PERFORMANCE OF LOWLAND RICE-UPLAND RICE-VEGETABLE/COWPEA SEQUENCES AS INFLUENCED BY SOME SOIL PROPERTIES IN THE INLAND VALLEY

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ABSTRACT

Continual annual inflow of nutrients with the flooding water from adjacent uplands was considered to be the most important factor in maintaining high productivity of inland valleys (IVs). The potential of IVs to maintain high productivity was examined by growing three crops in sequence within a year without supplemental irrigation. Field experiments were conducted at the University of Agriculture Abeokuta, Nigeria in 2000-2003 to determine the influence of one-cropped, two-cropped and three-cropped sequences on some soil properties in the inland valley. Lowland rice (*Oryza sativa* L.)-upland rice-fallow, lowland rice-upland rice-cowpea (*Vigna unguiculata* (L.) Walp), lowland rice-upland rice-okra (*Abelmoschus esculentus L.*), lowland rice-upland rice-amaranth (*Amaranth cruentus*), and lowland rice-fallow-fallow sequences, which ran concurrently constituted a cropping cycle. The first, second, and third crops in all the cropping cycles were planted in May, October and January, respectively. The grain yield of lowland rice obtained from lowland rice-fallow-fallow sequence did not decline unlike the yield from two-cropped and three-cropped sequences as the cropping cycle advanced. The yield of upland rice and vegetable dropped significantly in the 2002/2003 cropping cycle as a result of the residual effect of the preceding 2000/2001 and 2001/2002 cropping cycles. The upland rice had negative residual effects on the succeeding okra but enhance the productivity of amaranth. The best crops combination of the three-cropped sequence was BW 311-9-upland rice-amaranth. The two-cropped and three-cropped sequences with or without legume do not seem to make any difference in terms of soil fertility maintenance. The annual inflow of nutrient could not match with the demand two-crop and three-crop sequences. Hence, higher rate of inorganic fertilizer is required for the two-crop and three-crop sequences after two cropping sequences.

Key words: Rice sequence, Soil properties, Inland valley

INTRODUCTION

The term 'inland valley' (IV) is used to refer to any small valley, which is not located on the coast. Seepage and runoff are the major hydrological processes in an inland valley (Oosterbaan *et al.*, 1987). Increased sustainable cultivation of IVs, which generally have more fertile soils and more available water than the adjacent uplands, promises to relieve the pressure on over exploited upland soils while adding significantly to food production in the developing nations, particularly in Africa (IITA, 1990). Continual annual inflow of nutrients with the flooding water from the adjacent uplands was considered to be the most important factor in maintaining the high productivity of IVs (Mitsch and Ewel, 1979). Inland valley in West Africa shows considerable potential for intensified and sustainable land use (Izac *et al.*, 1991).

Inland valley in West Africa occupied between 22-52 million ha of land Windmeijer and Andresse, 1993). The 3,000,000 ha of the fertile soils of IV in Nigeria with residual moisture in the dry-season, offers attractive opportunities for the arable farmers to grow off-season high value crops (World Bank 2001). Nigeria has eight IVs (Sokoto Basin, Chad Basin, Middle Niger Basin, Benue Basin, South-western Zone, South-Central, South-eastern and the Basement Complex).

Before year 2000, the IVs were mainly used for growing lowland rice and some pockets of vegetables during the dry season. However, the World Bank sponsored Project tagged First National Fadama Project, has popularized the use of fadama (inland valley) for vegetable production during the dry season. The success of the First National Fadama Project prompted World Bank in partnership with the Global Environment Facility (GEF) to grant $10 million to help Nigerians sustain the management of wetlands, known as "fadamas" in April 2006 (World Bank 2006).

In South Western Nigeria, rain-fed cropping systems predominate in the IV ecology with lowland rice as the principal crop grown between May and September. Under the prevailing traditional farming system, one crop of lowland rice is grown per year because of under development of inland valleys (WARDA, 1993). In Nigeria, some farmers grow one single crop of lowland rice in the early cropping season follow by fallow till next cropping season. Most farmers practice double cropping in the IVs. Lowland rice is planted in the early cropping season (April and May) and harvested in late season (August and September depending on the length of maturity of the variety). The IVs are then allowed to drain until such a time when the land is no longer saturated and will support upland crop, such as vegetables or maize (*Zea mays* L.) during the dry season (lowland rice-fallow-vegetable sequence).

The quest for increase in food production to meet the teaming population of Nigeria, the land use efficiency was improved by increasing land intensification of two crops to three crops within a year (Adigbo *et al.*, 2007). The increase in crop intensification of inland valley for low land rice, upland rice production and dry season vegetable farming has placed high demand on soil nutrients thereby imposing threat to the sustainability of the soil. The focus of this study is to examine the effect of one-crop, two-crop and three-crop sequences on soil properties (N, P, K, organic matter, bulk density and pH) and yield of various crops of the inland valley.

MATERIALS AND METHODS

The experiments were conducted in three years (2000/2001, 2001/2002, and 2002/2003 cropping seasons) at the bottom of the inland valley of the University of Agriculture, Alabata, Abeokuta (7°20'N, 3° 23'E), Nigeria. The top 1- 20 cm soil layer had pH (1:2 soil: water) of 6.64, 17.4 mg/kg K, 45.50 g/kg organic matter (Walkley-Black method), 2.40 g/kg total N (Macro-Kjedahl method) and 16.09 mg/kg Bray extractable P. The textural class of the soil was loamy soil. The soil series of the experimental site was Ikire (Aquic Ustifluvents) (Aiboni, 2001). The average annual rainfall is 1148 mm and average daily temperature is 28 °C for period of 21 years. Rainfall data during the study are showed (Fig. 1). At the first peak of the bimodal rainfall during the rainy season and water table was above the soil surface. The water table receded to the soil level in August and became flooded again at the second peak of rainfall in September of each year. The IV used in this study was fallow for 12 years.

The experiment was laid out in a split-split plot design with three replicates. Two lowland rice varieties namely, BW 311-9 and FAROX 317-1-1-1 were planted in May. These constituted the main plot treatment and were planted in 437 m^2 (19 m x 23 m) in plot size. The two varieties of early-maturing upland rice namely, ITA 257 and ITA 150 planted in October were the subplot treatments (19 m x 7 m), and a fallow check (19 m x 3 m). Three upland crops (okra /amaranth /cowpea) planted in January after harvesting the upland rice and the fallow check were assigned to the sub-sub-plots (4 m x 3 m).

The agricultural calendar year, which began in May and ended in April of the following year constituted a cycle. This experiment was conducted in three agricultural calendar years of 2000/2001, 2001/2002, and 2002/2003 cycles. Each cycle consisted of five concurrent sequences namely: (1) lowland rice-upland rice-fallow (2) lowland rice-upland rice-okra (3) lowland rice-upland rice-amaranth (4) lowland rice-upland rice-cowpea (5) lowland rice-fallow-fallow. Each sequence commenced in May with the planting of lowland rice as the first and the main crop. This was harvested in September. Two early maturing, upland rice cultivars were planted in October and harvested in December in 1st to 4th sequences. Two vegetables (okra and amaranth) and cowpea were planted as the third crop in January and harvested in March in the 2nd to 4th sequences whereas the 1st and 5th sequences was left fallow. Each sequence was replicated three times on the same site.

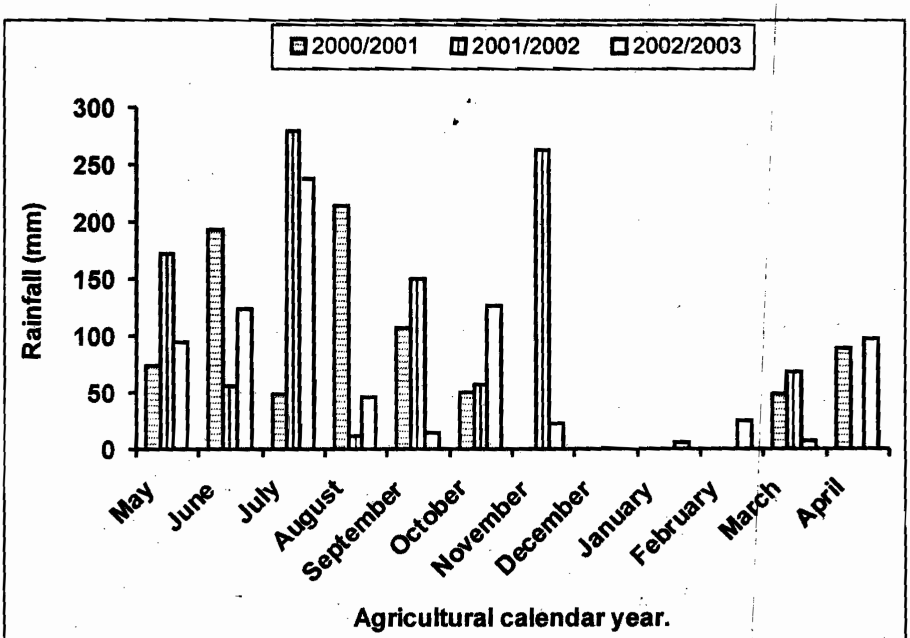

Fig. 1. Rainfall data in Abeokuta during the study period (2000/2001, 2001/2002 and 2002/2003 cropping cycles.

2.1 Cultivation of lowland rice

The land was cleared and raised beds (4 m x 3 m) sub-sub plots were manually constructed early in May before the soil got saturated. The two lowland rice varieties were sown in May 2000, 2001, and 2002, respectively at 20 cm x 20 cm on a 4-m row plot giving a total stand population of 250,000 plant stands per hectare. The lowland rice was harvested in October, September and September 2000, 2001 and 2002, respectively. The first and sixteenth row, were considered as the border rows while the second, third, fourteenth, and fifteenth rows were considered as sample rows. The net plot was made up of the fourth to the thirteenth rows.

The partially decomposed upland rice straw that was used for mulching in cowpea/vegetables crop was incorporated during land preparation for lowland rice whereas the residues of the preceding vegetables/cowpea were used for mulching in lowland rice plots. The basal fertilizer was applied at the rates of 30 kg N ha^{-1}, 7 kg P ha^{-1}, and 13 kg K ha^{-1} in the form of N: P: K (20:10:10) at 14 days after planting (DAP) while the top dressing was 30 kg N/ha in the form of urea for all treatments at 70 DAP. The fertilizer application and management of crop residue generated were maintained for the crops in the all the sequences.

2.2 Cultivation of upland rice

The seeds of upland rice spaced at 20 cm x 20 cm on 4 m-row plot were sown in October 2000, 2001 and 2002, respectively. Though, two varieties of upland rice were sown on flat in 2000/2001 cropping cycle. Raised beds of were used in 2001/2002 and 2002/2003 cropping cycles to enhance 2000/2001 stand establishment on the flat. The first and sixteenth rows were border rows while the second, third, fourteenth and fifteenth rows were sample rows. The fourth to thirteenth rows were net plot.

Lowland rice straws in lowland rice-upland rice-fallow, lowland rice-upland rice-okra, lowland rice-upland rice-amaranth, and lowland rice-upland rice-cowpea sequences were always removed because of bulky lowland rice straw during the bed construction for upland rice. The basal fertilizer N: P: K (20:10:10) was applied at the rates of 30 N, 7 P, 13 K kg/ha 14 DAP and the top dressed with 30 kg N/ha of urea for all treatments, 60 DAP.

2.3 Cultivation of vegetables/cowpea

The crops grown during the dry season were okra cv NHAe-47-4, amaranth, and cowpea cv IT90K-76. These crops were established on the residual soil moisture at the spacing of 80 cm x 20 cm for cowpea and 80 cm x 50 cm for okra while amaranth was drilled in at 40 cm between rows using amaranth seed (1.28 kg) and 10 litres of fine soil mixture technique. The crops grown during the dry season in the first cycle were sown in February, 2001 whereas those of second and third cycles were sown January, 2002 and 2003 sown, respectively.

The rice straws of the preceding upland plant and weed in the fallow plots were used as mulching during the vegetable/cowpea. No fertilizer was applied to cowpea. The basal fertilizer (N: P: K 20:10:10) was applied at the rates of 60 N, 13 P and 25 K kg/ha 20 DAP as a single dose for vegetables.

2.4 Data collection

Three plant samples were taken from each plot for biomass at 45 DAP (tillering stage), 50% heading and at maturity. These samples were oven-dried to constant weight at 70°C.

Plant height was measured at maturity. At the maturity, brown panicles were harvested with the aid of a harvesting knife from the net plot. The harvested panicles were sun dried, threshed and grain yield weighed and converted to t/ha.

2.5 Soil Samples

Composite soil samples were taken from the entire experimental site before the experiment for the determination of pH, organic carbon, N, P and K. Soil samples were taken from the sub-sub plots in April, September and January prior to lowland rice, upland rice and vegetables/cowpea cultivation, respectively in second and third cycles of the experiment. These samples determined the effects of preceding cropping on pH, organic carbon, N, P, and K between each cropping cycle. The moisture content was monitored weekly at 20 cm depth throughout the growth period of upland rice using gravimetric water content method and later converted to volumetric soil moisture (Klute, 1986).

The groundwater table was measured by using piezometer. Open pan evaporation data were collected from the meteorological station. The weekly total of the evaporation data was compared with the weekly rainfall depth equivalent.

The data generated from the lowland rice, upland rice, vegetables and pre and post soil chemical properties were subjected to analysis of variance using split-split plot design. MSTAT-C program version 2.00 (Freed, 1988) was used to run these analyses.

RESULTS AND DISCUSSION

Performance of lowland rice as influenced by preceding cowpea, amaranth, fallow and okra crops and soil chemical properties.

Lowland rice variety FAROX 317-1-1-1 had significantly taller plant and higher grain yields than BW 311-9 (Table 1) as earlier reported by Okeleye *et al.* (2002) who evaluated several lowland rice varieties for grain yield performance. Biomass at tillers of lowland rice in lowland rice-fallow-fallow sequence was higher than those of the other sequences whereas the biomass at harvesting of lowland rice in lowland rice-upland rice-fallow and lowland rice-fallow-fallow sequences were higher than those of the other sequences. This difference could be attributed to the inclusion of fallow during the season in the two-crop (lowland riceupland rice-follow) and one-crop (lowland ricefallow-follow) sequences. Consequently, the product of microbial decomposition of the preceding crops during the dry season fallow period of one-crop and two-crop sequences could have enhanced the growth of lowland rice. Grain yield of lowland rice in the various sequences with or without upland rice were similar. This suggests that the inclusion of upland rice in the sequence did not affect the performance of the lowland rice (main crop). Hence, the niche could be used to grow upland rice without yield reduction of the other crops in the sequence.

There was no significant difference in all soil properties except K in 2001/2002 among the various pre-lowland rice crops and fallows within the cropping cycles (Tables 2 and 3). The significant differences of K among the preceding dry season crops could be due to fertilizer application and the species of crop planted as preceding crop to lowland rice (Table 3). There was the likelihood of fertilizer residue arising from the fertilizer applied to the preceding okra and amaranth. The stability of potassium in a lowland ecology due to adherence to the soil colloid, enhance its ability to resist leaching. However, difference of K among the pre-lowland rice crops were not observed in 2002/2003 and 2003/2004 cropping cycles. This is understandably so because of the number of crops in the sequence. For example between 2001/2002 and 2002/2003, three crops were grown namely: lowland rice, upland rice and dry season crop before the data was collected in May 2002).

The fallow plot that succeeded upland rice had similar effects on the soil properties with those of okra, amaranth and cowpea plots in terms of residual effects on the subsequent crops of lowland rice.

Okra and amaranth, which were previously treated with fertilizer, had no residual effects on growth and yield performance of the succeeding lowland rice. Similarly, two cowpea varieties, which were expected to fix N for the succeeding crop of lowland rice, had no significant residual effect. This non-residual effect could be due to the leaching and the activities of denitrifying bacterial in the soil NO_3 during the dry-to-wet transition period (George et al., 1994). This connotes that the soil N was unaffected whether soil was cropped to vegetable, cowpea or left fallow (George et al., 1995). The authors concluded that the primary advantage of including grain legumes in sequence with lowland rice is to increase output of harvested N from the cropping system, not positive N contribution to rice. The foregoing argument (George et al., 1995) explained why there were no differences among the plots of preceding crops of fertilized vegetables and those of legume and fallow.

The N level and pH levels decreased while soil bulk density increased significantly in 2002/2003 and 2003/2004 compared to 2001/2002 (Table 4). The increase in bulk density could be attributed to the construction of raised bed during the cultivation of upland rice in 2001/2002 and 2002/2003 cropping cycles. The levels of K and OM decreased progressively and significantly as the cropping cycle advanced from 2001/2002 to 2003/2004.

The declining effect of the sequential cropping in the cropping cycles on all the soil properties determined became pronounced after the first two cycles in the two-crop and three-crop sequences. This is a pointer to the fact that the sustainability of lowland rice in lowland rice-upland rice- okra, lowland rice-upland rice-amaranth, lowland rice-upland rice-cowpea and lowland rice-upland rice-fallow sequences in the inland valley would not go beyond two cycles. However the soil chemical properties and grain yield of rice-fallow-fallow did not show any decline in the third cropping cycle compared to the other crop sequences. This suggests that lowland rice-fallow-fallow may be more sustainable on long-term basis than the others. However, organic matter content of the soil, which is the key to soil productivity, is above the critical level. Thus, additional fertilizer to the lowland rice in two-cropped and three-cropped sequences was likely to sustain productivity on long time basis given the fact that there are annual inflows of sediments from the adjacent uplands.

Performance of upland rice as influenced by preceding lowland rice and soil chemical properties

The biomass at flowering of upland rice grown in the previous plots of BW311-9 was significantly higher than that of FAROX 317-1-1-1 in 2001/2002 cropping cycle (Table 5). Similarly, plant heights of upland rice obtained from the plots previously grown to lowland rice variety BW 311-9 were consistently taller than those in the plots of FAROX 317-1-1-1 in the three cropping cycles. Furthermore, the preceding lowland rice variety FAROX 317-1-1-1 had higher grain yields than BW311-9. The soil chemical properties determined from soil sampled prior to upland rice cultivation showed that the N level in the plot previously grown to BW 311-9 was significantly higher than that of FAROX 317-1-1-1. This is an indication that FAROX 317-1-1-1 places higher demand on nitrogen than BW 311-9. These perhaps, could explain why upland rice in the plot previously grown to BW 311-9 had better growth and yield performance than those grown in the plots of FAROX 317-1-1-1.

The grain yields of the two upland rice varieties were similar. However, ITA 150 had significantly higher plant height than ITA 257. These results agree with the finding of Adigbo *et al.* (2003). There was a general decrease in soil fertility status between cropping cycles. The general decrease in grain yield of upland rice in 2001/2002 and 2002/2003 compared to 2000/2001 was a true reflection of the general decline in soil fertility status. Beside, the preceding lowland rice residues were always removed during bed forming because of its bulkiness and anaerobic condition of the soil that limit decomposition (Linn and Doran, 1984). Thus, the nutrients immobilized within the straw of the lowland rice were not available to the succeeding upland rice. These facts could explain also in part the difference observed in the declining grain yield of lowland rice obtained from the two-cropped and three-cropped sequences compared to one-cropped sequence. Apart from gradual decline in soil nutrient as the cropping sequence advanced, the similarity in the nutrient observed after the upland rice crop suggested that any of the two upland rice varieties could be planted in-between lowland rice and dry season cropping.

Performance of cowpea/vegetable as influence by upland rice and soil chemical properties

The rainfall pattern during the dry season played a significant role in disease and pest development as well in the soil chemistry of inland valley ecology (Fig.1). The rainfall pattern accounted for the difference in yield of vegetables and cowpea between 2000/2001 and 2002/2003 cropping cycles. The rainfall depth equivalent was substantially higher than evaporation in 2002/2003 compared to 2000/2001 cropping cycle. The wider gap between evaporation and the moisture in the soil in 2002/2003 cropping cycle was due to the rainfall during the dry season (Fig 2).

The lower fresh leaf weight of amaranth in the 2000/2001 cropping cycle compared to that of 2002/2003 was due to the early rains and the residual effect of fertilizer applied to the preceding upland rice during the dry season (Table 6). Amaranth responded to the residual fertilizer carryover positively, thus, making it to be a better utilizer of residual N fertilizer. Mohanty *et al.* (1989) reported a similar result that rice, as a succeeding crop appeared to be a better utilizer of residual fertilizer N compared to green gram. The higher leaf area with corresponding lower fresh pod weight of okra (30% pod reduction) in the 2002/2003 cropping cycle compared to 2000/2001 cropping cycle could be attributed to the negative residual effects of the fertilizer carried over from the preceding upland rice. Mohanty *et al.* (1989) gave a similar report of negative residual effect of fertilizer on the grain yield of green gram.

Grain yield of cowpea were significantly higher in 2000/2001 than in the 2002/2003 cropping cycle. This difference in cowpea grain yield could be attributed to the rainfall in 2002/2003 cropping cycle with the associated lamb's tail pod rot disease caused by *Choamephora* spp. (Toler and Dukes, 1965).

The rainfall depth equivalent at 20 cm depth of the soil in 2000/2001 and 2002/2003 cropping cycles were consistently higher than those of evaporation (Fig. 2). This suggests that evapotranspirative demand of vegetable and cowpea crops could be met by the residual moisture. Furthermore, the range of groundwater table of the experimental site during the growth of vegetable/cowpea at the peak of the dry season was 44.5-72.3 cm. This shallow groundwater table is an indication that water requirement of the vegetables and cowpea could be met by capillarity.

The general decline in organic matter content, N, P, k levels and increase in bulk density as the cropping sequences advance particularly the two-crop and three-crop sequences could be attributed to the cropping intensification. The soil properties of lowland rice-fallow-fallow plot consistently had a comparably higher pH, OM, N, P, K and lower bulk density than the plots cropped twice and thrice in all the cropping cycles. The levels of N, P and K in plots cropped once were above the critical level in the rating of soil fertility classes, whereas those in the plots cropped twice and thrice, especially those of 2002/2003 and 2003/2004 cropping cycles, were below the critical level (Enwezor *et al.*, 2002). Paddy fields in the lowlands receive new sediments deposited from run-off that carried eroded topsoil down from the uplands, thus perpetuating soil fertility and productivity (FFTC, 2007).

Table 1: Effects of one-, two- and three-crop sequences on the performance of lowland rice in the 2000/2001, 2001/2002 and 2002/2003 cropping cycles.

Treatments	Biomass (kg/m^2) at									Plant height (cm)			Grain yield (t/ha)		
	Tillering			Flowering			Harvest								
	2000/ 2001	2001/ 2002	2002/ 2003	2000/ 2001	2001/ 2002	2002/ 2003	2000/ 2001	2001/ 2002	2002/ 2003	2000/ 2001	2001/ 2002	2002/ 2003	2000/ 2001	2001/ 2002	2002/ 2003
Lowland rice (LR)															
BW 311-9	0.45	0.50	0.32	3.13	3.41	1.89	7.74	5.07	3.53	106.9	115.1	120.1	3.44	3.28	2.59
FAROX 317-1-1-1	0.53	0.56	0.33	3.84	2.71	2.42	7.36	5.18	3.50	129.5	131.2	131.3	3.89	4.28	2.80
SE (LR)	0.026	0.013	0.24	0.26	0.07	1.15	0.39	0.23	0.83	1.10	1.61	1.92	199.45	105.94	163.74
Crop sequences (CS)															
LR-fallow-fallow	0.60	0.58	0.51	3.48	3.22	3.01	9.07	5.76	4.60	119.1	122.1	128.6	3.29	3.38	3.01
LR-UR-fallow	0.45	0.58	0.28	3.87	2.68	2.00	9.60	5.47	3.16	119.2	127.3	125.7	3.54	3.77	2.46
LR-UR-cowpea	0.52	0.52	0.32	3.60	3.15	1.92	6.87	4.95	3.33	117.1	124.2	123.3	3.87	3.81	2.75
LR-UR-amaranth	0.45	0.50	0.26	3.32	3.40	1.85	6.08	4.54	3.28	117.7	118.5	125.5	3.97	4.05	2.61
LR-UR-okra	0.44	0.48	0.26	3.16	2.87	1.99	6.13	4.70	3.30	118.0	123.7	125.5	3.65	3.89	2.60
LR-UR-cowpea															
SE (CS)	0.028	0.073	0.027	0.329	0.24	0.158	0.933	0.53	0.178	2.73	2.40	0.056	509.64	272.89	175.77
SE (LR x CS)	0.059	0.029	0.53	0.59	0.16	2.57	0.87	0.51	1.86	2.45	3.61	4.30	446.0	236.89	366.14

LR = lowland rice, UR = upland rice, CS = crop sequence

Trea

Table 2: pH, organic matter and bulk density of the experimental site before lowland rice in 2001/2002, 2002/2003 and 2003/2004 cropping cycles

Treatments	pH			Organic matter (g/kg^{-1})			Bulk density (g/cm^{3})		
	2001/ 2002	2002/ 2003	2003/ 2004	2001/ 2002	2002/ 2003	2003/ 2004	2001/ 2002	2002/ 2003	2003/. 2004
Lowland rice (LR)									
BW311-9	6.44	6.27	6.34	42.49	26.11	23.59	1.13	1.24	1.23
FAROX317-1-1-1	6.47	6.36	6.27	42.51	27.49	23.84	1.10	1.27	1.22
SE (LR)	0.01	0.03	0.10	0.74	0.47	2.17	0.04	0.06	0.04
Upland rice (UR)									
ITA257	6.45	6.34	6.32	42.93	27.43	24.45	1.18	1.25	1.22
ITA150	6.46	6.29	6.29	40.09	26.17	22.98	1.12	1.25	1.23
SE (UR)	0.04	0.04	0.04	1.76	1.49	1.09	0.03	0.03	0.02
SE (LR x UR)	0.06	0.06	0.05	2.49	2.11	1.53	0.04	0.04	0.03
p sequences (CS)									
UR-okra	6.47	6.32	6.32	45.65	29.62	23.90	1.08	1.25	1.27
UR-amaranth	6.47	6.32	6.29	42.27	29.87	24.90	1.12	1.29	1.22
UR-IT90k-76	6.40	6.35	6.27	39.45	22.85	21.52	1.16	1.24	1.21
UR-IT90k-277-2	6.47	6.22	6.32	41.90	25.57	23.62	1.13	1.24	1.24
UR-Fallow$_{2}$	6.47	6.38	6.34	43.22	26.08	24.62	1.01	1.25	1.19
fallow-fallow$_{1}$	6.40	6.4	6.5	40.7	29.5	33.0	1.20	1.10	1.10
(CS)	0.05	0.10	0.08	2.78	2.36	1.72	0.04	0.03	0.03
(LR)	0.06	0.14	0.11	3.93	3.34	2.43	0.06	0.04	0.05
(UR x CS)	0.06	0.14	0.11	3.93	3.34	2.43	0.06	0.04	0.05
(LE x UR x CS)	0.09	0.20	0.16	5.56	4.72	3.43	0.08	0.06	0.07

Fallow$_{1}$= after lowland rice,
Fallow$_{2}$ =after lowland rice and upland rice

Perhaps the annual inflow of nutrients from the adjacent could not march with the level of demand occasioned by the intensification particularly N, P and K. However, the organic matter monitored in all the cropping sequences was above the critical level (Enwezor *et al.*, 2002). The importance of organic matter as an essential component for the retention and gradual release of nutrients, as well as a source of nutrient has been documented (Ragland and Boonpuckde, 1988; Willet and Intrawech, 1988; Adetunji, 2005). To maintain high yield in the two-crop and three-crop sequences therefore, the levels of inorganic fertilizer which was restricted to 60:30:30 could be increased after two cropping year when grain yield drop was observed.

Generally, dissimilarity in soil chemical properties particularly N prior to planting of upland rice varieties suggests that the combination lowland rice variety BW 311-9 and any of the upland rice variety (BW 311-9-upland rice) might be considered the best sequence. Also as stated earlier, the similarity in soil chemical properties prior to planting of vegetable/cowpea also confirms the fact that any combination of the upland rice varieties will suffice. But the different response of amaranth and okra to the residual fertilizer effects of the preceding upland rice suggests that the best three crops combination was BW 311-9, any upland rice variety and amaranth (BW 311-9-upland rice-amaranth).

Table 3: Nitrogen, phosphorus and potassium contents of the experimental site before lowland rice in 2001/2002, 2002/2003 and 2003/2004 cropping cycles.

	Nitrogen (g/kg^{-1})			Phosphorus (mg/kg^{-1})			Potassium (mg/kg^{-1})		
Treatments	**2001/ 2002**	**2002/ 2003**	**2003/ 2004**	**2001/ 2002**	**2002/ 2003**	**2003/ 2004**	**2001/ 2002**	**2002/ 2003**	**2003/ 2004**
Lowland rice (LR)									
BW311-9	2.12	1.31	1.18	8.34	8.38	6.32	16.07	9.77	6.56
FAROX317-1-1-1	2.13	1.37	1.20	8.80	7.99	6.82	17.00	9.81	6.79
SE (LR)	0.04	0.02	0.10	1.78	1.51	1.10	0.05	0.002	0.34
Upland rice (UR)									
ITA257	2.15	1.37	1.23	8.26	7.92	7.31	16.85a	9.72	6.87
ITA150	2.10	1.31	1.15	8.88	8.45	6.83	16.24b	9.87	6.48
SE (UR)	0.11	0.08	0.03	1.78	1.14	1.33	0.007	0.10	0.17
SE (LR x UR)	0.15	0.12	0.04	1.67	1.61	1.89	0.01	0.14	0.24
Dry season crops (DS)									
Okra	2.28	1.48	1.21	9.19	9.71	7.83	17.81a	10.21	6.18
Amaranth	2.11	1.49	1.25	9.48	9.06	7.21	17.10b	9.48	6.21
IT90k-76	1.97	1.14	1.08	8.24	6.83	5.70	15.18e	9.18	7.49
IT90k-277-2	2.09	1.28	1.18	7.19	6.90	6.45	15.94d	9.51	6.91
Fallow$_2$	2.16	1.30	1.23	8.73	8.42	8.15	17.10b	9.48	6.21
Fallow$_1$	2.05	1.5	1.6	13.8	12.0	10.6	16.60c	14.4	12.0
SE (DS	0.14	0.12	0.09	2.01	0.83	1.38	0.10	0.57	0.31
SE (LR x DS)	0.19	0.17	0.13	2.84	1.18	1.95	0.15	0.81	0.44
SE (UR x DS)	0.19	0.17	0.13	2.84	1.18	1.95	0.15	0.81	0.44
SE (LR x UR x DS)	0.27	0.23	0.18	4.02	1.66	2.75	0.21	1.14	0.63
CV (%)	18.00	25.64	21.62	66.29	28.77	55.09	1.77	16.46	13.32

Fallow$_1$ = after lowland rice,
Fallow$_2$ = after lowland rice and upland rice

Table 4. Effect of sequential cropping on pH, organic matter and bulk density of the experimental site before lowland rice.

Treatments	PH	Organic matter (g/kg^{-1})	Bulk density (g/cm^3)	N (g/kg^{-1})	P(mg/kg^{-1})	K(g/kg^{-1})
Cropping cycles (CC)						
2001/2002	6.46a	42.50a	1.11b	2.12a	8.57	16.57a
2002/2003	6.32b	26.80b	1.25a	1.34b	8.18	9.79b
2003/2004	6.31b	23.71c	1.23a	1.19b	7.07	6.59c
SE (CC)	**0.04**	**1.03**	**0.18**	**0.005**	0.70	**0.18**
Lowland rice (LR)						
BW311-9	6.35	30.73	1.20	1.54	7.68	10.80
FAROX317-1-1-1	6.37	31.28	1.19	1.57	8.20	11.17
SE (LR)	0.03	0.84	0.02	0.04	0.57	0.15
SE (CC x LR)	0.05	1.46	0.03	0.07	0.99	0.26
Upland rice (UR)						
ITA257	6.37	31.60	1.19	1.58	7.83	11.12
ITA150	6.35	30.40	1.20	1.52	8.05	10.83
SE (UR)	0.03	0.84	0.02	0.004	0.57	0.15
Crop sequences (CS)						
LR-fallow-fallow	6.80	33.10	1.07	1.70	11.0	14.33
LR-UR-fallow	6.40	31.31	1.19	1.57	8.43	11.31
LR-UR-Okra	6.37	33.06	1.20	1.66	8.91	11.56
LR-UR-Amaranth	6.36	32.35	1.21	1.62	8.58	11.09
LR-UR-IT90k-76	6.64	27.94	1.20	1.40	6.92	10.54
LR-UR-IT90k-277-2	6.33	30.37	1.20	1.52	6.85	10.41
SE (D)	0.05	1.33	0.02	0.01	0.91	0.24

Table 5: Growth, grain yield and some soil Chemical properties of upland rice in a two-crop sequence 2000/2001 and 2002/2003 cropping cycles.

	Biomass (kg/m^2) at						Plant height at Maturity (cm)		Grain yield (t/ha)	
	Tillering		Flowering		Harvest					
Treatments	**2000/ 2001**	**2002/ 2003**	**2000/ 2001**	**2002/ 2003**	**2000/ 2001**	**2002/ 2003**	**2000/ 2001**	**2002/ 2003**	**2000/ 2001**	**2002/ 2003**
Lowland rice (LR)										
BW 311-9	0.53	0.323	2.24	1.24	2.76	1.76	109.6	107.4	0.83	0.73
FAROX 317-1-1	0.47	0.27	2.19	1.19	2.78	1.78	105.6	102.4	0.78	0.68
SE (LR)	0.21	0.21	1.12	1.15	1.02	1.02	0.33	0.11	0.01	0.016
Upland rice (UR)										
ITA 257	0.52	0.32	2.21	1.21	2.79	1.76	94.6	92.2	0.83	0.74
ITA 150	0.47	0.27	2.22	1.22	2.74	1.74	120.6	118.6	0.78	0.68
SE (UR)	0.14	0.14	0.49	0.49	0.72	0.72	1.31	1.40	0.07	0.71
SE (LR x UR)	0.20	0.20	0.69	0.69	1.01	1.01	1.86	1.98	101.0	100.87
Treatments	**pH**		**OM (g/kg^{-1})**		**N (g/kg^{-1})**		**P (mg/kg^{-1})**		**K (mg/kg^{-1})**	
BW311-9	6.64	6.52	41.62	34.20	2.02	1.71a	5.53	4.55	10.78	9.73
FAROX317-1-1	6.67	6.53	42.29	30.43	2.01	1.65b	6.22	6.12	10.16	9.24
SE	0.03	0.02	4.60	0.40	0.025	0.004	0.30	0.38	0.31	0.38

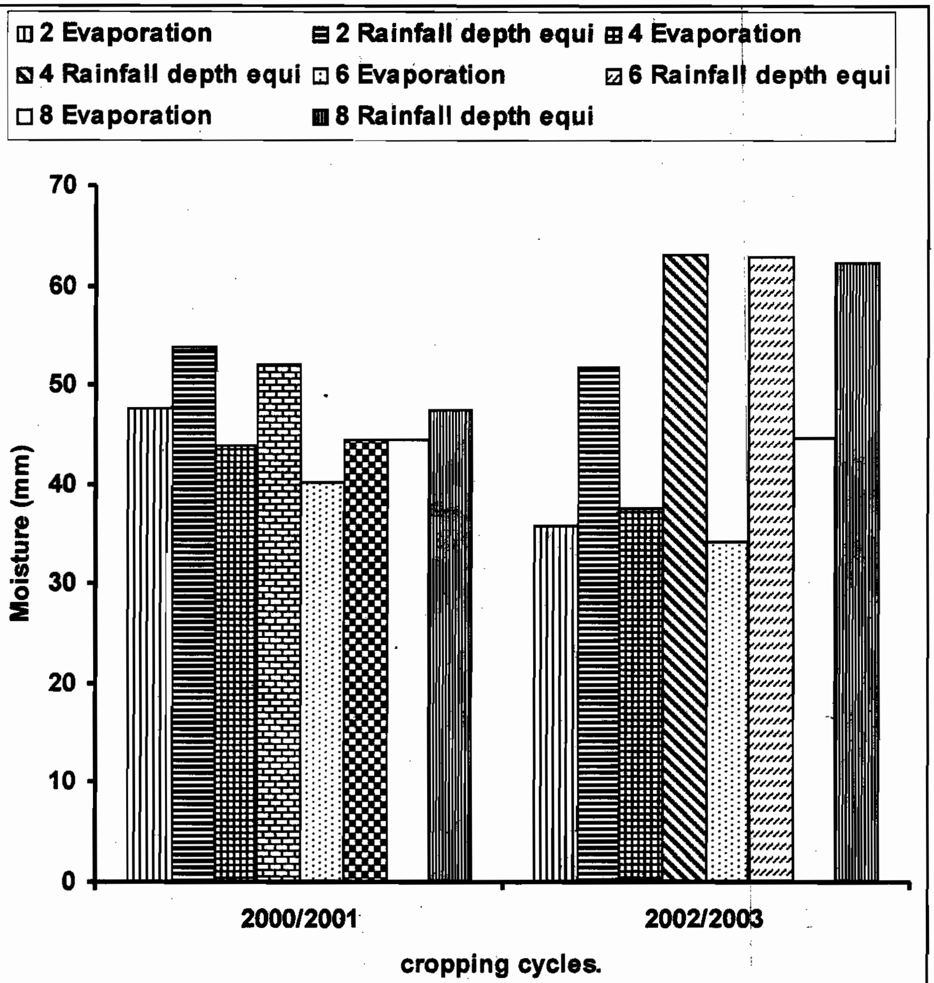

Fig.2 Comparison of rainfall depth equivalent (mm) and evaporation (mm) during the growth period of vegetables/cowpea

Table 6: Effects of lowland rice and upland rice on yield of okra, amaranth and cowpea

Treatments	Leaf area of cowpea (cm^2)	Leaf area of okra (cm^2)	Fresh pod wt. of Okra (t/ha)	Fresh leaf weight of amaranth (t/ha)	Grain yield (t/ha) of cowpea
Cropping cycle (CC)					
2000/2001	258.0	402.6	5.57	2.86	1.56
2002/2003	288.9	724.2	3.90	11.85	0.99
SE (CC)	13.16	4.51	0.11	0.18	0.086
Lowland rice (LR)					
BW 311-9	268.1	558.2	5.64	7.14	1.31
FAROX 317-1-1-1	278.9	568.6	3.82	7.57	1.24
SE (LR)	13.16	15.02	0.57	0.63	86.75
Upland rice (UR)					
ITA 257	284.4	578.7	5.27	7.35	1.30
ITA 150	262.5	548.1	4.20	7.36	1.45
SE (UR)	13.16	28.05	0.53	0.40	86.75
SE (CC x LR)	18.62	21.25	0.81	0.89	122.69
SE (CC x UR)	18.62	39.67	0.74	0.56	122.69
SE (LR x UR)	18.62	39.67	0.74	0.56	122.69
SE (CC x LR x UR)	46.33	56.09	1.05	0.79	173.51

CONCLUSION

The study revealed that grain yield of lowland rice obtained from one-cropped sequence did not decline unlike the yield from two-cropped and three-cropped sequences as the cropping cycle advanced. Preceding upland rice had negative residual effect on the yield of the succeeding crop of okra but enhance the productivity of amaranth. The best crops combination or sequence was BW 311-9-upland rice-amaranth. Two-cropped and three-cropped sequences with or without legume do not seem to make any difference in terms of soil fertility maintenance. Sequential cropping reduced soil pH, OM level, N, K content and increased the bulk density. The annual inflow of nutrient could not march with the demand of two-crop and three-crop sequences. Hence, higher rate of inorganic fertilizer is required for the two-crop and three-crop sequences after two cropping year.

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