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EFFECT OF GYPSUM AND DROUGHT ON POD INITIATION AND CROP YIELD IN EARLY MATURING GROUNDNUT (*ARACHIS HYPOGAEA*) GENOTYPES†

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SUMMARY

Gypsum application and irrigation increased yield in early maturing groundnut genotypes in experiments using line source and conventional irrigation. Response to gypsum varied with genotype; with some gypsum increased yields at all water application rates, in some genotypes there was no response, while with others gypsum increased yield in drought conditions.

In a separate study of the effect of gypsum and drought on pod initiation and development in three groundnut genotypes, gypsum did not greatly influence pod initiation when adequate irrigation was applied, but was beneficial when water was withheld during pod set and again during pod filling. Crops where the combination of gypsum and genotype were most advantageous in the first drought period subsequently grew more slowly so that there were no final differences in response to gypsum. Cultivar EC 76446(292) had a higher requirement for gypsum and was more susceptible to drought than the other two genotypes.

G. Rajendrudu y J. H. Williams: *Efecto del yeso y la sequía en la iniciación de las vainas y el rendimiento de cultivo en los genotipos de cacahuate de maduración temprana (*Arachis hypogea*)*

RESUMEN

La aplicación de yeso y riego aumentaron el rendimiento en los genotipos de cacahuate de maduración temprana en experimentos utilizando el riego de línea de salidas con intervalos crecientes y el convencional. La respuesta al yeso varió según el genotipo; en algunos genotipos, el yeso aumentó el rendimiento para todas las tasas de aplicación de agua, en algunos genotipos no hubo respuesta, mientras que en otros el yeso aumentó el rendimiento bajo condiciones de sequía.

En una investigación aparte del efecto del yeso y la sequía en la iniciación y el desarrollo de las vainas en tres genotipos de cacahuate, el yeso no afectó mucho la iniciación de las vainas si se aplicaba un riego adecuado, pero resultó ser beneficioso cuando no se regaba durante la formación de las vainas y también durante el relleno de éstas. Los cultivos en que la combinación de yeso ye genotipo era más ventajosa en el primer período de sequía posteriormente crecieron más lentamente, no habiendo diferencias finales en la respuesta al yeso. La variedad EC 76446(292) tuvo una mayor exigencia de yeso y fue más susceptible a la sequía que los otros dos genotipos.

INTRODUCTION

Calcium nutrition is often a yield limiting factor for groundnut production as it is necessary for pod growth and development. Calcium (Ca) is absorbed from the soil mainly by the subterranean pegs and developing pods and Ca taken up by the roots is not usually available for pod growth and development (Beringer

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and Taha, 1976; Bunting and Anderson, 1960; Chahal and Virmani, 1973; Skelton and Shear, 1971). Ca applied to the fruiting zone increases the number of pods per plant (Radder and Biradar, 1973) and gypsum application between 10 to 30 days after penetration of gynophores into the soil increases the percentage of developed pods. When Ca was deficient in the fruiting zone, Harris (1949) observed that only 1% of gynophores developed into pods.

Groundnut genotypes are known to differ in their nutritional Ca requirements, and in their responses to Ca fertilization under well-watered conditions (Slack and Morrill, 1972; Walker *et al.*, 1976; Walker and Keisling, 1978; Beringer and Teketa, 1979). Large-seeded groundnut cultivars usually respond more favourably to supplemental Ca than small-seeded ones. However, it seems unlikely that seed size *per se* is the only factor influencing responses, since the Ca requirement of the large-seeded cv. Florigiant appears to be closer to that of small-seeded genotypes than that of other large-seeded genotypes (Hartzog and Adams, 1973; Walker *et al.*, 1976). Walker and Keisling (1978) also reported that cv. Tifrun had a greater soil Ca requirement than the similar-sized cv. Florunner.

Calcium deficiency may be caused by a number of soil factors: low cation exchange capacity, cation imbalance, or lower availability due to drought. Gillier (1969) and Hallock and Allison (1980) reported that drought decreased Ca uptake and thus induced Ca deficiency in groundnuts. In a pot study, Balasubramanian and Yayock (1981) found that gypsum tended to reduce the detrimental effect of late moisture stress on pod yield in groundnut.

However, little detailed research has been reported on the effects of Ca levels in the soil under drought conditions. This study was undertaken to investigate the influence of gypsum application and water supply on the initiation, development and yields of groundnut genotypes.

MATERIALS AND METHODS

Experiment 1

This experiment was conducted in the post-rainy season (November 1981 to March 1982) on a medium-deep alfisol at the ICRISAT Centre near Hyderabad (17° 32′ N, 78° 16′ E). For the first 80 days after sowing (DAS), the crop was grown with adequate and uniform irrigation, after which variations in drought were created using line source (LS) sprinkler irrigation, which systematically varied water supply, applied at weekly intervals (Hanks *et al.*, 1976). Water application was monitored at 1 m intervals from the sprinkler line. The main plots consisted of two gypsum treatments (0 and 500 kg ha^{-1}) and the sub-plots 25 early maturing *fastigiata* groundnuts. Treatment combinations were replicated three times, and the plot size for different irrigation treatments within the line source gradient was 2 × 0.6 m.

The seed was sown in rows at a spacing of 30 cm between rows and 15 cm within the row. The gypsum was placed on the surface close to the plants at flowering. Other crop management practices were as recommended for this season. At maturity the harvested pods were cleaned of soil, oven dried at 80°C for 48 hours and their yield determined.

Experiment 2

Six genotypes (mostly as in Experiment 1) were re-tested in the summer season (January to May) of 1983. The experimental design was a split-split-plot with four replications. The main plots consisted of two irrigation treatments (normal irrigation and no irrigation after 70 DAS), the sub-plots of two gypsum treatments (0 and 500 kg ha^{-1}) and the sub-sub-plots of the six genotypes. The seed was sown in rows 75 cm apart and at 15 cm intervals within the row. The sub-sub-plots were 3 X 5 m. Irrigation was uniform and regular from sowing until the pegging stage (two irrigations after the application of gypsum), after which the differential irrigation treatments were introduced. Regular water applications in the control irrigation treatment ensured no water stress, while in the stress treatments no further irrigation was applied. Other cultural practices were as in Experiment 1.

Experiment 3

This experiment was conducted in the post-rainy season (November 1981 to March 1982) using similar methods to those described in Experiment 1. Within the line source gradient, gypsum and genotype treatments were arranged in a split-plot design with four replications. The main plots consisted of three gypsum treatments (0, 500 and 2000 kg ha^{-1}) and the sub-plots three genotypes (TMV 2, EC 76446(292), hereafter called EC, and J 11). Four irrigation treatments were demarcated at different distances from the sprinkler line.

The crop was grown with uniform and adequate conventional sprinkler irrigation until 60 DAS, after which LS irrigation was given at seven day intervals to vary the water application. A single uniform irrigation (50 mm) was given to all treatments 95 DAS when the dry plots had reached the permanent wilting stage. Twenty five mm of unseasonal rain fell 105 DAS.

Pod initiation, development and yield were investigated by weekly samplings (0.6 m^2) from 74 to 116 DAS (maturity in the unstressed treatments). Plants were dug, washed free of soil and all the subterranean pegs, and pegs showing pod development, were counted. The pods were removed and dried at 80°C for 48 hours. The dried pods were weighed and separated into two maturity classes: (i) juvenile pods which shrivelled on drying and (ii) filling and mature pods which retained their shape on drying. These were further classified according to their internal pericarp colour (Gilman and Smith, 1977): (a) filling pods which had white internal pericarp colour and contained immature kernels and (b) mature pods which had discolouration (brown and black) on the internal pericarp. The pods in different classes were counted.

Statistical analyses

Due to the systematic nature of LS irrigation, analysis of the results using conventional analysis of variance techniques was not possible in Experiments 1 and 3. In Experiment 1 regression analysis techniques were used to establish the relationship between pod yield and applied water and to compare the effect of gypsum and genotype on this response.

Regression analyses in Experiment 3 showed that the growth parameters were linearly related to the cumulative amount of water applied. Only the results of the two extreme treatments (fully irrigated and driest treatments) are therefore presented in this paper. Because of the limitation imposed by the design, full analysis between the droughted and fully irrigated treatment was not undertaken. Statistical analysis for the effects of gypsum and genotypes was therefore done separately for each irrigation treatment, treating this unit as a split-plot design.

RESULTS

Experiment 1

Regression analyses showed that the relationships between pod yield and water applied (LS irrigation and rainfall received) during the period of differential irrigation were linear in all cases and that the correlation coefficients between pod yields and applied water were highly significant ($P<0.01$) in all combinations of genotype and gypsum treatments (Table 1). However, the correlations were poorer where gypsum had been applied than in the (no gypsum) control treatments in most genotypes. Gypsum significantly increased the regression for the mean of all genotypes, the higher intercept value indicating that yield was increased by gypsum in drought conditions.

Individual genotypes varied in their response to applied gypsum. In some genotypes, for example ICG 4601, yield was increased by gypsum treatment only in dry conditions. In other genotypes, for example Manfredi X M-13, there was no response to gypsum. The response to applied water (Table 1) can be directly compared for each genotype to establish the effect of gypsum and applied water on yield. Genotypes like ICG 4790, ICG 3280 and ICG 5197 had steeper slopes than other lines like CGC 4063 and ICG 3316. For most genotypes a lower 'b' term was associated with a higher incercept term but for some, like CGC 4063, gypsum increased the intercept and the slope remained constant.

Experiment 2

Yield reponses to gypsum application and irrigation differed among genotypes. Gypsum treatment did not increase yield in groundnuts grown with adequate irrigation and sometimes slightly decreased yields. But gypsum increased the yield of some genotypes, for example ICG 4601, when irrigation was withheld after the pegging phase (Table 2).

Table 1. *Regression analysis of pod yields (g m^{-2}) on the applied water (cm) for some selected early maturing groundnut genotypes without or top-dressed with gypsum (Experiment 1)*

	Linear regression analysis					
	No gypsum			500 kg gypsum ha^{-1}		
	a†	b‡	r	a	b	r
CGC 4063	24.59 (14.71)	9.16 (1.14)	0.87	60.10 (19.37)	9.49 (1.42)	0.82
ICG 221	88.49 (16.91)	13.75 (1.31)	0.91	135.43 (27.09)	10.28 (2.04)	0.74
ICG 2738	95.95 (13.94)	14.46 (1.14)	0.94	153.88 (30.55)	8.94 (2.29)	0.65
ICG 3263	72.76 (19.63)	13.78 (1.52)	0.89	111.02 (27.03)	11.08 (2.21)	0.78
ICG 3280	78.09 (33.90)	16.86 (2.58)	0.82	139.61 (37.51)	9.97 (2.82)	0.62
ICG 3316	10.67 (15.66)	11.01 (1.22)	0.80	35.39 (20.16)	6.12 (1.52)	0.66
ICG 3500	64.35 (15.93)	13.34 (1.28)	0.92	122.64 (24.72)	9.12 (1.90)	0.72
ICG 4601	58.39 (21.18)	14.88 (1.64)	0.89	158.09 (23.93)	8.94 (1.76)	0.74
ICG 4790	−30.85 (18.06)	18.03 (1.45)	0.94	11.33 (17.53)	13.49 (1.27)	0.92
ICG 5197	54.23 (45.83)	18.07 (3.50)	0.80	138.13 (31.03)	10.30 (2.23)	0.71
Manifredi X M-13	22.17 (14.47)	11.07 (1.12)	0.91	26.19 (12.93)	11.76 (0.95)	0.94
Overall mean of 25 genotypes	54.47 (5.10)	13.69 (0.40)	0.83	90.43 (6.06)	11.24 (0.45)	0.73

† a: intercept (g m^{-2}) at zero water application rate. ‡ b: regression coefficient (g m^{-2} cm^{-1}). Figures in parenthesis indicate SE.

Table 2. *Pod yields (kg ha^{-1}) of selected groundnut genotypes as influenced by irrigation and gypsum application (Experiment 2)*

	Irrigated		Droughted	
	No gypsum	500 kg gypsum ha^{-1}	No gypsum	500 kg gypsum ha^{-1}
ICG 2738	1200	1090	370	400
ICG 221	1230	1120	380	490
ICG 3500	1080	1040	290	350
ICG 4672	1630	1360	590	490
ICG 3263	1560	1300	520	510
ICG 4601	1670	1690	400	570
SE†	±100.4		±44.2	

† Because of large differences in response between irrigated and droughted treatments, separate SE values have been calculated.

Experiment 3

Juvenile pods. Both the gypsum applications increased the numbers of juvenile pods in irrigated TMV 2 and EC at 74 DAS, but not in J 11 (Fig. 1). The juvenile pod numbers of TMV 2 and J 11 had decreased by 81 DAS as a proportion of them became filling pods, but the number remained higher in the dry than in the wet treatment.

Peg to filling pod development. Although all combinations of gypsum and genotype produced juvenile pods, the gypsum and irrigation treatments had a large influence on the proportion of subterranean pegs which developed into filling pods (Fig. 2). This percentage was reduced by drought at all stages of

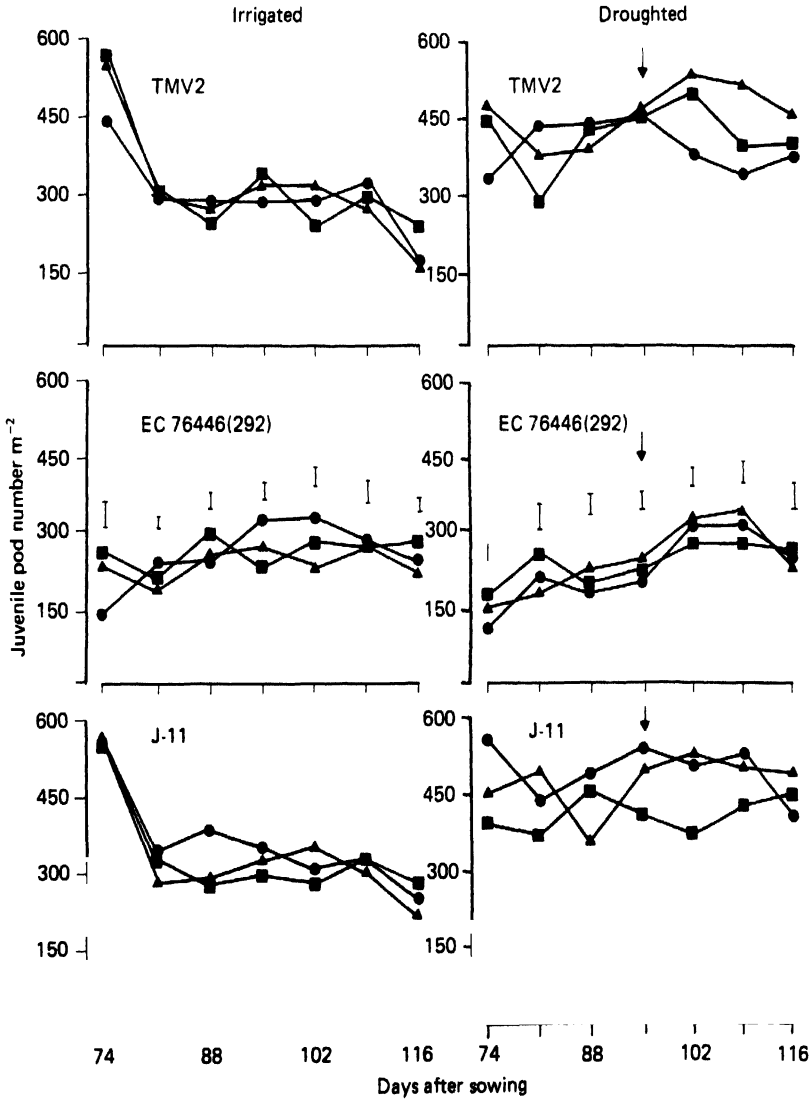

Fig. 1. Changes with time in the number of juvenile pods of three groundnut cultivars grown either with adequate irrigation or with a single irrigation between 60 and 116 DAS, as influenced by gypsum fertilization (●, 0 kg ha^{-1}; ▲, 500 kg ha^{-1}; ■, 2000 kg ha^{-1}. Vertical bars denote SE of mean for comparing gypsum treatments within genotypes. The arrows indicate the application of uniform irrigation.

growth although this stage of pod development was helped by gypsum application under drought conditions. At maturity the differences between the genotypes and gypsum treatments were no longer significant.

Filling pods. The number of filling pods was increased by gypsum application in all genotypes in the fully irrigated treatment between 74 and 95 DAS (Fig. 3). In dry conditions there were differences between treatments in the number of filling pods.

Mature pods. Mature pods did not form until 88 DAS in TMV 2 and J 11, and 95 DAS in EC (Fig. 4). In the dry treatment the largest number of mature pods developed when 500 kg ha^{-1} gypsum was applied, but only very few pods were formed by EC.

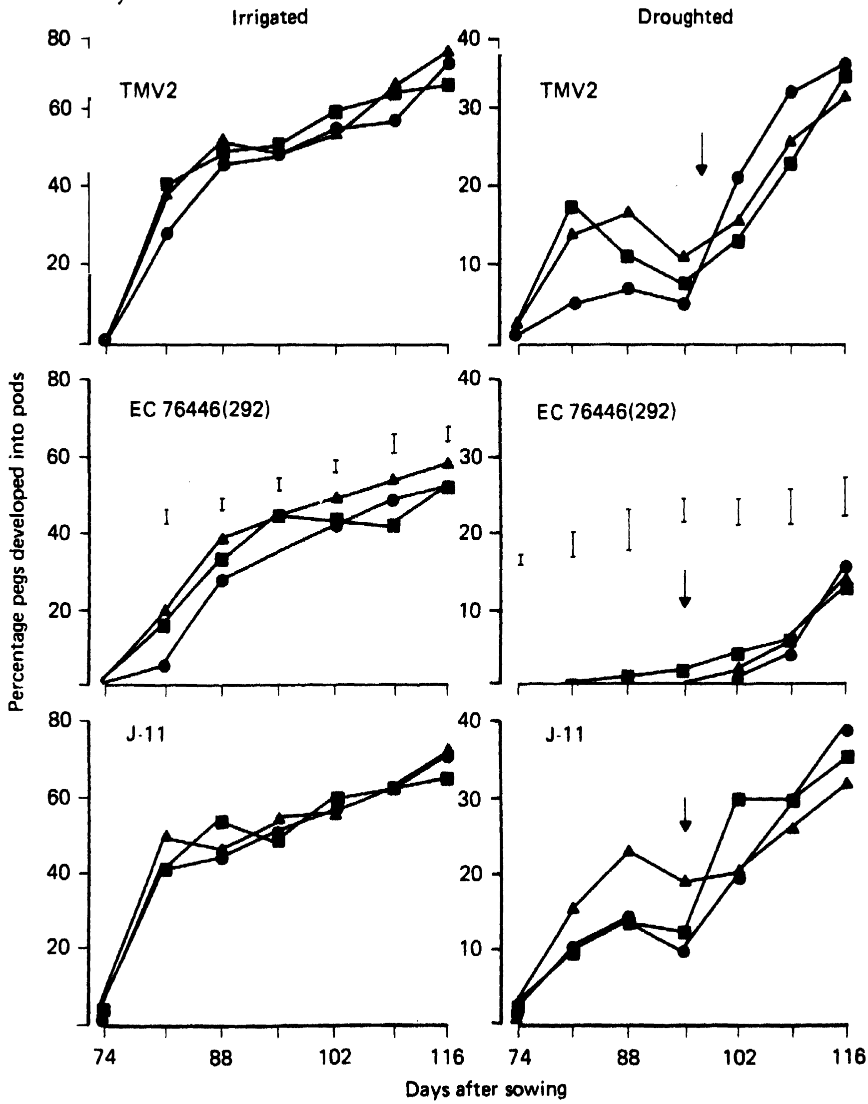

Fig. 2. Changes with time in the development of pods from subterranean pegs for three groundnut cultivars grown either with adequate irrigation or with a single irrigation between 60 and 116 DAS, as influenced by gypsum fertilization. Symbols as in Fig. 1.

Pod yield. There was no consistent effect of gypsum on pod yield in the irrigated plots (Fig. 5). During the first drying cycle both gypsum treatments increased the yield of TMV 2, there was some irregularity in the response of J 11, and very low yields were obtained from EC.

There were differences in pod yield at the start of the second drying cycle, but by 116 DAS the effects of gypsum had disappeared. Yield increases with time during the second drying cycle were linear, and the rates were estimated as the difference in yield between 95 and 116 DAS (Table 3). Growth was not estimated for all gypsum treatments in EC because the filling of pods was considerably delayed. The growth rate of J 11 and TMV 2 was slower in plots

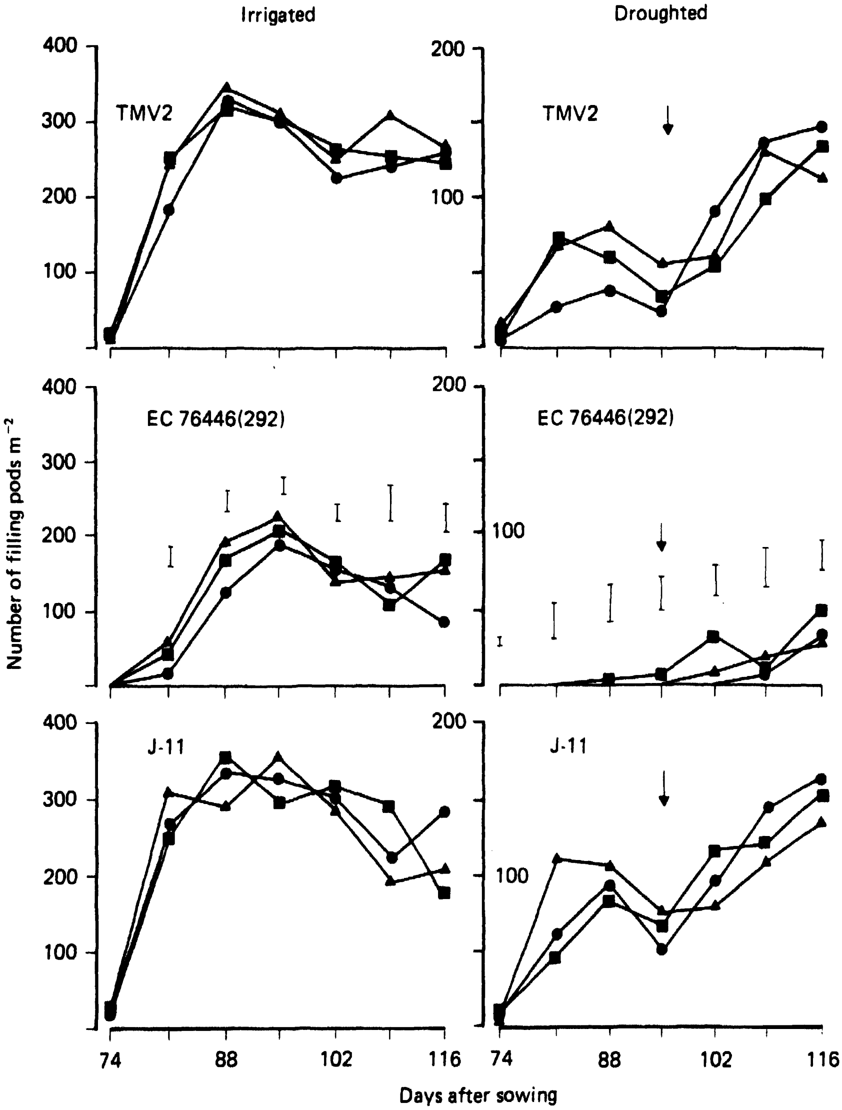

Fig. 3. Changes with time in the number of filling pods of three groundnut cultivars grown either with adequate irrigation or with a single irrigation between 60 and 116 DAS, as influenced by gypsum fertilization. Symbols as in Fig. 1.

with 500 kg ha^{-1} than in those with 2000 kg or no gypsum. The growth rate of EC was slower than that of the other genotypes.

DISCUSSION

Irrigation significantly increased pod yield in all three experiments. Moisture stress during the peg development and pod filling stages decreased the yield in all genotypes. The results of Experiment 3 agree with previous evidence that water deficits during pegging and pod development decrease yield primarily educing pod number (Skelton and Shear, 1971; Ono *et al.*, 1974; Boote

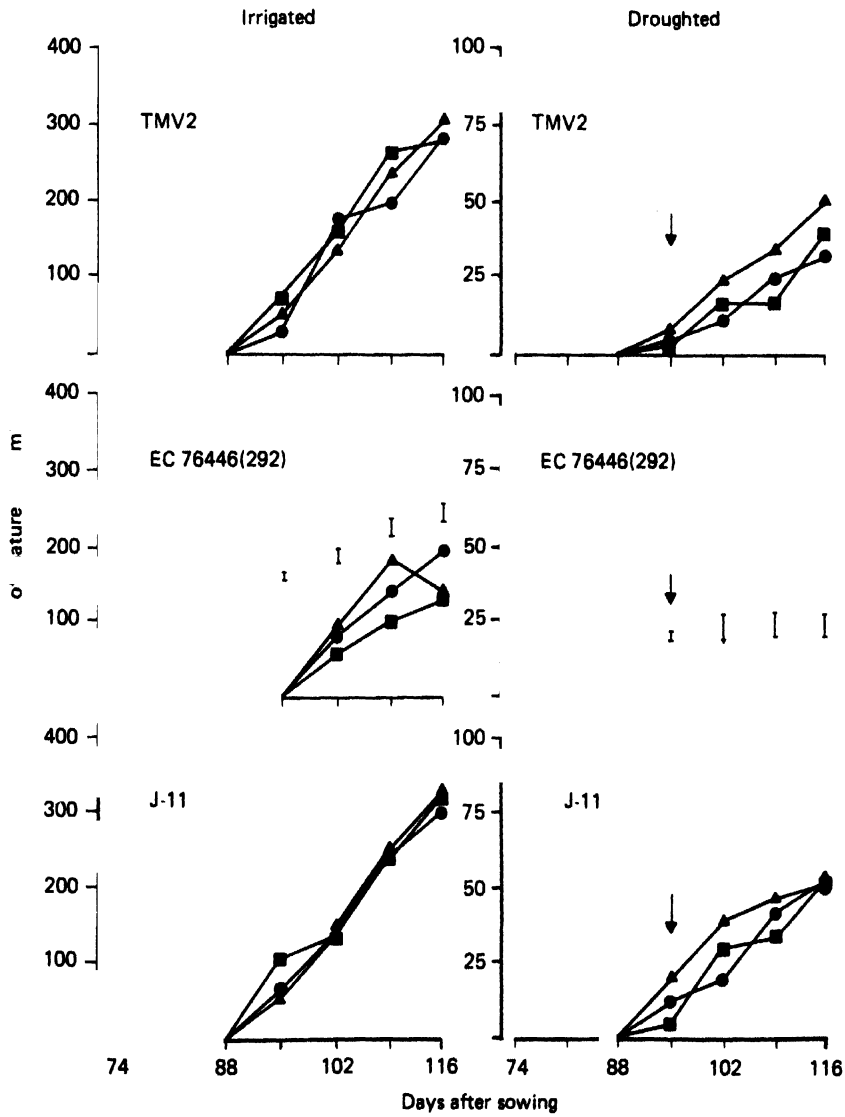

Fig. 4. Changes with time in the number of mature pods of three groundnut cultivars grown either with adequate irrigation or with a single irrigation between 60 and 116 DAS, as influenced by gypsum fertilization. Symbols as in Fig. 1.

Table 3. *Pod number and pod growth rates over the second drying cycle as influenced by genotype and gypsum application rates (Experiment 3)*

	Gypsum (kg ha^{-1})	Pod number m^{-2}	Pod growth rate (g m^{-2} day^{-1})
TMV 2	0	34	3.5
	500	73	2.4
	2000	43	3.0
J 11	0	66	3.3
	500	130	1.9
	2000	72	2.8
EC 76446(292)	0	–	–
	500	–	–
	2000	–	1.5

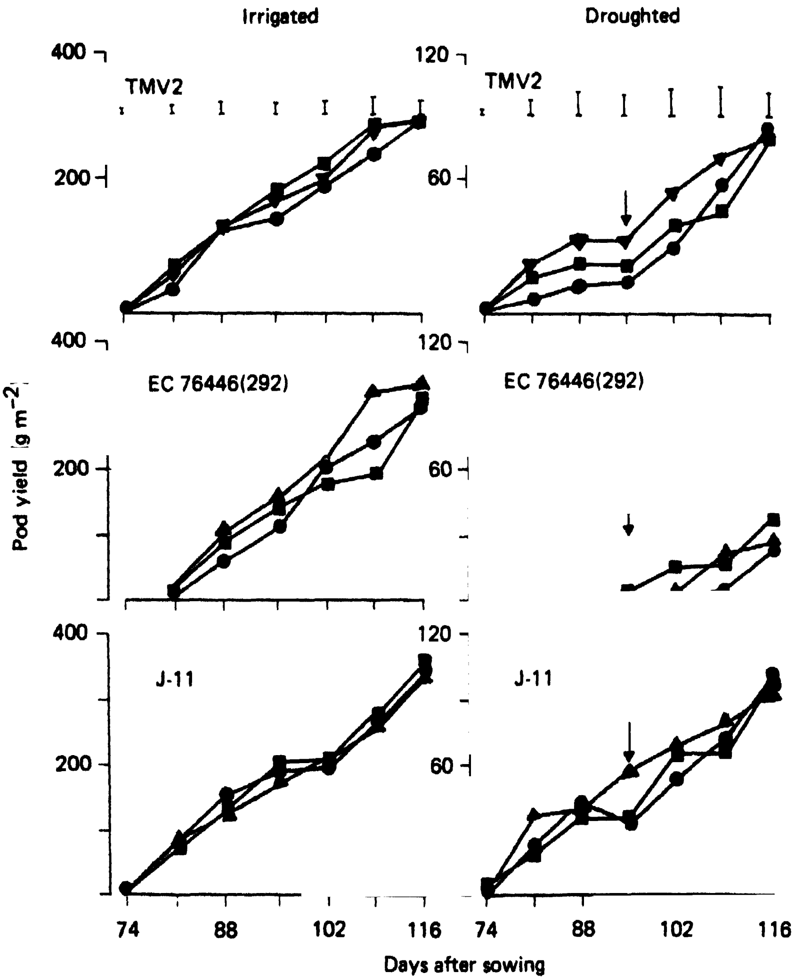

Fig. 5. Changes with time in the pod yield of three groundnut cultivars grown either with adequate irrigation or with a single irrigation between 60 and 116 DAS, as influenced by gypsum fertilization. Symbols as in Fig. 1.

et al., 1976; Pallas *et al.*, 1979). The adverse effect of moisture stress on pod yield was greatest in EC, which produced no mature pods in the driest plots without gypsum application. The differential responses of groundnut genotypes to moisture stress have been demonstrated before by Balasubramanian and Yayock (1981) among others.

In this study, although the soils were not deficient in Ca (763 and 800 ppm for Experiments 1 and 2, respectively) a response to applied gypsum was detected for some genotypes in the irrigated plots and responses were usually substantial in drought conditions. The observations that a dry spell at pod set and pod filling stages reduced the uptake of Ca by pods (Gillier, 1969) and that Ca fertilization increased yield in dry years (Hallock and Allison, 1980) suggest that the responses obtained here from the use of gypsum can mostly be attributed to its calcium content. However, it is possible that the sulphate component is also involved and further research on the topic is needed. When adequate irrigation was applied, gypsum did not significantly improve yield in the majority of genotypes.

The gypsum responses of some of the genotypes tested in drought conditions in Experiments 1 and 2 were similar, although quantitative differences between experiments were evident. For example, the response of ICG 4601 to gypsum was greater in Experiment 1, possibly due to the availability of small amounts of water at the dry end of the line-source gradient in this experiment. These small additions of water in the line source experiment may have a major influence on nutrient availability for the pods since they only wet the profile in the pod zone. However, there was an outbreak of tomato spotted wilt virus in Experiment 2 which in combination with drought in the very dry treatment resulted in premature plant death and may have limited the differences in yield of the two gypsum treatments.

The final yields of TMV 2 and J 11 in Experiment 3 differed from those in the preceeding experiments in that no gypsum responses occurred in the drought plots. However, a response to gypsum was observed after the first drought cycle, and the difference must be attributed to a variation in drought pattern between the two experiments. Although gypsum may be beneficial in single pattern droughts it may have little benefit in multiple stress patterns, and careful investigation both of responses for specific genotypes and likely environmental conditions are necessary before recommendations to farmers can be made.

The lack of response to gypsum observed in TMV 2 and J 11 when adequately irrigated could be due to a soil Ca content higher than the critical level necessary for pod development. Cultivar EC, with larger pods than the other genotypes, responded to applied Ca in both the wet and dry treatments, demonstrating variation among genotypes for Ca requirement.

The supply of Ca necessary for pod development (Harris, 1949) may be inadequate in dry soils; this may explain the failure of plants to develop juvenile pods further (Experiment 3) and the observation that mid-season droughts influence yield by limiting pod numbers (Pallas *et al.*, 1979). In this experiment the large seeded EC, which showed greatest response to Ca in good conditions, was the most susceptible to drought.

The possibility that pod size is affected by drought via Ca nutrition needs further investigation. In Experiment 3 the application of gypsum resulted in more rapid establishment of filling pods, both with and without adequate water, in the period before 88 DAS. This effect could be very important for two reasons. First, in the event of drought it seems to provide an escape mechanism by getting more pods past an apparently critical developmental stage, as was evident in this experiment during the first drying cycle. This effect might explain the positive yield response to Ca fertilization in drought conditions reported by Hallock and Allison (1980).

Secondly, in well watered conditions it apparently provides greater synchrony of pod initiation and therefore of pod maturity. This would decrease the time that the first initiated pods remain in the soil while the bulk of the pods achieve maturity, thereby diminishing the risks of pod rots and aflatoxin contamination. Hallock and Garren (1968) and Walker and Csinos (1980) reported that gypsum application resulted in reduced pod rotting and our observations of the effect of gypsum on improved pod synchrony suggests this may be a contributory factor.

In Experiment 3 the release of water stress before the second drying cycle resulted in substantial interactions of gypsum and genotype. The treatments which had most pods at the time of re-irrigation subsequently initiated fewer pods and grew more slowly during the second drought cycle. A strong negative correlation ($r = -0.87$ $P < 0.05$) was observed between pod numbers at the end of the first drying cycle and the subsequent pod growth rate of TMV 2 and J 11 (Table 3). This compensatory effect could have great significance in stabilizing yield in areas prone to mid-season droughts. However, little is known about the mechanism concerned.

EC had a different pod initiation and growth pattern during the second drying cycle but it is not possible to compare this response fully with that of TMV 2 and J 11 because no pods had been initiated at the time of re-watering in two of the gypsum treatments. However, from the limited data available the pod growth rate of the zero gypsum treatment (which initiated pods last) was greatest, suggesting that the negative association of pod numbers at the release of stress with pod growth rate following drought may also apply to EC.

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