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SURVIVAL AND EFFICIENCY OF NITROGEN FIXING BACTERIA WHEN INTRODUCED IN JAMAICAN AND MID-MISSOURI SOILS

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Survival and Efficiency of Nitrogen Fixing Bacteria When Introduced in Jamaican and Mid-Missouri Soils

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Summary

Biological nitrogen fixation technology has emerged as an effective tool in fighting world hunger. Much progress has been made in identification and isolation of effective and highly competitive rhizobia strains. However, few literature is available on the testing of these strains under field conditions in tropical soils, where they are needed most.

A research project to provide information on the competitiveness and survivability of certain introduced rhizobia strains was initiated 1985 in Jamaica. Field experiments utilizing 4 locations, two cowpea cultivars (Vita 3 and Mississippi Silver) and four rhizobia strains (JRC 29, IRC 26, IRC 503B, and 32 H1) were conducted each of the three years from 1985-1987. The inoculum strains JRC 29 and 32 H1 formed the majority of the nodules in the first year. This number declined in the second and third year. However, nodule occupancy for these strains (JRC 29 and 32 H1) were much higher than those reported for other strains in similar studies. During the third year (1987) of the study the strains JRC 29 and 32 H1 showed nodule occupancy averaging 80 and 65.5% respectively, at all locations. Strains IRC 26 and IRC 503B exhibited an average nodule occupancy of 17.4 and 21.6%, respectively, at the same locations.

The reaction of cowpea cultivars to inocula, were similar when growth and development was measured. However, 'Mississippi Silver' had higher grain yields than 'Vita 3'. Rhizobium strains differed in their ability to survive and influence crop growth at the different locations. Maximum growth and development was obtained by both cultivars when the Rhizobium strains, JRC 29 and 32 H1 were used. Our results demonstrated that the native strain JRC 29 survived much better than the introduced strains of IRC 26 and IRC 503B. In most locations the competitiveness and survival of 32 H1 was comparable to that of JRC 29.

INTRODUCTION

Establishment of effectively nodulated legumes is dependent on the ability of the introduced strains of rhizobia to compete and survive in the presence of indigenous rhizobia. The availability of effective Rhizobium strains is limited, especially in the tropics, where indigenous populations of rhizobia are generally low and ineffective (Ahmad and McLaughlin, 1985, Uddin et al., 1984). Much of the increase in world food production in the past thirty years can be attributed partly to the increased use of N fertilizer. However, with recent limitations in the availability and dramatic increases in the cost of N fertilizer in Jamaica, there have been both a reduction in the use of this fertilizer and a decline in crop productivity for Jamaican farmers. Grain legumes are one of the protein sources for a large segment of the Jamaican population. Although red kidney bean and cowpea have been grown in Jamaica for many years, little attention has been given to the nodulation and nitrogen fixation process of these crops. These crops are usually grown in small holdings by poor Jamaican farmers who cannot afford chemical fertilizers. As a result, crop yields are low, and innovative cultural practices to improve crop production are necessary.

Inoculation with effective Rhizobium can enhance cowpea productivity in Jamaica (Aarons and Amad, 1986). Effective nodulation and N_2 fixation is affected by fluctuations in soil temperature (Osa-Afiana and Alexander, 1982), soil moisture (Bushby and Marshall, 1977), soil erosion (Habte and El-Swaify, 1988), indigenous rhizobia population (Kvien et al., 1981, Amarger and Lobreau, 1982) available fertilizer N (Eaglesham et al., 1982) and survival and persistence of introduced rhizobia (Date, 1976). Ahamed et al., (1981) have shown the potential for the use of inoculants in cowpea production in highly leached and erodable tropical soils. Cowpea farmers in Jamaica cannot afford to inoculate on a year-to-year basis, therefore, it would be desirable to have effective Rhizobium strains that are able to survive in Jamaican soils for several years. Previous survival studies have been done using Jamaican soils (Aaron and Ahamad

1987) in laboratory settings. However, with the large diversity present in soils, field research is necessary to obtain Bradyrhizobium capable of adequate competitiveness and persistence under field conditions. This study was undertaken to examine the success of introduced inocula against indigenous rhizobia strains and also to assess the effectiveness and survivability of four cowpea rhizobia (Bradyrhizobium sp.) strains, (IRC 26, IRC 5036, H132, and JRC 29) at several locations in Jamaica.

MATERIALS AND METHODS

A total of five experiments were conducted (1985-1987) at five sites, representing different soil types and areas with and without previous legume production (Table 2). Soils were sampled at the initiation of the study, to a depth of 20 cm and some chemical characteristics determined. The indigenous rhizobial population was determined from subsamples of the initial soil samples by the most-probable-number (MPN) method (Weaver and Frederick, 1972). At all locations the residual levels of N was below 0.2%.

Cowpea rhizobia

The four strains of rhizobia used in the study are listed in Table 1. Preliminary experiments were conducted and they were all shown to have high effectiveness in nodulation and N_2 fixation with the two cowpea cultivars used.

Preparation of Inocula and Seed Inoculation

Cultures of each strain were grown in yeast mannitol broth (YEMB) (Vincent 1970) on a rotary shaker for 5-6 days at room temperature. The broth culture contained no less than 10^8 cells/ml (Plate and Petroff- Hausser count). This broth culture (50 ml) was injected into the polyethylene bags (one per test row) containing 100 g sterile peat obtained from the Nitragin Company (Milwaukee, WI). The bags were sealed immediately and hand shaken thoroughly to

mix broth with peat. The cultures were allowed to age in an incubator at 30°C for 15 days, then stored at 4°C until initiation of studies in Jamaica.

Immediately before experiments were planted seeds of the cowpea cultivars, Mississippi Silver and Vita 3 were sterilized (Somasegaran and Hoben, 1985). Sterile seeds were allowed to air dry under a laminar flow hood and placed in sterile whirl-pak for transportation to the experimental sites. Seed bed preparation differed with location. This was done to simulate the common planting technique used in the area. At Lawrence Field, Aqualta Vale and Christiana conventional tillage was used to prepare the seed beds, while at Albert Town and Endevor a no-tillage production method was used for preparation of plots. Seed furrows were opened after areas were cleared of all vegetation. In all areas, research was conducted in plots where no crops were grown for at least 3 years. There was no addition of chemical fertilizer at any location for the duration of the study.

Experimental Design

Identical experimental design was used for each experiment. The inoculum treatment was replicated three times and arranged in a randomized block design for each cowpea cultivar. Three row experimental plots measuring 5 m x 2 m were used for each treatment. The treatments for each location were 5 rhizobia strains plus a control (no inoculum) and 2 cowpea cultivars. Plots were constructed with 2.5 m alleys between treatments to restrict any contamination while cultivating or other plot maintenance. At planting, 2.5 cm deep furrows were opened with a Planter Jr. (Troy, New York) one row hand operated plow. Sterile seeds of the cowpea cultivars were hand planted (14 seeds per meter), ensuring no contamination between treatments. The inoculants were applied directly to the seed furrow at a rate of 6.7 g m^{-1}. Control plots were inoculated with sterile peat. Plate count from serial dilution of subsamples from each bag containing the peat base inoculum was conducted to determine rhizobia count at planting. Plots were marked with steel rerods and replanted with sterile seeds each growing season.

Evaluation for Strain Effectiveness and Survival

Two randomly selected plants were harvested from the center row at the mid to full bloom stage, (45-55 days after germination). Nodules from these two plants were removed and stored in desiccating vials (Vincent, 1970) until serotyping was done. All serotyping was completed within 3 months after nodule harvesting, by the agglutination method described by Somasegaran and Hoben (1985). Antisera production were done in the laboratory at Lincoln University. Nodule occupancy was the indicator for competitiveness and survivability over the duration of the study. Nodules from control plants were tested against all the antisera. At the end of the study (1987) soil samples were taken from each plot and the rhizobia population was determined by MPN.

Growth Development and Yield

Plant growth and development was monitored throughout the growing season and recorded as plant height, plant width, number of nodes to flowering, shoot dry weight, and root dry weight. Nodule number and mass were recorded from plants removed when samples were taken to collect nodules. Crop yields measured as weight of dry pods were taken from the two outside rows per plot, at the 80% dry stage (80-95 days after germination).

RESULTS AND DISCUSSION

Seeding establishment and early growth were unsatisfactory at the Albert Town site in 1985. Further experimentation at this site was eliminated. Due to delayed harvesting, excessive shattering and severely reduced yield, no yield data is reported for 1986. Serotyping of nodules from the control plots was done and it was confirmed that these nodules were not formed as a result of the applied rhizobia.

Competition and Survival

Weaver and Frederick (1974) suggested that the number of viable rhizobia cells in the inocula should be 10^3 greater than the indigenous rhizobia population to allow for a minimum of 50% nodule occupancy by the introduced strain. This was easily obtained in our study, as a result of the low indigenous rhizobia population (Table 2). There were significant variations in nodule occupancy from site to site for the duration of the study 1985-87 (Table 3-5). Percent nodules occupied by strains at any one location also varied. Recovery of applied inoculum strains in 1985 (a measure of rhizobia competitiveness) was highest for JRC 29 and 32H1 at all locations with both cowpea cultivars (Table 3). In comparison to Rhizobium strains JRC 29, and 32H1, the strain IRC 26 gave the lowest nodule occupancies at all four locations in all three years of the study (Table 3-5).

The low nodule occupancy by both IRC 26 and IRC 503B was observed with both cowpea cultivars. This indicates that the specificity for host plant did not vary with cultivar as suggested by Klubek et al. (1988). Nodule occupancy declined over the duration of the study (1985-1987), irrespective of the cowpea cultivar or Rhizobium strain. These results are similar to those obtained by Brockwell et al., (1982) and supports the conclusion that competitiveness and survival are not always controlled by the same factors. Highest percentage nodule occupancy occurred with the native Rhizobium strain JRC 29. The persistence of this strain was also significantly higher than those of the other strains used. These results are comparable to reports by Aarons and Ahmad (1986) who found that temperatures typical to hot tropical growing conditions had only minor effect in reducing number of JRC 29 cells in a peat carrier. Averaged over both crops and all locations, the competitiveness, and persistence of the introduced strains are summarized as follows:

	Competitiveness (% Nodule occupancy)	Persistence (% Nodule occupancy)
JRC 29	88.5	80.0
IRC 26	30.8	13.3
IRC 503B	46.3	21.6
32H1	82.7	65.5

JRC 29 was followed by 32H1 as the most persistent strain with a 65.5% nodule recovery rate in the third year. These high recovery rates by JRC 29 (80%) and 32H1 (65%) may be attributed to the fact that JRC 29 is a strain indigenous to Jamaica and 32H1 has shown high tolerance to the high temperatures and flooding typical to that of tropical areas (Ahmad et al., 1981). Poor response of both cultivars to the strains IRC 26 and IRC 503B may be due to one or more of the following soil factors: moisture (Osa-Afiana and Alexander 1979), pH (Vidor et al., 1981), temperature (Aarons and Ahmad 1987, Boonkerd and Weaver 1981), and N-fertilization (Eaglesham et al., 1982). These factors along with poor specificity to the cowpea used, may be the reason for such poor recovery rate by strains IRC 26 and IRC 503B. With the diversity of the chemical and physical properties of the soils used (Table 1), it is understandable why there was so much variation in nodule occupancy for the location utilized.

PLANT GROWTH AND DEVELOPMENT

In general cowpea growth and yields were lower than those obtained in the USA. Several factors contributed to this reduction, but the major ones were reduced soil fertility and some flooding, especially at the Agualta Vale site.

Plant height and shoot dry weight were significantly higher at Lawrence Field and Christiana, than Endevor and Agualta Vale (Table 6 and 7). The reduced yields and low nodule occupancy at Endevor were believed to be a result of no-till production practices used, while periodic flooding contributed to the reduced yield at Agualta Vale.

Both plant height and shoot dry weight were influenced by rhizobia strains (Table 6). Plants treated with JRC 29 had the highest plant height and shoot dry weight at all locations. The increased dry weight of plants treated with JRC 29 and 32H1 is an indication of the effectiveness of these strains which occupy a significantly higher number of the nodules (Table 4). Increased dry matter accumulation by legumes is a reasonable indicator that the Rhizobium strain associated with the legume is effective in fixing nitrogen (Amad et al., 1981). The effect of indigenous Bradyrhizobium on N_2-fixation was also reflected in low shoot dry weight at all locations (Table 6). The Vita 3 cultivar is indeterminate and, therefore, had higher shoot length than Mississippi Silver.

There were significant increases in grain yield in response to inocula treatments (Table 7). Yields from the cowpea cultivar Mississippi Silver were generally higher those that of Vita 3. This yield was significantly higher with JRC 29 compared to that of the inoculated plots. The newly introduced cowpea cultivar to Jamaica showed excellent compatibility with the Rhizobium strain isolated from native cowpea plants (Aaron and Ahmad, 1987).

In summary we have demonstrated that:

(a) the Rhizobium strain JRC 29 had the best survival rate over the duration of the study, indicating that Rhizobium strains indigenous to Jamaica are capable of competing favorably with introduced effective rhizobia.

(b) Rhizobium strain JRC 29 was most efficient in enhancing cowpea growth development and yields.

(c) The most effective introduced Rhizobium strain was 32H1.

(d) difference in survival and efficiency of the rhizobia, at the various locations indicates specificity of rhizobia for locations in Jamaica. Selections of sites to produce cowpea in Jamaica should be selected on the basis of Rhizobium effectiveness and survival on the soil of the selected area.

'ACKNOWLEDGEMENT

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BENEFITS AND POTENTIAL BENEFITS FROM THE RESEARCH

To Jamaica: 1) Results from this study have contributed significantly to the decision of the Scientific Research Council of Jamaica, in initiating a program investigating the possibility of using Rhizobium strain JRC 29 in a peat base inoculum for legume production.

2) The production (yield potential) of cowpea, has increased with the planting of the cultivar Mississippi Silver. The cowpea Mississippi Silver not only increased marketable yield but also increased the crop base for a very important grain crop on the island.

3) The Graduate Student who worked on the project for one year is now back in Jamaica working on a farm that produces cowpea. Knowledge gained on this project is directly transferred to the farmers by this individual.

4) The use of inoculum to increase legume crop productivity, will become normal practice in Jamaica in the near future.

To Lincoln University: 1) The results of these research were presented at the meetings of the Caribbean Food Crop Society held in Ocho Rios, Jamaica in August 1988. At the conference discussions were held with Dr. James Beaver, University of Puerto Rico, Dr. Russell Freed, Michigan State University, Dr. George Wilson, Jamaica Agriculture Development Foundation and Dr. Wayne McLaughlin, Jamaica, Scientific Research council, outlining research findings from this project. The decision was made to write a research proposal aimed at investigating other aspects of the N_2-fixation process in tropical soils. This proposal was written and has been funded to an amount of over $200,000.

2) Contacts have been developed with various agriculture affiliated organizations in Jamaica. This allowed Dr. L. McLaren of the Jamaican Ministry of Agriculture to visit Lincoln University and present a seminar to Lincoln University's faculty in June of 1989. During Dr. MacLaren's visit the research needs of Jamaica were discussed. Several Lincoln University faculty are presently investigating ways of conducting joint research projects with the Ministry of Agriculture Jamaica.

3) The experience gained by the Principal Investigator through this project has been invaluable. As a result of the work in Jamaica interest was developed in certain crops which could be grown as ethnic crops in Missouri. Consequently, research was initiated to study potential production of certain ethnic crops in Missouri. Results from these studies have been encouraging and a research proposal is submitted to USDA-CSRS for funding.

4) Efforts to investigate N_2-fixation capabilities of the exotic legume crops have been launched in collaboration with other researchers at Lincoln University.

To USAID: Results from these studies are applicable to other tropical areas that have USAID mission and adequate measures will be taken to disseminate this information.

Publications:

Marsh, D.B. and J.R. Suah. 1988. Survival of introduced cowpea rhizobia in Jamaica soils. Proceedings of the 25th Annual Caribbean Food Crop Conference Ocho Rios, Jamaica.

Marsh, D.B. 1987. Production of specialty crops for ethnic markets in the USA. HortSci. 23:628.

Marsh, D.B. and A. Hines. 1986. The effect of introduced wild Rhizobium strains on the efficiency of known effective Rhizobium strains. Biannual Research Directors Symposium Atlanta, Georgia. Abst.

Swartz, H. and D.B. Marsh. 1988. Forage potential of Vita 3 cowpea in Mid-Missouri. Missouri Sheep Report. University of Missouri-Columbia.

Marsh, D.B. 1989. Survival of Bradyrhizobium sp. introduced into several Jamaican soils. Being reviewed for submission to Letters in Applied Microbiol.

LITERATURE CITED

Aarons, S. and M.H. Ahmad. 1986. Examining growth and survival of cowpea rhizobia in Jamaican peat. Letters in Applied Microbiol. 2:115-118.

Aarons, S. and M.H. Ahmad. 1987. Growth and survival of cowpea rhizobia in bauxitic silt loam and sandy clay loam soils. FEMS Microbiology Ecology 45:77-83.

Ahmad, M.H., A.R.J. Eaglesham, S. Hassouna and B. Seaman. 1981. Examining the potential for inoculant use with cowpeas in West Africa soils. Trop. agri. (Trinidad) 58:325-335.

Ahmad, M.H. and W. McLaughlin. 1985. Ecology and genetics of tropical Rhizobium species. Biotech. Adv. 3:155-170.

Amarger, N. and J.P. Lobreau. 1982. Quantitative study of nodulation competitiveness in Rhizobium strains. Appl. Environ. Microbiol. 44:583-588.

Bookerd, N. and R.W. Weaver. 1981. survival of cowpea rhizobia as affected by soil temperature and moisture. In: Biological Nitrogen Fixation Technology for Tropical agriculture (ed) P.H. Graham and S.C. Harris. pp 201-205. CIAT. Cali, Columbia.

Brockwell, J., R.R. Gault, M. Zorin, and M.J. Roberts. 1982. Effects of Environmental variables on the competition between inoculum strains and naturalized populations of Rhizobium trifolic for nodulation of Trifolium subterraneum L. and on rhizobia persistence in the soil. Aust. J. Agr. Rec. 33:803-815.

Bushby, H.V.A. and V.C. Marshall. 1977. Some factors affecting the survival of root nodule bacteria on desiccation. Soil Biol. Biochem. 9:143-147.

Date, R.A. 1976. Principles of Rhizobium strain selection. In: symbiotic nitrogen fixation in plants. P.S. Nutman (ed) p 137. Cambridge University Press, Cambridge.

Eaglesham, A.R.J., A. Ayanaba, V.R. Rao and D.L. Eskew. 1982. Mineral N effects on cowpea and soybean crops in Nigerian soil. Plant Soil 68:171-181.

Habte, M. and S.A. El-Swaify. 1988. survival of Rhizobium in an Oxisol subjected to incremental simulated erosion. Soil Sci. Soc. Am. J. 52:1313-1316.

Klubek, B.P., K.L. Hendrickson, R.M. Zablotowig, J.E. Skwara, E.C. Varsa, S. Smith, T.G. Islieb, J. Maya, M. Valdes, F.B. Dazzo, R.L. Todd, and D.D. Walgenback. 1988. Competitiveness of selected Brady Rhiziboum japonicum strains in midwestern USA soils. Soil Sci. Soc. Am. J. 52:662-666.

Kvien, C.S., G.E. Ham and J.W. Lamberts. 1981. Recovery of introduced Rhizobium japanicum strains by soybean genotypes. agrón. J. 73:900-905.

Osa-Afiana, L.O. and M. Alexander. 1979. Effect of moisture on the survival of Rhizobium in soil. Soil Sci. Soc. Am. J. 43:925-930.

Osa-Afiana, L.O. and M. Alexander. 1982. Differences among cowpea rhizobia in tolerance to high temperature and desiccation in soil. Appl. Environ. Microbiol. 43:435-439.

Somasegram, P. and H.J. Hoben. 1985. Methods in legume - Rhizobium. Technology Niftal.

Uddin, M.R., W. McLaughlin and M.H. Ahmad. 1984. Competition between inoculum and native rhizobia for nodulation of cowpea (Vigna unguiculata): use of a dark nodule strain. Plant Soil 81:305-307.

Vidor, C., P.E. Lovata and R.H. Miller. 1981. survival of steptomycin-resistant mutants of Rhizobium phaseoli in nonsterile soil. In: Biological Nitrogen Fixation Technology for Tropical Agriculture (ed) P.H. Graham and S.C. Harris. pp 201-205. CIAT Cali, Columbia.

Vincent, J.M. 1970. A manual for the practical study of root-nodule bacteria. International Biological program handbook No. 15. Blackwell Scientific.

Weaver, R.W. and L.R. Frederick. 1972. A new technique for most probable number counts of rhizobia. Plant Soil. 36:219-222.

Weaver, R.W. and L.R. Frederick. 1974. Effect of inoculum rate on competitive nodulation of Glycine max L. Merrill. II Field Studies. Agron. J. 66:233-236.

Table 1. Rhizobium strains and site of origin.

STRAIN	HOST PLANT	ORIGIN OF ISOLATE
JRC 29	Cowpea	Jamaica
IRC 26	Cowpea	Nigeria
IRC 503B	Cowpea	Nigeria
32H1	Cowpea	USDA-Beltsville

Table 2. Properties of soils at the 5 locations.

Sites	Particle Size %			pH (0-15 cm)	Crop History for Legume	Indigenous Rhizobia Cell/g
	Sand	Silt	Clay			
Lawrence Field	15.6	38.0	56.4	0	-	$<10^2$
Endevor	18.4	22.5	39.1	6.4	-	$<10^2$
Albert Town*	15.2	53.0	31.8	5.9	+	2.1×10^2
Christiana	15.1	26	58.9	5.9	+	1.9×10^2
*Agualta Vale	23.8	35.2	41.0	6.0	+	1.8×10^2

*Results from Albert Town experiments are not reported due to poor crop response. The Agualta Vale site replaced Albert Town later the same year.

Table 3. Nodule occupancy (%) by applied cowpea rhizobia strains in 4 location in 1985.

	Mississippi Silver			
	Locations			
Strains	Lawrence Field	Endevor	Christiana	Agualta Vale
JRC 29	91	89	88	82
IRC 26	31	28	26	21
IRC 503B	56	48	41	33
32H1	82	81	84	78
LSD 1%	15	11	12	18
	Vita 3			
JRC 29	94	91	94	79
IRC 26	39	31	36	35
IRC 503B	58	45	52	38
32H1	90	86	88	73
LSD 1%	8	10	14	11

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Table 4. Nodule occupancy (%) by applied rhizobia strains in 1986.

	Mississippi Silver			
	Location			
Strains	Lawrence Field	Endevor	Christiana	Agualta Vale
JRC 29	89	80	84	80
IRC 26	15	18	20	18
IRC 503B	21	24	31	31
32H1	73	70	15	11
LSD 1%	12	9	15	15
	Vita 3			
JRC 29	86	76	91	78
IRC 26	20	29	28	21
IRC 503B	35	34	40	30
32H1	81	78	71	74
LSD 1%	14	18	11	18

Table 5. Nodule occupancy (%) by applied cowpea rhizobia strains in 1987.

	Mississippi Silver			
	Locations			
Strains	Lawrence Field	Endevor	Christiana	Agualta Vale
JRC 29	82	84	86	79
IRC 26	12	19	11	8
IRC 503B	21	16	18	6
32H1	54	12	18	21
LSD 1%	24	12	18	21
	Vita 3			
JRC 29	74	76	87	72
IRC 26	15	11	13	18
IRC 503B	21	28	35	28
32H1	73	72	70	71
LSD 1%	21	18	16	14

Table 6. The effect of inoculation on plant height (cm) and shoot dry wt. (g) of two cowpea cultivars: 1987.

	Mississippi Silver							
	Locations[y]							
	A[z]		B		C		D	
	PL Ht	Shoot DW	PL Ht	Shoot DW	PL Ht	Shoot DW	PL Ht.	Shoot DW
JRC 29	63	61	50	48	56	59	44	35
IRC 26	48	46	42	39	51	44	32	30
IRC 503B	61	38	50	28	52	35	28	21
32H1	55	59	31	42	40	49	38	19
No Inoculum	42	29	28	29	32	30	29	18
LSD 1%	5	6	4	8	3	7	3	
	Vita 3							
JRC 29	82	68	86	61	91	63	59	58
IRC 26	62	49	54	48	59	59	43	42
IRC 503B	71	51	68	36	63	35	41	35
32H1	64	29	42	29	38	28	39	30
No Inoculum	50	24	20	25	31	19	28	21
LSD 1%	8	4	8	5	4	5	7	6

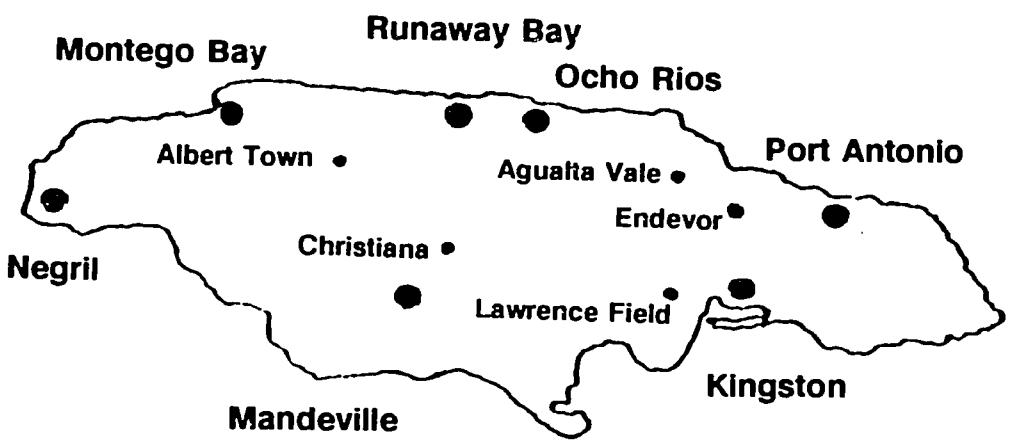
[z]Locations A = Lawrence Field B = Endevor C = Christiana D = Agualta Vale
[y]data average of 5 plants per plot.

Table 7. The effect of inoculation on shoot dry wt (g) and grain yield (kg/plot) of two cowpea cultivars: 1986.

	Mississippi Silver							
	Locations[y]							
	A[z]		B		C		D	
	Shoot DW	Yield	Shoot DW	Yield	Shoot DW	Yield	Shoot DW	Yield
JRC 29	56	.406	35	.310	51	.410	21	.301
IRC 26	35	.179	30	.165	38	.218	25	.190
IRC 503B	40	.296	38	.200	42	.341	19	.218
32H	42	.289	3	.210	46	.217	15	.208
No Inoculum	31	.152	35	.121	35	.141	12	.111
LSD 1%	4	.086	3	.091	6	.181	3	.150
	Vita 3							
JRC 2	85	.386	72	.198	92	.396	51	.346
IRC 26	52	.151	49	.146	58	.212	35	.210
IRC 503B	58	.192	51	.131	60	.216	42	.218
32H1	49	.210	41	.200	58	.151	32	.186
No Inoculum	45	.181	35	.135	50	.130	30	.128
LSD 1%	4	.091	2	.104	3	.064	3	.101

[z]Locations A = Lawrence field B = Endevor C = Christiana D = Agualta Vale
[y]Data average of 5 plants per plot.

JAMAICA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Ocho Rios
Albert Town
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Port Antonio
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