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Upland Rice Cultivars For Improved Acid Upland Rice-Based Farming Systems

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Baseline surveys at IRRI's key research site for acid upland rice-based farming systems in Claveria, Mindanao, indicated that upland rice-based patterns were less widespread than maize-based pattems. This was attributed to a number of unique constraints associated with upland rice production, including late-maturing cultivars that prevented production of a succeeding crop. Cultivar evaluations of elite upland rice breeding materials were conducted to identify promising cultivars adapted to the acidic (pH < 5.0) and infertile soil conditions typical of farming systems in the majority of acid upland areas. Heavy emphasis was on early-maturing cultivars to increase total system productivity by making it feasible for upland farmers to grow sequences of 2-3 crops per year.

A tiered system of cultivar evaluations was carried out for 5 years. IR 30716-B-1-B-1-2, IR 3880-2-3, IR 47686-6-2-2-1 and IR 12979-24-1 (Brown) were outstanding in consistency in yield across years, outperforming the released variety UPL Ri-5, and local varieties Dinorado, Speaker and Kayatan. Tests under farmer management in rice-maize patterns confirmed these results. The use of early-maturing and high yielding upland rice varieties significantly increased the total system productivity of upland rice-based patterns by promoting much higher yields of a following maize crop.

Keywords: Upland rice, acid soil, cultivar, maize, cropping pattern

Acid upland soils cover a large land mass in South and Southeast Asia. In the Philippines, acid upland soils (pH < 5.0) cover about 9.6 M hectares representing about 31% of the country's total land. The unifying characteristics pertaining to agriculture in this diverse body of soil are their generally severe nutrient limitations and imbalances, which pose major constraints to high productivity of field crops. Highly acidic upland soils are usually low in phosphorous and the nutrient cations of potassium, calcium and magnesium, and often contain toxic levels of exchangeable aluminum and manganese.

Drought, weeds, blast and insect pests are also major constraints to upland rice production. These adverse factors cause many farmers to limit upland rice production to subsistence levels. In this environment, traditional rice varieties are associated with low grain yield (0.5-1.5 t/ha). Although some of the soils are of marginal potential productivity, many can be highly productive if knowledge and careful husbandry are applied to their management.

Developing improved upland rice cultivars specifically-adapted to the constraints of acid soils is a necessity to improve the productivity and livelihood of these marginal lands. On-farm upland rice-based cropping system research was initiated by IRRI and the Department of Agriculture (DA) in the acid uplands at Claveria, Misamis Oriental in 1985. One of the major issues was the feasibility for upland farmers to grow upland rice-based crop sequences of 2-3 crops per year (Magbanua et al, 1986).

The indigenous upland-rice based cropping pattern, rice-fallow, occupied 11 per cent of their total land area (Fig. 1) Mandac et al, 1986). Most upland rice at the site was grown with no preceding or following crop. The lack of a second crop was practiced partly to minimize the rate of soil fertility decline, since no fertilizer was used on rice, and rice was usually grown on less fertile locations (Magbanua et al, 1987). But one major constraint to double cropping is that all available rice cultivars matured much later than maize.

Any crop following a rice crop has much higher probability of exposure to severe terminal drought stress than crops following maize. The improved upland rice cultivars that was available to date (UPL Ri-5) matured in 130-140 days. At 300-500 meter above sea level it did not fulfill the requirements of an early maturing upland rice.

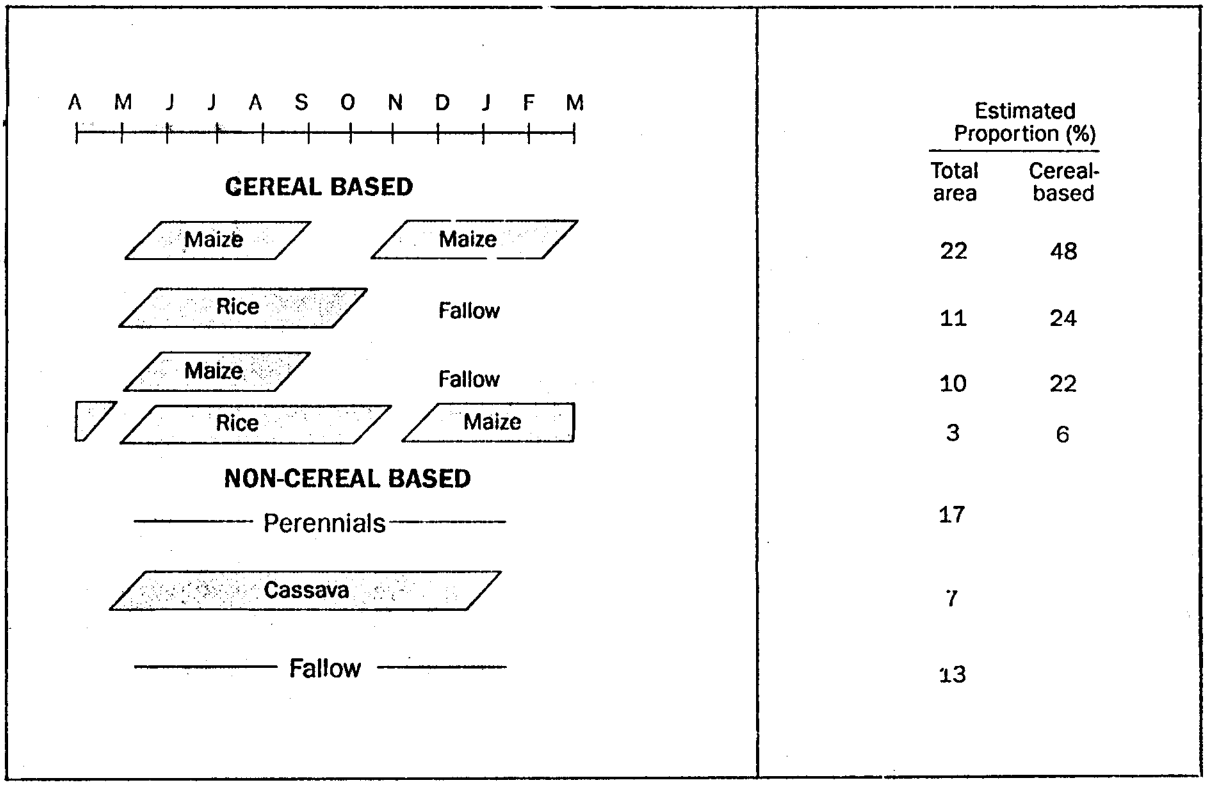

Fig. 1. Dominant existing cropping patterns at Claveria site. 1984 baseline survey. Source: Agricultural Economics Department, IRRI.

Identification and characterization of earlier maturing cultivars of less than 120 days was necessary for the development of improved cropping systems in this acid upland environment. Such cultivars must be adapted to acidic infertile soil with low inherent fertility, and have drought tolerance, blast resistance, and insect resistance for yield stability.

Large scale upland rice cultivar evaluation was conducted in association with cropping systems research in Claveria, Misamis Oriental. Elite upland breeding materials identified at early and advanced stages of selection were observed in large on-farm nurseries.

The objectives of the work reported in this paper were to: 1) evaluate promising upland rice selections in relation to the locally grown varieties under farmers' management on a field scale on acid upland soils; and 2) compare the total system productivity of two-crop upland rice-based patterns composed of upland rice followed by maize. We tested the hypothesis that maize performance is influenced by the different maturities of the component rice cultivars, and the total yield of rice + maize would be maximized with earlier maturing cultivars of upland rice, even if shorter growth duration resulted in lower rice yields.

MATERIALS AND METHODS

The soil properties of the research site are given in Table 1. A tiered system of cultivar evaluation in the acid upland environment was employed for 5 years (Fig. 2). **Tier** 1 was the Acid Upland Observation Trial (AUOT), designed as the initial multisite evaluation of IRRI upland rice breeding materials for more acidic infertile soils.

Tier 2 was the Acid Upland Yield Trial (AUYT). This trial was a replicated yield trial designed to evaluate promising breeding materials for more acidic upland environments of low soil inherent fertility under two different phosphorous application levels.

Tier 3 was the Acid Upland Environment Specific Yield Trial (AUESYT). These trials were designed to evaluate the performance of new upland rice breeding materials identified to evaluate the entries of the AUYT with outstanding performance at the Claveria research site. The experimental procedures closely followed those of the AUYT.

Tier 4 was the Farmers' Managed Yield Trial (FMYT). This trial was designed to evaluate the select few outstanding entries emanating from the prior tests under farmer-management. Performance was monitored in replicated trials within larger fields, in comparison to the prevalent locally grown varieties.

Table 1. Chemical and physical properties of a representative soil profile at Claveria, Misamis Oriental.

Analyses	Profile Depths (cm)		
	0-11	11-21	21-56
pH (1:1) 1N KCl	4.1	4.1	3.9
0.01 M $CaCl_2$	4.3	4.3	4.3
NaF	9.3	9.2	9.8
Org. C (%)	1.84	1.71	0.56
Total N (%)	0.19	0.18	0.08
Exch. Cations (m.e./100 g)			
Na	nil	0.02	0.02
K	0.10	0.09	0.03
Mg0.69	0.52	0.18	
Ca	2.74	2.78	1.05
CEC (m.e./100 g)	10.6	10.5	8.0
Bray P (ppm)	9.8	8.7	9.7
Olsen P (ppm)	6.1	3.7	3.2
Avail. Zn (ppm)	1.3	1.2	0.8
Exch. Al (m.e./100 g)	0.58	0.52	1.27
Particle size (%)			
Clay	75	61	84
Silt22	36	14	
Sand	3	3	2
Field Classification	Fine, mixed isohyperthermic Ultic Haplorthox		

Adapted from Mamaril et al (1985).

The materials were tested under two levels of fertility.

The composition of the different tiers of upland rice cultivar evaluation across years is presented in Table 2. In 1985, AUOT and AUYT were conducted in our location with 280 and 49 entries, respectively. The IURYN-85 and IURON- 85 were conducted in Barangay Ane-i and Patrocenio, with corresponding entries of 20 and 72, respectively. In 1986, Environment Specific Yield Trials and Farmer Managed Yield Trials were given high priority and were conducted in 2 and 5 locations, respectively. In 1987, the number of new breeding materials significantly increased from 480 in 1986 to 780 in 1987 in AUOT. The AUESYT and FMYT were discontinued in 1988, being replaced by cultivar evaluation through superimposed plots within cropping pattern tests, and through the comparison of promising selections as components in an upland rice maize crop sequence.

This paper focuses on the two latter studies. The results of the AUYT, AUOT, Environment Specific Yield Trials and Farmer Managed Yield Trials were reported in IRRI (1986-1988) and Mercado and Garrity (1988).

Upland Rice Cultivar Evaluation Superimposed on Cropping Pattern Tests

Cropping pattern tests under farmer management were employed in the research program to holistically evaluate the performance of prospective crops and crop sequences within the managerial constraints of a larger-scale production situation. Five farms were selected, with one farm each in five barangays of lower Claveria where upland rice production systems were most prevalent.

Each cropping pattern field was divided into two mainplots which represented two distinct levels of cash flow constraint in growing upland rice, a moderate cash flow level and a low cash flow level. The moderate cash flow represented a level of input investment judged to be near economic optimality, based on the body of prior agronomic research at the site (IRRI, 1986; 1987; 1991) and on extensive agroeconomic survey data (Mandac and Flinn, 1986). The low cash flow level was applied within the framework of attempting to optimize the input mix in the situation that cash for input investment was highly limiting, a common situation among farmers.

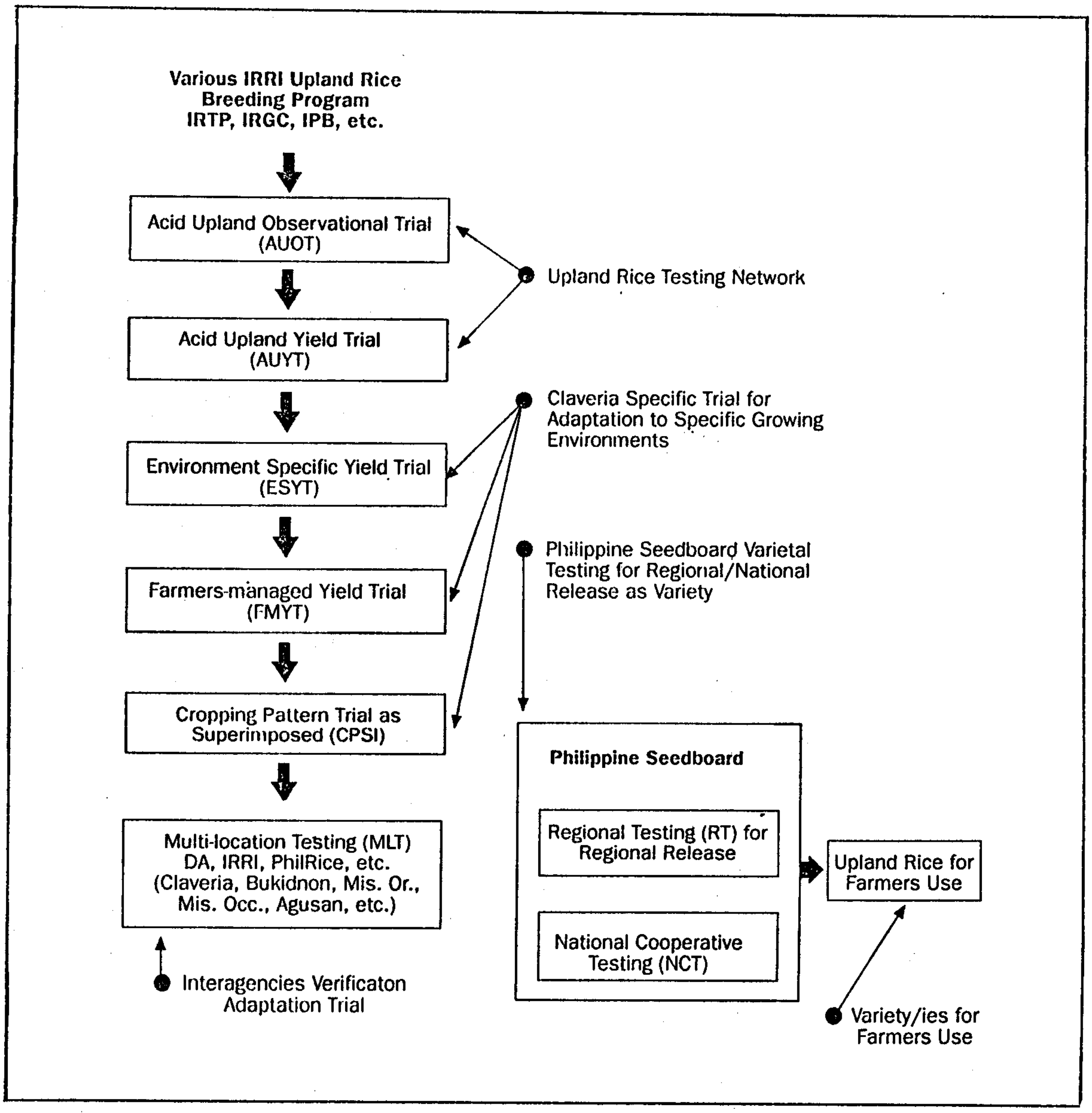

Fig. 2. Schematic diagram of the flow of upland rice breeding materials.

Ten elite upland rice selections and checks were seeded in large plots within a portion of each cash flow main plot. These treatments were superimposed on the main rice crop grown on the rest of the field. The rice cultivars were subplots in a split plot design. Each of the five farmers' fields served as a replicate of the entire trial.

The moderate cash flow treatment consisted of the following: Land preparation of 2 - 3 plowings and 2 harrowings within 2 - 3 weeks, a seeding rate of 90 kg/ha, with the seed drilled in furrows 30 cm apart. The fertilizer application rate was 50- 10.5 N-P-K per hectare, with P applied basally, and one-half of the N applied at 14 days after emergence (DAE), and the remaining half applied at 7 days before panicle initiation (DBPI). Weed control involved interrow cultivation at 14 and 28 DAE followed by a handweeding.

The low cash flow treatment employed the same intensity of land preparation, and the same seed rate and row spacing Fertilizer application was limited to 25 kg N/ha applied 7 DBPI. Weed control included the two interrow cultivations but without handweeding.

Comparison of Promising Upland Rice Selections in an Upland Rice-Maize Sequence

At the start of first crop of upland rice, the experimental field was plowed and harrowed twice using an animal-drawn mold board plow. On the onset of the rainy season, eight promising upland rice selections and checks were planted in a randomized complete block design (RCB). Each variety was planted in 5m x 6 m plots (30 m^2) in 4 replications. The seeds were drilled in rows 30-cm apart. The seed was treated

Table 2. Number of entries in different tiers of the upland rice cultivar evaluations conducted across years (1985-89) in various locations in Claveria, Misamis Oriental.

Year	Experiment	No. of Entries	No. of Locations
1985	AUOT	280	1
	AUYT	49	1
	IURYN-85	20	1
	IURON-85	72	2
	Total	421	6
1986	AUOT	480	1
	AUYT	56	1
	AUESYT	20	2
	FMYT	10	5
	Total	566	9
1987	AUOT	780	1
	AUYT	56	1
	AUESYT	16	2
	FMYT	10	5
	Total	862	9
1988	AUOT	360	2
	AUYT	56	1
	CPSI	10	5
	UPL-MZ	6	1
	Total	422	8
1989	AUOT	320	1
	AUYT	56	1
	CPSI	10	5
	UPL-MZ	8	2
	Total	394	9

Legend:
AUOT - Acid Upland Observational Trial
AUYT - Acid Upland Yield Trial
AUESYT - Acid Upland Environment Specific Yield Trial
IURYNM - International Upland Rice Yield Nursery Medium
IURON - International Upland Rice Observational Nursery
FMYT - Farmer Managed Yield Trial
CPSI - Cropping Pattern Superimposed Trial

with carbosulfan at the rate of 0.3 a.i. kg./ha. prior to establishment. Hoe weeding was done at 14 and 28 DAE followed by handweeding. During the grain filling stage, Deltamithrin was applied at the rate of 0.1 a.i. kg/ha. to control rice bugs.

A succeeding maize crop was planted 21 days after harvesting the preceding upland rice crop from each plot. This was observed to be the lowest turnaround period that is practical for small-scale upland farmers with animal power, when the land is plowed and harrowed between crops. Thus, the maize seeding date was dependent on the specific harvest date of each upland rice cultivar. Therefore it varied with differences in the maturity dates of the rice. Before planting maize, the field was plowed once and then harrowed. The field was furrowed in rows 60-cm apart. The maize seeds were planted 25 to 30-cm apart. The seeds were treated with carbosulfan at the rate of 0.3 kg a.i./ha. Phosphate was applied basally at the rate of 10.5 kg P/ha. Nitrogen was applied at a rate of 50 kg/ha at 30 DAE. Hoe weeding was applied at 14 DAE, and interrow cultivation was done at 30 DAE, immediately after the application of N.

RESULTS AND DISCUSSION

Upland Rice Cultivar Evaluation Superimposed on Cropping Pattern Tests

The grain yields of the promising upland rice selections are presented in Table 3. Most of the entries responded positively to P application as indicated by the moderate cash flow mean yield of 2.03 t/ha compared with the low cash flow mean of 1.60 t/ha. IR 30716-B-1-B-1-2 had the highest yield in low cash flow compared with other entries, but it did not respond as positively to P application in moderate cash flow. IR 47686-6-2-2-1 was superior in both cash flow situations and had the highest mean of yield 2.56 t/ha (Fig. 3). Among the very early cultivars CNA 5164 yielded highest in both cash flows, with an overall mean of 1.52 t/ha.

UPL Ri-5 was the released cultivar included in the test. It had been adopted by a substantial number of farmers in the surrounding region during the past several years. Its mean yield was average for the test. It did not show superiority inspite of its relatively late maturity compared to all of the other cultivars (Fig. 4). The figure also indicates that UPL Ri-5 had a low yield per day compared to the other entries. It matured usually at 130 - 140 days at 300-400 masl.

IR 47686-6-2-2-1, IR 3880-2-3 and IR 30716-B-1-B-1-2 had the highest yield per day at 20.70, 19.18 and 18.76 kg/day, respectively. IAC 25, the earliest maturing entry, did not have a high grain yield per day. In this parameter it was similar to UPL Ri-5. IAC25 was the only entry that matured in less than 100 days. It did not perform well under severely stressed conditions. This was possibly due to the lack of time to recover from stress events that affect cultivars with exceptionally early maturity. IRAT 144, an entry harvested at 107 days after emergence, had a relatively high yield per day.

Comparison of Promising Upland Rice Selections in an Upland Rice-Maize Sequence

The importance of yield per day as an upland rice character becomes evident when the productivity of the entire cropping pattern, rather than simply the yield of the rice crop, is the performance criterion. Figure 5 shows the yield of each component crop of rice and maize, and the sum of their yields for each cultivar combination.

IAC 25 was the lowest yielding cultivar in the test, but the yield of the subsequent maize crop (3.50 t/ha) was the highest among all combinations. IAC25 followed by maize also produced the highest cumulative yield over both crops (6.40 t/ha of grain). UPL Ri-5 was the highest yielding rice cultivar in the trial at 5.69 t/ha. However, the subsequent maize crop was very poor due to unseasonably late planting. The late seeding date of maize after UPL Ri-5 carried the maize into severe drought stress. Rainfall frequency and amount declined in January and February, producing a very low grain yield of 0.24 t/ha. IR30716-B-1-B-1-2 and IR 47686-6-2-2-1 had much higher grain yield than IAC25 but the subsequent maize crops following these cultivars were markedly lower than for the very early cultivar.

Figure 6 illustrates the phenology of the planting of each component crop relative to the rainfall pattern. The subsequent maize crop of the early maturing upland rice experienced good rainfall throughout the growing period, in contrast with the late-maturing cultivars. The moisture was good during the early stage of the late maize crops, but drought occurred at the reproductive stage, having a critical effect on grain yield.

The maize crop growth period subsequent to the late-maturing upland rice cultivars (> 120 days) was pushed toward the drier periods of the growing season. This resulted in poor grain yield. The relative maturity of the cultivars becomes important in situations where the annual growing period of field crops is restricted. This is usually the case in unimodal monsoonal climates, wherein rainfall is also erratic toward the end of the crop year.

The results of the second year of the experiment are presented in Table 4. Almost all rice entries performed well with a mean grain yield of 3.18 t/ha, IR 30716-B-1-B-1-2 was the highest yielding entry (4.7 t/ha), with a yield significantly higher than all the others entries. The yields of the very early entries (maturing in less than or equal to 100 days), CNA 5164 and IAC 25, were comparable to UPL Ri-5 which matured in 137 days. Kayatan, a traditional variety, yielded lowest (1.36 t/ha) but had a high total biomass yield (5.49 t/ha).

Maize planted after IAC 25, CNA 5164 and IR 30716-B-1-B-1-2 had significantly higher yields (4.78, 4.33 and 4.29 t/ha, respectively) compared to maize following the other entries (Fig. 7). The maize yields preceded by the check upland rice varieties yielded significantly lower compared to maize following the other entries. Maize after Kayatan, which matures in 167 days had the lowest grain yield and dry matter yield of 2.07 and 3.04 t/ha. respectively. The maize crop subsequent to UPL Ri-5 also yielded

Table 3. Grain yield of promising upland rice selections under two management levels superimposed on the cropping pattern trials in acid upland environments. Claveria, Misamis Oriental. 1988 WS.

	Variety	Low Cash Flow	Moderate Cash Flow	Mean
1.	CNA 3145	1.22 bc	1.43 c	1.33 d
2.	CNA 4130	1.41 a-c	1.41 c	1.41 d
3.	CNA 5164	1.46 a-c	1.58 c	1.52 cd
4.	IAC 25	1.15 c	1.41 c	1.23 d
5.	IR 12979-21-1 (Brown)	1.56 a-c	2.55 ab	2.05 a-c
6.	UR 30716-B-1-B-1-2	2.08 a	2.06 bc	2.07 a-c
7.	IR 3880-2-3	1.89 a-c	2.774 ab	2.31 ab
8.	IR 47686-6-2-2-1	2.02 ab	3.10 a	2.56 a
9.	IRAT 144 5	1.59 a-c	2.03 bc	1.81 b-d
10.	UPL Ri-5 (check)	1.66 a-c	1.98 bc	1.82 b-d
	Mean	1.60	2.03	1.82

Table 4. Grain yield and other agronomic characters of promising upland rice varieties in an upland-rice-maize sequence. Claveria, Misamis Oriental. 1989 WS.

Cultivar	Grain Yield (t/ha)	Dry Matter (t/ha)	Plant Ht. (cm)
CNA 5164	2.98 b	2.23 a	110
Dinorado	3.01 b	5.57 ab	130
IAC 25	3.37 b	3.14 cd	114
IR 30716-B-1-B-1-2	4.78 a	3.32 cd	81
IR 47686-6-2-2-1	3.07 b	4.45 bc	120
Kayatan	1.36 c	5.49 ab	165
Speaker	3.28 b	6.35 a	158
UPL Ri-5	3.57 b	4.64 bc	102
Mean	3.18	4.40	
CV (%)	19.35	24.02	
LSD (0.01)	1.23	2.12	
(0.05)	0.90	1.55	

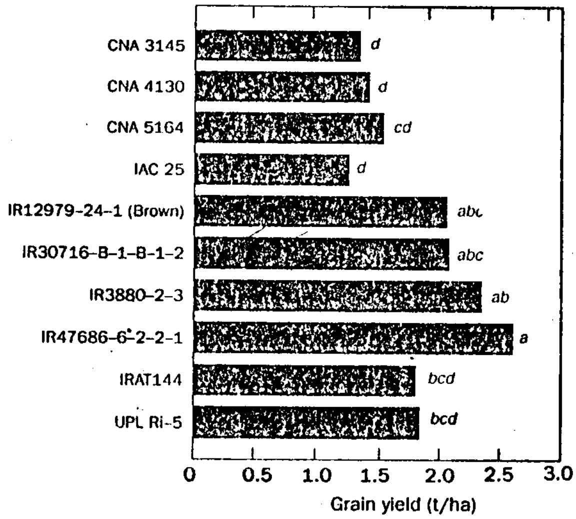

Fig. 3 Grain yield (t/ha) of promising upland rice selections under two management levels superimposed on cropping pattern tests. Claveria, Misamis Oriental. 1988 WAS.

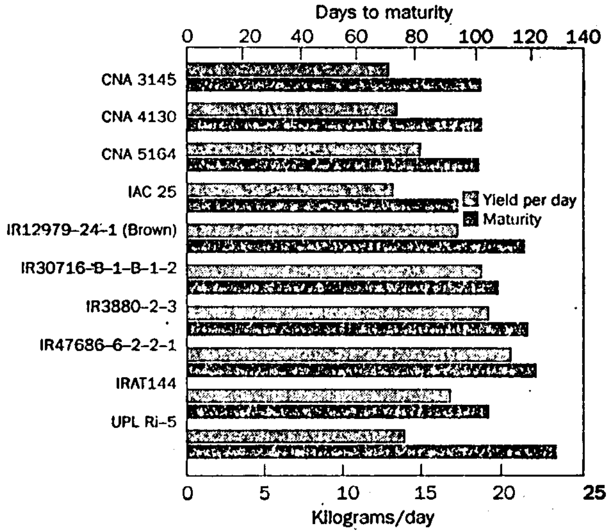

Fig. 4 Yield per day and maturity of primising upland rice selections under two management levels superimposed on cropping pattern tests. Claveria, Misamis Oriental. 1988 WAS.

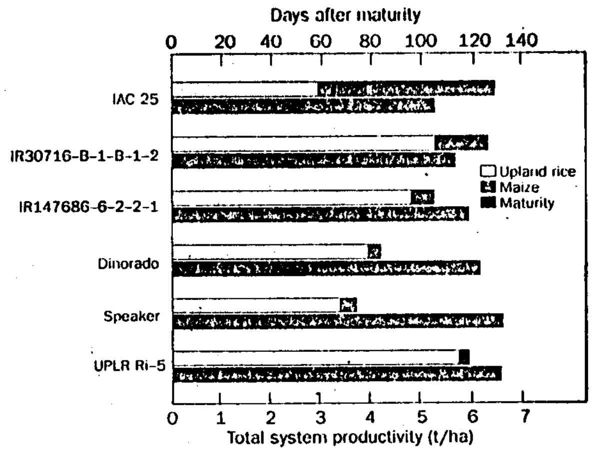

Fig. 5 Total system productivity of upland rice-maize crop sequences as affected by the different maturities of the component upland rice cultivars. Claveria, Misamis Oriental. 1988 WAS.

comparatively low, as it had in the previous year.

Figure 8 illustrates the relationship between the grain yield of the subsequent maize crop as affected by the maturity of the preceding upland rice crop. There is a proportional decrease in maize yield of approximately 46 kg for every day of delay in the maturity of the upland rice cultivar beyond 100 days. Thus, predicted maize yields decline 1380 kg/ha with a 130 day rice cultivar, and decline 2760 kg/ha with a 160 day traditional variety.

The common upland rice-based crop sequence of rice-fallow is mainly practiced because of the late maturity of the first crop of rice. This delay the establishment of second crop toward progressively drier periods of the crop year. This greatly increases the risk of failure of the maize crop, and causes predictable crop losses. Farmers would rather leave their land fallow rather than invest in a high-risk crop. Frequent maize crop failure is the inevitable situation when early-maturing rice cultivars are not grown.

Our results suggest that rice cultivars of 100-110 days are now available that tend to both maximize rice yields while providing the opportunity to follow rice with a productive maize crop. IR 30716-B-1-B-1-2 is an example or a prototype of such cultivars. It matures

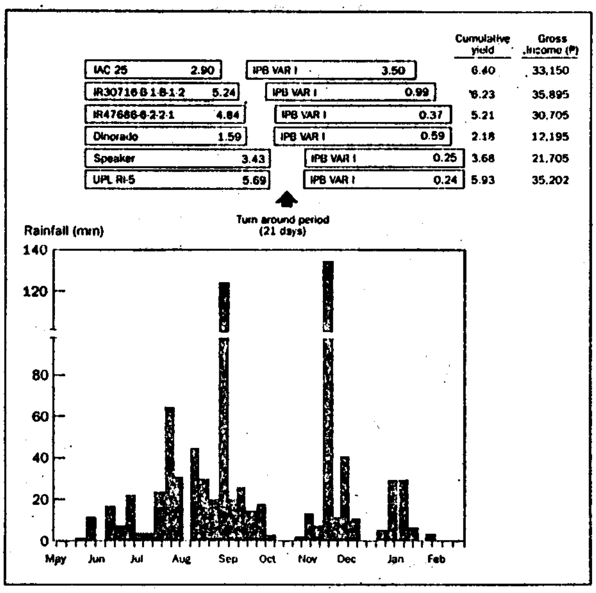

Fig. 6 Cumulative yield of an upland rice-maize crop sequence as affected by rainfall distribution and different maturities of the component rice cultivars. Claveria, Misamis Oriental. 1988 WAS.

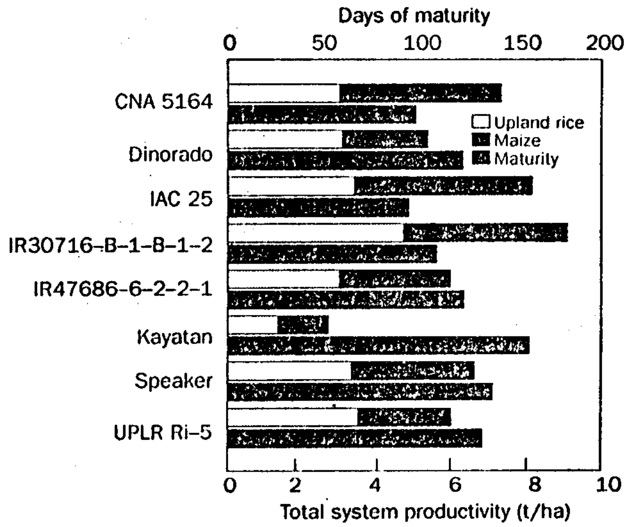

Fig. 7 Total system productivity of an upland rice-maize crop sequences as affected by the different maturities of component upland rice cultivars. Claveria, Misamis Oriental. 1989 WAS.

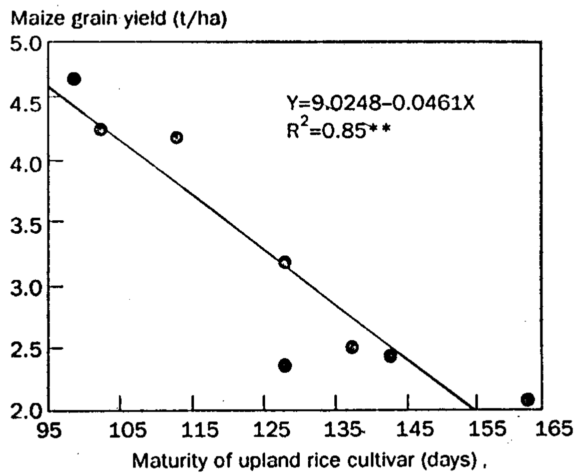

Fig. 8 Relationship between grain yield of maize and the maturity of the preceding upland rice cultivar in an upland rice-maize crop sequence. Claveria, Misamis Oriental. 1989 WAS.

in 108-110 days and has consistently yielded superior across years and locations. It produces a yield per day of 30 kg/ha. compared to 24 kg/ha for UPL Ri-5. Over four years of tests its average yields were higher than those of UPL Ri-5 while its duration was more than 20 days shorter. By enabling a successive crop to be grown such cultivars have major implications for enhancing the total productivity of upland rice-based cropping systems.

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