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LAND PREPARATION AND CROP ESTABLISHMENT FOR RAINFED LOWLAND RICE

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LAND PREPARATION AND CROP ESTABLISHMENT FOR RAINFED LOWLAND RICE[1]

ABSTRACT

New rice technology -- short duration varieties, herbicides, and tillage machinery with higher horsepower -- may make new systems of land preparation and crop establishment economically feasible. To identify conditions for adaption of alternative systems and to determine where further research is necessary, the characteristics of the traditional rainfed rice land preparation transplanting system and its alternatives are reviewed.

The major advantages of wetland tillage are reduction of draft requirements, improved weed control, ease of transplanting, enhancement of soil fertility, and reduction of percolation losses. The major disadvantages of wetland tillage are increased late-season drought risk, high transplanting labor requirements and power unit size limitations. Once the soil has been puddled, the method of crop establishment is restricted to transplanting or direct seeding of pregerminated seeds. Rainfed areas suitable for direct seeding are limited by drainage control. Weed intensity is an important consideration in determining whether rice should be transplanted or direct seeded.

Forms of dryland tillage for rice have been practiced in limited but suitable environments. The major advantages of dryland tillage are early crop growth that can be obtained from early rainfall, elimination of labor for seedbed preparation and transplanting, adequate trafficability for large power units, maintenance of soil structure for upland crops following rice (or increased time for a second rice crop), and reduction of many insect and disease pressures. The major disadvantages are high draft requirements, comparatively exacting early weed control requirements, comparatively high fertilizer losses, and exposure to soil-inhabiting insects and blast disease.

As with wetland tillage, possible methods of crop establishment are restricted once soil has been prepared in the dry state. Common establishment methods are broadcasting, drilling, and dibbling. The different establishment methods produce similar grain yields provided weeds can be controlled. The choice of a weed control technique compatible to establishment method is critical.

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Ultimately the choice of a land preparation-establishment system is determined by benefits and costs associated with alternative methods. Studies have shown that changes in technology and factor price relationships can result in significant changes in land preparation and crop establishment methods.

Because of the heterogeneity of rainfed rice environments, there can be no single set of recommended practices. Further research on land preparation and planting systems is needed to determine the possible advantages that advanced technology offers for specific environments.

LAND PREPARATION AND CROP ESTABLISHMENT FOR RAINFED LOWLAND RICE

Millions of experienced rice farmers prepare land for a rainfed rice crop guided by their judgment of soil texture, soil moisture, and rainfall patterns, topography, and degree of weed infestation. They use tillage methods that are within their labor and power resources. Stable yields and high returns are the objective of their field work but regardless of the strategies they use, yields vary from year to year and field to field. Thus, when deciding tillage and stand establishment methods, farmers who grow rainfed rice must keep in mind the expected, but often uncertain, rainfall.

For any crop, tillage practices usually greatly affect plant growth during the germination, seedling emergence, and stand establishment stages (Larson 1963).

Tillage practices that create conditions for rapid intake and temporary storage of water in the surface soil or in the tilled layer are needed to prevent runoff. If a farmer is asked why he performs a particular tillage operation, he may give different reasons. It is therefore imperative to seek answers to the questions relating to every tillage operation: Is it necessary? Would the crop grow as well or perhaps better without it? Is there value in plowing to loosen the soil only to repack it to the same bulk density it had before plowing? These and other questions should be carefully posed to select tillage practices based on sound scientific research (Blake 1963). Our discussion centers on land preparation and crop establishment methods for lowland rainfed rice. We examine tillage operations and establishment methods and discuss how they may vary depending on the moisture available from rainfall, soil factors, and resources available to the farmer.

SYSTEMS OF LAND PREPARATION AND CROP ESTABLISHMENT IN RAINFED LOWLAND RICE

For rainfed rice, the onset of the monsoon and, thus, the day length and solar radiation available during the growing season, determines planting time. Usually, tillage for rainfed rice is performed either when soil water is nearly saturated or saturated (wetland tillage) or when soil water is at less than field capacity (dryland tillage). A puddled seedbed is the objective of wetland tillage whereas a loose, granular seedbed is the objective of dryland tillage.

Rainfed wetland tillage

Wetland tillage. Before an alternative tillage method is advocated, the benefits of land preparation by traditional puddling must be considered.

During plowing, weeds and stubble are plowed under. Harrowing, actually several harrowings at shallow depths before rice seedlings are transplanted, turns the remaining weeds and stubble into the reduced soil layer. The lack of oxygen in the reduced layer inhibits weed germination and greatly reduces the weed population (De Datta 1973). In addition, soil puddling caused by the tillage substantially increases the water retained by the soil (Fukuda and Tsutsui 1968, Sanchez 1973, De Datta and Kerim 1974, Wickham and Singh 1977).

Because puddling reduces the chance of soil drying, the rainfed puddled system should produce a higher rice yield than a rainfed nonpuddled system.

The soil's penetration resistance decreases drastically after a soil has been soaked only a few days (Choon 1974). That decrease has two important implications.

- Draft requirements for plowing come into a range suitable for draft animals and power tillers.
- The soil's load-bearing capacity decreases and rolling resistance increases, both of which hamper tillage by large tractors.

When clay soils are plowed and harrowed at about soil saturation, several changes -- for example, markedly reduced air-filled pore volume, lower permeability, increase in moisture suction, lower resistance to raindrops, and increase in deformability -- take place in the soil (Koenigs 1963). An important difference between a dry soil and a puddled soil is the presence of oxidized and reduced soil layers. Ponnamperuma (1977) discussed electrochemical changes of submergence and the beneficial effects of reduction on the availability of nutrients to rice.

Puddling, as practiced in much of tropical Asia, although it involves a great amount of labor, has been widely accepted. The major advantages of rainfed wetland tillage are summarized as:

- Improved weed control.
- Ease of transplanting.
- Establishment of a reduced soil condition, which improves soil fertility and fertilizer management.
- Reduced draft requirements for tillage.
- Reduced percolation losses, and therefore conservation of rainfall as standing water during crop growth.
- Time delay imposed by puddling requirements increases chances of sustained rainfall.

The major disadvantages of wetland tillage for rainfed rice are:

- Delayed planting and harvesting, which may subject the crop to late season drought or reduce the possibility of successfully growing a second rice crop.

- The transplanting labor requirement (where topographical characteristics dictate transplanting must be practiced to avoid seed and young seedling submergence).

- Limitations on characteristics of power units suitable for tillage in the wetland fields.

Crop establishment method following wetland tillage. Once a soil has been puddled, manual transplanting of 20- to 40-day-old seedlings is by far the most common method. Broadcast-seeding of pregerminated seeds ranks a distant second. Other methods such as mechanical transplanting, dapog transplanting, and drilling of seeds have not been perfected for use in rainfed fields.

Water control is more critical for broadcast-seeded than for transplanted rice. Broadcast-seeding of pregerminated seed is limited in adaptation to the rainfed rice field because of a requirement for good drainage control, which means that the rice fields must be on land with sufficient slope to drain away undesired water from early heavy rains. Furthermore, broadcast-seeding requires a puddled surface that is level and smooth so that water will not accumulate in depressions and drown seedlings shortly after germination.

Where paddies are located in landscapes with enough relief to effect timely surface drainage and reduce flooding after intense early rainstorms, farmers can broadcast-seed rice with minor stand loss. In a Philippine Bureau of Plant Industry-IRRI cropping systems project at Iloilo, farmer-cooperators achieved high yields for the first crop in a rainfed 2-crop pattern for 2 years through broadcast-seeding methods (Table 1). The broadcast method reduced labor input and eliminated the difficulty in making proper seedling age coincide with completion of puddling for transplanting.

Weed control is an important consideration in determining whether transplanting or broadcasting should be used as a method of planting. Weed problems are

Table 1. Farmer-cooperator yields of first rainfed direct-seeded (broadcast) and second rainfed direct-seeded and transplanted rice crops, 1976-77 and 1977-78 wet seasons.[a] Iloilo Province, Philippines.

	First crop			Second crop					
				Direct seeded			Transplanted		
Season	Observations (no.)	Yield (t/ha)	SD (t/ha)	Observations (no.)	Yield (t/ha)	SD (t/ha)	Observations (no.)	Yield (t/ha)	SD (t/ha)
1976-77	41	5.3	1.5	37	2.2	1.6	4	3.5	1.4
1977-78	22	5.9	1.1	13	1.4	1.8	9	1.7	1.2

[a] SD = standard deviation.

greater in the broadcast-seed method than in transplanted rice (De Datta and Bernasor 1973).

Rainfed dryland tillage

Dryland tillage for lowland rice production in tropical Asia is practiced on a limited area. However, recent technological advances may cause an increase in area where dryland cultivation is suitable.

For many years, farmers in Bangladesh, northeast India, and Indonesia have seeded rainfed wetland rice directly on nonpuddled soils in bunded fields at the beginning of the rainy season. This method of rice culture is called *aus* cropping in Bangladesh and northeast India, and *gogo-rancah* in Indonesia.

The method takes advantage of early rainfall and allows time for a second crop of rice to be grown. The soil is tilled dry either manually or by animal-drawn implements. Often, the field is not prepared to a fine surface, and rice does not germinate uniformly and weeds grow vigorously. Risk of drought damage also increases.

The *aus* and *gogo-rancah* systems evolved locally in response to biological, physical, and economic factors. However, the following developments may make dryland tillage techniques economically feasible for a wider area:

- Early-maturing modern rice cultivars provide an opportunity to grow two rice crops if the first crop can be harvested sufficiently early.
- Power tillers and small tractors are manufactured in several tropical Asian countries at comparatively low costs and can be used for tillage and interrow cultivation; the greatest problem of using the *aus* and *gogo-rancah* systems over wider areas is a need for quick tillage of a dry field.
- Low-cost herbicides aid in combating early weed growth.
- Expanding population pressure, which simultaneously increases food demand and increases the agricultural labor force, has put more pressure on the land for increased food production.

Dry seeding of rainfed rice was tried recently on limited areas in the Philippines. In applied research trials at Bulacan, it was observed that on land prepared at the end of the previous wet season, a newly emerged rice crop survived a period of drought. In contrast, a crop seeded at the same time, but on land prepared just before seeding, suffered considerable drought damage. It was suggested that crop survival was due to the availability of soil moisture covered by a soil mulch during the dry season.

Bolton and De Datta (1977) ran experiments at IRRI in the dry and wet seasons to verify the conservation of soil moisture by a soil mulch, and to determine whether moisture was conserved because of weed control or because of the dry soil mulch. They also compared the time required for early dry-seeding of a rice crop after the dry soil mulch and that required for transplanting a crop after traditional wetland tillage.

Plots where land preparation was at the end of the previous wet season had a dry soil mulch from February to May. The soil moisture tension (SMT) under the mulch never exceeded 33 centibars. In contrast, the SMT in weedy-fallow plots was 5 bars at a depth of 15 cm by the end of the dry season despite a water table within 1 m of the soil surface during the whole period. Weed-free untilled plots conserved some moisture, but not as much as that conserved with the dry soil mulch (Fig. 1). Use of a dry soil mulch has potential as a practice to conserve soil moisture for early direct-seeded rice.

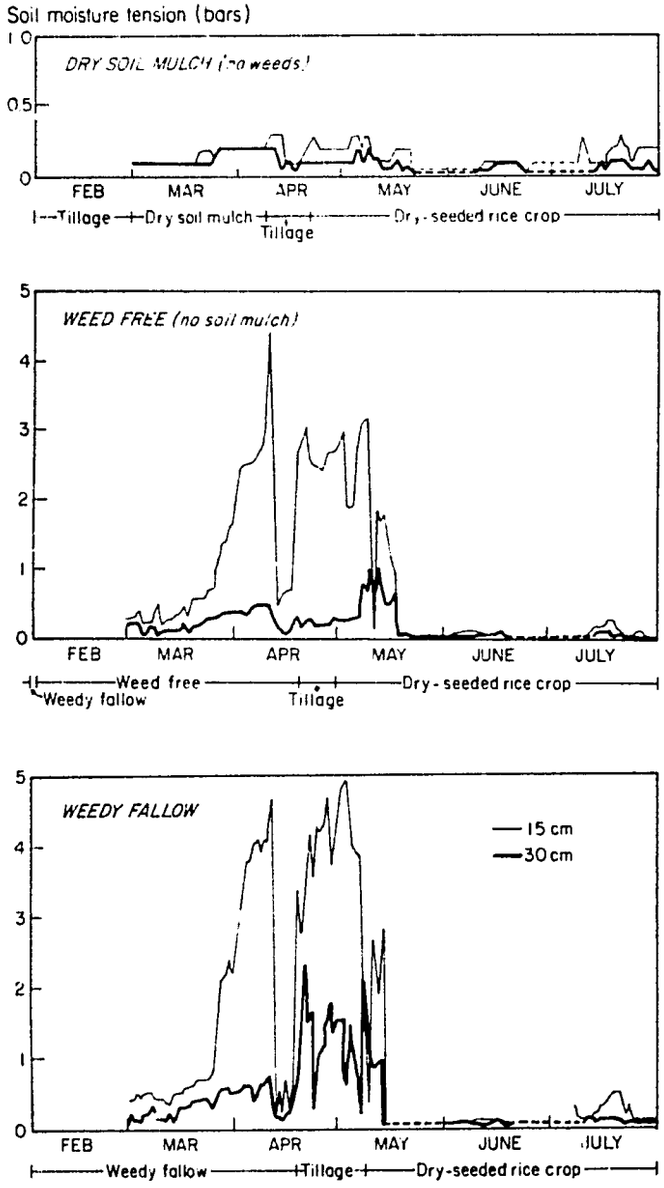

Fig. 1. Soil moisture tension under a dry soil mulch did not exceed 33 centibars at any time during the 1976 dry season. Some moisture was conserved by keeping the plots weed free, but moisture tension was higher than in the soil mulched plots. Plots that were fallow and on which weeds were allowed to grow had 5 bars of soil moisture tension at a 15-cm depth by the end of the dry season. IRRI, 1976 (Bolton and De Datta 1977).

During the 1977 crop seasons, Singh and De Datta (1978) conducted a similar experiment. The tillage treatments are summarized in Table 2. All dry-season treatments were followed by a dry-seeded crop except a weedy fallow followed by puddling and transplanting, the system practiced by most rice farmers in rainfed areas in tropical Asia. The latter treatment was not part of the main experiment but was imposed adjacent to the main experimental plots. Four cultivars (IR1529-430-3, IR2035-117-3, IR9575, and IR20) were dry-seeded or transplanted as subplots on the main tillage-mulch plots. Because the four cultivars had different growth durations, harvesting occurred over a range of dates for all tillage treatments.

During the dry season (February to late May), after shallow tillage (10 cm), deep tillage (20 cm), and straw incorporation, SMT did not exceed 40 centibars when land preparation was completed at the end of the previous wet season (Fig. 2). By comparison, SMT at 15 cm in weedy-fallow plots rose to 5 bars by the end of the dry season (Fig. 3). SMT was lower in weed-free fallow and straw-mulch treatments (Fig. 4), than in the weedy-fallow treatment (Fig. 3), but higher than in treatments involving tillage operations during the dry season (Fig. 2).

Straw mulching and weed-free fallowing during the dry season conserved about equal soil moisture but the amount was less than that conserved with shallow tillage, deep tillage, and straw incorporation. Furthermore, after the dry-season shallow-tillage, deep-tillage, and straw-incorporation treatments, rice could be seeded 2 days earlier than after the weed-free treatment, 10 days earlier than after the straw-mulch treatment, and 24 days earlier than after the weedy-fallow treatment. Land preparation for the transplanted crop was delayed until the beginning of July by insufficient rains for puddling, which gave harvest dates from 5 to 8 weeks later than those of the same cultivar planted with one of the dry-seeding tillage systems. Thus, two crops of transplanted rice could be grown on dry-seeded plots but only one could be grown on puddled soil.

Yields from all tillage treatments are in Table 3. Varietal differences were also apparent. Across tillage treatments, IR9575 yielded highest (4.4 t/ha) and IR20 lowest (2.4 t/ha) but a variety-tillage interaction was not detected.

The IRRI studies demonstrated moisture conservation in a montmorillonite clay soil with a dry-soil mulch during the dry season. Most of the moisture was conserved by soil mulching, not by weed control. Although such stored moisture could be of value to rice seedlings encountering drought at the onset of the wet season, a major benefit of early dry-season land preparation is time saved for the following wet-season crop. The earlier, more timely establishment of the first crop allowed a second crop later in the wet season. Although the second crop produced considerably lower grain yield than the first, the two-crop total for rainfed dry-seeded rice was 2 t/ha higher than that for the transplanted rice grown after weedy fallow (Table 3). Yields were also poor for a weedy fallow during the dry season, followed by first a dry-seeded and then a transplanted crop.

Using a somewhat different approach to examine the effect of preseason tillage on rainfed rice yields in Surinam, Hasselbach and van Amson (1965) found differences due to early and late fallow period disking on soils with a long history of rice production, even though soils were puddled before planting

Table 2. Summary of treatments used in 1977 soil-water conservation experiments.

Dry season operations		First crop			Second crop	
Treatment	Tillage operations	Planting operations	Planting date	Range of harvest dates	Transplanting date[a]	Range of harvest dates
Dry soil mulch, 10-cm tillage	Rotovating thrice in January and February; rotovating once 30 April	Dry seeding - furrows spaced at 25 cm, 80 kg seed/ha	30 April	10-28 Sept.	3 Oct.	11-23 Jan.
Dry soil mulch 20-cm tillage	-do-	-do-	30 April	-do-	3 Oct.	-do-
Straw incorporation (5-t/ha rice straw, incorporation by 10-cm tillage)	-do-	-do-	30 April	-do-	3 Oct.	-do-
Straw mulch (5-t/ha rice straw	Rotovating thrice between 30 April and planting	-do-	10 May	17 Sept-4 Oct.	10 Oct.	17-29 Jan.
Weed-free fallow (herbicide treated)	Rotovating twice between 30 April and planting	-do-	2 May	11-29 Sept.	3 Oct.	11-23 Jan.
Weedy fallow, dry-seeding	Plowing once on 9 May rotovating thrice between 10 May and 24 May	-do-	24 May	29 Sept-15 Oct.	20 Oct.	27 Jan.-9 Feb.
Weedy fallow, transplanting	Plowing and harrowing twice between 1 July and 20 July	Transplanting 28-day old seedlings in 20 x 20-cm hills, 2-3 seedlings/hill.	20 July	1-21 Nov.	-	-

[a] In preparation for transplanting, all plots were plowed once and harrowed twice between the last date in the range of harvest date and the transplanting date.

after all disk treatments. Preseason disking increased yields by as much as 1.1 t/ha. In a follow-up test, both late disking and wet fallow produced statistically significant responses on 23 yellow mottled and 9 sandy clay soils, but not on 7 other soils. The responses were 0.29 t/ha and 0.25 t/ha, respectively, for fallow period disking and flooding. There was no interaction between treatments. These experiments suggest that other factors besides soil water conservation may lead to increased rice yields following dryland preparation.

The type of tillage a farmer chooses depends on a number of factors, but in tropical Asia, the puddling system evolved out of necessity. If there is a switch to direct-seeded rice on dry soil, the puddling process must be evaluated against salient land and rainfall factors.

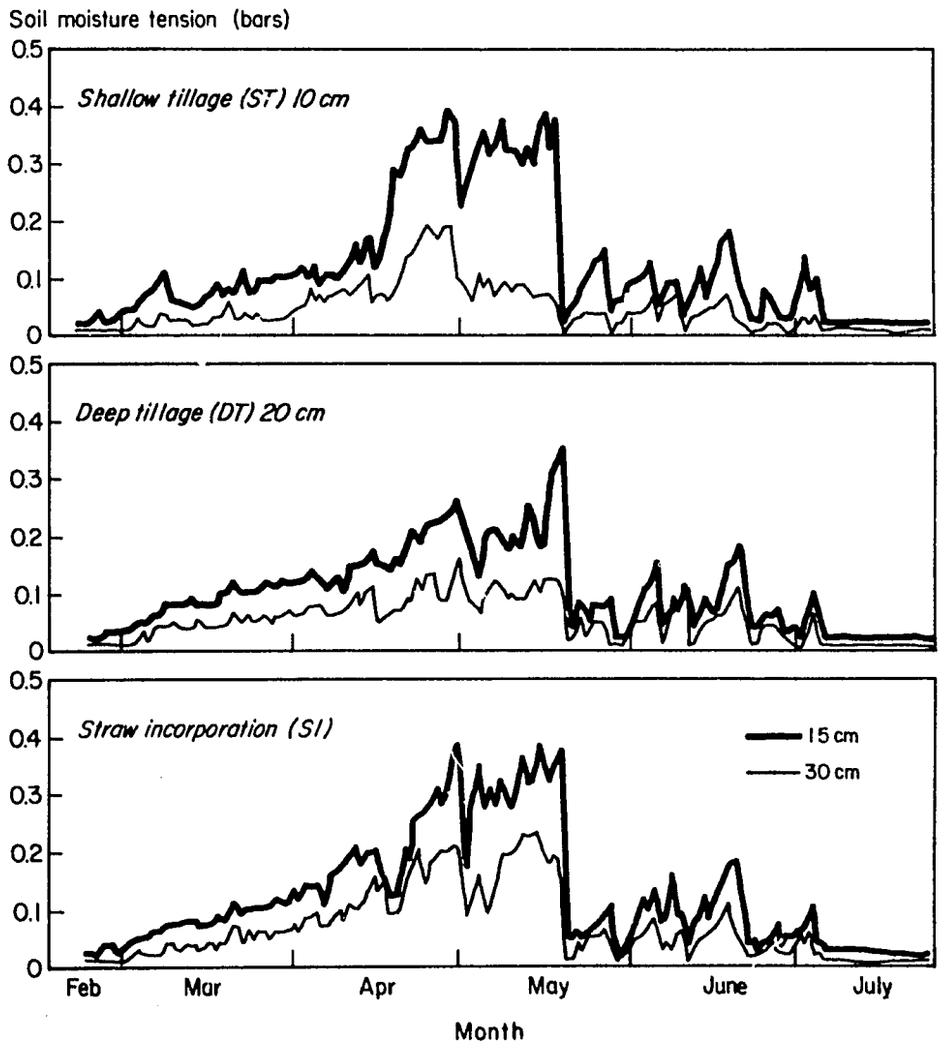

Fig. 2. Effect on soil moisture tension of a dry soil mulch generated by shallow tillage (10 cm deep) and deep tillage (20 cm deep) and straw incorporation at 5 t/ha (10 cm deep) during the dry season followed by (fb) a dry-seeded rice crop. Tillage consisted of 3 rotovations in January/February fb 1 rotovation in April. Rices were dry-seeded on 30 April. IRRI, 1977 dry and wet seasons (Singh and De Datta 1978).

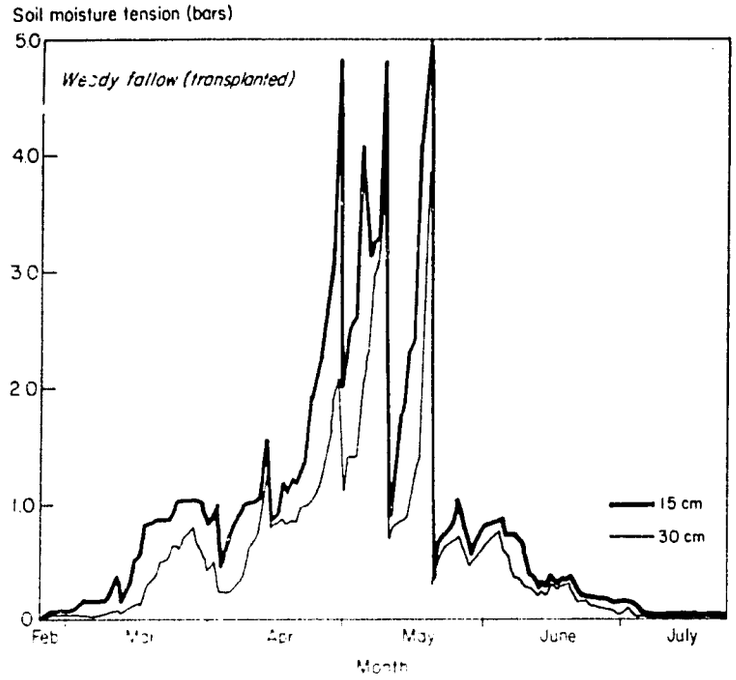

Fig. 3. Effect on soil moisture tension of a dry-season weedy fallow followed by a transplanted rice crop. Tillage consisted of 2 plowings and 2 harrowings. The seedbed was sown 22 June and seedlings were transplanted 20 July. IRRI, 1977 dry and wet seasons (Singh and De Datta 1978).

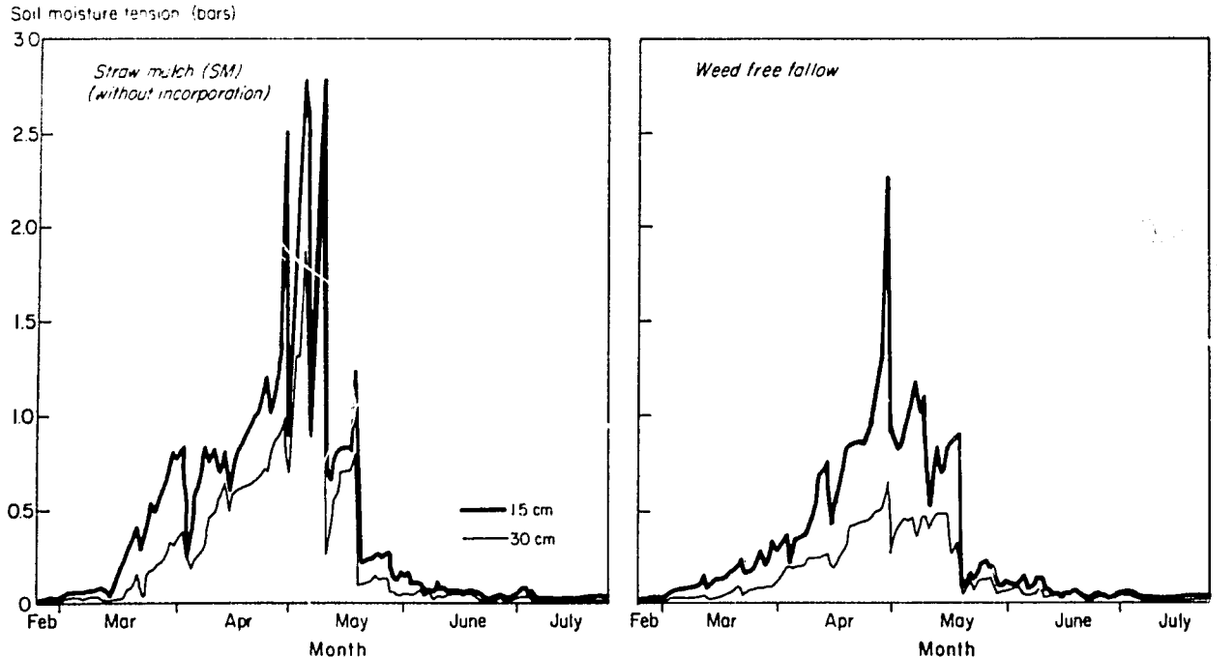

Fig. 4. Effect on soil moisture tension of straw mulch at 5 t/ha (without incorporation) and weed-free fallow treatments during the dry season followed by a dry-seeded rice crop. Tillage consisted of 3 rotovations in straw mulch and 2 rotovations in weed-free fallow plots. Rices were dry-seeded on 10 May and 2 May in straw mulch and weed-free fallow plots, respectively. IRRI, 1977 dry and wet seasons (Singh and De Datta 1978).

Table 3. Grain yields of rainfed-bunded rice as influenced by different dry soil mulch and straw mulch treatments. IRRI, 1977 wet season.

Crop	Grain yield[a] (t/ha)						
	Shallow tillage (10-cm)	Deep tillage (20-cm)	Straw incorporated (5 t/ha)	Straw mulch (5 t/ha)	Weed-free fallow	Weedy fallow, dry-seeded	Weedy fallow, transplanted[b]
First	3.6	3.6	3.7	3.4	3.2	2.5	3.1
Second	1.6	1.6	1.8	1.4	1.7	1.1	-
Total	5.2	5.2	5.5	4.8	4.9	3.6	3.1

[a] Av. 4 replications and 4 varieties. [b] Not included in the experiment analysis but tested in adjacent areas.

The major advantages of dryland tillage for rice are:

- Initial crop growth is obtained from early monsoon rainfall, whereas in wetland preparation the rainfall is used for land-soaking and puddling under.
- Labor associated with seedbed preparation-land preparation-transplanting operations is reduced.
- Large power units can be employed for primary and secondary tillage operations.
- Where a nonrice crop follows an unpuddled rice crop, soil structure is more favorable for stand establishment and root development of the nonrice crop.
- Insect and disease sources that increase on alternate hosts during the period required for wetland soaking and puddling are avoided.

The major disadvantages of dryland preparation are:

- Draft power requirements are high and often beyond the financial reach of rice farmers in the Asian tropics.
- Early weed control requirements are comparatively exacting and critical.
- Percolation losses are comparatively high, leaving the crop more susceptible to periodic drought stress.

- The crop may be exposed to several soil-inhabiting insects and to blast before the accumulation of standing water.
- Fertilizer requirements will often be higher.

Crop establishment methods following dryland tillage

As with puddling, dryland tillage restricts methods of rice crop establishment. To most farmers of tropical Asia, mechanical drilling is not a forseeable alternative. Common alternative methods are:

- broadcasting-seeding on a level field,
- broadcasting-seeding over shallow furrows and passing a spike-toothed harrow at 45° to concentrate seed in rows,
- hand-drilling -- placing seed in shallow furrows opened by an animal-drawn apparatus -- and
- dibbling seed so that seedlings emerge in hills at uniform spacings.

Broadcast method. Few experiments have compared dryland tillage methods for establishment of rainfed lowland rice. One such comparison we made showed little difference between grain yield obtained by broadcasting on leveled field and seeding on furrows opened with a *lithao* (Table 4). The *lithao* is satisfactorily used on loose upland soils, but not on heavy, cloddy wetland soils. Furthermore, the *lithao* method also requires extra field operations.

Hand drill method. Hand-drilling produced yields that averaged more than 4 t/ha on 48 farmer-cooperators' fields during the 1977 wet season in Pangasinan (Table 5). The table includes data combined for rainfed and partially irrigated fields but the effect of irrigation was nil during the wet season. Rainfed yields were in fact higher. Of the 48 observations, the first 24 farmers to plant obtained yields that averaged 0.4 t/ha more than the remaining 24 farmers.

Dibbling method. The dibbling method permits easier weed control and produces an environment less suitable for insects and diseases. Morever, placement of the seed below the soil surface may reduce lodging susceptibility. Dibbling in dry soil is practiced in parts of Java. Scientists of the Central Research Institute for Agriculture report that yields exceed 4 t/ha if adapted varieties are grown with appropriate fertilization and weed control (Fagi 1974, Saefuddin et al 1978). Dibbling is labor-intensive, but as water accumulates in the field, the farmers use a two-direction rotary or *landak* weeding, which improves weed control.

Two 1977 wet-season experiments in rainfed fields determined how far in advance of the onset of rains rice could be seeded in dry soil without adverse emergence, stand establishment, and yield effects. We found

Table 4. Grain yields (av. of IR1561-228-3 and IR30) as affected by 7 patterns of rainfall in the Philippines and by 2 methods of stand establishment by dry seeding.

Rainfall pattern[a]	Grain yield (t/ha)	
	Dry seeded in rows opened with lithao[b]	Dry seeded broadcast
A	3.2	3.3
B	1.9	2.3
C	4.2	3.8
D	2.1	2.1
E	2.9	2.9
F	5.3	5.5
G	4.5	4.8
Av.	3.4	3.5

[a] Description of rainfall pattern not essential to comparison of the two seeding methods. In the Philippines, rainfall pattern Type A and Type B each have a long wet season (WS) during the high sun period (HSP) (April through September); pattern A has a 5-month dry season (DS) and pattern B has a 4-month DS. Type C and Type D each has a short DS (1-3 months). The DS of Type C occurs during the low sun period (LSP) (October through March), while the DS of Type D is during the HSP. Type E and Type F each have a marked WS of heavy rainfall; the WS of Type E occurs during the LSP and the WS of Type F is during the HSP; Type G has an even distribution of rainfall with no marked seasonality.

[b] The lithao is a carabao-drawn farm implement with 5 teeth spaced at 20 cm, used primarily to make furrows in planting upland rice, and is indigenous to the provinces of Cavite and Batangas, Philippines.

Table 5. Yields of dry-seeded rice, 48 farmers' fields combined rainfed and partially irrigated observations. Crop year 1977-78, Manaoag, Pangasinan.

Yield range (t/ha)	Observations (no.)	Av. yield (t/ha)
< 3.5	7	3.1
≥ 3.5 < 4.5	16	4.2
≥ 4.5 < 5.5	17	5.0
≥ 5.5 < 6.5	5	6.1
> 6.5	3	6.9
	48	5.06

that seed could remain in the soil for several weeks without major adverse effects. That implies that farmers can plant rice well ahead of the onset of the rains if land can be prepared (Table 6). Regardless of planting date, seed planted before the onset of rains germinated after the initial soaking rains.

Table 6. Effect of seeding date on yield of dry-seeded rice in Pangasinan and Iloilo, 1977 wet season.

Pangasinan		Iloilo	
Seeding date	Yield (t/ha)	Seeding date	Yield (t/ha)
22 April	4.5	6 May	3.6
27 April	5.0	11 May	4.2
2 May	4.9	16 May	4.0
7 May	4.6	21 May	3.7
12 May	5.1	26 May	3.8
17 May	4.6	31 May	3.7
22 May	5.0	5 June	4.5
27 May	3.9	10 June	4.5
Treatment MS	652899^{ns}	537695^{ns}	
$s_{\bar{x}}$	300	371	
CV (%)	13	18	

INCREASING YIELDS OF THE SECOND RAINFED RICE CROP

With modern, early maturing rice varieties, the possibility of increasing rice production by growing two rainfed rice crops is a viable possibility in regions receiving 6-7 months or more of rainfall at a rate exceeding 200 mm/month. In some areas two rainfed rice crops are possible where there are only 5-6 months of rainfall. The performance of the second crop depends heavily on avoidance of late-season drought. There are three major considerations for reduced drought stress on the second crop:

1. earliness in planting of the first crop,
2. second crop establishment method, and
3. reduced, faster tillage for the second crop.

Early planting of first crop

Early first crop plantings are possible through dry-seeding, as mentioned previously. Figure 5 shows the differences in time of harvest between

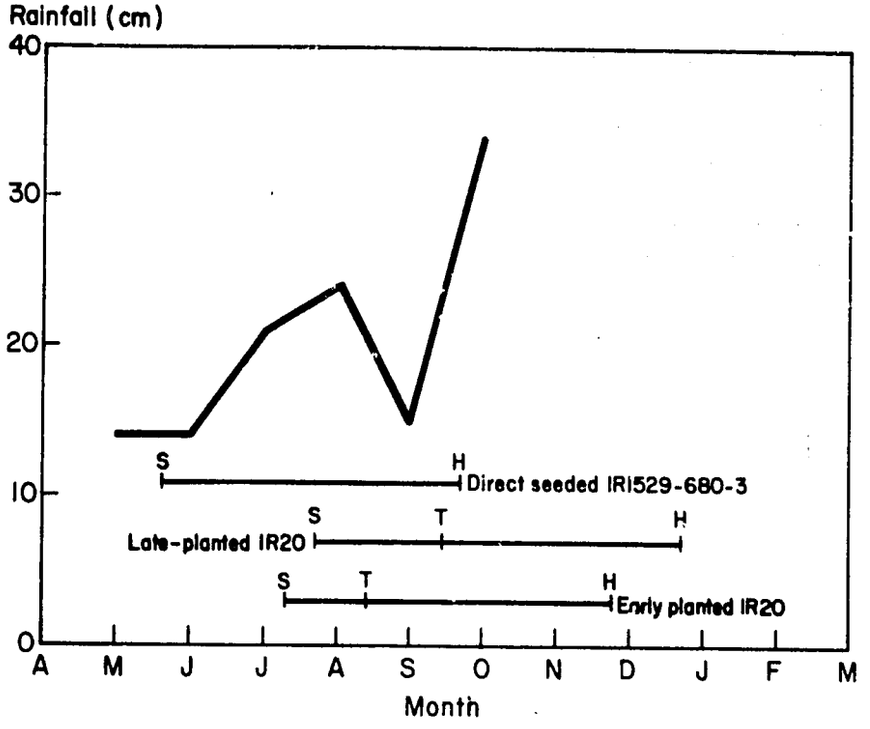

Fig. 5. Time of seeding and harvesting of direct-seeded IR1529-680-3 and transplanted IR20 in relation to amount of rainfall. San Rafael, Bulacan, 1973 wet season. IRRI, 1974.

dry-seeding of IR1529-680-3 and transplanting of IR20 in a Philippine study (IRRI 1974). IR20 was not transplanted until sufficient water had accumulated to allow puddling in late July.

IRRI water management research shows that from 200 to 700 mm of water is used during the land preparation operations before rice transplanting (Wickham 1977). Analysis of rainfall data indicates that a dry-seeded rice crop in experiments at Pangasinan and Iloilo, Philippines, completed 30-50 days of growth before 400 mm of rainfall had accumulated.

Dry-seeding gave a net time saving of more than 4 weeks for the second rice crop in Pangasinan but only a 1-week saving in Iloilo, assuming 3-week-old seedlings would have been transplanted as the first crop after the fields were puddled. Similar advantages attributable to dry-seeding of the first crop were obtained by Singh and De Datta (1978). They showed that the delay in transplanting the first crop on a puddled soil left insufficient time to plant a second crop within the same season.

Second crop establishment

Transplanting may reduce the field duration of a second crop by 2 or 3 weeks, lowering the risk of late-season drought stress during the critical grain-filling period. Evidence of this effect is in Table 1 -- higher yields and lower yield variability associated with transplanted second

crops compared with those associated with direct-seeded crops. Furthermore, the frequency of crop failures after direct-seeding was twice for transplanting.

Second crop tillage

Another factor in delayed planting of a second rice crop is the time to prepare land for the second crop. Studies in several rice-growing regions of Asia, including Sri Lanka (Mittra and Pieris 1968), Malaysia (Seth et al 1971), Indonesia (Varley 1970), and the Philippines (Moomaw et al 1968, De Datta et al 1977), demonstrate that the degree and duration of tillage operations may be substantially reduced without adversely affecting crop growth and yield of rice. However, those trials were conducted at experiment stations with mechanized tillage, and most had good water conditions. Reduced tillage operations and reduced turnaround time for rainfed rice systems require study with farmers' resources and tillage implements.

ECONOMIC FACTORS AFFECTING CHOICE OF LAND PREPARATION AND CROP ESTABLISHMENT

As already noted, because of a wide diversity in the rainfed rice-growing environment, a wide range of land preparation and crop establishment practices is being used. Ultimately, the choice of appropriate land preparation and crop establishment in a given area is determined by the benefits and costs associated with alternative methods. The benefits can be measured in terms of higher yields, greater cropping intensity, or reduction in risk of yield loss. The costs include power for tillage, planting or transplanting labor, and weed control. These are important factors that influence the benefits and costs and, hence, the decision to use a particular land preparation or crop establishment procedure in a given area.

In much of the rainfed rice-growing environment, delayed planting results in a yield loss because of the greater probability of drought in the crop-ripening stage and a change in environmental factors such as solar energy and temperature. The pattern of yield reduction varies from year to year and from place to place and even among varieties.

An example of the types of yield reduction encountered is illustrated in Figure 6, which is based on three surveys in a rainfed rice-growing area of Central Luzon. Modern varieties were grown on two-thirds of these farms even as early as 1971. The average yield reduction appears to be about 30 kg/day as the harvest extends into November and December. However, the introduction of IR36, an early maturing variety (100-110 days for IR36 vs 120-140 days for IR8 and IR20), had a dramatic impact on production and yield because farmers advanced their harvesting date.

It takes about a month after the onset of the rains before there is sufficient moisture for puddling. Thus, rainfed area farmers typically transplant and harvest a month later than many farmers with good irrigation. It is practical in many rainfed areas to consider alternative methods of land preparation and planting.

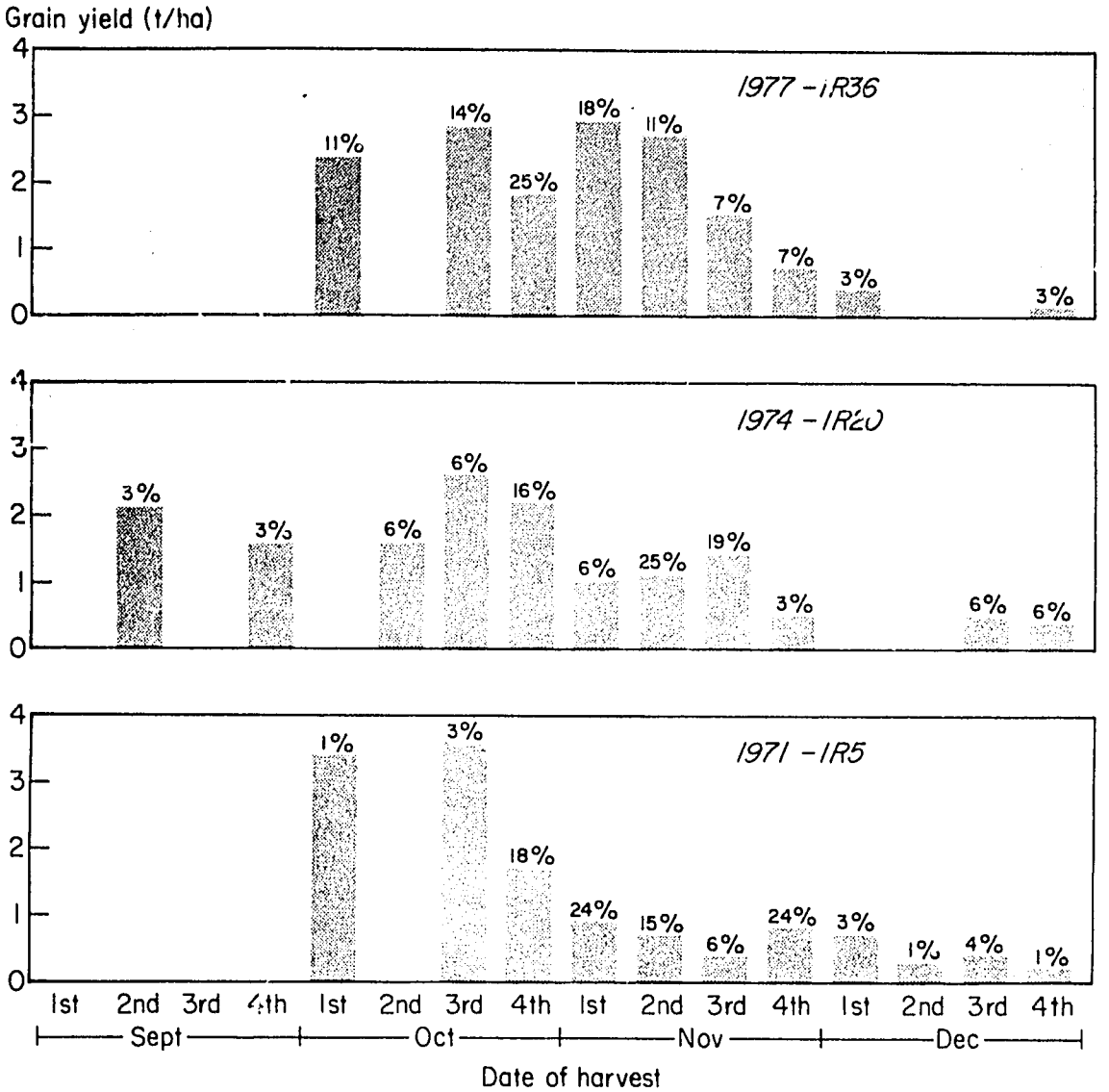

Fig. 6. Average rice yield of the most widely planted variety in each of 3 years by date of harvest in rainfed areas of Bulacan and Nueva Ecija, 1971 to 1977. (Figure above each bar refers to percentage of area harvested.

Power requirements

A study by Orcino and Duff (1974) determined power requirements and yield differences when rice fields were prepared with different combinations of animal and tractor power on three irrigated and one rainfed site (Table 7, 8). It cannot be assumed from the results that tillage of rainfed soils typically requires more power input per hectare. However, penetrometer readings on the rainfed soil were twice as high as those in the irrigated soil, indicating that the rainfed fields were not as well soaked. If a water buffalo works 6 hours/day, a hectare of rainfed Kapalangan soils can be prepared in about 3 weeks. But there is only from 0.5 to 1.0 working animal/ha on rainfed farms in this area. Thus, with the animal power available, a month or more may be required to prepare a hectare.

Table 7. Land preparation treatments in 3 barrios, Nueva Ecija, 1973 wet season.

Treatment	Land preparation method			
	Primary		Secondary[a]	
	Power source	Implement	Power source	Implement
1	65-hp tractor	Rotary tiller	Carabao	Comb harrow
2	14-hp tiller	Rotary tiller	Carabao	Comb harrow
3	7-hp tiller	Moldboard plow	7-hp tiller	Comb harrow
4	Water buffalo	Moldboard plow	7-hp tiller	Comb harrow
5	Water buffalo	Moldboard plow	Carabao	Comb harrow

[a] Secondary tillage consists of 2 passes over the field repeated 3 times at 1-week intervals. Source: Orcino and Duff 1974.

An economic survey in the same rainfed barrios indicated that use of a 4-wheel tractor for primary tillage reduced land preparation time from 37 to 27 days (Bautista and Wickham 1974). Assuming that this reduction in time could be translated into higher yields (Fig. 6), the value of the 300-kg additional yield is only slightly higher than the custom rate for rotovating 1 ha. A few farmers in those rainfed barrios hire tractors, and principally when planting is delayed because of late rains. The average rainfed-area farmers, who grow only 1 crop of rice and obtain yields of less than 2 t/ha, cannot afford the power investment needed to reduce the time required for puddling and transplanting the monsoon crop.

Double cropping

The introduction of a short-season variety such as IR36 clearly has a much greater impact on production and profits than the increase in farm power. The situation may differ in areas where double cropping is feasible.

IRRI cropping systems research (municipalities of Oton and Tigbauan, Iloilo province, Philippines) provides one example of a rainfed area that can be partly double-cropped. Lands prepared before 1 July are wet-seeded (broadcast on puddled soil) to early maturing varieties. The wet-seeding method saves time and labor, and facilitates the growing of two crops (Table 9). There

Table 8. Site characteristics, soil conditions, and level of inputs used in land preparation trials in 3 barrios, Nueva Ecija, 1973 wet season.

Site treatment	Labor inputs (hr/ha)			Soil penetrometer reading[a] (depth in cm for 35 psi)	Mean yield[b] (t/ha)
	Plow	Harrow	Total		
Baluarte (shallow hardpan)					
T1	4	30	34	11.5	3.85
T2	6	30	36	12.1	3.80
T3	12	12	24	11.5	3.65
T4	27	11	38	12.3	3.88
T5	27	31	58	11.[illegible]	3.74
Pulo I (medium hardpan)					
T1	5	40	45	6.8	3.97
T2	8	41	49	8.8	4.00
T3	13	21	34	7.5	4.14
T4	34	20	54	7.7	4.01
T5	32	40	72	8.6	3.[illegible]
Pulo II (deep hardpan)					
T1	4	42	46	10.9	3.53
T2	7	42	49	10.9	3.57
T3	9	20	29	11.0	3.65
T4	27	21	48	9.0	3.57
T5	27	39	66	9.3	3.71
Kapalangan (rainfed)					
T1	7	47	54	6.6	3.08
T2	11	53	64	6.0	2.93
T3	-	-	-	-	-
T4	61	21	82	5.1	2.97
T5	63	66	129	6.2	3.01

[a] At beginning of land preparation. [b] Averaged over the 3 weed treatments.
Source: Orcino and Duff 1974.

appears to be little difference in yield between wet-seeded and transplanted rice, although this is not well documented. On lands prepared after 1 July, late-maturing varieties are transplanted and only a single crop is harvested.

The Iloilo case shows a particularly skillful adjustment by rainfed farmers to make more efficient use of limited power and water supplies. Although animals

Table 9. Most important advantages and disadvantages of planting wet-seeded rice reported by 39 farmer-respondents in Iloilo, 1976.[a]

Advantages and disadvantages	Farmers reporting (%)
Advantages	
Labor is less	74
Cost is lower	72
Double cropping possible	61
More tillers	51
Good yield	46
Disadvantages	
Water availability early in season	67
Weed problem	67
Risk is great	61
High seed requirement	46
High fertilizer requirement	41

[a] Source: Roxas et al 1977.

Table 10. Major reason given for either broadcasting or transplanting rice by a sample of 94 farmers.[a] Amphoe Bang Nam Prieo, Changwat Chachoengsuo, Thailand, 1975.

Reason	Farmers reporting (%)
For broadcast only (78%)	
Cost is lower	38
Cost is lower and yield is same or higher	26
Labor is less	23
Other reasons	11
	100
For transplanting only (10%)	
Sure that yield will be higher	33
Weeds easier to control	17
Less fertilizer is required	15
Other reasons	35
	100

[a] Source: Lokaphadhana 1976.

are now the principal source of power, the potential for increasing productivity by double cropping may require mechanization of land preparation in the future.

On much of the Central Plain of Thailand water control is poor and land is tilled dry, and rice is sown on dry soil before the rains come. Since weed control is a serious problem, yields are substantially lower. Where water control is adequate, farmers normally shift to transplanting. However, a study (Lokaphadhana 1976) shows that some farmers are switching from transplanted to wet-seeded rice. The situation appears to be similar to that in Iloilo in that two crops of rice are grown. The major reasons Thai farmers gave for broadcasting and transplanting are in Table 10.

Labor costs

Perhaps the most dramatic shift in method of rice stand establishment in recent times occurred in Burma. The motivating force was a rise in the wage rate for labor relative to the farm rice price. Richter (1976) reports that as a result of these wage-price changes, an estimated 1.4 million ha of formerly transplanted land was broadcast-seeded and the estimated reduction in yield was 0.5 t or more/ha.

Weed control

The decision on method of tillage for rainfed rice is also related to weed control. Land preparation is in fact a form of weed control. More thorough tillage reduces the weed problem later.

But we have clearly observed that rainfed farms are likely to be underpowered. Furthermore, intermittent rains lead to drying of the paddy, which not only encourages weed growth but also makes it impossible to recommend the inexpensive preemergence herbicide treatments used in irrigated areas. If weeds are not adequately controlled in the early stages of stand establishment, the yield losses in broadcast rice may be severe. That is one of the risks particularly associated with dryland preparation.

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