Influence of Bradyrhizobium Strains on Peanut Advanced Breeding Lines (*Arachis hypogaeae* L.) Yield in North Cameroon

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Summary

Peanut yields may be reduced due to early season nitrogen deficiency. A study was conducted in 1994 and 1995 at two locations (Guiring and Guetale), the peanut belt of Cameroon, to investigate the use of Bradyrhizobium strains to improve the nitrogen use by selected peanut advanced breeding lines. Thirty treatments were arranged in a 5 x 6 factorial and grown in a randomized complete block with four replications in 1994 and three in 1995. The treatments were a factorial set of five peanuts lines tested with four introduced inoculants, one local strain and the nitrogen treatment. Results over locations and years showed significant differences among strains for plant stand and seed weight, and among peanut lines for all traits except days to flowering. Genotypes CGS-269 (1.225 t/ha) and CGS-1272 (1.032 t/ha) had the best average yields for the locations tested. The strain x host interaction was significant for plant stand, pod length and pod yield. The environment x strain x host interaction was also significant for haulm yield. Strain NC92 (-) (45.2 plants/7 m^2) produced higher plant stands than nitrogen treatment (40.3 plants/7 m^2) or indigenous strain (41 plants/7 m^2), but was not significantly superior to other strains. Strain NC92 (+) performed poorly for seed weight. The combination of peanut line CGS-1272/NC-120 and CGS-383/NC92(+) produced the highest means for pod length (58.2 cm). Genotype CGS-269 with strain NC-120 produced the highest pod yield (1.483 t/ha). Although the strain x host interaction was not significant for haulm yield, there was a good performance of line CGS-1272 with 3G4B20 and NC92 (+) which outyielded the indigenous/CGS-1272 combination by 20.3% and 17.8%, respectively.

Résumé

Influence des souches de Bradyrhizobium sur le rendement des lignées avancées d'arachide (*Arachis hypogaea* L.) au Nord Cameroun

*Les rendements de l'arachide (*Arachis hypogaea *L.) peuvent être réduits à cause des déficiences précoces en azote au début de la saison culturale. Une étude a été menée en 1994 et 1995 sur deux sites, notamment Guiring et Guétalé. Trente traitements arrangés en factoriel 5 x 6 et disposés en blocs complètement randomisés avec quatre répétitions en 1994 et trois en 1995 ont été mises en culture. Les traitements étaient constitués de cinq lignées d'arachide, quatre souches exotiques de rhizobium, une souche locale et l'azote appliqué sous forme minérale. Les résultats au travers les sites et les campagnes ont montré d'une part, des différences significatives entre les souches pour la densité et le poids en grains, d'autre part entre les lignées d'arachide pour toutes les variables sauf le nombre de jours semis-floraison. Les génotypes CGS-269 (1,225 t/ha) et CGS-1272 (1,032 t/ha) ont eu les meilleurs rendements à travers les sites. L'interaction entre les souches et les lignées a été significative pour le nombre de plants, la longueur des gousses et le rendement en gousses. La triple interaction, environnement x souche x plante hôte a été aussi significative pour le rendement en fanes. La souche NC92(-) a donné une meilleure densité de plants que l'azote et la souche indigène (45,2 et 40,3 plants/7 m^2, respectivement), mais n'a pas été significativement supérieure à d'autres souches. La souche NC92(+) a eu une mauvaise performance pour le poids de grains. Les combinaisons entre la lignée CGS-1272 et la souche NC-120 d'une part, et entre la lignée CGS-383 et la souche NC92(+) d'autre part, ont eu la moyenne la plus élevée pour la longueur des gousses (58,2 cm). Par ailleurs, le génotype CGS-269 et la souche NC-120 ont eu le meilleur rendement en gousses (1,483 t/ha). Malgré la non-signification statistique de l'interaction souche x hôte pour le rendement en fane, on a constaté une bonne performance de la combinaison entre la lignée CGS-1272 et les souches 3G4B20 et NC92(+) qui a dépassé la souche indigène/CGS-1272 d'environ 20,3% et 17,8%; respectivement.*

Introduction

Observations made in North Cameroon peanut (*Arachis hypogaea* L.) fields showed nitrogen deficiency symptoms in the preflowering growth stage (6). Such deficiencies could contribute to the low yields encountered in the region. Peanuts grown in the region are generally nodulated by an indigenous but inefficient Bradyrhizobium strain population. In addition, nitrogen fertilizers are becoming more and more expensive to buy, making them less readily available to poor farmers. To circumvent this problem, a rhizobium x peanut lines trial was conducted during two growing seasons (1994, 1995) at two locations (Guiring and Guetale).

Biological nitrogen fixation is tightly controlled by the combination of two genetic systems of both the host and the Rhizobium strain. In addition, these systems are affected by the environment and the interaction between these factors. It was reported effective combinations of peanut genotypes and Rhizobium strains under field and laboratory conditions (2, 9). It was also reported a significant increase in pod yield of one cultivar (Robut-33-1) when inoculated with strain NC92 but none when inoculated with other effective strains (3). A similar result was observed in North Cameroon when 28-206, the most popular cultivar grown in the country, yielded a significant yield increase when inoculated with strain NC92 (6, 7).

Unlike the genetic systems of the host and of the Rhizobium strain which could be controlled by artificial manipulations

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Table 1
Patterns of total rainfall during crop seasons at the experimental sites

Environment	Year	Location	Rainfall (mm)	Means (mm)
1	1994	Guiring	670.2	
2	1994	Guetalé	751	710.6
3	1995	Guiring	964	
4	1995	Guetalé	1068	1016

Source: Meteorological service of IRAD Maroua, Cameroon, 1998.

(crossing between individuals, followed by selection to obtain better progenies), environmental factors cannot be controlled in field conditions. The environmental factors that affect biological nitrogen fixation were described: soil moisture, soil nitrogen level (4).
The objectives of this study were: (1) to examine the need for inoculation of new peanut advanced breeding lines; (2) to determine the effect of the strains on yield performance and other agronomic characteristics of North Cameroon promising lines; (3) to examine the nitrogen-fixing capacity of introduced rhizobium strains compared to that of a native strain, and (4) to examine the interaction between the rhizobium strain and peanut lines.

Materials and methods

The study was carried out during the 1994 and 1995 growing seasons (June – early October) at two locations i.e. Guiring and Guetale giving a total of four environments. The previous crop at both sites was sorghum. Soil types at Guiring and Guetale were, respectively, fluvents (new alluvial soils) and tropepts (less developed alluvial soils, slightly weathered) according to US taxonomy. Mean total annual rainfall is approximately 750 mm and the duration of the growing period is 120-150 days with recurrent drought spelts. Rainfall during the 2-year trial was irregular (Table 1).

Thirty treatments were arranged in a 5 x 6 factorial and grown in a randomized complete block design with four replications in 1994 and three replications in 1995 (1). The thirty treatments were combinations of five peanut lines, four introduced inoculants, one indigenous strain and a mineral nitrogen treatment. The peanut genotypes used were CGS-269, CGS-1272, CGS-383, CGS-384 and K3237-80, an introduction from Nigeria. The four Bradyrhizobium strains (from North Carolina State University, USA) were NC92 (+), 3G4B20, NC92 (-) and NC-120, and finally, the local strain (indigenous to the soil) and the nitrogen treatment.

Experimental plots consisted of four 7 m long rows. Seeds were spaced 20 cm within rows and 50 cm between rows. Inoculation was performed at planting time and was applied as a liquid suspension at a rate of 350 ml of mixture (1 liter of water + 1 gram of rhizobium strain) per row; only the two inner rows of each plot were inoculated. After inoculation, rows were covered with soil by six different persons using hoes. Each hoe was assigned to a specific strain to avoid cross contamination. Nitrogen was applied as urea at 80 kg /ha two weeks after planting.

The following observations were done on the two inner rows of each plot: plant stand at harvest (7 m^2), number of days from planting to flowering (days), number of days from planting to maturity (days), pod and seed dry weight (about 8% moisture) (kg), 20-pod length (cm), 100-seed weight (g), plant height in cm (Guiring 1994 only), haulm weight (kg), and meat content or shelling percentage (%) calculated from pod and seed weights [(seed weight /pod weight) *100)]. Pod, seed and haulm (biomass) weights were obtained using a laboratory scale (Universal) with precision to 0.1 g, and converted onto t/ha; haulm weight was obtained in the field using a field scale ("Peson") with precision to 0.5 kg, and converted onto t/ha. After shelling, 100 seeds were sampled and weighted using an electronic scale with precision to 0.1 g (Mettler PC 4400).

Analysis of variance by environment was first performed using PROC GLM procedure of SAS (5). Mean separation was carried out, where appropriate, using the Least Significant Difference (LSD) method (8). Since the number of replications varies among years and given that the interactions of genotypes with locations and years must be taken into account, the analysis of variance combined over years and locations was performed from genotypes-environments means (1). The environments (combination of locations-years) were considered as random effects in the linear model while genotypes were considered fixed effects.

Results and discussion

Guiring

The combined analysis over years showed a significant difference at the 5% level of probability only for seed weight. The strain x host interaction was significant for plant stand while the strain x year interaction was significant for number of days from planting to flowering and pod length, indicating that plant stand for a given peanut line varies depending on the strain, and that strain performance varies from year to year. Strain NC-120 yielded the highest seed weight and was significantly different from NC92 (+) and from the indigenous strain (Table 2). Strain 3G4B20 significantly yielded higher plant height than NC-120, nitrogen treatment and the indigenous microflora. Significant strain x host interaction was observed for plant height (one year data) (Table 2).

Significant differences were found among genotypes for pod length, seed weight meat content and haulm yield. Genotype CGS-1272 significantly outyielded the others for haulm yield (Table 2).

Guetale

No significant difference was found among strains for any traits. The effect of years was significant for plant stand, days to flowering, days to maturity, pod length, haulm yield and meat content. The strain x year interaction was significant for plant stand and number of days from planting to flowering. The strain x year x host interaction was highly significant for haulm yield. Variation among genotypes was highly significant for pod length, seed weight, pod and seed yields. Genotypes CGS-269 and CGS-1272 had the highest means even though no significant difference existed for certain traits (Table 3). The combination of CGS-1272 / NC92 (+) and CGS-1272 / 3G4B20 strains produced the highest and significant haulm yield as compared to CGS-1272 / NC92 (-) and CGS-1272 / NC-120 strains, nitrogen and the indigenous microflora.

Combined analysis over environments

As stated earlier, a combination of location-year gave a total of four environments. The effect of the environment

Tableau 2
Rhizobium x host study: strains and host means at Guiring, for selected plant growth and yield parameters over two two cropping seasons (1994 &1995)

Strains	Stand (7 m²)	Flowering (days)	Maturity (days)	Pod length (cm)	Seed weight (g)	Pod yield (t/ha)	Seed yield (t/ha)	Meat content (%)	Plant height (cm)	Haulm yield (t/ha)
NC92(+)	49.6	28.6	108.8	52.3	35.7	0.850	0.490	57.9	32.0	1.875
NC92(-)	51.7	28.7	108.7	52.6	36.7	0.871	0.500	57.9	31.6	2.200
NC-120	45.1	29.2	108.9	53.3	37.7	0.522	0.472	57.0	30.5	1.909
3G4B20	49.1	29.1	109.3	52.6	37.1	1.008	0.612	60.1	34.4	2.012
Nitrogen	45.1	29.8	109.3	51.9	36.7	0.724	0.440	57.9	30.2	1.751
Indigenous	47.0	29.3	109.3	53.0	36.3	0.798	0.464	57.7	29.9	1.796
LSD (0.05)	ns	ns	ns	ns	1.0	ns	ns	ns	3.0	0.334
Genotypes										
CGS-269	55.0	29.1	108.2	57.5	43.5	1.208	0.735	60.7	34.8	1.996
CGS-1272	54.8	29.8	109.6	58.1	39.2	1.031	0.553	53.3	34.2	2.30
CGS-384	44.0	29.2	110.2	51.0	33.9	0.572	0.317	56.2	27.9	1.896
CGS-383	45.5	29.0	109.0	51.2	36.0	0.750	0.469	61.8	28.8	1.775
K3237-80	41.2	28.5	108.2	45.2	30.9	0.666	0.407	60.3	31.4	1.622
Means	47.9	29.1	109.0	52.6	36.7	0.854	0.496	58.4	31.4	1.924
LSD (0.05)	ns	ns	ns	2.5	4.8	ns	ns	3.2	4.0	0.305

Table 3
Rhizobium x host study: strains and host means at Guétalé, for selected plant growth and yield parameters over two cropping seasons (1994 &1995)

Strains	Stand (7 m²)	Flowering (days)	Maturity (days)	Pod length (cm)	Seed weight (g)	Pod yield (t/ha)	Seed yield (t/ha)	Meat content (%)	Haulm yield (t/ha)
NC92(+)	39.1	29.4	111.1	50.8	35.8	0.688	0.404	58.4	2.239
NC92(-)	38.7	30.9	111.4	51.0	36.0	0.696	0.381	55.0	2.097
NC-120	37.8	31.1	110.6	50.6	36.1	0.786	0.425	55.0	2.245
3G4B20	37.8	29.6	111.7	50.8	36.4	0.710	0.408	65.7	2.178
Nitrogen	35.6	30.4	111.4	50.6	34.9	0.649	0.372	56.0	1.899
Indigenous	35.1	31.3	111.2	49.9	35.6	0.704	0.418	58.3	2.176
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Genotypes									
CGS-269	47.7	29.5	109.5	55.7	42.4	1.243	0.744	67.5	2.412
CGS-1272	44.0	29.7	113.4	56.4	41.0	1.032	0.547	53.4	3.340
CGS-384	32.2	30.9	113.1	49.3	34.2	0.441	0.250	56.7	1.733
CGS-383	32.4	30.6	112.3	48.5	34.2	0.484	0.285	58.6	1.628
K3237-80	30.4	31.5	108.3	43.0	27.0	0.329	0.182	55.1	1.582
Means	37.3	30.4	111.3	50.6	35.8	0.706	0.401	58.1	2.139
LSD (0.05)	ns	ns	ns	1.5	1.6	0.632	0.409	ns	ns

was highly significant for all traits but seed and pod yields, meat content and harvest index. Variation among strains was significant for plant stand and seed weight ($p< 0.10$). The effect of lines was highly significant for all traits except days to flowering. The strain x host interaction was significant for plant stand, pod length and pod yield ($p< 0.10$). The environment x strain was significant only for days to flowering, indicating that flowering differs among strains depending on the specific environment. The environment x strain x host interaction was significant for haulm yield.

Strain NC92 (-) had the highest plant stand compared t mineral nitrogen treatment and indigenous strain but wa not significantly superior to NC92 (+) and 3G4B20. Strai NC-120, had the highest seed weight, but not different fro NC92 (-) and 3G4B20. Strain NC92 (+) performed poorly f seed weight (Table 4). As far as haulm yield, pod yield an seed yield are concerned, no significant differences wei observed among the strains and the uninoculated treatme performed as well as the inoculated ones.

The combination of genotype CGS-269 with strains NC92 (+) and NC92 (-) produced the highest plant stand, significantly superior to indigenous / CGS-269 combination (LSD= 7.2, $p< 0.05$). The combinations of NC-120 / CGS-1272 and NC92 (+) / CGS-383 produced the highest and significant means for pod lenght (58.2 cm, LSD= 1.6 cm, $p< 0.05$) as compared to that of the indigenous strain (Table 5). In addition, CGS-269 with NC-120 produced the highest and significant pod yield (1.483 t/ha, LSD=0.168 t/ha, $p< 0.10$). Although the strain x host interaction was not significant for haulm yield, there was good performance of CGS-1272 with 3G4B20 and NC92 (+) (3.470 t/ha and 3.581 t/ha, respectively) which

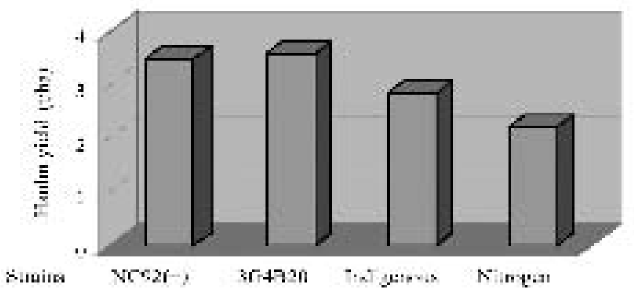

Figure 1: Interaction between line CGS-1272 with some selected rhizobia strains for haulm yield (t/ha).

Table 4
Rhizobium x host study over environment: strains and host means for selected plant growth and yield parameters

Strains	Stand (7 m²)	Flowering (days)	Maturity (days)	Pod length (cm)	Seed weight (g)	Pod yield (t/ha)	Seed yield (t/ha)	Meat content (%)	Haulm yield (t/ha)
NC92(+)	44.4	29.0	110.0	51.5	35.8	0.769	0.447	58.1	2.130
NC92(-)	45.2	29.8	110.1	51.8	36.4	0.783	0.441	56.4	2.128
NC-120	41.8	30.1	109.9	52.0	36.9	0.804	0.448	56.0	2.145
3G4B20	43.4	29.4	110.5	51.7	36.7	0.895	0.510	62.9	2.128
Nitrogen	40.3	30.1	110.3	51.2	35.8	0.687	0.406	58.0	1.854
Indigenous	41.0	30.5	110.3	51.4	36.0	0.751	0.441	58.0	2.063
LSD (0.05)	3.45	ns	ns	ns	0.91	ns	ns	ns	ns
Genotypes									
CGS-269	51.3	29.3	108.8	56.6	43.0	1.225	0.740	64.1	2.287
CGS-1272	49.0	29.7	111.5	57.3	40.1	1.032	0.550	52.9	3.037
CGS-384	38.1	30.0	111.7	50.2	34.0	0.506	0.284	56.4	1.782
CGS-383	38.9	29.8	110.6	49.9	35.1	0.617	0.377	60.2	1.672
K3237-80	35.8	30.0	108.2	44.1	29.1	0.497	0.294	57.7	1.594
Means	42.6	29.8	110.2	51.6	36.3	0.775	0.449	58.2	2.074
LSD (0.05)	10.5	ns	2.2	1.0	2.4	0.303	0.197	6.0	0.818

Table 5
Rhizobium x host study: strains by host interaction means over environments for selected agronomic traits and yield parameters

Strains	Genotypes	Stand (7 m²)	Flowering (days)	Pod length (cm)	Seed weight (g)	Pod yield (t/ha)	Seed yield (t/ha)	Meat content (%)	Haulm Yield (t/ha)
NC92(+)	CGS-269	54.7	29.4	50.0	42.9	1.192	0.718	59.4	2.196
NC92(+)	CGS-1272	50.0	29.4	50.0	40.3	0.993	0.530	53.5	3.470
NC92(+)	CGS-383	38.7	29.1	58.2	33.2	0.609	0.353	58.0	1.787
NC92(+)	CGS-384	41.9	29.3	50.2	33.2	0.640	0.390	60.2	1.383
NC92(+)	K3237-80	36.6	27.9	49.9	29.3	0.412	0.246	59.6	1.815
NC92(-)	CGS-269	54.5	30.2	44.4	42.5	1.231	0.703	57.1	2.363
NC92(-)	CGS-1272	48.1	30.0	56.5	39.7	1.018	0.519	50.8	2.96.0
NC92(-)	CGS-383	43.8	29.7	57.4	34.5	0.532	0.300	50.3	1.840
NC92(-)	CGS-384	41.2	29.6	50.8	37.0	0.629	0.385	60.3	1.800
NC92(-)	K3237-80	38.3	29.3	50.7	28.2	0.507	0.296	55.7	1.676
NC-120	CGS-269	51.9	29.2	43.7	43.8	1.483	0.802	54.0	2.446
NC-120	CGS-1272	51.4	29.7	58.2	41.5	1.030	0.594	56.0	3.135
NC-120	CGS-383	28.2	30.3	57.2	33.8	0.479	0.234	54.7	1.867
NC-120	CGS-384	41.5	30.2	50.2	35.1	0.573	0.344	59.1	1.646
NC-120	K3237-80	34.2	31.2	43.6	30.2	0.475	0.269	56.3	1.628
3G4B20	CGS-269	49.9	28.3	56.0	42.2	1.169	0.762	61.0	2.309
3G4B20	CGS-1272	50.5	29.4	58.0	40.7	1.123	0.566	49.9	3.581
3G4B20	CGS-383	37.5	30.2	49.7	35.6	0.495	0.284	54.6	1.718
3G4B20	CGS-384	39.2	29.2	50.2	35.9	0.794	0.505	62.5	1.605
3G4B20	K3237-80	40.1	29.7	44.6	29.2	0.714	0.430	58.5	1.428
Nitrogen	CGS-269	49.7	29.0	56.7	42.9	1.162	0.738	62.3	2.457
Nitrogen	CGS-1272	47.7	29.9	56.7	39.1	0.983	0.519	52.6	2.221
Nitrogen	CGS-383	41.5	30.4	49.4	33.1	0.385	0.221	57.3	1.509
Nitrogen	CGS-384	34.4	30.4	49.1	34.6	0.485	0.293	60.3	1.768
Nitrogen	K3237-80	28.3	30.7	44.2	29.5	0.419	0.256	57.5	1.236
Indigenous	CGS-269	47.3	29.9	57.1	43.4	1.115	0.715	62.8	1.951
Indigenous	CGS-1272	46.2	30.0	56.1	39.3	1.043	0.573	54.4	2.855
Indigenous	CGS-383	38.7	30.3	50.7	34.1	0.558	0.309	55.7	1.896
Indigenous	CGS-384	35.5	30.2	48.9	34.9	0.581	0.339	58.7	1.832
Indigenous	K3237-80	37.4	31.2	44.4	28.1	0.458	0.270	58.4	1.780
LSD (0.05)		7.2	ns	1.6	ns	0.168	ns	ns	ns

outyielded the indigenous /CGS-1272 combination by 20.3 and 17.8%, respectively (Table 5). This increase in haulm yield represents more than one hundred and fifthy thousand francs CFA (about 250 euro) that the farmer can earn in addition to the price of grain. Furthermore, the pod yields of these combinations are acceptable.

Conclusion

The results obtained from this study indicate that the inoculation of peanuts with Bradyrhizobium strains in Northern Cameroon can result in yield increases and improvement of agronomic characteristics of promising lines as reported in previous studies (6, 7). The most striking result is the interesting haulm yield increase, resulting from the combination of CGS-1272 with strains NC92 (+) and 3G4B20 (Figure 1). Biomass from peanut is extensively used for animal feeding in the region.

It also appears that Bradyrhizobium strains differed in their effectiveness and were affected by the host and the environment. Nitrogen fixation might have been reduced in 1995 experiments since the rainfall (1016 mm) was much higher than the previous growing season, which recorded only 710.6 mm (Table 1); the influence of soil moisture on Nitrogen fixation was reported previously (4).

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