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USING THE N-15 METHOD TO DETERMINE N-SOIL, N-GREEN MANURE, AND N-UREA AVAILABILITY AFTER SIX SEASONS IN AN ALLEY CROPPING SYSTEM

Elsje L. Sisworo, Haryanto and Ania Citraresmini

Center for the Application of Isotopes and Radiation Technology, BATAN

ABSTRACT

USING THE N-15 METHOD TO DETERMINE N-SOIL, N-GREEN MANURE, AND N-UREA AVAILABILITY AFTER SIX SEASONS IN AN ALLEY CROPPING SYSTEM. Nitrogen (N) is the most important nutrient for crop growth and production. This study was conducted to determine whether in each of six seasons and after these seasons the N-soil, N-green manure, N-green manure + urea, and N-urea is still available for crops. Upland rice and corn were planted successively for six seasons. In each season upland rice and corn were planted and applied with N-fertilizers at rate of: control (0N), N1 (100% green manure), N2 (50% green manure + 50% urea), N3 (100% urea). N-15 labelled urea was added at each season to determine the A-value of the crops.

In each seasons it was shown that crops used N-soil as well as N-fertilizer. With the increase of the availability of N-fertilizers the use of N-soil decrease and so could preserve N-soil. With preservation of N-soil it could be assumed that soil quality has increased. The N-15 method could be used to determine the availability at each fertilizer rate's in each season and at the end of the sixth season.

INTRODUCTION

According to SANCHEZ [1] arable rainfed upland soils in the humid tropics is dominated by acid soils of low inherent fertility known as Oxisols and Ultisols. In Indonesia, Ultisols, which are classified as Red Yellow Podzolic soils are estimated to cover 47.5 million ha or 24.9 percent of the total land area [2]. The major part of this available rainfed upland soils are characterized as acid soils with shallow crop root development, relatively coarse texture, low CEC (Cation Exchange Capacity), low organic matter (OM) content, and having 2000 to 3000 mm of annual rainfall [3]. MUELLER *et al* [4] and Vander KRUIJS *et al* [5] based on their measurement suggested that 150 to 25 kg ha^{-1} of soil nitrogen (kg N ha^{-1}) may be lost each year from freshly cultivated soil in the acid humid tropic soils.

Looking at their data [4 and 5] it could be concluded that this could lead to rapidly decrease of soil fertility especially concerning nitrogen. This could easily happen to acid rainfed soils in Indonesia. In more general terms it could be expressed that this large lost of N will decrease the soil quality.

HAVLIN *et al* [in 6] stated that many interrelated factors in a soil influence its productivity or potential capacity. These properties represent soil quality collectively. Although all these properties are important, but soil organic matter content is the most critical because of its influence in many biological, chemical and physical on soil productivity.

One of the forms of soil deterioration which generally occur in Indonesia is the decrease of soil organic matter (SOM) resulting in inability of soil to aid crop productivity.

STEVENSON [7] forwarded that plant cuttings, light OM, microorganism OM, water-soluble OM, and humus or stable OM are all included SOM. Plant cuttings could be classified as light OM.

Therefore, alley cropping or hedgerow inter-cropping system could provide OM and nutrient by applying the crop cuttings to the soil.

Besides that the alley crop which root system could develop deeper than the main crop root system, could catch the nutrient lost from the main crop and recycle them by acting as a safety net [3]. Returning OM to mineral soil has several important advantage meanings related closely with fundamental items of sustainable agriculture. These advantages are increase of soil CEC, forming of stable soil aggregates, supplying energy for soil microorganism, increase water retention needed for crop growth [7 and 8].

Our study was conducted to provide information of the influence of alley crop cuttings to improve soil quality using the ^{15}N method expressed as N-availability of soil, alley crop cuttings, and chemical fertilizers during and after six seasons.

MATERIALS AND METHODS

The details of the three years (6 seasons) experiment is described below.

Alley crop

The alley crop used in this experiment was *Gliricidia sepium*, which has an N_2-fixing capability about 57% [9]. The alley crop was two years old when the experiment started. At that time the alley crop had good growth, having a height of 2 to 2.5 m with normal branches and plant distance in the row 40 cm and between rows 10 m. No fertilizer were applied to the alley crop which had been grown from cuttings.

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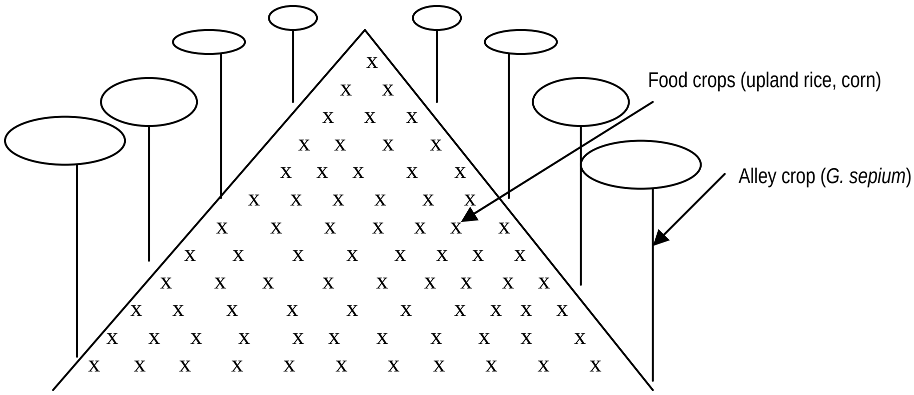

Figure 1. Diagram of the alley crop system done in this experiment

Food crops

Food crops used in this experiment was upland rice var. Danau Tempe (2 – 3 seeds / hole) and corn var. Arjuna (2 – 3 seeds / hole). The food crops were planted successively for six seasons (3 years).

The planting of each crop in the 3 years is as follows.

1st year		2nd year		3rd year	
Start of rainy season	End of rainy season	Start of rainy season	End of rainy season	Start of rainy season	End of rainy season
S1 : 1st season	S2 : 2nd season	S3 : 3rd season	S4 : 4rd season	S5 : 5th season	S6 : 6th season
Upland rice	Corn	Upland rice	Corn	Upland rice	Corn

The food crops were harvested at crop maturity, for upland rice it was around four months after planting (AP) and for corn it was three months AP.

The food crops were planted in yield plots of 8m x 10m. In each yield plot an isotope plot of 2m x 1.6m was used to be applied by ^{15}N-fertilizer.

Treatments applied

The treatment applied were,

Code of Treatments	N-urea (kg N/ha)	N-alley crop fresh cuttings (t/ha)
N0 (control)	0	0
N1	0	15 (100%) equal to 56.4 kg N/ha
N2	33.75 (50%)	7.5 (50%) equal to 28.2 kg N/ha
N3	67.50 (100%)	0

Notes : 33.75 and 67.50 kg N/ha is equal to 75 and 150 kg urea/ha respectively.

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Urea was applied in two parts, 1/3 at planting and the rest of urea was applied 1 month after planting for both food crops.

^{15}N-labelled ammonium sulphate (AS) with a 10.12% ^{15}N abundance was applied at a rate of 2.5 g AS/isotope plot at planting and 5 g AS/pot at the second application. The application of ^{15}N was done simultaneously as the urea application in the yields plots.

The soil of the land used in this experiment is Red Yellow Podzolic which physical and chemical properties is presented in Table 1.

Table 1. Chemical and physical properties of soil at the experiment location, Batumarta, South Sumatera

pH (H_2O)	5.20
(KCl)	4.20
P_2O_5 (Bray) (ppm)	15.20
N (%)	0.15
C (%)	1.92
C/N	12.8
CEC (me/100g)	
K	0.30
Ca	1.70
Mg	1.00
Na	0.10
Sand (%)	19.17
Silt (%)	43.15
Clay (%)	37.68

Experimental design

The experimental design used is the Randomized Complete Block Design. Each treatment was replicated four times.

The data was analysis using an ANOVA procedure.

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RESULTS AND DISCUSSION

Dry weight and total-N uptake

Perusal of the data presented in Table 2, showed that, application of nitrogen (N) either in the form of green manure 100% (N1), green manure 50% + urea 50% (N2), and urea 100% (N3) showed a steady increase in any weight above the control (N0).

Table 2. Dry weight and total N-uptake (N-to) of plants as influeced by application of green manure, green manure + urea, and urea in six successive seasons.

	Plant dry weight					N-total uptake				
	N0	N1	N2	N3	Ro-S	N0	N1	N2	N3	Ro-S
	t /ha					kg N/ha				
S1	1,522	1,850	2,473	3,968	2,458	11,075	14,053	19,598	32,238	19,241
S2	2,835	3,757	8,989	11,670	6,813	24,000	30,680	76,640	97,523	57,211
S3	6,307	8,623	9,714	9,766	8,602	65,400	87,743	99,848	100,505	88,374
S4	2,089	2,975	2,769	3,100	2,733	20,453	30,958	30,595	31,633	28,409
S5	5,057	6,172	7,107	6,477	6,477	45,525	53,390	62,445	69,015	57,569
S6	1,160	1,598	3,115	4,824	2,674	11,560	18,958	42,018	57,193	32,432
Ro-N	3,162	4,163	5,694	6,477	-	29,652	39,297	55,190	64,684	-

	F-calculated	F-table 5%	F-table 1%	F-calculated	F-table 5%	F-table 1%
N	80,148**	2,74	4,07	63,147**	2,74	4,07
S	140,613**	2,35	3,29	111,146**	2,35	3,29
NxS	10,106**	1,81	2,31	6,162**	1,81	2,31
Repl	0,386ns	2,74	4,07	0,887ns	2,74	4,07
CV (%)	17.65			20.51		

Notes :

- All the data are a mean of 4 replicates
- N0, N1, N2, N3 : control (0N), 100% green manure, 50% green manure + 50% urea, 100% urea respectively
- S1, S2, S3, S4, S5, S6 : 1st season to 6th season
- S1, S3, S5 : plant – rice : grain + straw
  S2, S4, S6 : plant – corn : grain + stover
- ** = highly significant difference (P<0.01), * = significant difference (P<0.05)
  ns = not significant difference
  CV = Coefficient of Variance (%)
  All the notes are valid for the next tables.

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The increase of dry weight shown by the N application (N1, N2, N3) as presented in Table 2, showed that N is a main nutrient which is needed for plant growth, here expressed in dry weight. The season showed some contradiction between upland rice and corn. Upland rice showed an increase in dry weight since it first planting (S1) to S3 and S5, with its peak in S3. The dry weight for upland rice from the lowest to the highest is S1 < S5 < S3. While for corn the highest dry weight was reach in its first planting (S2) than decrease in S4 and S6, showing values from the largest to the lowest S2 > S4 > S6.

For upland rice and corn the increase in dry weight is apparently in line with the N applied for each season, as shown by data in Table 2 (interaction V x N). Here it is shown that for each season the highest dry weight was reach with the application of N3. Nevertheless the increase of N1 and N2 is also shown.

The increase of dry weight for upland rice showed that there must be N residues from the previous season which will increase the N availability besides the fresh application of N making better growth showing an increase of dry weight after the first planting season.

While for corn the highest dry weight was found in S2 after upland rice and showed a sharp decrease in S4 and S6. These findings in contradictive to the findings for upland rice. It could be that this is due to the seasons. As mentioned in Materials and Methods upland rice was planted at the beginning of the rainy season while at the end of the rainy season corn was planted.

For S2 apparently the rainy season was quite long, resulting in high dry weight of corn, while in S4 and S6 the rainy season must be shorter, which was not enough for optimum growth.

The total N-uptake showed data which are all in line with the dry weight. As well known the total N-uptake is a result of dry weight multiplied by percentage of total N (dry weight x %N-total). So all the high or low dry weight will result in low or high total N-uptake. This is due to the %N-total of grain and upland rice is steady around 1% and of its stover around 0.6 to 0.7%.

From all the data presented in Table 2 it could be forwarded that N has a significant influenced to increase the dry weight of rice and corn for each season.

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Percentage of N-15, N-soil and N-fertilizer

The percentage of N-15, N-soil and N-fertilizer as presented in Table 3 will be shortened to %N-15, %N-soil, %N-fertilizer will be %N-N1, %N-N2, %N-N3.

The most important data when using the N-15 technique, is the N-15 data itself and its interpretation. By using the N-15 data, the percentage of N-soil and N-fertilizer could be determined [9].

Looking at Table 3, it is shown that the percentage for the control (N0) where no N in either form of green manure or urea is applied, the %N-15 is the highest and then decrease from N1 towards N3 (N0 = 5.50% > N1 = 4.14% > N2 = 3.48% > N3 = 2.91%).

What do these data mean? It means that with the deminishing %N-15 is due to increase of N-available, in this case N-green manure (N1), N-green manure + urea (N2) and N-urea (N3). This showed that the N applied as green manure, green manure + urea and urea is made available for the food crops.

For the season regardless, which crop is planted, the highest %N-15 was found in S1 and decreased in S2, and from that point onward decrease drastically as shown by the data in Table 3 (S1 = 11.21% > S2 = 9.67% > S3 = 1.08% > S4 = 0.59% > S5 = 0.85% > S6 = 0.66%). This is assumed due to the availability of N-sources soil and especially fertilizers increase onward from S1 to S6 which should have diluted the N-15 up to small percentages.

It could be perusaled too, that for the successive season the N-15 will decrease with the application of fertilizer at the rate of N1, N2 or N3. This is assumed as stated previously due to the increase of N-available from the fertilizer at the advange of the seasons.

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Table 3. Percentage of N-15N, N-soil, N-fertilizer of plants as influenced by application of green manure, green manure + urea, urea, in six successive seasons

	$\%^{15}N$					%N-soil					%N-fertilizer [a]				
	N0	N1	N2	N3	Ro-S	N0	N1	N2	N3	Ro-S	N0	N1	N2	N3	Ro-S
S1	16.06	11.74	9.54	7.49	11.21	83.94	62.16	50.32	38.80	58.80		26.11	40.14	53.71	39.99
S2	12.17	9.69	8.72	8.08	9.67	87.83	61.64	59.74	55.41	66.15		28.70	31.55	36.52	32.25
S3	1.91	1.10	0.94	0.36	1.08	98.09	59.33	54.80	21.74	58.49		39.57	44.27	77.90	53.91
S4	0.81	0.64	0.48	0.41	0.59	99.19	74.16	57.52	49.35	70.05		25.21	42.01	50.25	39.15
S5	1.16	0.98	0.62	0.66	0.85	98.84	85.71	53.29	57.82	73.91		13.31	46.10	41.52	33.64
S6	0.90	0.70	0.56	0.49	0.66	99.11	76.76	60.97	53.30	72.53		22.55	38.47	46.22	35.74
Ro-N	5.50	4.14	3.48	2.91		94.50	69.96	56.10	46.07			25.91	40.42	51.02	

	F-calculated	F-table		F-calculated	F-table		F-calculated	F-table	
		5%	1%		5%	1%		5%	1%
N	800.856**	2.74	4.07	129.845**	2.74	4.07	33.480&&	2.74	4.07
S	59.525**	2.35	3.29	8.936**	2.35	3.29	6.489**	2.35	3.29
NxS	15.668**	1.81	2.31	2.920**	1.81	2.31	2.201*	1.81	2.31
rep.	0.844^{ns}	2.74	4.07	1.076^{ns}	2.74	4.07	1.089^{ns}	2.74	4.07
CV (%)	17.65			13.54			27.29		

[a] %N-fertilizer : N1 = 100% N-green manure, N2 = N-50% green manure + 50% urea, N3 = N-100% urea respectively

<u>Availability and uptake of N-soil and N-fertilizer</u>

As shown in Table 4, N-fertilizer expressed as N1, N2, N3, while without N addition is N0 (control). In Table 4 it is shown that N0, meaning N-soil available is much higher than N available of N1 and N2. But N3 gave the highest N-available. It is obvious with the amount of N applied by N1 and N2 is not high enough to provide more N-available compared to N3. While for the soil apparently the biomass gathered has build up quitte a high N in the soil so the N-soil available could reach large amounts.

For the seasons it is clearly shown by Table 4, that in the first seasons (S1 and S2) the N-available was not as high as the following seasons (S3 to S6). Apparently with the passing of seasons the N available has build up to large N-available. This could be assumed large N-available found in S3 to S6 could be due to building up of the residues of N-applied. This residues added to the below ground biomass which was contributed by the underground growth of the crops. The large N-availbale could also be considered as the increase of soil quality towards the better.

Another interesting data is for N0. Here it could be observed, that with the passing of the seasons the N-soil available (N0 x S) increased and reach large amounts of N. As mentioned before, this could be due to the build up of the under ground growth of the crops for six seasons although no N-fertilizer was added. This too could be considered as the improvement of soil quality.

Looking at the same Table, it is obvious whether no fertilizer (N0) or fertilizer applied would not influence the N-soil uptake by crops. This could mean that by application of fertilizer (N1, N2, N3) the N-soil could be preserve, and declining of N-soil which made the soil quality decrease could be prevented.

The N-soil uptake for each season is different for different crops. Upland rice after S1, that is at S3 and S5 showed much higher the N-soil uptake than that of corn, which data were derived from S4 and S6. It could be that the upland rice had developed better root systems compared to corn. This made the chance of the upland roots to have more contact with the soil particles compared to corn. This is one of the reason why the N-soil uptake by upland rice is higher than that of corn. While corn is assumed to have not so extensive root growth is related to the season where this crop was grown. As mentioned before in S4 and S6 corn was grown after upland rice, that means toward the end of the rainy season. The dry season started earlier than that in S2, causing the decrease of soil-water available, which could have restricted root growth and resulting in lower N-soil uptake compared to upland rice.

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Table 4. N-soil, N-green manure, N-green manure + urea, N-urea available and uptake of N-soil, N-green manure, N-green manure + urea, N-urea by plants.

	N-available from soil, green manure, green manure + urea, urea					N-soil uptake					N-green manure, green manure + urea, urea uptake			
	N0	N1	N2	N3	Ro-S	N0	N1	N2	N3	Ro-S	N1	N2	N3	Ro-S
	kg N/ha					kg N/ha					kg N/ha			
S1	24.535	9.207	20.417	34.189	22.087	9.292	8.754	9.825	12.391	10.066	3.647	7.909	17.450	9.669
S2	34.788	9.830	14.922	18.562	19.526	20.699	19.067	45.730	54.601	35.024	8.624	24.118	35.021	22.588
S3	256.835	166.345	241.409	1029.637	423.556	64.117	52.443	54.870	21.859	48.322	34.335	43.359	65.958	47.764
S4	578.481	163.698	392.868	567.103	425.537	20.284	22.938	23.519	15.703	19.141	7.820	12.810	15.797	12.142
S5	404.062	75.276	405.678	285.612	292.657	44.906	45.969	31.881	39.205	40.490	6.700	30.200	29.362	22.154
S6	521.453	155.851	327.784	460.100	366.297	11.457	14.549	26.536	31.049	20.898	4.277	15.240	25.863	15.127
Ro-N	303.359	96.701	233.846	399.200		28.459	27.287	31.080	29.135		10.944	22.272	31.512	
	F-calculated		F-table			F-calculated		F-table			F-calculated		F-table	
			5%	1%				5%	1%				5%	1%
N	50.706**		2.74	4.07		0.727 ns		2.74	4.07		23.768**		2.74	4.07
S	75.516**		2.35	3.29		40.828**		2.35	3.29		21.462**		2.35	3.29
NxS	162.627**		1.81	2.31		7.519**		1.81	2.31		1.153 ns		1.81	2.31
rep.	0.120 ns		2.74	4.07		0.296 ns		2.74	4.07		1.363 ns		2.74	4.07
CV (%)	33.9					31.49					48.02			

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CONCLUSION

The data obtained showed that nitrogen (N) whether applied in the form of alley crop cuttings (N1) , alley crop cuttings + urea (N2) or urea only (N3) has a significant influence to increase rice and corn growth for each season. For the successive seasons the %N-15 decreased with the application of fertilizers at the rate of N1, N2, N3. This is assumed caused by the dilution of N-15 applied by the fertilizers applied. Apparently the application of fertilizers could preserve the N-soil and this could be regarded as an increase of the soil quality.

The N-15 method was able to determine the availability of N-soil, N-N1, N-N2 and N-N3 after six seasons and by this it could show whether there is an increase or decrease in soil quality.

LITERATURE CITED

1. SANCHEZ, P.A. 1976. "Properties and management of soils in the tropics", John Wiley, N. York.
2. SANTOSO, D. 1988. Development of phosphorus fertilizers used in acid soils in Indonesia, *in* "Nutrient Management for Sustainable Crop Production in Asia (A.E. Johnston and Syers, J.K., eds) CAB International, Walingford, Oxon, UK.
3. Van NOORDWIJK, HAIRIAH, M.K., GURITNO, B., SUGITO, Y., and ISMUNANDAR, S. 1996. Biological management of soil fertility for sustainable agriculture in acid upland soils in Lampung. Agrivita 19, No. 4, 131 – 135.
4. MUELLER – HARVEY, I., JUO, A.S.R., and WILD, A. 1985. Soil organic, C, N, S and P after forest clearance in Negeria : mineralization rates and spatial availability. Journal of Soil Science 36, 585 – 591.
5. Van der KRUIJS, A.C.B.M., WONG, M.T.V., JUO, A.S.R., and WILD, A. 1988. Recovery of ^{15}N-labelled fertilizer in crops, drainage water, and soil using monolith lysimeters in South East Negeria. Journal of Soil Science 39, 483 – 492.
6. HAVLIN, J.L., BEATON, J.D., TISDALE, S.L., NELSON, W.L. 1999. "Soil Fertility and Fertilizers", 6th ed., Prentice Hall, Inc., Simon & Schuster, Upper Saddle River, New Jersey.
7. STEVENSON, F.J. 1994. "Humus Chemistry, Genesis, Composition, Reaction", 2nd ed., John Wiley and Sons, New York.

ISSN 1907-0322

8. MASUMOTO, S. 1999. Production of composts fitting to humid tropical soils as one of the sustainable agriculture technologies. Proc. Intl. Sem. Toward Sustainable Agriculture in Humid Tropics Facing 21st Century. Bandar Lampung, Indonesia, Sept. 22 – 28, 1-9.

9. IAEA. 1990. Use of Nuclear Techniques in Studies of Soil-Plant Relationships (ed. G. Hadarson) pp 223.