Peanut Science (1981) 8, 125-128

The Effects of Irrigation, Inoculants and Fertilizer Nitrogen on Peanuts (*Arachis hypogaea* L.). II. Yield

V. M. Reddy*, J. W. Tanner, R. C. Roy[1] and J. M. Elliot[2]

ABSTRACT

The peanut is a recent introduction into southern Ontario. In order to develop appropriate production practices, the effects of irrigation, inoculation and N fertilization on yield were investigated. Irrigation and inoculation each increased the yield by about 27%, and the effect of each of these factors was greater in the presence of the other. No significant yield difference (2992 kg/ha on average) was observed between the use of powdered peat or granular inoculants containing the same strains of rhizobia. However, a yield difference was observed between inoculants containing different strains of rhizobia. Nitrogen application at planting time did not increase the yield of uninoculated peanuts, but a split application, applied at planting and 60 days later, increased the yield by 28% over the uninoculated control. Increasing the N application at planting decreased the yield and 100-kernel weight of inoculated peanuts.

Key Words: Soil NO_3, NH_4 nitrogen, irrigation, inoculants.

Drought has been shown to affect peanut yield and grade. The effects depend on the duration and intenstiy of the drought and the stage of crop growth (10, 11). Significant yield reductions have been observed even with short periods of drought during flowering (12). Increases in yield have been obtained by one to two irrigations at flowering and pod filling (15,19). Holford (5) obtained a positive correlation between pod yield and the amount of rainfall received during the first 64 days of the growing period (from planting to maximum flowering). Joshi and Kabaria (8), in a 21-year study, found that rainfall from full-pegging to pod development (51-80 days after planting) was significantly correlated with yield, while total rainfall or number of rainy days during the growing season showed no correlation.

A number of investigators obtained a yield response to inoculation with *Rhizobium* in soils new to peanuts (16,18). However, no responses to inoculation were obtained in soils where peanuts appeared regularly in the rotation (14,21). In recent years, peanut yields have been increased by granular inoculants where no responses to peat inoculants could be obtained (3,6,20). A granular inoculant is supposed to supply many more bacteria per seed and be easier to handle than a peat inoculant (6).

Peanut responses to fertilizer N have been inconsistent. These variable responses may be attributed to differences in climate, soil, managerial conditions, and cultivars. The most consistent responses to fertilizer nitrogen have been obtained in studies where the soil conditions were not suitable for nodulation (14). Fertilizer N has been shown to inhibit root hair infection and nodule initiation, development, and function (4). The lack of a yield response in soybeans to applied N occurred because soil N replaced symbiotic nitrogen fixation as the nitrogen source (1,22). Hence an estimate of soil nitrogen level is also essential for proper interpretation of responses to fertilizer nitrogen and rhizobia inoculation.

The peanut was recently introduced into southern Ontario. In order to recommend appropriate production practices, experiments were conducted to study the effects of irrigation, inoculation, nitrogen fertilization, and possible interactions among the three factors on nitrogen fixation and yield. The effects of the above factors on nitrogen fixation were presented previously (13); those on yield are given in this report.

Materials and Methods

Experiments were conducted during the summers of 1976 and 1977 on a farm adjacent to the Agriculture Canada Tobacco Research Station, Delhi, Ontario, on a fox loamy sand soil with medium to high levels of phosphorus and potash.

In 1976: An experiment was laid out in a split-split-plot design, with sub-sub-plots containing 7 rows (40 cm apart) of 7 m length, replicated four times. The main plot treatments were (a) irrigation and (b) no irrigation. Sub-plot treatments were (a) no inoculant, (b) commercial powdered peat inoculant[3] (Peat-I) and (c) granular inoculant[3]. The sub-sub-plot treatments were (a) 0, (b) 25, (3) 50, and (d) 100 kg N/ha broadcasted as ammonium nitrate. The two inoculants did not contain the same strains of rhizobia.

In 1977 an additional peat inoculant (Peat-II), containing the same strains of rhizobia as the granular inoculant, was added to the inoculation treatments (sub-plot), also a split application of nitrogen treatment (sub-sub plot) in which 25 kg N/ha was applied at the time of planting and another 25 kg N/ha was applied 60 days later, was included.

The cultivar 'Comet' was used in both years. The details of cultural practices adopted in the experiment have been presented in an earlier paper (13). Soil NO_3-N and NH_4-N levels were monitored during the growing season by collecting 15 soil cores from the surface 20 cm of each plot at 2 week intervals. They were either analysed immediately or frozen and analyzed at a later date. They were screened through a 2 mm sieve, extracted with a 1:2 (w/v) ratio of soil to distilled water, and the NO_3-N content of the extract determined with a nitrate ion electrode (Orion No. 90-01) (9). Soil extracts for NH_4-N determinations were obtained by using a 1:2 (w/v) ratio of soil to 2M KCI solution. All extracts, after shaking on a wrist-action shaker for 1 hour, were filtered through Whatman No. 1 filter paper and the NH_4-N content of the filtrate was determined with an ammonia electrode (Orion 95-10) (2). Moisture percentages of soil samples were determined after oven drying (100 C) to a constant weight. The nitrate and ammonium nitrogen contents were expressed on an oven-dry basis.

One 5-meter row of each plot was dug by shovel on September 24, 1976 and September 31, 1977. The pods were removed by hand, placed in onion sacks, cured in a commercial peanut drying wagon at 32 C and shelled in a U.S. Federal inspection sheller.

All the data were subjected to analysis of variance. Duncan's New

[1]Department of Crop Science, University of Guelph, Ontario, N1G 2W1, Canada

[2]Research Station, Agriculture Canada, Delhi, Ont. N4B 2W9, Canada

[3]The Nitragin Company, Milwaukee, Wisconsin

Multiple-Range Test was used to compare the main and sub-plot treatments, and regression analysis was used to study the responses due to sub-sub plot treatments.

Results and Discussion

1976 experiment: As a result of the late planting and abnormally cool weather in 1976, the maturity of the crop was delayed and the plants were not harvested until after a killing frost on September 22 (Table 1). Pod yields were low and the differences among the treatments were not significant.

1977 experiment: Warm dry weather from June until the beginning of August necessitated three irrigations, each of 2.54 cm (June 16, July 13, and July 22). By mid-August the irrigated plots could be distinguished visually by their color and greater growth of foliage. Dry weather during the flowering and poding period (June-July) adversely affected the yield of the unirrigated peanuts. Also, there were significant yield responses to inoculant application (Fig. 1). There was a significant interaction between the irrigation and inoculation treatments (Fig. 1, Table 2). The inoculated plots gave a greater response to irrigation (750 kg/ha) than the uninoculated plots (500 kg/ha). This same interaction may be interpreted as the relative differences between inoculated and uninoculated treatments were more distinct under irrigation.

The Peat-II and granular inoculants produced higher yields under both irrigated and unirrigated conditions than the Peat-I inoculant, suggesting that the *Rhizobium* strains contained in these two inoculants were more efficient. This can be supported by the data on nodulation and $N_2(C_2H_2)$ fixation (13). There was no significant difference between the two formulations containing the same strains of rhizobia, indicating that formulation did not appear to be a significant factor.

There was also a significant interaction between inoculants and fertilizer levels. In the uninoculated plots, N application at planting time did not increase the pod yield (Fig. 2). This is not surprising in view of the rapid loss of nitrate and ammonium from these soils after application (Fig. 3, 4). Although nitrate and ammonium were applied at the same rate, even at the earliest sampling dates the levels of ammonium were relatively low compared to the nitrate levels, indicating a rapid nitrification of ammonium. Within 50 days, the applied fertilizer N was essentially gone, resulting in an extreme nitrogen deficiency situa-

Table 1. Effect of irrigation, inoculants, and fertilizer nitrogen on pod yield, kernel weight, SMK, and shelling % of peanuts (*Arachis hypogaea* L.) in 1976.

Treatments	Pod yield	Kernel yield	SMK[1]	Shelling percentage
	kg/ha			
Unirrigated	905	376	273	41.2
Irrigated	994	407	204	40.6
No inoc.	912	405	244	43.7
Peat inoc.	970	371	209	38.5
Gran. inoc.	967	398	262	40.4
0 kg N/ha	1096	496	310	44.8
25 kg N/ha	953	409	252	43.4
50 kg N/ha	918	370	232	40.1
100 kg N/ha	830	290	161	35.3

Sound mature kernels were those that rode a 0.56 x 1.90 cm oblong screen.

Table 2. Effects of irrigation and inoculants on 100-kernel weight of peanuts in 1977 at Delhi.

Treatments	100-kernel weight	
	Irrigation	No irrigation
	g	
No inoculant	30.3 b*	27.0 d
Peat-I	32.8 a	27.6 cd
Peat-II	33.4 a	28.4 c
Granular	32.9 a	28.3 c

* Means followed by the same letter do not differ significantly according to Duncan's new multiple-range test at 5% level.

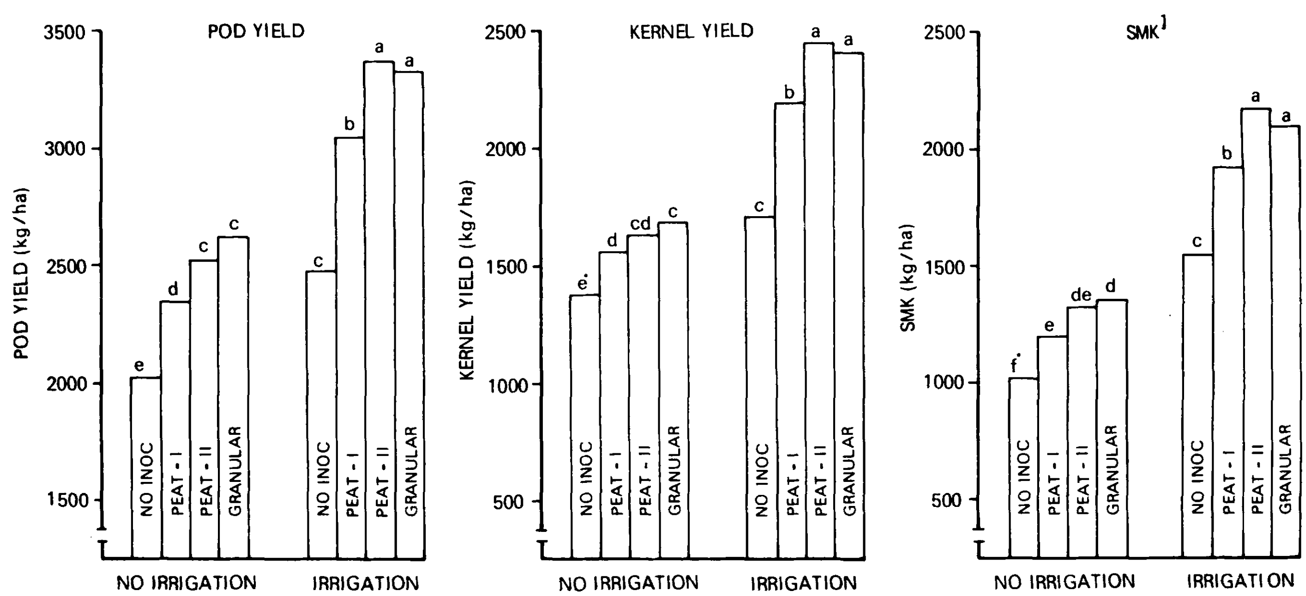

Fig. 1. Effect of irrigation and inoculants on peanut pod yield, kernel yield and SMK weight in 1977 at Delhi. 1 Sound mature kernels are those that rode a 0.56 x 1.91 cm oblong screen. * Means followed by the same letter do not differ significantly according to Duncan's new multiple-range test at 5% level.

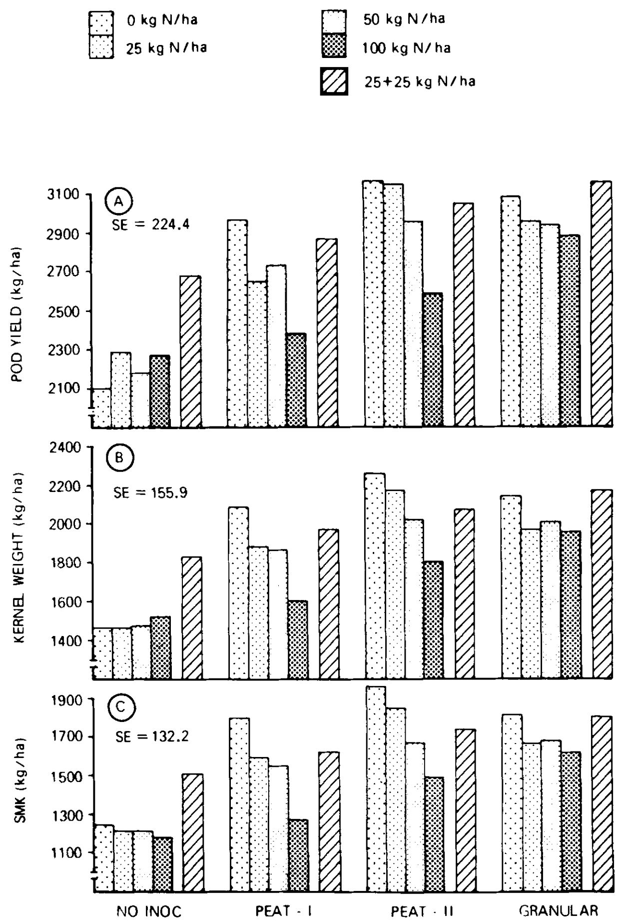

Fig. 2. Effect of fertilizer nitrogen on yield of peanuts treated with different inoculants in 1977 at Delhi.

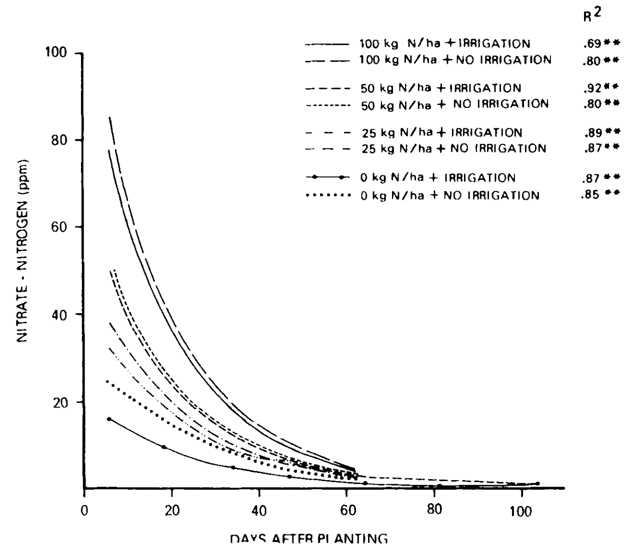

Fig. 3. Effect of irrigation and fertilizer nitrogen on soil nitrate nitrogen in 1977 at Delhi. Regression analysis was done after log conversion of the original data. Plotted data are retransformed from log conversions.
**** Significant at 1% level.**

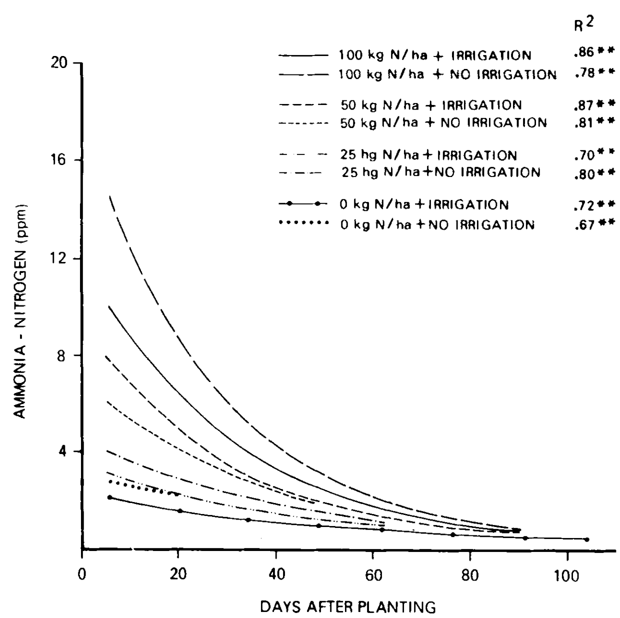

Fig. 4. Effect of irrigation and fertilizer nitrogen on soil ammonia-nitrogen in 1977 at Delhi. Regression analysis was done after log conversion of the original data. Plotted data are retransformed from log conversions.
**** Significant at 1% level.**

tion. This observation was supported by the significant yield increase with the split-application of N (Fig. 2). The second application was made 60 days after the first and resulted in a significant yield increase. Obviously, in these sandy soils, either good inoculation or repeated nitrogen applications are required to achieve good yields.

Fertilizer N application at planting time decreased the yield and 100-kernel weight of the inoculated peanuts (Fig. 2 and Table 3). These results are in contrast to those obtained from similar experiments on soybeans. In well-nodulated soybeans there is seldom a yield response to applied N; however, there have been no reports of decreases in yield at the levels of N fertilizer used in this experiment (17). The decrease in yield with increasing levels of fertilizer N observed in this experiment could be attributed to reduced nodulation and $N_2(C_2H_2)$ fixation of the inoculated peanuts (13). As a result of this early inhibition, the poorly developed symbiotic system failed to meet the N requirements of the plant once the soil N levels decreased. This hypothesis is supported by the observation that when the split application treatment was used, the yields were almost equal to those achieved without N fertilizer (Fig. 2).

Although the fertilizer N reduced the yields of all the inoculated peanuts, the pod yield reduction was less pronounced for peanuts inoculated with the granular inoculant (Table 3). Fertilizer N had no effect on kernel yield and SMK in plots which received granular inoculant. These observations are difficult to interpret. The fact that the Peat-II inoculant contained the same strains of *Rhizobium* as the granular inoculant eliminates strain difference as a factor. It could be speculated that the additional organic matter applied with the granular formulation served to decrease somewhat the inhibitory effect of the N fertilizer as reported by Weber (22) and Johnson and Hume (7) in soybeans. However, the amounts of organic matter applied in the granular inoculant would appear to be insufficient to show such pronounced effects, unless such effects could have been manifest in the rhizosphere of the seedling. It could also be possible that rhizobia in

Table 3. Effect of fertilizer nitrogen (basal application) on yield and 100 kernel weight of peanuts treated with different inoculants in 1977 at Delhi.

Treatment	Regression equation	R^2
A. Pod yield (kg/ha)		
No inoculant	Non sig.	-
Peat-I	Y = 2910.58 + (-5.2258X)	.838**
Peat-II	Y = 3228.14 + (-6.0175X)	.943**
Granular	Y = 3043.28 + (-1.8121X)	.877**
B. Kernel weight (kg/ha)		
No inoculant	Y = 1454.26 + (0.5723X)	.885**
Peat-I	Y = 2054.52 + (-4.5222X)	.949**
Peat-II	Y = 2269.02 + (-4.7399X)	.995**
Granular	Non sig.	-
C. SMK (kg/ha)		
No inoculant	Y = 1233.38 + (-5.5440X)	.971**
Peat-I	Y = 1767.68 + (-4.9298X)	.970**
Peat-II	Y = 1962.20 + (-4.9503X)	.977**
Granular	Non sig.	-
D. 100-kernel weight (g)		
No inoculant	Non sig.	-
Peat-I	Y = 30.60 + (-0.0137X)	.935**
Peat-II	Y = 31.82 + (-0.0193X)	.748**
Granular	Y = 31.30 + (-0.0160X)	.959**

** Significant at 1% level

the granular form supplied more rhizobia and survived for a longer period than in the powdered peat form, which allowed for good nodulation and for activity after soil N had disappeared (13). In contrast, with the soil peat inoculants there may not have been enough viable rhizobia remaining to provide adequate infection and nodulation after the soil N disappeared.

Conclusions

Peanut yields in these soils were increased by inoculation. Yield differences among inoculants were mostly due to the differences in the strains of rhizobia contained in the inoculants rather than the formulation. In the absence of adequate levels of *Rhizobium* in the soil or inoculation, repeated application of N fertilizer would be necessary to obtain high yields. Also, fertilizer N applied to well nodulated peanuts decreased yields in these soils. Considerable yield increases were obtained by irrigating the crop as needed, which was determined by visual observations of the soil and the crop.

Acknowledgements

Financial assistance and research facilities were provided by the Ontario Ministry of Agriculture and Food and Agriculture Canada (New Crop Development Fund). Appreciation is also extended to Agriculture Canada Research Station, Delhi for providing the research facilities.

Literature Cited

1. Allos, H. F. and W. V. Bartholomew. 1955. Effect of available nitrogen on symbiotic fixation. Proc. Soil Sci. Soc. Amer. 19:182-184.

2. Banwart, W. L., M. A. Tatabai and J. M. Bremner. 1972. Determination of ammonium in soil extracts and water samples by an ammonia electrode. Commun. Soil Sci. Plant Anal. 3:449.

3. Barksdale, W. E. 1977. Granular inoculants produce new payoffs for growers across peanut belt. The Peanut Farmer 13:42-45.

4. Gibson, A. H. 1977. Influence of environment and managerial practices on the legume-*Rhizobium* symbiosis. *In* A treatise on dinitrogen fixation. Sect. IV. Agronomy & Ecology. A. H. Gibson, ed. R. W. F. Hardy, General ed. Wiley-Interscience Publ. pp. 420-450.

5. Holford, I. C. R. 1971. Effect of rainfall on yield of groundnuts in Fiji. Trop. Agric. (Trinidad) 48:171-175.

6. Johnson, C. 1976. Soil inoculants pump yields in tests. The Peanut Farmer 12:52.

7. Johnson, H. S. and D. J. Hume. 1972. Effects of nitrogen sources and organic matter on nitrogen fixation and yield of soybeans. Can. J. Plant Sci. 52:991-996.

8. Joshi, S. N. and M. M. Kabaria. 1972. Effect of rainfall distribution on yield of groundnut (*Arachis hypogaea* L.) in Saurasta. Indian J. Agric. Sci. 42:681-684.

9. Mack, A. R. and R. B. Sanderson. 1971. Sensitivity of the nitrate-ion membrane electrode in various soil extracts. Can. J. Soil Sci. 51:95-104.

10. Martin, C. K. and F. R. Cox. 1977. Effect of water stress at different stages of growth on peanut yields. Proc. Amer. Peanut Res. and Educ. Assoc., Inc. pp. 91 (Abstr.).

11. Pallas, J. E., J. R. Stansell and T. J. Koske. 1977. Plant soil water relations of Florunner peanuts under droughty conditions. Proc. Amer. Peanut Res. and Educ. Assoc., Inc. pp. 89 (Abstr.).

12. Prevot, P. and M. Ollagnier. 1957. The water problem in groundnuts. Oleagineux 12:215-223.

13. Reddy, V. M. and J. W. Tanner. 1980. Effect of irrigaiton, inoculants and fertilizer nitrogen on peanuts (*Arachis hypogaea* L.) I. Nitrogen fixation. Peanut Sci. 7:114-119.

14. Reid, P. H. and F. R. Cox. 1973. Soil properties, mineral nutrition and fertilizer practices. *In* Peanuts - culture and uses. A symposium. C. T. Wilson, ed., Amer. Peanut Res. and Educ. Assoc., Inc., Stillwater, Oklahoma.

15. Sandhu, R. S., J. S. Saini and T. Singh. 1972. The effect of irrigation and fertilizer levels on the yield and quality of groundnut C501. Punjab Agric. Univ. Res. J. 9:535-540.

16. Schiffman, J. and Y. Alper. 1968. Effects of *Rhizobium* - inoculum placement on peanut inoculation. Expl. Agric. 4:203-208.

17. Semu, Ernest and D. J. Hume. 1979. Effects of inoculation and fertilizer N levels on N_2 fixation and yields of soybeans in Ontario. Can. J. Plant Sci. 59:1129-1137.

18. Shimshi, D., J. Schiffman, Y. Kost, H. Bielorai and Y. Alper. 1967. Effects of soil moisture regime on nodulation of inoculated peanuts. Agron. J. 59:397-400.

19. Singh, B. P., K. Singh and T. P. Yadava. 1971. Effect of irrigation and fertilizer levels on the yield and quality of groundnut. Haryana Agric. Univ. Res. J. 1:11-14.

20. Stoddard, C. D. 1977. Soil inoculation hits paydirt with a bang. The Peanut Farmer 13:29-31.

21. Walker, M. E., N.A. Minton and C. C. Dowler. 1976. Effects of herbicides, a nematicide and *Rhizobium* inoculant on yield, chemical composition and nodulation of Starr peanuts (*Arachis hypogaea* L.). Peanut Sci. 3:49-51.

22. Weber, C. R. 1966. Nodulating and non-nodulating soybean isolines: II. Response to applied nitrogen and modified soil conditions. Agron. J. 58:46-49.

Accepted July 1, 1981