	0.78	2.34	1.40
	2240	Planting	1.94	2.16	0.57	0.86	2.15	1.46
	1120	Pegging	2.16	2.64	0.58	0.88	2.52	1.38
	1680	Pegging	1.83	2.54	0.52	0.92	2.43	1.52
$LSD_{(0.05)}$			0.31	0.39	0.11	0.16	0.26	0.32

Table 6. Calcium, magnesium, and potassium content of hull tissue from agricultural and by-product calcium.

Treatment	Rate	Application timing	Hull					
			Ca		K		Mg	
			1998	1999	1998	1999	1998	1999
	kg/ha		ppm					
Check	–	–	0.244	0.309	0.595	0.877	0.064	0.076
By-product Ca	560	Planting	0.300	0.302	0.603	0.720	0.058	0.061
	1120	Planting	0.333	0.299	0.611	0.758	0.055	0.059
	1680	Planting	0.389	0.338	0.633	0.777	0.057	0.053
	2240	Planting	0.408	0.378	0.641	0.760	0.057	0.059
	1120	Pegging	0.302	0.294	0.618	0.848	0.058	0.055
	1680	Pegging	0.314	0.354	0.586	0.762	0.059	0.053
Agricultural Ca	1120	Planting	0.362	0.327	0.598	0.681	0.056	0.049
	1680	Planting	0.388	0.393	0.609	0.603	0.056	0.049
	2240	Planting	0.433	0.367	0.673	0.586	0.062	0.045
	1120	Pegging	0.323	0.314	0.624	0.589	0.060	0.049
	1680	Pegging	0.315	0.297	0.566	0.596	0.057	0.048
$LSD_{(0.05)}$			0.034	0.081	0.82	0.025	0.007	0.018

Table 7. Calcium, magnesium, and potassium content of kernel tissue from agricultural and by-product calcium.

Treatment	Rate	Application timing	Ca		Mg			K	
			1998	1999	1998		1999	1998	1999
					Atascosa Co.	Wilson Co.			
	kg/ha		ppm						
Check	–		0.072	0.080	0.240	0.245	0.281	0.739	0.192
By-product Ca	560	Planting	0.078	0.076	0.213	0.233	0.276	0.739	0.184
	1120	Planting	0.083	0.073	0.208	0.233	0.283	0.739	0.178
	1680	Planting	0.087	0.082	0.218	0.215	0.304	0.730	0.182
	2240	Planting	0.087	0.083	0.203	0.228	0.285	0.725	0.182
	1120	Pegging	0.083	0.077	0.218	0.235	0.293	0.720	0.191
	1680	Pegging	0.085	0.083	0.220	0.235	0.302	0.724	0.197
Agricultural Ca	1120	Planting	0.086	0.077	0.210	0.225	0.302	0.716	0.191
	1680	Planting	0.089	0.087	0.208	0.218	0.281	0.726	0.182
	2240	Planting	0.085	0.083	0.210	0.213	0.283	0.714	0.189
	1120	Pegging	0.082	0.080	0.215	0.227	0.289	0.719	0.188
	1680	Pegging	0.082	0.081	0.208	0.223	0.285	0.700	0.190
$LSD_{(0.05)}$			0.01	0.01	0.013	0.013	0.019	0.026	0.013

Harris and Brolmann, 1966; Sullivan *et al.*, 1974).

Generally, magnesium levels in kernel tissue decreased with the application of Ca when compared with the non-treated control in 1998 at both locations (Table 7). However, in 1999, by-product Ca at 1680 kg/ha applied at planting or at pegging and agricultural Ca at 1120 kg/ha applied at planting resulted in an increase in Mg levels when compared with the non-treated control. Sullivan *et al.* (1974) reported no difference in Mg content of the seed between the non-treated control and the Ca applications, while Hallock and Allison (1980) reported Mg levels decreased when Ca was applied at pegging compared with at-planting Ca applications.

Potassium content in kernel tissue in 1998 was lower with agricultural Ca at 1680 kg/ha applied at pegging when compared with the non-treated control, while in 1999 only by-product Ca at 1120 kg/ha applied at planting resulted in lower K levels than the non-treated control (Table 7).

In summary, under growing conditions found in south Texas, by-product Ca or agricultural Ca should be equally effective sources of supplemental Ca for peanuts. Peanut yield was increased and pod disease decreased with either type of Ca applied at planting or pegging. Response of disease development and peanut pod yield to Ca rate and application timing were not consistent.

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