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UPLAND RICE IMPROVEMENT UNDER SHIFTING CULTIVATION SYSTEMS IN THE AMAZON BASIN OF PERU

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North Carolina Agricultural Experiment Station

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Upland rice is the main crop produced in the Peruvian Amazon Basin. The agricultural system consists of a shifting process in which rice and other crops are grown after clearing and burning a forest. The results of a 19 month research study on the poorly drained soils are presented. Varietal experiments show the superiority of short-statured plants in being able to double the yields of traditional varieties. Spacing experiments point toward significant yield increases over conventional spacing methods and the benefit of closer spacing in the presence and absence of Pyricularia Oryzae attacks. Lastly, fertilization experiments show the responses of first and second rice crops to nitrogen, phosphorous and potassium. Factors which can limit continuous cropping in this soil and climate are weed control and the change from broadleaved to grass population. The fertility decline common in shifting cultivation systems did not severely affect yields during the rice crops.

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Upland Rice Improvement Under Shifting Cultivation Systems in the Amazon Basin of Peru

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Upland Rice Improvement Under Shifting Cultivation Systems in the Amazon Basin of Peru

Introduction

Upland rice is the most important annual crop produced in the Peruvian Amazon Basin (Cha, 1967). This immense ecological region occupies approximately half of Peru's land surface and extends deeply into Brazil, Bolivia, Colombia and Ecuador. Its agriculture is based almost entirely on a shifting cultivation system in which rice and other crops are grown after clearing and burning a forest, after which the fields are abandoned to the fast forest regrowth. Although less than 20 percent of Peru's rice is presently produced in this region, its vast potential in view of forthcoming road connections with the rest of the country and Brazil prompted the National Rice Program to initiate a research project on upland rice improvement there. This bulletin summarizes the results of the first 19 months of research conducted on poorly drained soils.

Review of the Literature

The Peruvian Selva consists of two distinct ecological regions. The High Selva or Ceja de Montaña occupies the easternmost Andean valleys of Jaen-Bagua, Central Huallaga, Satipo and Pachitea. The altitude ranges from 300 to 1000 meters above sea level and the valley soils have high base status. The Amazon Basin proper or Selva Baja occupies the area east of the last Andean chain. The Basin's overall slope is extremely gentle; for example, the altitude at Yurimaguas is 183 meters and at Iquitos, 390 kms away, it is 108 meters. However, large areas have a strong local relief composed of terraces of different ages along the broad, meandering rivers.

Climate

The predominant climate type is the Humid Tropical Forest according to Tosi (1962). It is characterized by mean annual temperatures greater than 24°C, annual rainfall between 2,000 and 4,000 mm and evapotranspiration coefficients lower than 1. A strip along the Ucayali river near Pucallpa is its only exception, where rainfall is considerably lower. A short dry season of varying intensity occurs during the months of June to September (Sanchez, 1969). Temperatures and relative humidities are high and constant.

Soils

Approximately 2 percent of the Selva Baja's soils have been mapped at the reconnaissance level (ONERN, 1969). The Yurimaguas soil survey recently mapped over half a million hectares around that city into broad soil associations (ONERN, 1967). These studies indicate the predominance of well and poorly drained Ultisols and Alfisols, plus a small but important

proportion of young alluvial soils along the river margins (Zamora, 1966). The proportion of true Oxisols in the Selva Baja seems low. Tables 1 and 2 illustrate the distribution and characteristics of the main soils groups. Upland rice is grown on both acid and fertile alluvial soils not subject to permanent flooding.

Table 1. Principal soils of the 562,440 has. mapped around Yurimaguas

Great Soil Groups	Suborder (7th Approx.)	% of area mapped	Soil Series
Red-yellow podzolic	Udults	28.9	Shanusi, Yurimaguas
Ground water laterites	Aquults,	27.7	Pucallpa
Tropical humic gleys	Aqualfs	19.0	Aguajai (permanently flooded)
Forested alluvials	Aquults	8.3	Sanango (not floodoble), Loreto (floodable).
Brown forest	Fluvents	7.0	Santa Maria (calcareous)
Tropical podzols	Psamments	3.2	Sipa
Others		5.9	Convencion, Perene, Apurimac and lakes.

Adapted from ONERN, 1967.

Table 2. Representative properties of major rice soils in Yurimaguas (A horizon)

Soil Series	pH	% O.M.	Avail P kg/ha	Avail K kg/ha	% Base Satn.	% Clay
Shanusi	4.8	1.3	39	56	32	14
Yurimaguas	4.6	2.9	9	338	42	12
Pucallpa	4.2	3.5	6	307	33	22
Sanango	7.5	1.9	11	338	100	12
Loreto	7.5	6.0	17	338	97	28

Source: ONERN, 1967.

Cultural practices

Upland rice is grown on both flat and sloping areas. The main cropping system is known locally as "altura" or "tacarpo" to distinguish it from a small proportion of the rice area which is broadcast on the deposition shores of major rivers during the dry season known as "barriales". Land preparation in the tacarpo system starts with the cutting and burning of a mature secondary forest during the drier months of July to September. Without further land preparation, the jungle farmer drops an average of 8 to 20 seeds of a varietal mixture, known as Carolino in the north and Estaquilla in the south, in holes ranging from 8 to 15 cms in depth bored with a pointed stick called "tacarpo". Spacing between holes averages 50 x 50 cms in a very irregular pattern due to the high proportion of the soil occupied by tree trunks, stumps, fallen and partly burned branches. The crop is neither fertilized nor irrigated. The cultural practices between planting and harvesting are limited to manual weedings sometimes supplemented

with a 2,4-D application to control broad-leaved weeds and regrowth from fallen trees. The rice blast disease, caused by *Pyricularia oryzae*, is the most serious disease and occasionally devastates entire farms. Rats, other rodents, birds and insects also cause serious damage. Due to the varietal mixture and the excessive spacing, the crop matures disuniformly and the farmers harvest panicle by panicle. Yields are low, between 1,000 and 1,500 kg/ha. The fields are normally left to the very fast jungle regrowth, which attains full height in 8 to 15 years, and are cut again to start a new cycle. Land is abundant; people are scarce (Nureña and Sánchez, 1970).

Experimental Procedure

The Yurimaguas area was selected for this study because of its representative soil and climatic conditions of the Selva Baja and also because it is the largest and most rapidly expanding upland rice producing area in the country. A 5-hectare field located on a fairly flat area beyond the third terrace from the Shanusi river was lent to the National Rice Program through the courtesy of Mr. Domingo Loero Jr. of Hacienda San Ramón S.A. The soil is classified as Pucallpa clay loam, a Typic Tropaqualf, clayey, mixed, isohyperthermic (Sánchez and Buol, 1971). Its analysis appearing on Table 3 shows a thin dark A horizon underlain by acid layers rich in exchangeable aluminum with visible manganese concretions. A secondary forest of approximately nine years of age was cut and burned in the conventional manner in September, 1968. The monthly rainfall averages during this period appear in Fig. 1 plotted against the 20-year average. This figure shows no unusual departure from the average except for dry periods during February and April, 1969. Temperature and relative humidities were essentially normal.

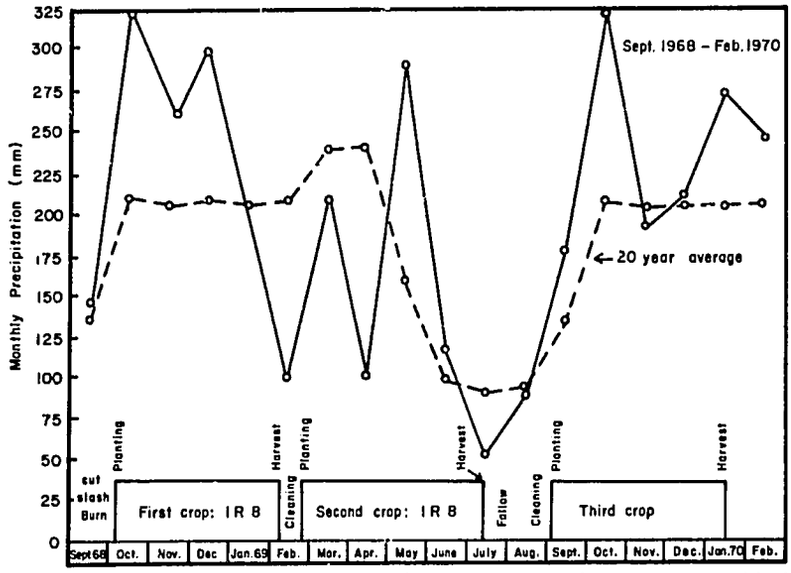

Fig. 1. Monthly rainfall distribution during the study period compared with the 20-year average.

Preliminary trial

The first rice crop was grown for seed production purposes in 0.5 to 1.5-hectare plots to evaluate several seemingly logical improvements on varieties, closer spacing, fertilization and weed control at a farm scale. Three promising varieties, SML457-Apura, IR8 and IR5 were seeded in the conventional way but with spacings of 35 x 35 or 45 x 45 cms between holes. The fields were fertilized with 20 kg N/ha as urea approximately 30 days after seeding. Two 2,4-D applications at the rate of 2 lt a.i./ha were applied to control broadleaf weeds and regrowing trees.

Varietal experiments

After the first harvest, the field was divided into several formal experiments. Two observational yield trials and five replicated yield trials were conducted during this period to evaluate the performance of short-statured plant types under upland conditions. A total of 349 varieties and selections from the Philippines, Surinam, United States, and the Peruvian Coast were evaluated in 10 or 15 m^2 plots planted with a stick and spaced 25 x 25 cms. The experiments received from 20 to 50 kg N/ha as urea and were sufficiently hand weeded. Grain yields were obtained from a 5 m^2 area devoid of border effects and adjusted to 14 percent moisture. Plant characteristics and yield components were measured in four hills chosen at random and free of border effects. Unless stated otherwise, the same methodology was followed in other experiments.

Planting methods

The conventional seeding method of sowing from 8 to 20 rice seeds in holes dug with a tacarpo stick, which are left uncovered and spaced irregularly at an average of 50 x 50 cms, was considered inefficient due to germination problems, poor competition with weeds, uneven ripening and perhaps lower yields. A possible advantage of wider spacing could be the attenuating effect on blast attacks due to micro-climate with lower humidity than closer spacing. Most farmers cannot expect to plow their land due to the myriad of tree trunks, branches, and roots present; however, they could reduce the spacing between holes. In some areas, where mechanized cutting of the forests is feasible or where a continuous second or third crop could be grown after most of the branches and roots have rotted, drilling rice in rows could be accomplished after rototilling with small hand tractors. These possible improvements were studied in two experiments planted in January and October, 1969 using the variety IR8 which was resistant to the blast disease until September but became highly susceptible afterwards (Huerta, *et al*, 1970).

The January 1969 experiment compared the conventional "tacarpo" system with 50 x 50 cms spacing and 14 seeds per hole against a "modified tacarpo" of 25 x 25 cms spacing with 3, 5, 7, and 14 seeds per hole which produced seeding densities of 17.5, 35 and 70 kg/ha, and with direct seeded rows drilled at 3-4 cms deep, and spaced at 25 cms between rows with seeding densities of 25, 50 and 100 kg/ha. The experiment was planted on January 16, 1969 on 25 m^2 plots arranged in a randomized complete block design with four replications. The hole depth (a great source of variability)

was calibrated at 10 cms. The holes were left open as is normally done. The experiment received a total of 100 kg/ha of N and P_2O_5 using urea and ordinary superphosphate as sources. All of the phosphorus and half of the nitrogen was applied below the seeds at planting and the rest of the N was applied at the panicle initiation stage. Weeds were controlled by hand, and germination failures in some holes due to excess or lack of water were corrected a week after planting. Rainfall during the growth period (Fig. 1) was beneficial to the crop. No incidence of blast was observed.

The second experiment compared three planting systems: drilled rows at 25 cms, drilled rows at 15 cms, tacarpo at 25 x 25 cms at 25, 50, 75, and 100 kg/ha seed densities were tested against the conventional tacarpo of 50 x 50 cms at densities at 25 and 50 kg/ha (20 and 40 seeds per hole) with the same variety. Fertilizer applications of 100 kg N/ha and 200 kg P_2O_5/ha were applied in the same manner as in the first experiment. The experiment was laid out in 15 m² plots in a randomized complete block design with three replications. Cultural practices were similar to the former experiment except that no corrections due to poor germination were carried out. Stand counts at 15 days after seeding provided a comparison of germination ability between planting systems.

Fertilization experiments

Two experiments were conducted during the first and second crops after clearing to determine the responses to nitrogen, phosphorus and potassium. The first trial sown in November 1968, consisted of 24 N, P, K combinations arranged in a centroid design with two replications. The SML-Apura variety was sown in tacarpo holes spaced at 25 x 25 cms with 16 seeds per hole. The second fertilizer trial compared five P and K levels, and two N levels broadcast in halves at the tillering and panicle initiation stages. The IR8 variety was drilled in rows in October 1969 and spaced at 25 cms with a seeding density of 50 kg/ha. The design was a randomized complete block with two replications. A third fertilizer experiment was installed during the same week to evaluate variety-nitrogen interactions. It consisted of five varieties of contrasting plant type and six nitrogen levels arranged in a randomized complete block design with three replications. The experiment was direct-seeded in rows spaced at 25 cms at a seeding density of 50 kg/ha. Phosphorus at the rate of 200 kg P_2O_5/ha was broadcast and incorporated in the topsoil with a rake. Half of the nitrogen was applied 21 days after seeding and half at panicle initiation. The fertilizer materials used were urea, ordinary superphosphate and potassium sulfate.

Continuous cropping experiment

In the half hectare of the first IR8 crop harvested on February 10, 1969, continuous cropping was attempted to determine the feasibility of keeping rice growing in spite of the weed control and fertility decline problems common to this system (Nye and Greenland, 1960). The second crop consisted of two experiments, one in which the ratoon of the original crop was compared with a second seeding and the second consisted of a simple rotation with several bean species. The ratoon crop-reseeding experiment was laid out in 25 m² plots in a randomized complete block design with four replications. The fertilizer differentials were 0 and 50 kg N/ha, applied half

at cutting or seeding and half at approximately the panicle initiation stage. All plots were weeded by hand prior to planting and three times during crop growth. Part of the lot used for the second continuous rice crop harvested on July 14, 1969 was cleaned of weeds on September 4. Low rainfall during July and August prevented the seeding of the third upland rice crop until the onset of the rainy season. The third crop was actually a replicated yield trial with 34 varieties in 10 m^2 plots arranged in a randomized complete block design with two replications. Seeding was done on September 5, 1969 in tacarpo holes at 25 x 25 spacing and a seed density of 75 kg/ha. The experiment received a total of 150 kg N/ha in split applications at planting and 66 days after and 50 kg P_2O_5/ha at planting. Weeds were satisfactorily controlled but a serious blast attack affected the varieties to different degrees. In a portion of the field which had already had two previous crops a multiplication plot of IR8 was seeded on October 12 in a similar manner but without fertilization.

Results and Discussion

Preliminary trial

The performance of the three rice varieties planted in large scale are shown in Table 4. These results show how the use of improved varieties and simple cultural practices duplicated the area average yields at the farm level. No serious blast outbreaks were observed. IR8 produced the most promising results due to its higher tillering capacity and early maturity. The slightly higher yields of Apura were partly due to a better location but its late maturity, low tillering capacity and higher grain sterility caused serious doubts about its potential for the region. Several Apura crops failed in farmers' fields in areas affected by droughts and lower soil fertility. IR5 did not seem promising because of its longer growing season and obvious blast susceptibility.

Varietal performance with time

The main results of the variety trials appear in Table 5. The complete results of the seven experiments and evaluation for blast resistance in International Uniform Blast Nurseries have been described elsewhere (Nureña, 1969, 1970; Velazquez, Huerta and Sánchez, 1970, and Huerta, *et al*, 1970). The combination of high yielding ability, blast tolerance and acceptable grain quality has not yet been found. This table shows the variability in yields obtained from various experiments planted at different times of the year. The extremely low yields during the May and June planting were caused by severe water stress throughout the growth period, during Yurimaguas' weak dry season. IR4-2, IR4-93-2 and IR8 averaged between 3.5 and 3.0 tons/ha or almost twice than the local check, Carolino. Two recent entries, IR224-7-1-1 and IR480-5-9-2, produced over 6 tons/ha in the September planting, significantly outyielding IR8 and others. These have been blast resistant up to this date, and IR480 shows excellent grain appearance. No varieties have been released to farmers, mainly because of blast susceptibility.

Table 3. Characteristics of the soil used in the research project

Horizon (cm)		pH	% O.M.	Olsen P ppm	Exchangeable cations (meq/100g) Al	Ca	Mg	K	Na	CEC (sum)	% Base satn.	% Clay	Clay minerals Ko.	Mt.	Ill.
A_1	0-5	5.5	4.6	7	0.55	14.0	5.5	0.72	0.36	21.13	97	46	xx	xx	x
B_{21g}	5-25	4.9	1.3	1	9.20	10.8	6.5	0.66	0.38	27.55	67	56	xx	xx	x
B_{22g}	25-80	5.0	1.1	1	12.50	9.0	6.0	0.42	0.42	28.35	56	54	x	xxx	0
B_{23g}	80-100	5.2	0.7	1	14.55	10.4	7.3	0.44	0.68	33.37	56	64	x	xxx	tr

Source: Sanchez and Buol, 1971.

Table 4. First crop results at the Yurimaguas Experimental Field

Variety	Grain yields kg/ha[1]	Days to 50% flowering	Growing season (days)	Plant height (cms)	Tillers/ m^2 harvest	Panicles/ m^2	Grains/ panicle	% unfilled grains
SML457-Apura[2]	3,663	134	175	145	162	136	212	18
IR8[3]	3,151	102	125	92	355	310	180	2
IR5[4]	2,882	126	165	86	158	142	130	4

[1] *Average farm yield for the area 1000-1500 kg/ha.*
[2] *Planted Sept. 17-21; harvested March 10, 1969.*
[3] *Planted Oct. 8-11, 1968; harvested Feb. 10, 1969.*
[4] *Planted Nov. 4, 1968; harvested April 18, 1969.*

Table 5. Varietal performance as a function of time under upland conditions in Yurimaguas. Treatment means in kg/ha at 14% H_2O

Date of seeding: Variety or selection	Nov. 1968	Jan. 1969	May 1969	June 1969	Sept. 1969	Nov. 1969	Blast[1] reaction
IR4-2	6300	3040	903	1030	5589	4116	S
IR4-93-2	3507	3372	2338	1820	4708	N.T.	S
IR8	5067	3290	734	833	4820	3840	S
IR5	3253	3852	1505	1891	2700	N.T.	S
IR11-222-4	3095	3575	736	691	4028	2142	S
SML457-Apura	2900	2893	1411	1306	N.T.	N.T.	M
Carolino (local)	2933	1712	421	439	2253	2011	S

N.T.: Not tested.

[1] *: Worst reading in blast nurseries.*

Planting systems, seed density and spacing

Results of the first experiment of this series (Table 6) show that reducing the spacing, either by rows 25 cms apart or by tacarpo holes 25 x 25 cms, significantly increased yields over the conventional practice. The highest yields were obtained at the medium planting density of 35 to 50 kg/ha in the modified tacarpo (5676 kg/ha) and the row seeding (5934 kg/ha) systems both of which were significantly superior to the other treatments in each planting system but not between themselves. The high yield of 4251 kg/ha in the conventional treatment reflects the better than average management practices. The number of panicles per m^2 was the yield component most closely related to yield increases with closer spacing. The differences between the 25 x 25 cms spacing and 25 cms rows were probably offset by panicle size as it has happened elsewhere (Sánchez and Calderón, 1970). Closer spacing increased yields up to 1.7 tons/ha or by 40 percent over the check plot.

The second experiment of this series permitted a comparison of seedling emergence between the "tacarpo" and drilled planting systems. Fig. 2 shows a significantly higher germination and seedling establishment percentage in the drilled row systems than in the tacarpo holes, with the exception of the 25 x 25 cms tacarpo at the lowest plant density equivalent of 5 seeds/hole. The hazards of leaving seeds exposed in open holes is substantial since birds and rodents immediately attack them, holes get full of water during heavy rains and the germinated coleoptiles can dry out during sunny weather. Although the holes are left open, some soil falls into them from the sides and partially covers the seeds. The better moisture relations attained with drilled rows is obvious from the results of this experiment. Tacarpo holes covered with soil are also unsatisfactory because of their extreme depth of seeding.

Thirty-five days after seeding, the experimental field was heavily attacked by blast with lesion sizes No. 5 and 6 during a drought period, which resulted in a large proportion of dead leaves and plants. The experiment seemed lost, but it recovered after subsequent heavy rains at about

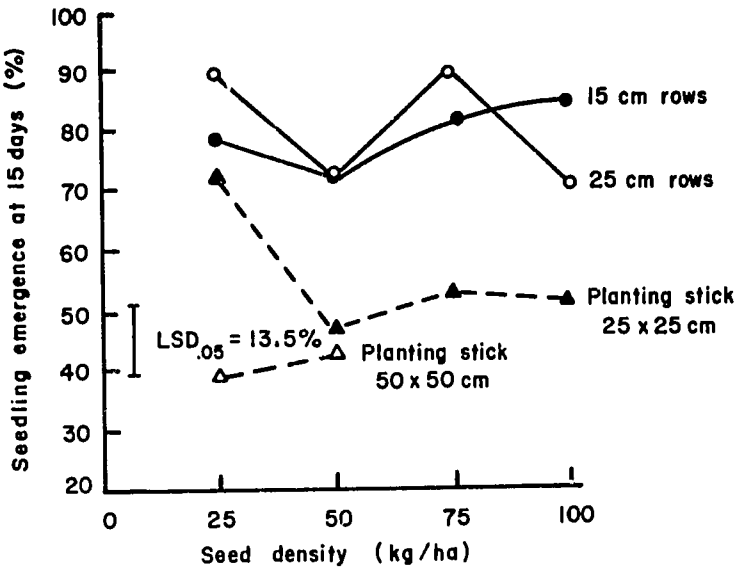

Fig. 2. Influence of drilled row and open hole (tacarpo) planting systems and seed densities on the % seedling emergence of upland IR8 rice.

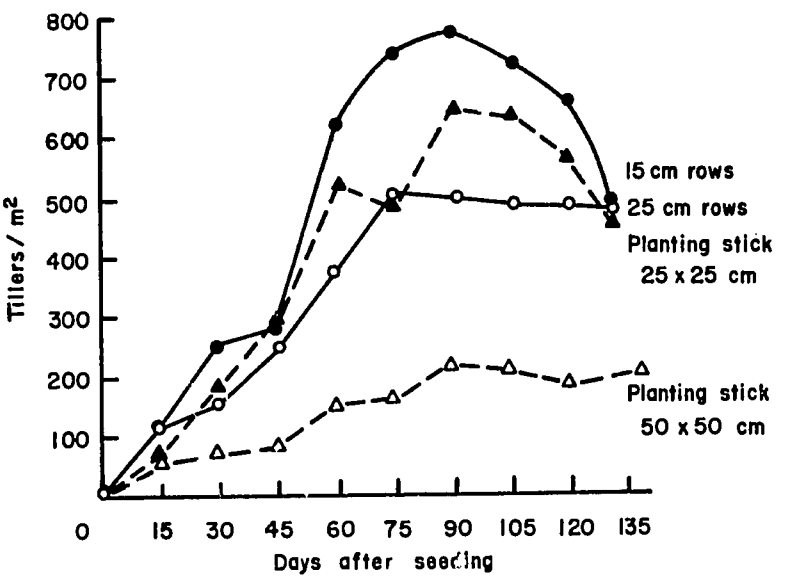

Fig. 3. Tiller production pattern in four planting systems of upland IR8 rice affected by blast attacks. Seed density 50 kg/ha.

Table 6. Effects of planting systems and seeding densities on the performance of IR8 rice under upland conditions. January 1969 planting. Mean of 4 replications

Planting system	Seed density		Yields kg/ha (14% H_2O)	Days to 50% flowering	Panicles/ m^2	Ineffective tillers/m^2	Panicles/ hill
	kg/ha	seeds / hole					
Rows 25 cms	25	—	5282	98	668	12	—
	50	—	5934	96	712	36	—
	100	—	5504	90	682	58	—
Tacarpo holes 20 × 25	15.5	3.5	5013	115	444	10	28
	35	7	5676	109	482	52	30
	70	14	5175	102	520	64	33
Tacarpo holes 50 × 50	17.5	14	4251	112	197	31	49

$LSD_{.05}$: 312 kg/ha $CV(X)\%$: 22.6%.

Table 7. Effects of planting systems and seed densities on the performance of upland IR8 rice affected by blast attacks. October 1969 planting. Mean of 3 replications

Planting system	Seed density		Yields kg/ha (14% H^2O)	Days to 50% flowering	Panicles/ m^2	Ineffective tillers/m^2	% unfilled grains	% dead area
	kg/ha	seeds per holes						
Rows 25 cms	25	—	2868	113	317	132	50	20
	50	—	3959	111	299	194	62	7
	75	—	3524	115	256	169	41	20
	100	—	4195	111	333	131	43	12
Rows 15 cms	25	—	3591	112	390	190	49	12
	50	—	4410	113	350	138	39	7
	75	—	3790	107	380	120	44	4
	100	—	3804	110	382	244	53	6
Tacarpo holes 25 x 25	25	5	4205	112	333	96	46	9
	50	10	3635	110	364	88	50	14
	75	15	3430	110	305	148	60	10
	100	20	3570	110	289	112	45	5
Tacarpo holes 50 x 50	25	20	3222	112	122	53	54	6
	50	40	2556	120	100	120	57	6

$LSD_{.05}$: 869 kg/ha $CV(X)$: 14.8%

60 days after seeding. The resulting yields (Table 7) were much lower than in the previous experiment. The tillering pattern (Fig. 3) shows a reduction in tillering rate during the blast attack followed by later increases which resulted in a high proportion of ineffective tillers. These lower yields were associated with a lower number of panicles/m², a higher proportion of ineffective tillers, a proportion of unfilled grains in the order of 50 percent and a variable proportion of empty areas caused by plant death as well as higher statistical variability (Table 7).

In the row-sown systems, the lowest seed density produced lower yields than the other three, which showed no clear trend among themselves or within row spacings. The modified tacarpo system of 25 x 25 cms spacing produced similar yields as the row-sown system. The conventional tacarpo spacing of 50 x 50 cms produced significantly lower yields of approximately 1 ton/ha less than the 25 x 25 cms spacing.

This experiment shows that even in the presence of a severe blast attack, closer spacings are still superior to the conventional practice. Apparently, no favorable microclimate effects of wider spacing were reflected in growth or yields.

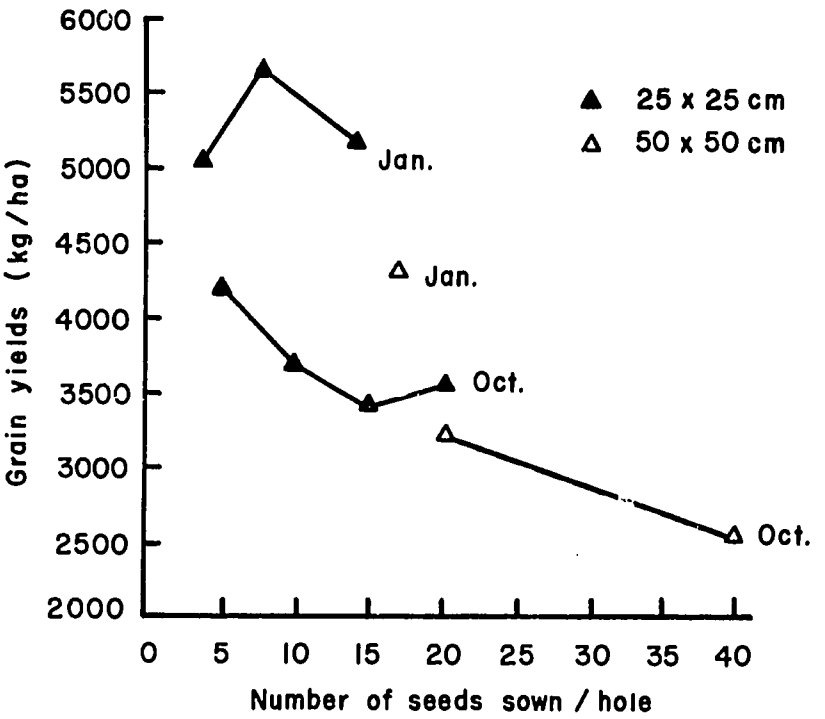

Fig. 4. Effects of the number of seeds sown per hole on upland IR8 yields under two spacings and two planting dates.

In both experiments, planting in holes at 25 x 25 cms spacing produced yields comparable to direct seeding in rows. Farmers who cannot plow their land could increase their yields by closer spacing. However, the number of seeds planted per hole is inversely proportional to yields as shown in Fig. 4, which could result in considerable certified seed savings, although many farmers believe that the greater the seeding density the higher the yields. Sample counts by the authors have shown that farmers drop up to 40 or 50 seeds per hole.

Fertilization

Results of the first N, P, K trial after clearing the jungle appear in Fig. 5. No significant responses were observed. The native fertility was high enough to produce over 5000 kg/ha with the Apura variety. The second N, P, K trial, installed as a second crop and without previous P or K additions, showed again the absence of responses to P and K and a small response to N (Figs. 6 and 7). The lower yields obtained are associated with a blast attack during the second month of growth.

The variety-nitrogen experiment planted as a second crop is shown in Fig. 8. The blast attacks affected most severely the local varieties Carolino and Lambayeque G-49 with Grade 6 lesions, followed by IR5 and IR8 with Grade 5 and IR4-2 with Grade 4 lesions. These results show no nitrogen responses in the lodging-susceptible local varieties. IR4-2 produced the best yields and responded positively, up to 60 kgN/ha, but the economic optimum seemed closer to 30. IR8 showed an erratic response caused by low panicle production at the 60 and 90 kgN/ha with increases at higher rates. IR5 responded at a slower rate perhaps due to a heavier blast infestation. These results show the yield superiority of the short plant types and a moderate response to nitrogen only with more tolerant varieties. Superior plant type and higher blast tolerance happen to be correlated in this experiment.

Continuous cropping

After the first IR8 crop reported in Table 4, the ratoon was compared with plots reseeded with the same variety. Low rainfall during the initial growth stages (Fig. 1) caused severe water stress. The results appearing on Table 8 show the poor performance of the ratoon crop which was reflected in the low number of "hills" which ratooned and low tillering in relation to the reseeded crop. No nitrogen response was observed.

Several bean species produced up to 710 kg/ha of dry beans after the first rice crop and during the dry season, showing some potential for pulses and other crops to be rotated with rice.

The third rice crop yielded from 1771 to 6257 kg/ha depending on the variety, with a mean of 4064 kg/ha. The unfertilized contour plot averaged 2582 kg/ha. A summary of several three-crop combinations from October 8, 1968 to March 1970 appears in Fig. 9.

The optimum combination, two consecutive crops of IR8 followed by IR224-7-1-1, produced the equivalent of 12183 kg of rice per hectare in 14 months and 20 days counted from the first day of seeding to the last harvest.

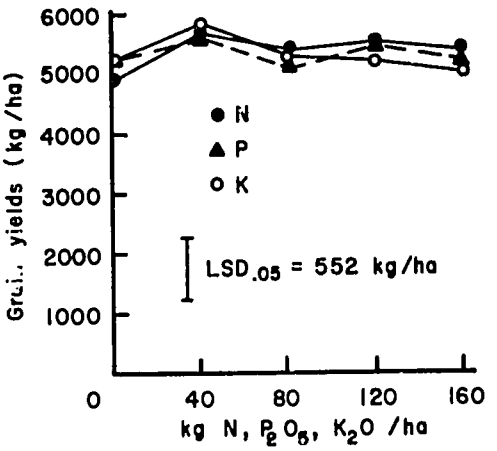

Fig. 5. Individual responses to N, P and K on the first upland rice crop grown after cutting a forest. SML457-Apura variety. Nov., 1968—March 1969.

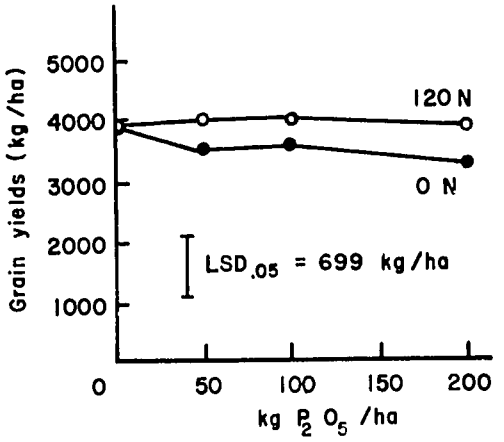

Fig. 6. Phosphorus response of two levels of nitrogen in upland IR8 rice. Oct. 1969 through Feb. 1970. Mean of K treatments and two replications.

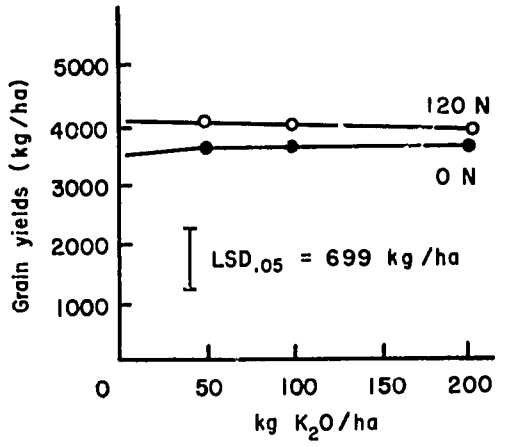

Fig. 7. Potassium response at two levels of nitrogen in upland IR8 rice. Oct. 1969—Feb. 1970. Mean of P treatments and two replications.

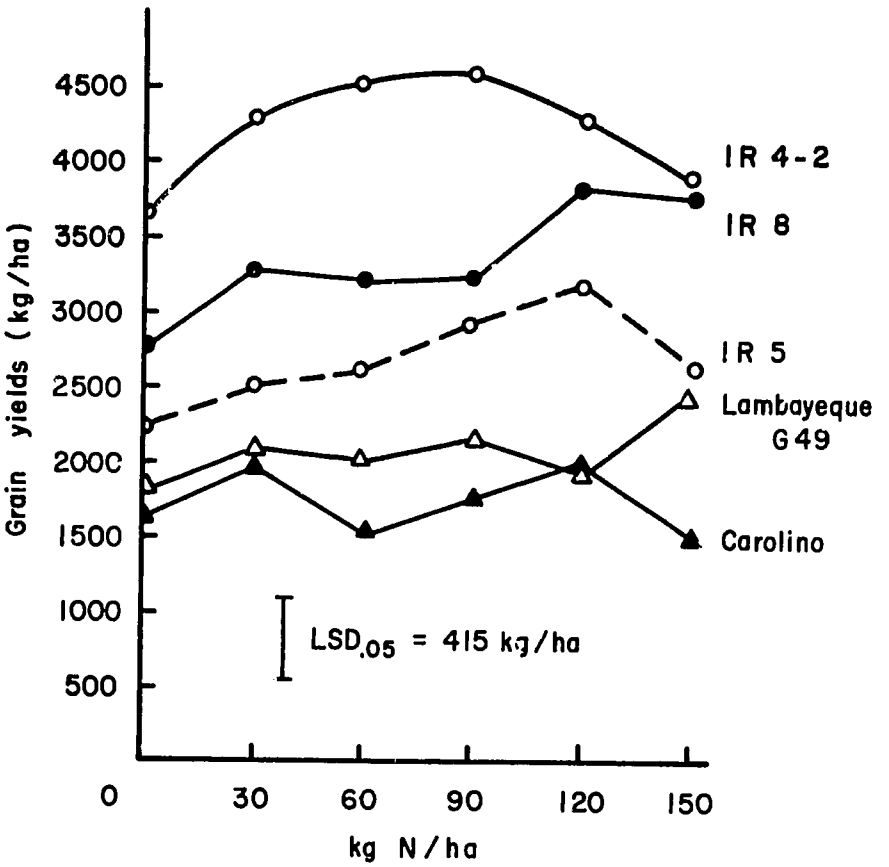

Fig. 8. Varietal response to nitrogen under upland conditions in Yurimaguas. Oct. 1969.

Table 8. Second crop results comparing a reseeded and ratoon crop of IR8 in Yurimaguas. February 28-July 14, 1969

Second crop	N applied kg/ha	Yields kg/ha	Days to 50% flowering	Days to harvest	Ponicle/ m^2	Hills/m^2 harvested
Reseeded	0	2,521	96	123	382	15.3
Reseeded	50	2,775	93	122	444	15.4
Ratoon	0	666	50	96	127	6.2
Ratoon	50	598	51	96	129	6.5
CV(X)% :		8.4	1.3	1.5	13.4	4.4
$HSD_{.10}$:		237	2	3	62	0.8

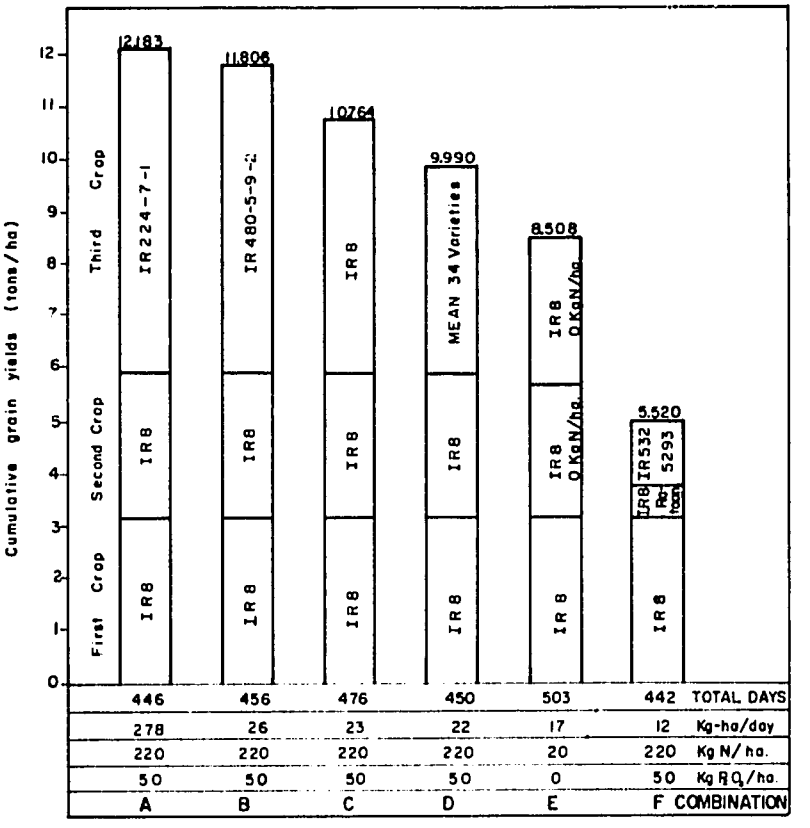

Fig. 9. Cumulative production of several three consecutive upland rice crop combinations. Oct. 1968 to March, 1970.

Combination B which includes the only agronomically relevant, blast tolerant variety to date in the Selva also showed a high production level of 11806 kg/ha in exactly 15 months. Three consecutive crops of IR8 produced 10764 kg/ha, probably because of its blast susceptibility during the third crop. The mean value of the 34 varieties included in the third crop added a total of 9990 kg/ha for the three crops in 14 months and 21 days. In all these cases the total fertilizer applications were 220 kg N/ha and 50 kg P_2O_5/ha.

The minimum fertilizer level combination "E" which received 20 kg N/ha and no phosphorus produced 8508 kg/ha in 16 months and 16 days. The worst combination "F" consisted of the ratoon crop followed by the selection IR532-E293 which was extremely susceptible to blast, resulted in 5520 kg/ha in 14 months and 16 days.

These studies have shown the physical feasibility of continuous cropping in acid Tropaqualfs presently under the shifting cultivation in the Amazon Basin of Peru. The yields obtained in about 14 months are almost 10 times the local average obtained with one crop and conventional practices. The economic feasibility of continuous cropping has not been yet determined; it probably depends on an economical weed control system. The hand weedings used to prevent forest regrowth in these experiments may have been too expensive. The 2,4-D applications now used to control broad-leaved weeds and tree regrowth are effective only during the first two crops because the weed population then changes almost exclusively to grasses. Experiments are in progress to test effective herbicides on both first and second generation weeds. Small hand tractors with rotary weeders could be effective after the second crop when most of the forest residues have rotted away.

This experiment has also shown that the fertility decline of this Tropaqualf, upon breaking the forest-soil nutrient cycle, is not so fast as to seriously limit a third consecutive upland rice crop, since about 8.5 tons/ha were produced with only an application of 20 kgN/ha. Soil profile examinations after harvesting the third crop showed a mass of fine fibrous roots concentrated in what remains of the A horizon, about 5 cms thick. A few large and fleshy roots penetrated the supposedly infertile B horizon down to 19 cms, where the water table was at the time. These roots had no iron coatings and apparently were taking up water from the subsoil, while the fibrous mat near the surface may have concentrated on nutrient uptake. A fourth consecutive crop including rice and other crops has been planted, and plans are to keep the field in constant production. These results are probably not applicable to the better drained Paleudults with lower base status than this Tropaqualf.

Summary and Conclusions

A series of experiments was conducted from September 1968 to March 1970 on a Typic Tropaqualf soil under a humid tropical forest vegetation in the Amazon Basin of Peru, where upland rice is grown under a traditional shifting cultivation system. A 5-hectare field was cut and burned in the conventional manner and first planted to 0.5 to 1.5-hectare plots for seed production purposes which yielded about 3,000 kg/ha.

Varietal improvement trials have shown the superiority of short-statured plants like IR8, which can double the yields of the traditional varieties. Most of the agronomically promising short types are susceptible to the blast disease particularly after September 1969. Experiments planted at different months showed the poor results obtained by plantings during the short dry season. Regardless of rainfall distribution, IR varieties yielded twice as much as local varieties throughout these trials.

Spacing experiments have shown significant yield increases over the conventional 50 x 50 cm wide spacing both in drilled rows and in holes dug at a 25 x 25 cms spacing. The beneficial effect of closer spacing was evident in the presence and absence of serious *Pyricularia oryzae* attacks.

Fertilization experiments have shown no N, P, K responses during the first rice crop and only moderate N responses during the second crop in the

order of 30 to 60 kg N/ha. The local lodging-susceptible varieties showed no response to nitrogen.

Three consecutive upland rice crops produced a maximum of 12 metric tons/ha of rice in 14 months and 20 days, including necessary fallow periods during the dry periods, with the use of short plant types, closer spacing and manual weed control.

The factors which could limit continuous cropping in this soil and climate seem to be weed control and the change from a broadleaved to grass population after two crops. The fertility decline common in shifting cultivation systems has not severely affected yields during the first three rice crops.

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