Report on Travel to Mali
August 21-August 28, 1999
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SM-CRSP Project: *Decision Aids for Integrated Nutrient Management*

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Objectives:

- Assess nitrogen fixation by cowpea in the core experiment
- Train local scientists on measurement of nitrogen fixation
- Evaluate data generated in the core experiment during the 1998 growing season
- Demonstrate the use of the first software version of NuMaSS (formerly IntDSS) to scientists and students at Sotuba and the Cinzana Research Station
- Become familiar with on going nutrient and crop management research in Mali

Itinerary:

Saturday, August 21	Departed Raleigh
Sunday, August 22	Arrival Bamako- Met Dr. Doumbia and transported to Mande Hotel .
Monday, August 23	Visited Director General and other IER staff at Sotuba Research Station in the morning and traveled to Cinzana Research Station in the afternoon.
Tuesday, August 24	Sampled selected cowpea plots in the core experiment for nodulation and trained station staff on how to sample for nodulation.
Wednesday, August 25	Installed IntDSS software on several computers at station and trained staff to use it.
Thursday, August 26	Traveled to Dougouba Village to observe Dr. Doumbia's on farm test on manure management while Mr Brahma and station staff resampled high P and high lime plots to assess variation in nodulation of cowpea
Friday, August 27	Traveled from Cinzana Station to Sotuba Station; Conducted training session on use of IntDSS software for 7 of Dr. Doumbia's students and staff members; gathered crop yield and biomass data from the 1998 core experiment; and departed Bamako for Paris at 10:00PM
Saturday, August 28	Arrived Raleigh 8:00PM

Observations on 1999 Core Experiment:

The millet and cowpea components of the core experiment in general showed good growth; the plots were free of weeds and there did not appear to be serious disease or insect problems. Some cowpea plots had several missing hills. There is much within plot variation in plant size especially for millet. Dr. Doumbia commented that this problem is common in farmer fields throughout Mali. This will make measurement of treatment effects difficult.

The within plot variation made it difficult to discern treatment effects on growth of millet or cowpea. Plants in the P0L0 treatment were generally smaller in size than plants in other treatments. There are no strong signs of N deficiency in the N0 treatment of millet. The N was applied on August 13 so there has not been much time for it to stimulate growth.

On checking plots of core experiment on August 25, we noted that while none of the millet in the core experiment was showing N deficiency an adjacent area had millet showing rather severe deficiency. Dr. Doumbia and Mr. Coulibaly suggest that lack of N deficiency in the experimental plots is due to the residual effect of the previous cowpea crop. This does seem like a plausible explanation. The first flowers on cowpea plants in the core experiment were noted on August 25.

Management Information on Core Experiment:

No lime was applied to the core experiment this year (1999) as pH of all treatments that received lime the previous year was above 6.5 at beginning of the growing season. Phosphorus was applied according to soil test. However, instead of adjusting available soil P levels to 50 (P1) and 100% (P2) of that recommended by NuMaSS as in the 1998 crop, P was applied to all treatments (including those with P0) to raise available soil P to the level recommended by the NuMaSS software (i.e. the P2 level). The millet and cowpea varieties in the core experiment are the same as last year. No fertilizer N was applied to the millet component of the core experiment in 1998. Given these discrepancies between the planned and actual treatments in the core experiments with millet and cowpea, lime and fertilizer inputs for the 1998 and 1999 cropping seasons are described in Table 1 and 2, respectively.

Table 1. Application rates of N, P (as triple superphosphate) and lime (as Diamou calcitic lime) to treatments in the cowpea and millet core experiments prior to planting in the 1998 season.

TREATMENT	AMOUNTS APPLIED	
LEVELS[a]	COWPEA EXPERIMENT	MILLET EXPERIMENT
	-------------------- kg ha^{-1} --------------------	
N0	0	0
N1	0	0
N2	0	0
P0	0	0
P1	8.3	6.5
P2	16.5	13.0
L0	0	0
L1	900	900
L2	1810	1810

[a] 0 = no applied fertilizer or lime; 1 = 50% of the level recommended by NuMaSS; 2 = 100% of the amount recommended by NuMaSS.

Measurement of Cowpea Nodulation:

Nodulated root systems were dug from one hill each for row 2 and row 9 of each plot. A block about 25 cm square around the base of plants and 20 cm deep was removed with shovels and soil was gently removed from roots to avoid stripping nodules. Shoots were cut from roots and placed in cloth bags for drying at 60 °C. Root systems were taken to the soils lab in Mason jars where nodules were removed, counted, washed, blotted dry on paper towels to remove surface moisture and weighed. Nodules were placed in scintillation vials for drying at 60 °C. The roots were washed and placed in cloth bags for drying.

Table 2. Application rates of N (as urea) and P (as triple superphosphate) to treatments in the cowpea (cropped to millet) and millet (cropped to cowpea) core experiments prior to planting in the 1999 season. No lime was applied to either experiment in this season.

COWPEA CORE EXPERIMENT			MILLET CORE EXPERIMENT		
TREATMENT	**N**	**P**	**TREATMENT**	**N**	**P**
	----- kg ha^{-1} -----			----- kg ha^{-1} -----	
N0P0L0	0	9.0	N0P0L0	0	8.3
N2P0L2	71	5.7	N0P0L2	0	7.0
N2P1L2	71	6.4	N0P1L2	0	8.0
N2P2L2	71	0	N0P2L2	0	7.2
N2P2L0	71	0	N0P2L0	0	7.2
N2P2L1	71	9.0	N0P2L1	0	5.7
N2P1L1	71	3.6	N0P1L1	0	3.0
N0P2L2	0	0.5	N2P2L2	71	2.0
N1P2L2	35.5	6.1	N0P2L2[b]	0	0
N0P2L2[a]	0	1.7	N1P1L1	35.5	3.4
N1P1L1	35.5	1.5			

[a] The only treatment where cowpea stover, when planted in the experiment, is left as residue in the field.
[b] The only treatment inoculated with a mixture of two efficient *Bradyrhizobium* strains from Zimbabwe, when planted to cowpea.

Lime application in the previous season had no significant effect on nodule number or nodule mass however treatment effects may have been masked by the high variability in these traits (Table 3). The P effect could not be evaluated because P was applied to all treatments in 1999. Nodules in all treatments had reddish brown central cortex indicative of leghemoglobin and indicating that nodules were probably functional in fixing nitrogen. Some plants had nodules with multiple lobes. The cental cortex of lobes was also reddish brown suggesting presence of leghemoglobin and functionality in nitrogen fixation.

Inoculation resulted in a higher mean nodule number but the variability was so high that statistical significance was not attained. As a result we decided to sample multiple hills from border rows in the high P, high lime plots with and without inoculation with a mixture of two efficient *Bradyrhizobium* strains from Zimbabwe to determine if inoculation decreased the variation in nodulation traits. These results are shown in Table 4. Inoculation resulted in a slight improvement in the variation in nodule number and nodule mass but coefficients of variation were still very high (67% and 58%, respectively). We had no way to directly determine whether the inoculant strains were successful in infection and nodule formation.

Table 3. The effect of lime application in 1998 on nodulation of cowpea grown in an Oxic Haplustalf on Cinzana Research Station Mali during 1999 season. Sampled at 40 days after planting.

TREATMENT	APPLIED P	APPLIED LIME*	NODULE NUMBER	NODULE FRESH WEIGHT
	kg/ha	kg/ha	/hill	/hill
N0P2L0	8.3	0	28	0.99
N0P2L2	7.0	1810	35	1.06
N0P2L2	8.0	1810	34	1.23
N0P2L2	7.2	1810	36	1.31
N0P2L2(Inoc)	0	1810 (Inoc)	46	1.19
N0P2L0	7.2	0	23	0.69
N0P2L1	5.7	900	40	0.94
N0P2L1	3.0	900	25	0.7
		$LSD_{0.05}$	NS	NS
		CV(%)	28	34

* Amount of lime applied in 1998.

Table 4. Comparison of variation in nodulation in high P and high lime plots that were either inoculated or not inoculated with a mixture of Bradyrhizobium isolates from Zimbabwe.

APPLIED			HILLS	NODULE NUMBER			NODULE FRESH WEIGHT		
P	LIME	INOC.	SAMPLED	MEAN	SD	CV	MEAN	SD	CV
kg/ha			#	#/hill			g/hill		
8.0	1810	yes	32	33	22	67	0.88	0.51	58
8.0	1810	no	27	22	17	77	0.89	0.9	101

Additional Cowpea Measurements to Be Made by Cinzana Staff:

- Dry weight of cowpea shoots and roots taken from core experiment on 8-24-99. These samples need to be ground and analyzed for total N at Sotuba.
- Weight of shoots and roots from plots sampled on 8-26-99 to assess effect of inoculation on variability in nodulation. These do not need to be analyzed for total N.
- Collect leaf litter and petioles that fall from cowpea plants during pod development from a defined plot area, weigh and subsample for total N analysis at Sotuba. This represents N that could become available to the following crop like millet.

The nodules collected can be discarded after weighing for fresh weight determination. Dan Israel took some nodules from plot 203 which would contain only symbiotic strains from the soil. He will attempt to isolate strains from these nodules that might be useful as inoculant for future experiments.

Training on Use of IntDSS Software:

The IntDSS program was installed on Mr. Coulibaly's laptop computer and another computer in the stations computer lab. Much of the Wednesday (August 25) was spent experimenting with the NuMaSS software and discussing the rationale of NuMaSS with Mr. Coulibaly and Dr. Doumbia. Dr. Doumbia raised concerns about how extension people in Mali will respond to the software and he was encouraged to bring these concerns to the group at the Philippines workshop. I emphasized that this is the first version and that upgrades based on user response at the workshop would be forthcoming. I think they have a reasonably good understanding of where the programming stands at this point in time. Overall their impression of the software seems quite favorable.

Dr. Doumbia's students and collaborators were trained in the use of the IntDSS software (7 people). The program had been installed on four or five laptop computers so I was able to lead them through the acidity, N and P components of the program. Most seemed to follow the program reasonably well and were proficient in obtaining recommendations for lime, P and N for relevant crops.

Experimentation with the NuMaSS software generated several questions. The program will calculate a stover yield from grain yield and reproductive:vegetative dry weight ratio, but it will not calculate total N in stover from estimated stover biomass and N concentration in stover. Why not? When1000 kg/ha was entered as target yield, the P module report gives an expected maximum yield of 600 kg/ha. Is 600 kg/ha some kind of default value for Mali? If the user checks "did not apply fertilizer" under prior nutrient management, the N module will calculate soil N based on previous crop yield and N concentration. This can lead to calculation of a high soil N value which dramatically reduces fertilizer N requirement for the current crop.

Discussions with Malian Scientists:

On Monday (August 23) I had a brief visit with the Director General, Dr. Abdoul Traore. He emphasized that legume crops were assumed to be supplying N for nonlegume crops in the rotation systems used in Mali but the fertility needs of these legume crops had not been adequately addressed. His implication was that legumes were not fixing as much N as thought due to P deficiency and or acidity constraints.

A microbiologist from the University of Mali (Professor Hinamoud Haiga) visited Cinzana Station on Wednesday (August 25). He indicated that he has isolated a symbiont from Lablab that does not seem to be in either the *Bradyrhizobium* or *Rhizobium* genus. His conclusion was based on physiological data and genetic data such as PCR-RFLP and sequence analysis. He also has an interest in developing an inoculum industry in Mali. He indicated that a local source of peat is available to use as an inoculant carrier. Professor Haiga might be a good contact if one decides to develop a biological N fixation project in Mali.

Most of Thursday (August 26) was spent with Dr. Doumbia visiting his on farm test in the area of Dougouba Village. He works with a farmer, Mr. Lassine Djire, who cultivates a 7 ha farm. In this area they have a practice in which rows with manure mounds are alternated with rows without manure mounds.. This practice has been used in this area for many years. Dr. Doumbia's on farm test with Mr. Djire comparing the traditional manure mound system with broadcasting and incorporation of manure convinced Mr. Djire to give up the traditional system. He does not have sufficient manure for application to all of his land each year. He rotates the area fertilized with manure so that over time all of his land receives nutrients supplied by the manure. Dr. Doumbia introduced me to the elders of Dougouba Village. These men make the key farm management decisions for their family groups.

I learned from Dr. Doumbia that use of cowpea in Mali is changing from a grain crop for human consumption to a hay crop which is cut and removed from the field before pods mature and leaves drop. This harvest while pods and leaves are green has relevance as to how the N credit is assigned to a cowpea crop that precedes a nonlegume crop in the N module of NuMaSS. He also indicated that animals are free to eat all residues on fields for a 6 month period of the year. *This means that rotational effects of cowpea on millet may be diminished on farmers fields compared to that observed in experiments on Cinzana Station.* He also indicated that many cowpea varieties that farmers use do not shed leaves like the variety selected for the core experiment. It is difficult to get a handle on the importance of the cowpea rotational effect on productivity of millet in the Cinzana region.

Other Observations:

There had been much rain just before I arrived. Many millet and cowpea fields between Bamako and Cinzana had standing water. A rain gauge has been installed in field adjacent to the core experiment.

On the trip to Dougouba Village, we also traveled to see the large dam and canal system on the Niger River near Markala. As much as 900,000 ha of rice could be irrigated by this system. At the present time about 80,000 ha of irrigated rice is produced in the region.
In general millet in the calcium movement experiment showed good growth, however the ever present within plot variation was apparent.

Data for the 1998 Core Experiment:

Yield and nitrogen accumulation data for the millet and cowpea crops grown in the 1998 core experiment were provided by Dr. Doumbia. Phosphorus and lime application had no significant effect on grain yield, and litter dry mass of cowpea (Table 5). Phosphorus application significantly increased (0.1 level of probability) stover dry mass and whole plant dry mass. The lack of significant effects on grain yield is related to the large variability (CV 42%).

Phosphorus and lime application had no significant effect on N accumulation in grain, stover, litter that shed during seed development and whole plant of cowpea (Table 6). This lack of statistical significance is associated with large plot to plot variations in grain yield and stover dry mass (CV'S of 52% and 35%, respectively).

In spite of the lack of statistical significance, there are several interesting aspects of the data worth noting. The cowpea crop accumulated about twice as much N as the millet crop grown in another area of the same field (see Table 7, 90 vs 45 kg N/ha). This indicates that the indigenous bradyrhizobial organisms that formed the nodules in symbiosis with cowpea were reasonably effective in fixing nitrogen. The stover and litter which shed during seed development contained an appreciable amount of N. For example, in the high P-high lime treatment stover and litter contained 55 kg N/ha or 65% of the whole plant N (Table 6). This amount of N could have a significant impact in rotations with millet and sorghum if returned to the soil.

Table 5. Effect of P and lime application on yield and biomass accumulation in cowpea grown on an Oxic Haplustalf on the Cinzana Research Station , Mali in 1998 season.

APPLIED		YIELD				GRAIN +
P	LIME	GRAIN	STOVER	LITTER[a]	TOTAL	STOVER
		-- kg ha^{-1}	--			
0	0	645	1017	788	2450	1662
0	1810	561	1295	612	2468	1856
8.3	1810	604	1634	775	3013	2238
16.5	1810	835	1942	818	3595	2777
16.5	0	776	2251	607	3634	3027
16.5	900	657	1572	905	3134	2229
8.3	900	508	1665	750	2923	2173
$LSD_{0.1}$		NS	809	NS	947	NS
CV(%)		42	29	25	18	26

[a] Leaves and petioles that shed from plants before harvest of grain.

Table 6. Effect of phosphorus and lime application on nitrogen accumulation by cowpea grown in an Oxic Haplustalf soil on the Cinzana Research Station, Mali in 1998 season.

APPLIED		N CONCENTRATION			N ACCUMULATION[b]				
P	LIME	GRAIN	STOVER	LITTER[a]	G	S	L	T	G+S
kg ha^{-1}		--- g N/kg dry weight ---			-------------------- kg N/ha ----------------------				
0	0	38.9	19.8	21.1	25.1	20.5	16.8	62.4	45.6
0	1810	40.0	23.0	20.3	22.3	27.7	12.3	62.3	50.0
8	1810	40.6	23.5	20.7	24.8	38.3	15.6	78.7	63.1
16	1810	43.0	19.7	19.9	36.7	38.4	16.2	91.3	75.1
16	0	43.7	20.1	20.2	35.3	46.7	12.0	94.0	82.0
16	900	46.0	22.2	20.9	29.1	35.0	18.9	83.0	64.1
8	900	44.9	20.2	21.8	23.2	31.4	16.4	71.0	54.6
$LSD_{0.05}$		NS	NS	NS	NS	NS	NS	NS	NS
CV(%)		15	20	6	52	35	23	20	28

[a] Leaves and petioles that shed from plants before harvest of grain.
[b] G=grain; S=stover; L=litter; T=total; G+S=grain + stover.

Because a source of fertilizer N was not available during the cropping season, the 1998 millet crop was grown without applied N. The high P,high lime treatment significantly ($P < 0.05$) increased grain yield relative to the P0L0,P0L2 and P2L0 treatments (Table 7). This indicates that although the crop received no applied N, residual soil N was sufficient to permit crop yield response to P and lime treatments. Lime and P had no significant effect on stover dry mass (Table 7).

Phosphorus and lime application had no significant effects on N concentrations in grain and stover of millet (Table 8). The high P,high lime treatment did increase total N accumulation in grain relative to the P0L0 (Table 8). It is worth noting that the millet crop in the high P,high lime treatment accumulated 45 kg N/ha from soil N reserves and that the grain yields were very good for this climatic zone.

The degree of response to lime and P application in the 1998 test was probably limited by the availabilty of N. Since N treatments have been implemented in the 1999 test much greater response to lime and P application is expected.

Table 7. Effect of phosphorus and lime application on yield and dry matter accumulation in millet grown on an oxic Haplustalf soil on the Cinzana Research Station, Mali in the 1998 season.

APPLIED		**YIELD**		
P	**LIME**	**GRAIN**	**STOVER**	**GRAIN + STOVER**
		------------------------------ kg/ ha ---------------------------		
0	0	1242	3284	4527
0	1810	1585	3820	5405
6.5	1810	1566	3968	5534
13.0	1810	2062	4355	6571
13.0	0	1518	3736	5255
13.0	900	2032	4113	6145
6.5	900	1576	4088	5663
$LSD_{0.05}$		489	NS	1082
CV(%)		17	13	11

Table 8. Effect of phosphorus and lime application on nitrogen accumulation by millet grown in an oxic Haplustalf soil on the Cinzana Research Station , Mali in 1998 season.

APPLIED		N CONCENTRATION		N ACCUMULATION		
P	**LIME**	**GRAIN**	**STOVER**	**GRAIN**	**STOVER**	**SUM**
kg/ha		--- g N/kg dry weight ---		--------------- kg N/ha -----------------		
0	0	13.8	4.0	17.1	12.9	30.0
0	1810	13.4	3.3	21.2	12.3	33.4
6.5	1810	14.0	3.1	22.1	12.2	34.3
13.0	1810	12.9	4.1	27.0	17.7	44.7
13.0	0	13.0	3.7	19.8	14.0	33.8
13.0	900	13.5	3.6	27.4	15.0	42.4
6.5	900	13.0	3.9	20.5	16.2	36.7
$LSD_{0.10}$		NS	NS	8.0	NS	11.0
CV(%)		6	23	20	30	17

List of Contacts:
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