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CEMENT AS A SUBSTITUTE FOR GYPSUM FOR IMPROVED POD-FILLING IN GROUNDNUT

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SUMMARY

Groundnut (*Arachis hypogaea*) cannot be grown economically on unamended acid soils because of poor pod-filling resulting from an inadequate supply of calcium. Gypsum improves pod-filling but in Mauritius it is now too expensive.

Field trials were conducted at two locations in 1994–95 and at four locations in 1995–96 to find out if cement could be used instead of gypsum. In three trials where the soil pH ranged from 5.4 to 6.3 and the soil calcium level from 2.4 to 6.9 cmol kg^{-1}, there were few empty pods and no response to gypsum or cement was observed. At the remaining three sites, the soil pH was 5.5, 4.9 and 4.3 and the soil calcium levels were 1.8, 0.39 and 0.92 cmol kg^{-1}, respectively. In the untreated plots at the three sites 17.4%, 27.5% and 50.6% of the pods were empty. Cement at rates of 525 and 700 kg ha^{-1} and gypsum at 1000 kg ha^{-1} applied to the foliage at flowering reduced the number of empty pods to less than 10% and significantly increased seed yield, shelling percentage and commercial-grade kernels. However, cement was not as effective when placed in the furrows at planting. At current prices, the use of cement was cost effective whereas that of gypsum was not. Cement may therefore be proposed as a replacement for gypsum for the improvement of pod-filling in groundnut.

INTRODUCTION

In the superhumid region of Mauritius, where the mean annual rainfall ranges from 2000 to more than 3600 mm (Padya, 1989) and in other countries where the soils are acidic, Virginia- and Valencia-type groundnut (*Arachis hypogaea*) cannot be grown because of poor pod-filling caused by calcium deficiency. Gypsum which contains readily-available calcium has been found to be effective in improving pod-filling (MSIRI, 1972) and its use has been recommended in Mauritius (MSIRI, 1975). However, gypsum is not always available, it is now very expensive and its application on groundnut may not be economical. Hence, there is a need to find a replacement for gypsum.

Various amendments can be utilized to raise the pH of soils and to supply calcium to groundnut. In Zambia the application of lime improved pod-filling of groundnut but the practice has not been adopted because it is too costly (Syamasonta, 1990). In Mauritius, coral sand and lime are used to correct soil acidity for sugarcane and cement has been recommended as an alternative when sand and lime are either not available or are too expensive (MSIRI, 1990). Cement contains 61.6% of calcium oxides and is readily available (Ng Kee Kwong *et al.*, 1993). It is effective in increasing both the pH and the calcium level of soils (Abdul Awal, 1988; Ng Kee Kwong *et al.*, 1993), but its use on groundnut has not been studied previously. The present study was conducted to investigate the effect of time and rate of application of cement on pod-filling of groundnut.

MATERIALS AND METHODS

In 1994 and 1995 six trials were planted in Mauritius (lat 20 °S long 57 °E) with the Virginia-type groundnut Veronica using randomized complete block designs with six replicates. In 1994 and 1995 trials were established in September at Réduit and Belle Rive. In 1995 two more trials were laid down in October and December at Union Park and Belle Vue Maurel respectively. The soil at Réduit is a Low Humic Latosol, at Belle Rive a Humic Ferruginous Latosol, at Union Park a Latosolic Brown Forest and at Belle Vue Maurel a Humic Latosol (Arlidge and Wong You Cheong, 1975). At planting when the soils were analysed pH varied from 4.3 to 6.3 and calcium levels from 0.39 to 6.93 cmol kg^{-1}. The annual rainfall of each site is given in Table 1.

At all sites the land was prepared with a disc plough and at Réduit alone a finer tilth was produced with a rotovator. At Belle Vue Maurel, the cane stools of the previous crop were first uprooted with a subsoiler. The plots consisted of four rows 4 m in length in 1994 and 6 m in length in 1995. The between-row spacings in the plot were 0.4 m and there was 0.8 m between plots. The intra-row spacing was 0.1 m. The whole plot was harvested to assess yield which was expressed as seed yield (shelled nuts) at 8% moisture content.

At planting 26 kg N, 26 kg P_2O_5, 40 kg K_2O and 4 kg MgO ha^{-1} in the form of the complex fertilizer 13 : 13 : 20 : 2 was spread at the bottom of the furrows. Linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methyl-urea) was applied as a pre-emergence herbicide to control weeds as recommended (Govinden *et al.*, 1994). Only the trials at Réduit were irrigated; overhead sprinklers used to supplement rainfall provided about 40 mm water per week. The recommended rate of 1000 kg gypsum ha^{-1} applied at flowering (Govinden *et al.*, 1994) was used in 1994. Cement was also applied at 525 kg ha^{-1} at flowering to supply the same amount of calcium oxide (320 kg ha^{-1}). In 1995, two rates of cement, 525 and 700 kg

Table 1. Chemical composition of soils and mean annual rainfall at six locations in Mauritius where trials were conducted in 1994 and 1995.

	1994		1995			
	Réduit	Belle Rive	Réduit	Belle Rive	Union Park	Belle Vue Maurel
pH (2 : 5 H_2O)	5.6	4.9	6.3	5.4	5.5	4.3
P_2O_5(ppm)	269	135	230	104	192	82
K_2O (cmol kg^{-1})	1.03	0.26	1.15	0.26	0.38	0.26
Ca (cmol kg^{-1})	4.39	0.39	6.93	2.40	1.80	0.92
Rainfall (mm)	1185	2646	2500	4574	4284	2060

ha^{-1}, were used and the cement was applied either in the furrow at planting or to the foliage at early flowering. In the latter treatment, the amendments were spread by hand on top of the foliage. The effect of the treatments was evaluated on dry seed yield, shelling percentage, the percentage of empty pods, seed grades and profitability.

The shelling percentage (proportion by weight of seeds to pods) was calculated after hand shelling. For grading samples of dry pods 200–300 g in weight from Belle Vue Maurel were shelled, and the seeds in each sample were weighed individually and the width measured with a micrometer. Virginia seed grades adapted from the National Peanut Council of America (1996) were used and the percentage by weight in each of the following grades was calculated: Virginia Extra-large (90–100 g 100 $seeds^{-1}$), Virginia Medium and Virginia No. 1 (52–75 g 100 $seeds^{-1}$) and Virginia No. 2 (splits < 52 g 100 $seeds^{-1}$). The profitability of gypsum and cement was assessed as the marginal rate of return given by the ratio of the extra revenue obtained to the extra cost of production incurred with the application of amendments. The variable costs were those of transport, amendments, labour for application of the amendments, drying and shelling of the extra pod yield. A kernel price of R 35 000 (US$1734) per tonne without any premium for quality was used. The price of gypsum and cement were R 17 500 (US$867) and R 1760 (US$87) per tonne respectively. The exchange rate at the time of writing was approximately R 20.18 = US$1. Analysis of variance was performed on the data. The percentage in each seed grade and the proportion of empty pods were analysed after arc-sine square-root transformation as recommended for percentages by Gomez and Gomez (1984).

RESULTS

No symptoms of phytotoxicity to cement were observed in any of the trials. At Belle Rive in 1995 and Réduit in 1994 and 1995 the pods were properly filled. In these three trials there was no significant response by any of the parameters to the treatments. In 1994 at Réduit, the shelling percentage was about 58% in all treatments; in 1995 it ranged from 63% to 64% at Réduit and from 52% to 56% at Belle Rive (data not presented). Consequently, the yield of seeds was unaffected by treatments (Table 2). At the other three locations, Belle Rive in 1994, Union Park and Belle Vue Maurel in 1995, the treatments produced significant differences in all the parameters recorded.

Dry seed yield

The yield of dry seeds increased with both gypsum and cement (Table 2). At Belle Rive in 1994, gypsum and cement increased yield by 66% and 64% respectively and, at Belle Vue Maurel yield with gypsum was 221% higher than that of the control with no amendment. Cement applied to the foliage at 525 or 700 kg ha^{-1} produced 141% and 177% higher yield. Cement spread at the two

Table 2. Effect of gypsum and cement on seed yield of groundnuts at six locations in Mauritius.

	Seed yield at 8% moisture content (t ha^{-1})					
	1994		1995			
Treatment (kg ha^{-1})	Réduit	Belle Rive	Réduit	Belle Rive	Union Park	Belle Vue Maurel
Gypsum (1000)	3.15	1.66	3.58	2.22	1.91	1.25
Cement at planting (525)	—	—	3.59	2.49	1.92	0.74
Cement at flowering (525)	2.87	1.64	3.63	2.09	1.80	0.94
Cement at planting (700)	—	—	3.84	2.26	1.84	0.70
Cement at flowering (700)	—	—	3.83	2.12	1.78	1.08
Control (no amendment)	2.78	1.00	3.64	2.23	1.36	0.39
s.e. transformed mean	0.3	0.14	0.25	0.15	0.15	0.11

rates in the furrows increased yield by 90% and 80% compared with the control. A smaller response which ranged from 31% to 41% was obtained at Union Park.

Proportion of empty pods and shelling percentage

At Belle Rive in 1994 and at Union Park and Belle Vue Maurel in 1995 the percentages of empty pods in the control treatments were 27.5%, 17.4% and 50.6% respectively (Table 3). The application of both gypsum and cement significantly reduced the proportion of empty pods at Belle Rive to 5.7% and 7.9%. At Union Park, when gypsum at 1000 kg ha^{-1} and cement at 525 or 700 kg ha^{-1} were dusted to the foliage at flowering, the proportions of empty pods were reduced to 2.9%, 3.6% and 4.1% respectively. Similarly, at Belle Vue Maurel in these treatments only 4.3%, 8.6% and 9.9% of pods were empty.

Table 3. Influence of gypsum and cement on pod-filling and shelling percentage of groundnut at three locations in Mauritius.

	Proportion of empty pods (%)			Shelling percentage (%)		
	1994	1995		1994	1995	
Treatment (kg ha^{-1})	Belle Rive†	Union Park†	Belle Vue Maurel†	Belle Rive	Union Park	Belle Vue Maurel
Gypsum (1000)	5.7 (12.7)	2.9 (9.7)	4.3 (11.4)	53.6	57.2	59.9
Cement at planting (525)	—	5.7 (13.5)	25.7 (30.3)	—	56.6	45.5
Cement at flowering (525)	7.9 (16.3)	3.6 (10.8)	8.6 (16.7)	57.6	56.7	55.8
Cement at planting (700)	—	7.1 (15.2)	23.5 (28.9)	—	55.7	46.6
Cement at flowering (700)	—	4.1 (11.3)	9.9 (17.5)	—	55.8	55.8
Control (no amendment)	27.5 (31.6)	17.4 (24.4)	50.6 (45.5)	45.3	46.8	35.4
s.e. mean	(2.4)	(1.7)	(2.7)	3.4	2.0	4.0

†Arc-sine square-root transformation in parentheses.

Table 4. Effect of gypsum and cement on grades of groundnut seeds from Belle Vue Maurel, Mauritius.

	Proportion by weight (%)		
Treatment (kg ha^{-1})	Virginia No. 2	Virginia Medium & Virginia No. 1	Virginia Extra-large
Gypsum (1000)	20.3 (26.3)†	46.8 (43.0)	32.9 (34.3)
Cement at planting (525)	38.7 (38.3)	39.7 (38.9)	21.6 (26.4)
Cement at flowering (525)	21.6 (27.0)	44.5 (41.8)	33.9 (34.8)
Cement at planting (700)	38.0 (37.5)	40.3 (39.3)	21.7 (26.1)
Cement at flowering (700)	23.5 (28.8)	44.0 (41.5)	32.5 (34.3)
Control (no amendment)	59.9 (51.0)	32.6 (34.6)	7.5 (11.6)
s.e. mean	(3.4)	(3.2)	(3.2)

†Arc-sine square-root transformation in parentheses.

However, cement was not as effective when placed in the furrows at planting at Belle Vue Maurel where there were 25.7% and 23.5% of empty pods with cement at rates of 525 and 700 kg ha^{-1}. At Union Park the difference in the percentage of empty pods between cement applied at flowering and at planting was less marked.

The effects of treatments on shelling percentage which are a reflection of pod-filling were similar to those observed on the proportion of empty pods (Table 3). Cement and gypsum increased the shelling percentage and there was no significant difference between the effects of the two rates of cement. At Belle Vue Maurel but not at Union Park cement was more effective in increasing shelling percentage when it was applied at flowering than when placed in the furrows.

Seed grade

At Belle Vue Maurel, 59.9% of the seeds in the untreated control were in the smaller Virginia No. 2 grade and only 7.5% were Extra-large (Table 4). The percentage in Virginia Medium and Virginia No. 1 grades were less variable between treatments and ranged from 32.6% to 46.8%. The application of gypsum or cement significantly reduced the proportion of Virginia No. 2 and increased that of the Extra-large grade. Again cement applied at planting was less effective in improving seed grade.

Profitability

At the time of the experiments cement at 525 and 700 kg ha^{-1} and gypsum at 1000 kg ha^{-1} cost R 924 (US$46), R 1232 (US$61) and R 17 500 (US$867) ha^{-1} respectively. At these rates, the mean increase in yield of groundnut at the three responsive sites in Table 2 resulting from the use of amendments at flowering represented rates of return on investment of 9.0 to 1 and 6.8 to 1 for cement and 1.2 to 1 for gypsum. Cement at 525 and 700 kg ha^{-1} applied at planting produced rates of return of 6.7 to 1 and 4.9 to 1.

DISCUSSION

At low soil pH, plants are adversely affected either by aluminium toxicity or by an inadequate supply of calcium. At a pH above 5.0 the solubility of aluminium in the soils of Mauritius is so low that aluminium toxicity is not a problem in sugarcane (*Saccharum officinarum*) (Ng Kee Kwong, 1993). At these pHs, amendments would not increase the soil exchangeable calcium status significantly and no increase in sugar yield is obtained (Ng Kee Kwong *et al*., 1980). The results of the present trials with groundnut confirmed these findings. At the three locations where the pH was higher than 5.0 and the calcium level between 2.4 and 6.9 cmol kg^{-1} no response was obtained to gypsum or cement. At these non-responsive sites there was no reduction in seed yield which confirmed the observation that cement had no phytotoxic effect. At the three other sites seed yield, shelling percentage and the proportion of pods that were filled decreased with increasing soil acidity and calcium deficiency. Consequently, both amendments significantly improved pod-filling and yield.

Although cement can supply the calcium requirement of groundnut on acid soils, the time of application is important. Hence when cement was applied at planting it was less effective than when it was spread onto the foliage. This indicated that in the former case the calcium may have been less available to groundnut for pod-filling possibly because some of it was bound in the soil. This hypothesis is consistent with the suggestion of Syamasonta (1990) that in soils with a pH less than 4.5 in Zambia, gypsum was less effective than lime in improving the growth of groundnut because the gypsum reacted with aluminium oxides which rendered the calcium unavailable to the plant. However, the lower response to soil-applied cement may also have been caused by the placement of the cement in the furrows and therefore well below the pod zone. Hence, much of the calcium was not available to the pods. The subterranean pegs and developing pods absorb their calcium requirement directly from the soil, and calcium taken up by the roots is not usually available to the pods (Rajendrudu and Williams, 1987). In Georgia, USA, high yield and good quality groundnuts are produced by supplying calcium in the top 8 cm of the soil during pegging and pod-filling. The incorporation of gypsum in the soil is not as effective as its application at flowering (Gascho *et al*., 1993).

The difference in response between Belle Vue Maurel in 1995 and Belle Rive in 1994 indicates that soil acidity may be relatively more important for pod-filling than the total soil calcium. Although the calcium level at Belle Vue Maurel was more than twice that at Belle Rive, at soil pH 4.3 there were more empty pods at the former site, indicating that the amount of available calcium was less. This may be a direct or indirect consequence of a lower soil pH. The difference may be due to a seasonal effect since one trial was planted in September 1994 and the other in December 1995. However, in Zambia, Syamasonta (1990) reported that the problem of empty pods is not a seasonal phenomenon but always occurs in specific areas with low soil pH and calcium level. Nevertheless, calcium deficiency can be caused by numerous soil and climatic factors which may vary seasonally. Drought can induce calcium deficiency by reducing its availability to and uptake by the plant, and substantial yield increases are obtained when gypsum is applied (Rajendrudu and Williams, 1987). In the trials reported here no water stress was observed.

The responses in 1995 at Belle Rive and Union Park suggest that the critical calcium level below which empty pods appear is between 1.8 and 2.4 cmol kg^{-1}. Hence, even when the pH was higher than 5.0 pod-filling could be a problem when calcium was below this critical level. This threshold level is higher than that observed in Zambia where pods remained empty when the pH was less than 4.5 and the calcium content ranged from 1.0 to 1.5 cmol kg^{-1} (Kelly, 1985) or less than 1.0 cmol kg^{-1} (Syamasonta, 1990). The difference in calcium threshold levels may also be partly due to genotypic variation in calcium requirements which are known to exist (Rajendrudu and Williams, 1987).

The application of cement at 525 kg ha^{-1} at flowering not only increased yield significantly but also produced the highest marginal rate of return (9 : 1). This rate of return is well above that which is considered necessary for the adoption of a new practice. It has been suggested that for the adoption of a new technology a minimum rate of return of 2 : 1 is required by farmers whereas adjustment to an existing practice needs a rate of 1.5 : 1 (CIMMYT, 1988). The use of cement is therefore profitable even when there is no premium for superior quality nuts as is the case in Mauritius. The findings of this study may be relevant to other countries which have constraints similar to those in Mauritius and where liming materials are either too expensive or not available. The benefits from cement applied to groundnut can even be substantially higher in countries where cement is cheaper or where there is a premium for quality nuts.

CONCLUSION

The results of this study demonstrate that the application of cement at flowering is as effective as gypsum in improving pod-filling in groundnut. At current prices, the use of gypsum at 1000 kg ha^{-1} is not cost effective whereas that of cement at equivalent rates gives mean returns of 9 : 1. Cement may therefore be proposed to replace gypsum for improving pod-filling in groundnut on acid soils in Mauritius.

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