EFFECT OF MANURE AND P-SOURCE FERTILIZER ON THE OPTIMIZATION OF SOIL WATER AND NUTRIENT USE FOR THE MAIN CROPPING SYSTEM IN SENEGAL PEANUT BASIN

M.SENE, M.DIACK, and A. N. BADIANE

ISRA, SENEGAL

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INTRODUCTION

In the Senegal peanut basin, fallow practices have almost disappeared fi-om the farmers land use system. This situation is strongly related to the introduction of peanut as a cash crop, but also results fi-om an increased demand for food crops by an increasing population. The high pressure on the naturally fragile soils combined with the drought problem observed during the last 30 years is detrimental to the annual and perennial vegetation cover. Therefore, through soil organic matter loss and acidification due to continuous cropping and/or grazing, the food production system has lost its resilience. In most farmer's field situations, the degradation of soil water characteristics favors an important deep water percolation beyond the rooting depth, even under moderate rainfall conditions. This also increases nutrient leaching risks. Manure applications and plowing are very efficient in reducing the water and nutrients loss through deep percolation by promoting a rapid crop root growth (Cissé, 1986).

Many studies have confirmed the efficiency of natural rock phosphate (RP) amendment at an appplication rate of 400 to 500 kg/ha every 4 to 5 years to correct soil P defiencies. (sources). On soisl with low pH, the agronomic efficiency of the rock phosphate ranges from 82 to 91 % compared with the triple super phosphate (Bationo et al, 1990). This value depends on the chemical characteristics of the rock phosphate mines for which comparison results of the study are available (Ndiaye, 1978 ; Cissé, 1980).

However, for phosphogypsum (PG) or the combination of RP and PG now being used in Senegal in the national 4-year program, there is little information in terms of agronomic value or soil P and Ca amendment efficiency. The on-going experimentation comparing those two minera1 compound is set to focus on that aspect. Assuming a positive effect of the combination of RP and PG, the objective of this study is to analyse for the main cropping systems the efficiency of appplying combined P source material and manure to a degraded soil to optimize water and nutrient plant uptake in order to attain a sustainable crop production increase.

MATERIALS AND METHODS

Experimental sites

The sites are selected according to the existing main cropping systems.Within the Peanut Basin, the improvement of food security can be achieved in three cropping systems. In the northern part of this agroecological zone, peanut followed by millet is the predominant if not the unique crop rotation, whereas in the southem part, peanut followed by corn is a common practice. In the low lands of the latter zone, continuous rice is practiced.

One site for long terme experiment is selected in each of these representive çrop systems : one site for peanut/millet rotation at Ouadior (Gossas Department) in the north, two sites for peanut/corn rotation in Nioro area (one at the ISRA Reseach Station and one on farm field near the station), and one site for continuous rice in the Koutango valley (west part of the Nioro Department).

All the selected sites under the upland conditions are çontinously cropped fields with degra ded soil fertility status, as illustrated by Nioro soil analyses data **(table 1).**

'Table 1 : Soil pysical and chemical characteristics (0- 10 cm). Nioro

PH KCl	A+L %	S %	C total %	C/N %	Ca meq/100g	T	S/T *100	P total %0	POlsen (ppm)
4,9	7,9	92,2	2,5	9,2	0,6	1,6	64,5	0,2	28,5

Treaments

Five teatments compared are shown in **table 2.**

For cropping systems where com or rice are involved, plowing is performed when implementing the treament, including the control. In fact, these two crops require deep tillage in order to express their potential. For the peanut/millet system, only a shallow hoeing is applied to prevent fertilizer loss from wind blow.

Fii 3a: CHANGE **IN SOIL** WATER CONTENT IN THE **PROFILE**

TREATMENT1: CONTROL

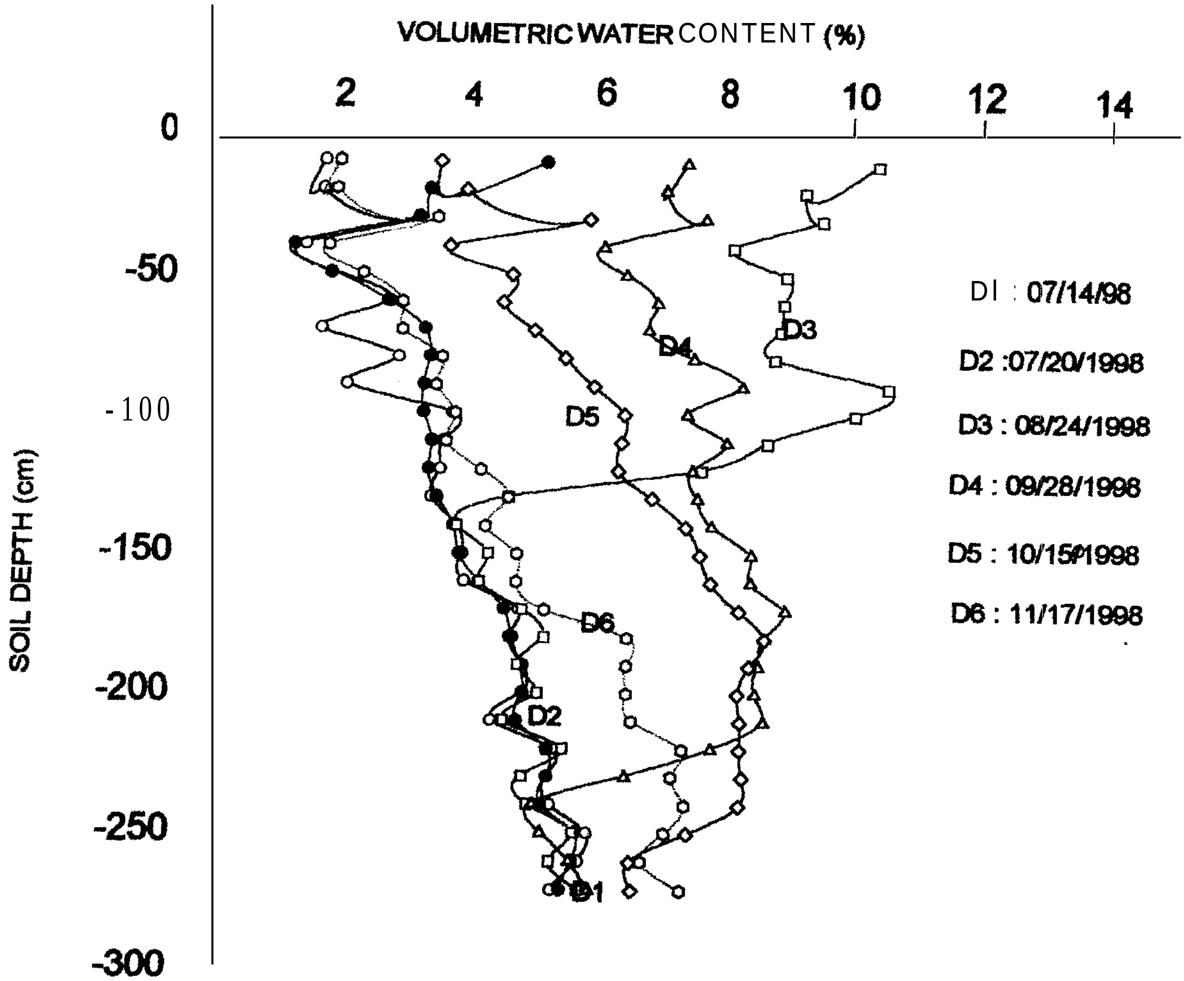


Fig. 3b : CHANGE IN **SOIL** WATER CONTENT IN THE PROFILE

TREATMENT2: MANURE

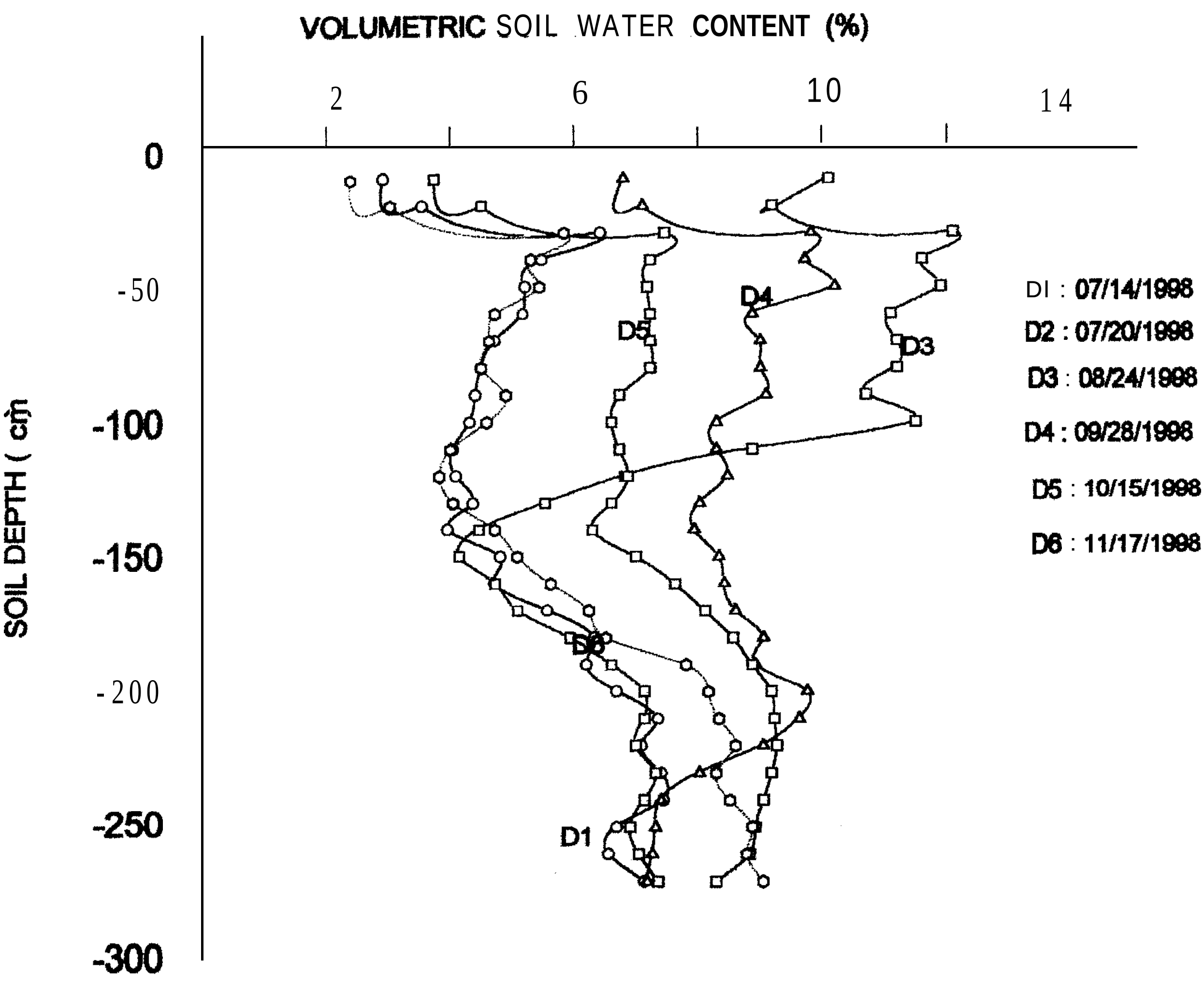


Table 2 : Treatment description in the different cropping systems

	Treatments				
Crop rotation	T1	T2	T3	T4	T5
Millet/peanut	N K	N P K	O.M.	RP + PG -	O.M. + RP-PG
Corn/peanut	P + N K	P + N P K	P + O.M.	P +RP + PG	P + O.M. + RP-PG
Continuous rice	P + N K	P + N P K	P + O.M.	P +RP + PG	P + O.M. + RP-PG

N and K for T1, and N, P and K for T2 are applied annually as urea , ammonium phosphate or KCI accordingly, the recommended rates are applied for the different crops.

T3 consists of manure application at the rate of 5 tons/ha every two years for the 2 first çropping systems, and at 3 tons/ha for the continuos rice system, whereas T4 refers to the application at the rate of 700 kg/ha every four years of RP and PG mix. Last, T5 is the combination of T3 and T4.

For all treaments from T3 to T5, N and K have been added on an annual basis prior to sowing. :

The experiment installed at Nioro station in 1997 does not include the T2 treatment, therefore only four treatments are compared.

The experimental design is a randomized complete bloc design with five treatments repeated fôur times.

The varieties used for the different crops are as follows :

a) for peanut : variety 55-437 at Ouadiour for short cycle duration (maturity at 90 days after sowing ; variety 73-33 at Nioro sites for 105 DAS or medium cycle ;

b) for com : var. Synthetic C (90 DAS)

c) for rice : upland rice variety DJ-684D (maturity at about 90 DAS). Besides this rice variety, the farmers was provided with two other salt tolerant varieties (Rock 5, and Var-1). The agronomic behavior of those varieties cultivated according the farmers practices in the bottom of the valley in submerged conditions have also been evaluated for general assessment of the Koutango lowlands with respect to rice production. In the farmer tice field, six microplots were randomly harvested for yield determinations.

Measurements and monitoring

Sites çharacterization

Soil samples have been collected for the characterization of the sites : Ouadiour, on-farm site at Nioro, and Koutango. For the on-station experiment at Nioro installed in 1997, site chararacterisation data done in 1995 (Agetip, 1995) are used. Another soil sampling was made after the corn harvest in december 1997. All the experimental plots have been sampled at the following depths (O-10, 10-20 and 20-40 cm). Some laboratory analysis data now available are presented in this report.

Soil water balance

This monitoring is done for plant water uptake but also for the pur-pose of nutrient balance. Soil water content in the soil profile is measured once a week at Nioro station site, and once every ten days elsewhere. Three methods are used : neutron probe, and TDR probe at Nioro station site, and the auger method elsewhere. Access tubes for neutron probe readings are installed at the depth of 265 cm ; i.e. deeper than the maximum crop root depths. As for the TDR method, the probe installation depth is limited by the probe length provided (120 cm). Concerning the soil water content measurement method using the auger, the depth of augering is limited by the wetting front as it avances in the profile during the rainy season. Tensionics are used to determine the soil water suction at the depth supposed to be the maximum rooting depth which is about 150 cm in sandy soils for peanut (Chopart, 1980). The longest tensionics available are 100 cm long, This explains the actual field installation depth in all experimental plots : 100 cm for plots having an installed acces tube, and 85 cm for the other plots. Daily tensionic: readings started in 1998, but late (on september 23 until november 1 1) due to equipment availabilty.

The water balance monitoring is not conducted for the on-farm experiment at Diamaguene site (near Nioro Research Station).

The soil water balance equation stated below allows the determination of the soil plant evapotranspiration for specified time increment durant the cropping season.

$R - D - r \pm \Delta S = ETR$

R = rainfall, D = drainage, r = runoff, AS = variation of stock, and ETR = evapotranspiration. All these components are in mm of water.

For drainage estimation, the Darcy law will be used. Soil hydraulic: conductivity is calculated using existing soil water characteristic studies for Nioro site (Cissé etal, 1990).

- classe A ; A + L = 20 % $K(\theta) = 7.54*10^{9}*\theta^{13.270}$
- classe B ; A + L = 21,5 % $K(8) = 2.31*10^{10}*\theta^{14.55}$
- classe A ; A + L = 20 % $K(\theta) = 6.29*10^{10}*\theta^{15.708}$

where A + L = clay + silt content ; K = hydraulic conductivity ; θ = volumetric water content. Darcy's Law equation will be used to determine the water drainage.

Nutrient balance

This is closely linked to soil water balance in general, and to soil water stock and drainage components in particular. It requires the use of the tensionics to sample soil solution at specified depths. Weekly soil solution samples have heen taken, starting late september. The nutrients of interest analysed are nitrates, ammonium, and Ca. The results are not yet available.

The nutrients lost through drainage, as part of the nutrient balance components. will be calculated by multiplying the water drainge and the ehemical concentration of the different elements analyzed.

Soil samples with deph at the biginning and at the end of each cropping season plant samples at harvest will be collected for analysis. This will allow the determination of nutrient dynimics in root zone and plant nutrient uptake.

Plant sampling

Plant samples were collected at flowering/pegging stage, around 60 days after sowing for foliar diagnosis. The sampling from each plot occurred after noticeable leaf chlorosis was observed on few treatment plots. Analysis of the plant samples is done for the following elements : N, P, K, P, Ca The plant analysis results are presented.

Field operations

The multi-location experiment started in 1997 on two sites ; i.e. Koutango (continuous rice) and Nioro (peanut/corn rotation at research station). The other sites were implemented in 1998. The cropping operations are presented (table 3).

Table 3 : Field operation scheduling in the three selected sites.

	Nioro		Koutango		Ouadiour
Operation	Corn (1997)	Peanut (1998)	Rice (1997)	Rice (1998)	Peanut (1998)
RP, PG or Lime application	06/30		07/19	08/10	07/23
Plowing	06/30	06/23	07/22	08/10	-
Sowing	08/05	07/20	07/24	08/21	08/5
N-K application		07/27		08/21	08/05
Thinning	08/05	-	07/31	09/17	-
Pre-emergence weeding	-				08/06
1st weeding	08/22	07/27	08/19	09/15	08/15
1st urea pplication	09/05	-	08/19	09/17	-
2nd urea application	09/20	-	09/14	10/02	-
2nd weeding	09/10	08/22	09/19	10/01	09/05
Redding	09/10				
Harvest	11/3	11/5	11/15	10/26	11/5

Rainfall input

Rainfall patterns are different for the 2 years (1997 and 1998) in figure 1.

Fig. Nioro **Fig.**1a: Cumulative Rainfali by **Decade** - 1997 **and** 1998

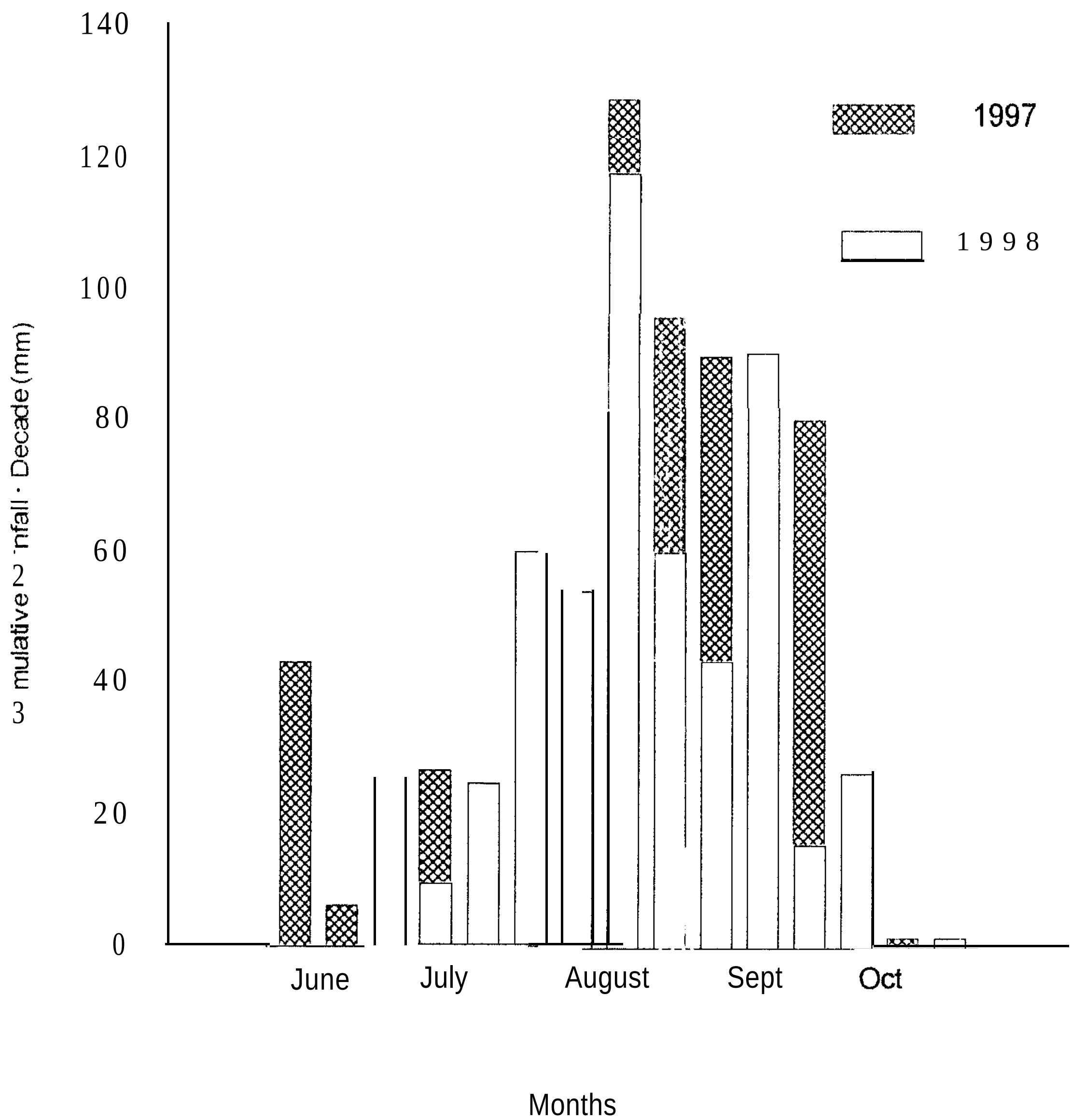


Fig.1b: Koutango Cumulative Rainfall per Decade - 1998

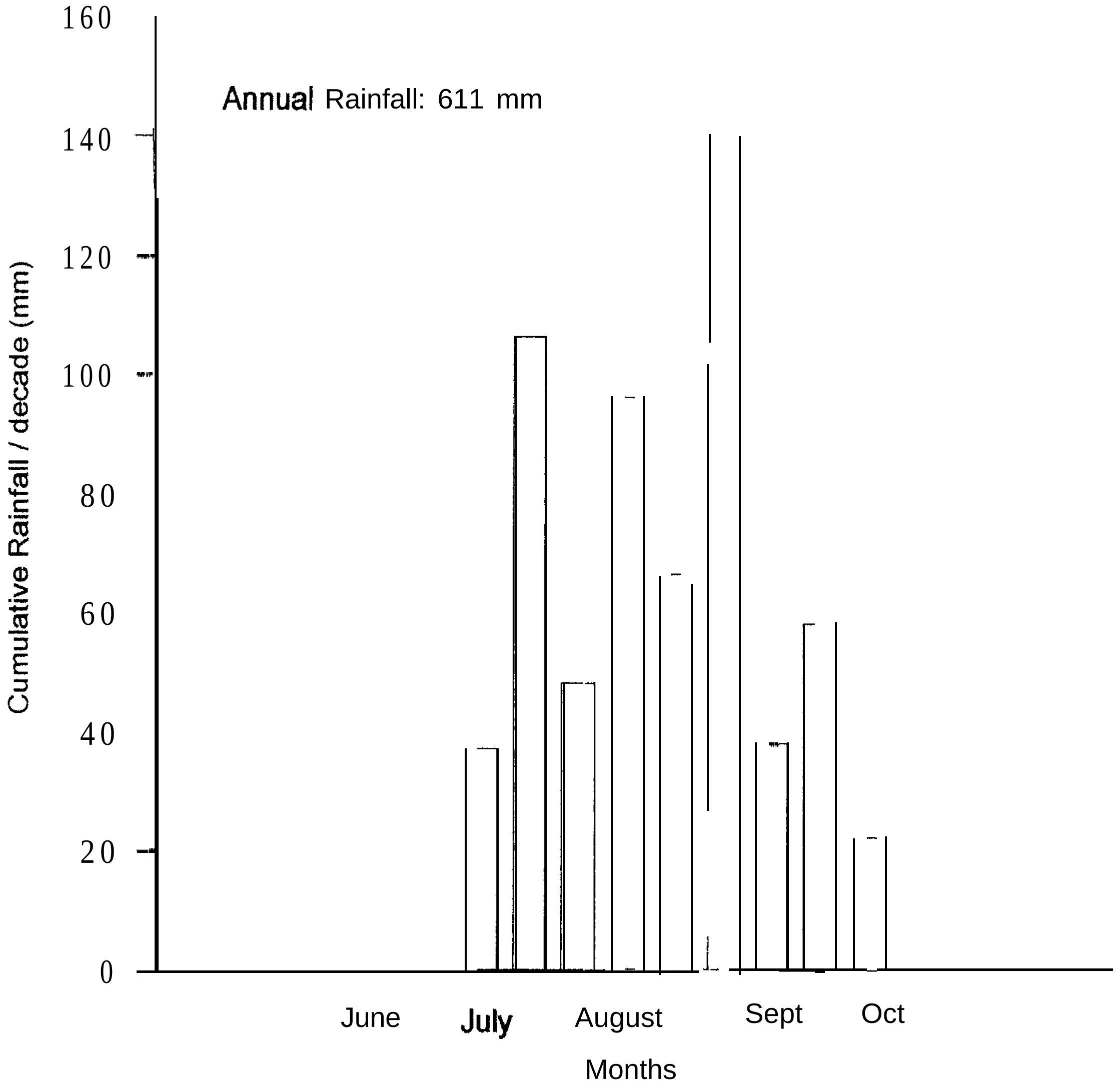
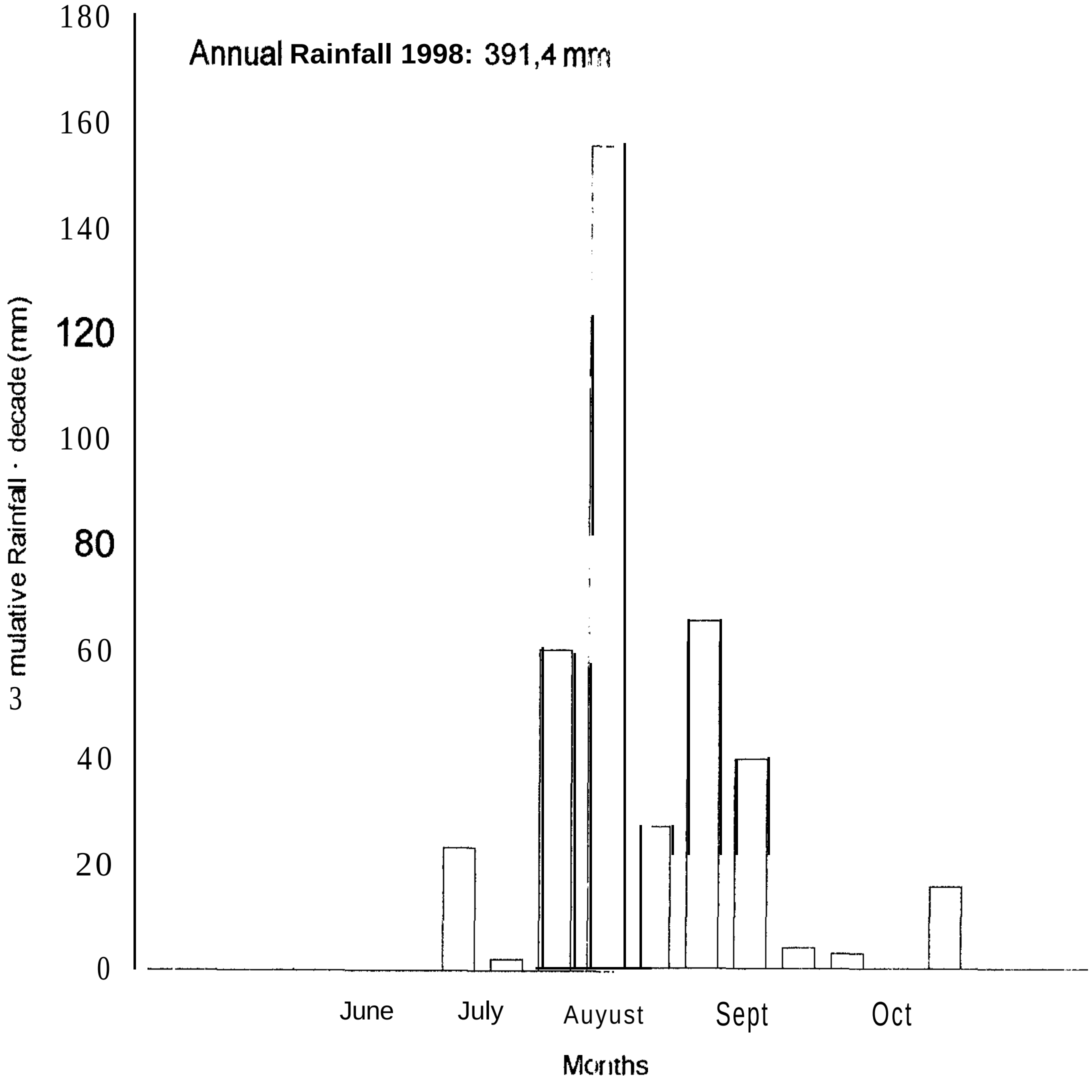


Fig. 1 c : Ouadiour Curnulative Rainfall - 1998



In fact, we have experienced one early rainy season in 1997 as opposed to a late rainy seany in 1998. In Nioro, the total annual rainfall is about the same for the 2 cropping seasons (580 mm). However, While the rainy season started early june 1997, the first important rain was recorded late July 1998. Although characterized by a rather short rainy season, the 1998 cropping season has a much better rainfall distribution. A long drought period (over 30 days) occurred early during the 1997 cropping season, causing a severe plant water stress, while in 1998 there were no major water stress problem, except at the crop maturity phase.

In Koutango unlike in Nioro or Ouadiour, heavy storms were recorded (160 mm on august 23 1997, and 100 mm on sepember 1998). Eventhough the soil vegetation cover at that time was well established, a important part of the water from this rainfall event is lost through runoff ; the soil profile being near saturation at this time of the rainy season. This positive aspect of this is the important input water to refill the Koutango river valley.

Data interpretation

This concerns the yield data, and the nutrients and water data. For most data, ANOVA methods will be implemented to compare treatement effects, whenever it is possible. Otherwise, comparison of mean will be used

Most of the experiments have started in 1998. Therefore, only partial data are available.

RESULTS AND DISCUSSION

a) On-Station experiment at Nioro

The yield components data (corn in 1997, and peanut in 1998) are presented in table 4 For corn, the ANOVA indicates no significant effect on grain yield or stalk, despite the difference of mean between the control and the other treatments. This is largely do to important variability within treatments. The corn grain yields obtained are low but higher than those obtained for phosphogypsum efficiency study (also presented in this workshop). It is assumed that the manure application the key factor to that difference. The soils samples collected from all plots down to the depth of 40 cm indicates an enrichment of the nutrient content (table 5), but also a downward movement of elements such as Ca (figure 2)

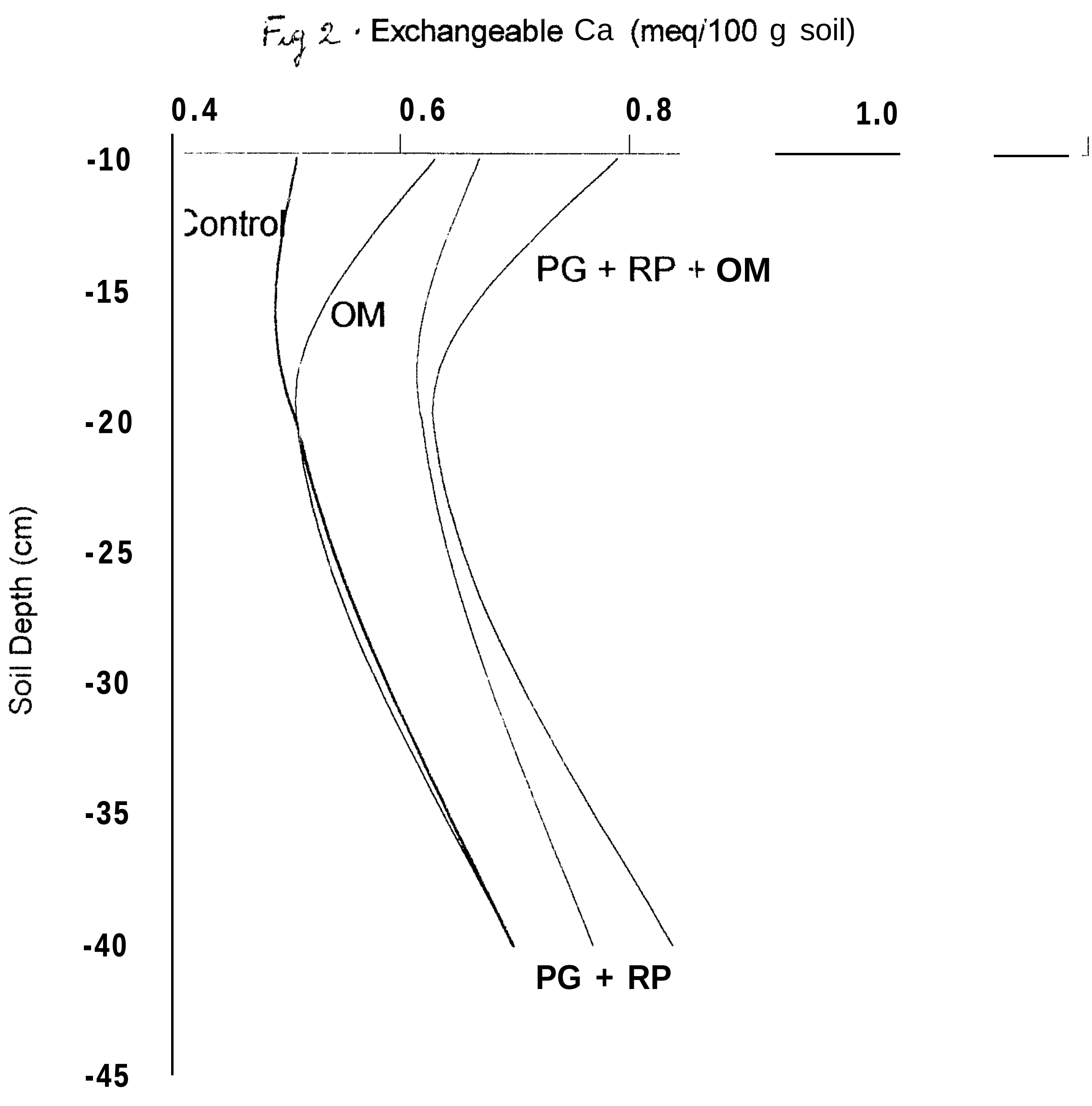


Figure 2. Ca dynamics along the soil profile - Corn 1997

Table 5 : Soil chemical analysis results after harvest in 1997. Nioro

Samples	Soil depth cm	pHwater	pHKcl	C a	Mg meq/100	S	T-	V %
T1 control	0-10	5,0	4,4	0,5	0,1	0,7	0,9	73,3
	10-20	5,2	4,3	0,5	0,1	0,7	0,9	76,5
	20-30	5,0	4,2	0,7	0,3	1,0	1,3	78,3
T2	0-10	5,2	4,6	0,7	0,1	0,8	0,8	98,0
	10-20	4,9	4,3	0,6	0,1	0,8	0,8	84,5
	20-40	4,9	4,2	0,8	0,3	1,0	1,2	82,7
	0-10	5,7	5,0	0,6	0,3	1,0	1,1	93,7
	10-20	5,3	4,3	0,5	0,2	0,7	0,9	76,5
	20-30	5,0	4,2	0,7	0,3	1,0	1,3	67,0
T4	0-10	5,3	4,9	0,8	0,2	1,1	1,2	84,3
	10-20	5,1	4,5	0,6	0,2	0,9	1,0	74,0
	20-30	5,0	4,3	0,8	0,2	1,2	1,6	73,3

For peanut in 1998, the plant population was close to the optimum in all plots. The overall mean yields are good compared to the average yield observed this year. However, no significant treatment effect for any yield component was obtained through the ANOVA. Around the middle of the rainy season, plant chlorosis were observed. Plant samples collected on each plot were analysed. The foliar diagnosis results (data not presented) show no significant difference between treatments.

Table : yield components at Nioro Station in 1997 and 1998

	Corn 1997				Peanut 1998		
Treatment	Stand	Stalk	Grain	Plant population	pod + hay	Hay	Pod
T1	16800	1800	712	83330	4000	2575	1420
T2	33230	3030	1740	82240	3750	2120	1640
T3	34690	3460	1820	91980	4590	2780	1810
'1-4	36420	3140	1880	90620	4480	2540	1940
Mean	30290	2860	1540	87040	4210	2500	1700
Sign. Level	N S	NS	NS	NS	NS	NS	NS
C V (%)	3 2	35	45	14.8	13.4	18.3	9.0

From the soil water monitoring done during 1998 growing season, changes in water content in the profile are shown (figure 3). Two major results can be drawn fi-om the these figures.
First of all, regardless of the treatment, the water content values are well below the water saturation values for this type of soil (Cissé, 1990 ; Sène, 1995). This could mean that water infiltrated in the soil is being used as long as the rains are falling.
Secondly, the wetting front has gone deep in the soil profile (below 2 na), so that water drainage has occurred. Soil water balance requit-es then an estimation of the drained water.

b) On-farm experiments

On-farm experiment in the corn/peanut cropping system Near Nioro Station

Yields components are shown in table 6. The plant population lower than that mentioned above for the on-station experiment is common in farm cropping situation. The ANOVA performed shows no significant treatment effects on peanut yield components.

Table 6: Peanut yield for on-farm experiment near Nioro. 1998

Treatment	Plant population	pod + hay	hay	pod
T1	70620	2430	1380	1050
T2	74270	2290	1260	1040
T3	61930	1830	1080	750
T4	71405	2430	1340	1090
T5	71400	2260	1310	950
Mean	69930	2240	1270	974
Sign. Level	NS	NS	NS	NS
CV (%)	8.8	19.3	20.3	22.3

Fig 3a: CHANGE IN SOIL WATER CONTENT !N THE PROFILE

TREATMENTI : CONTROL

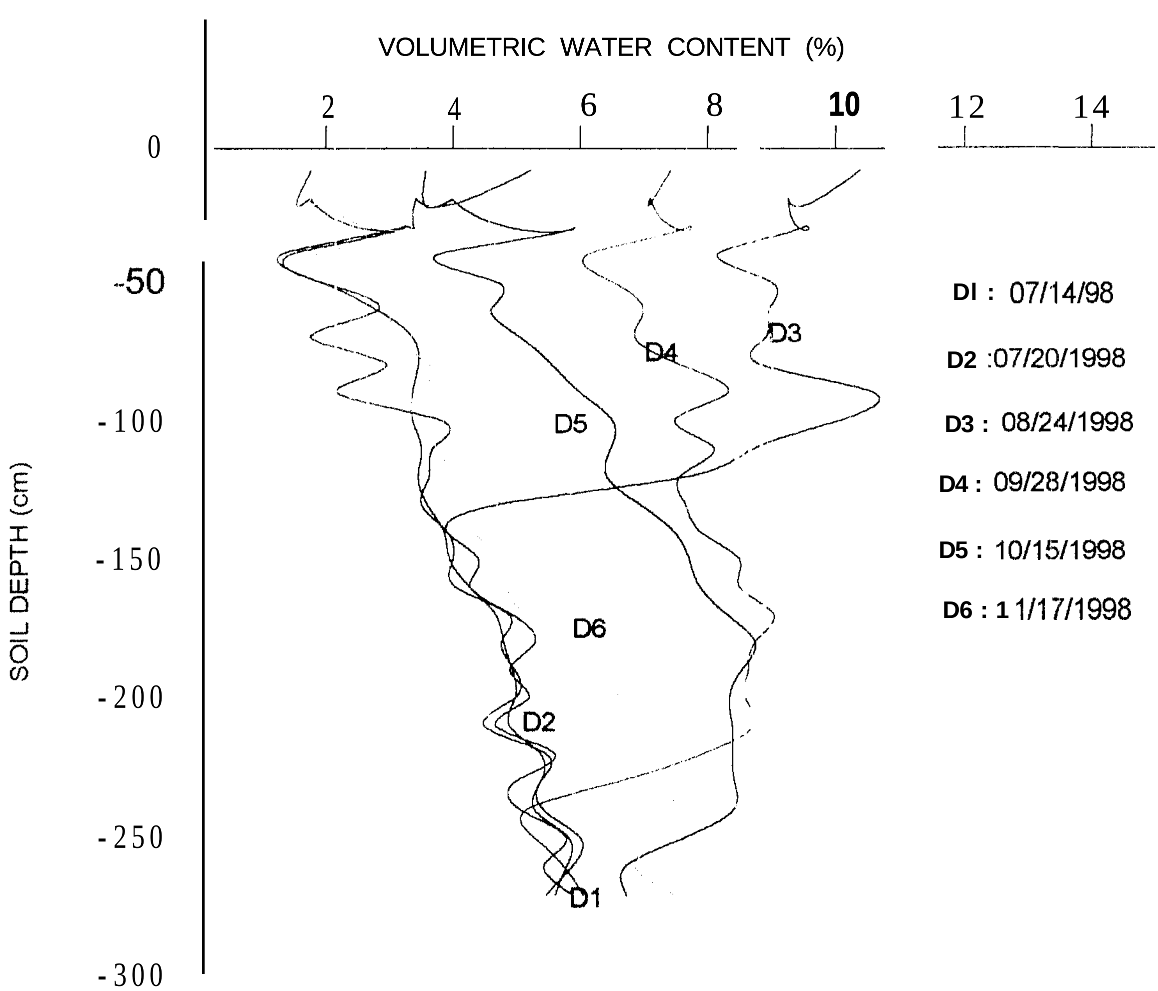
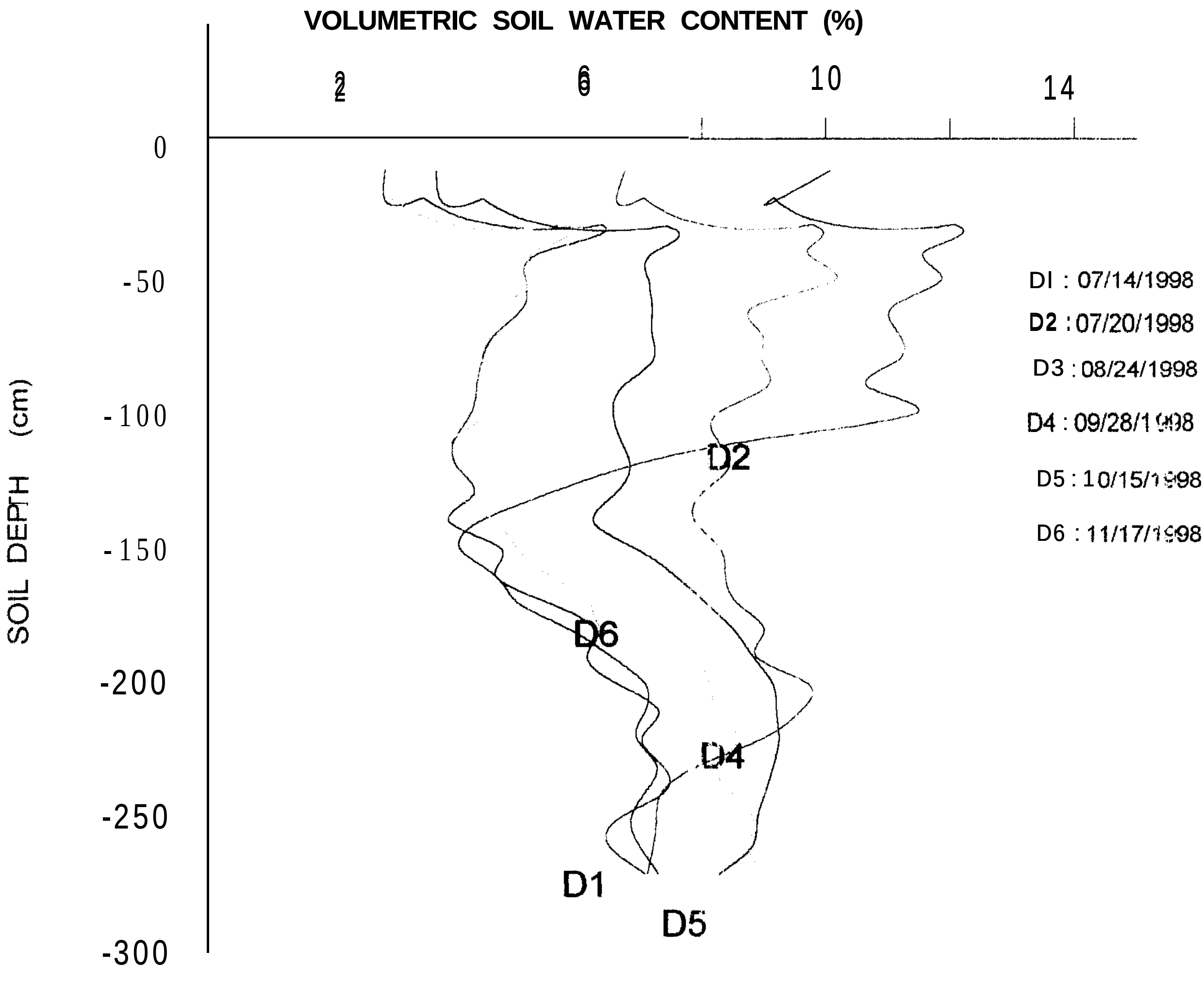


Fig.3 b : CHANGE IN SOIL WATER CONTENT IN THE PROFILE

TREATMENT2: MANURE



No ma.jor water stress has occurred during the rainy season, due to the good rainfall distribution. In this degraded soil fertility situation of the continuously cropped field (Diack etal, 1998), the lack of direct effect of P amendment application on peanut could indicate that nutrients added are not readily available for crop. As for the manure application, the lack of direct effect confirms research findings indicating that peanut respond better to residual effect.

On-farm exueriment at Ouadiour for the peanut/millet cropping system

The effect of PG and RP mix and/or manure on yields for the peanut/millet cropping system is shown (table 7). Despite the fairly good plant population obtained, the yield components namely hay and peg yields are low. There is no significant effect of the treatments. From the water balance measurements (data not shown), a very deep water percolation is observed. This indicates a low water use efficiency which also occurs in the sandy soil.

Table 7: Peanut yield for on-farm experiment at Ouadiour.

Treatment	Plant population	pod + hay	hay	pod
T1	87590	1130	740	370
T2	88420	1240	800	470
T3	86080	1080	710	390
T4	94080	1140	750	390
T5	87690	1130	740	390
Mean	88990	1140	750	380
Sign. Level	NS	NS	NS	NS
CV (%)	5.7	8,4	9,1	11,2

On-farm experiment at Koutango for the continuous rice cropping system in the valley bottom.

The yield components obtained using an upland rice variety are shown in table 8. The ANOVA shows no significant effect of the treatments. The paddy yields values with a mean of about 5 tons/ha show a real rice production potential in the valley.

The soil water profile monitoring indicates a fairly good water availability to crop, (data not shown). The water table during the cropping season has remained shallow (< l m) (data not shown). Therefore, chances are that the groundwater through capillary rise participates in plant water uptake when a drought period occurs.

Table 8: Effect of treatments on Rice Yield (var. DJ-684D) at Koutango. 1998

Treatment	Plant population	Paddy	Stalk	Panicle	WT of 100 gr
Fi-	325000	4463	4989	5264	2.32
Γ2	316666	4692	5320	5254	2.35
l-3	350625	4102	4267	4616	2.35
Γ4	304375	4440	5083	4983	2.4
Γ5	324791	4006	4286	4481	2.3
Wean	324292	4381	4789	4920	2.34
Sign. Level	NS	NS	NS	NS	NS
IV (%)	12.5	18.1	14,9	18.1	4.8

CONCLUSION

The long term experiments installed in three different cropping systems in the peanut basin address the sustainabilty of the food production increase, by means of the enhancement of soil fertility. It is assumed that the key factor there is the optimization of water and nutrient use. The results obtained fi-om the first year of implementation must the considered as the basis for a necessary continuation of the work underway. For the next cropping season, focus will be put on the determination of the diffèrent components of water and nutrient balance. Soil water percolation (drainage) for upland cropping systems and upward water flow in the rice root zone in the lowland system must be determined as accurately as possible. This poses the problem of required equipment. The additional needs in that regard concern the tensiometers for soil water pressure monitoring.