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# RAINFED LOWLAND RICE IN CAMBODIA: A BASELINE SURVEY

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*ABSTRACT*

Rainfed lowland rice (RLR) is planted in 88% of Cambodia's cultivated riceland. Data for the baseline survey of RLR production in Cambodia were drawn from interviews with 45 farmers in three provinces. Interview subjects produced rice exclusively through RLR cultivation. This report describes

- the place of RLR in Cambodian rice culture;
- farmers' family composition, farm assets, access to labor, and income sources;
- factors influencing farmers' crop-management and varietal choices, including size of landholding, field levels and related soil and water problems, farmers' classification of rice by maturity, and local varietal preferences based on cooking and eating quality and agronomic performance; and
- RLR crop management and cropping operations from nursery establishment to harvest and storage.

Constraints to intensifying RLR cultivation in Cambodia are discussed and conclusions and research recommendations are presented.



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# RAINFED LOWLAND RICE IN CAMBODIA: A BASELINE SURVEY

Cambodian farmers of rainfed lowland rice (RLR) manage a wide variety of traditional RLR cultivars in a diverse ecosystem. To set effective breeding priorities and plan research that addresses farmers' production constraints and increases yields, plant breeders and other agricultural scientists need to understand

- the amount and duration of rainfall and standing water;
- the soil types and field forms and levels;
- Cambodian RLR farmers' classifications of rice culture, field type, and field ecology;
- the farmers' classifications of the traditional varieties (TVs) they plant in their fields;
- the farmers' management of the TVs; and
- the farmers' constraints in managing RLR culture to fill their granaries.

Agricultural scientists must understand the ecosystem they are addressing and farmers' response to and management of it. Garrity et al (1986) noted that one of the major purposes of zoning and defining the RLR ecosystem is "to assist in the definition of breeding priorities and objectives."

In the RLR environment, fields are unirrigated and up to 50 cm of standing water accumulates in the fields for a part of the growing season (Garrity et al 1986). About 38 million ha are cultivated in RLR—28% of the land area cultivated in rice worldwide. In many South and Southeast Asian countries, RLR is the predominant rice culture, and future increases in rice yield in these countries must come from the RLR ecosystem (Garrity et al 1986). In 1989, RLR accounted for 1.6 million ha of Cambodia's cultivated rice area—88% of the country's total wet-season rice area (Table 1).

The RLR environment has a diversity of growing conditions. These vary with the amount and duration of rainfall in the fields, depth and duration of standing water, time of flooding, type of soil, and topography (Khush 1984). Cambodian RLR farmers must consider these and other factors in managing their ricefields and selecting appropriate varieties.

## SURVEY LOCATION

Cambodia's political and administrative divisions are, in descending order, *khait* (province), *srok* (district), *khum* (village cluster or commune), and *phum* (village).

Research on Cambodian RLR rice production, including interviews of 45 farmers, was carried out at one site in each of three provinces: Kandal (17 farmers), Kompong Speu (14 farmers), and Takeo (14 farmers). In each province, districts were chosen that have substantial RLR land (Table 2). Within those districts, village clusters were chosen in which the farmers depend on RLR for rice production. The village clusters and villages that were selected are listed in Table 3 and located in Figure 1.

### Kandal Province

Dong Kaw, the district chosen in Kandal Province, is new, having been created after 1979 from parts of Kandal Stung District and Phnom Penh Municipality. The selected village

**Table 1. Comparison of (a) cultivated land area of early-, medium-, and late-maturity RLR varieties to total RLR cultivated area, and (b) total RLR cultivated area to total wet-season area.[a]**

(a)

| Variety | 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|---|
| | RLR cultivated area (ha) | % of total RLR cultivated area | RLR cultivated area (ha) | % of total RLR cultivated area | RLR cultivated area (ha) | % of total RLR cultivated area |
| IR varieties[b] | 31,999 | 3 | 39,233 | 3 | | 0 |
| Early-maturity varieties | 173,046 | 16 | 210,817 | 15 | 339,500 | 21 |
| Medium-maturity varieties | 420,746 | 38 | 507,238 | 35 | 434,500 | 27 |
| Late-maturity varieties | 479,544 | 43 | 671,688 | 47 | 810,900 | 51 |
| Total | 1,105,335 | | 1,428,976 | | 1,584,900 | |

(b)

| 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|
| Wet season cultivated area (ha) | RLR percentage (RLR land area / Total wet season area) | Wet season cultivated area (ha) | RLR percentage (RLR land area / Total wet season area) | Wet season cultivated area (ha) | RLR percentage (RLR land area / Total wet season area) |
| 1,247,505 | 89 | 1,584,260 | 90 | 1,805,950 | 88 |

[a]Source: Department of Agronomy, Ministry of Agriculture, unpubl. data. [b]For 1989, cultivated area for IR varieties is included in cultivated area for early-maturity varieties.

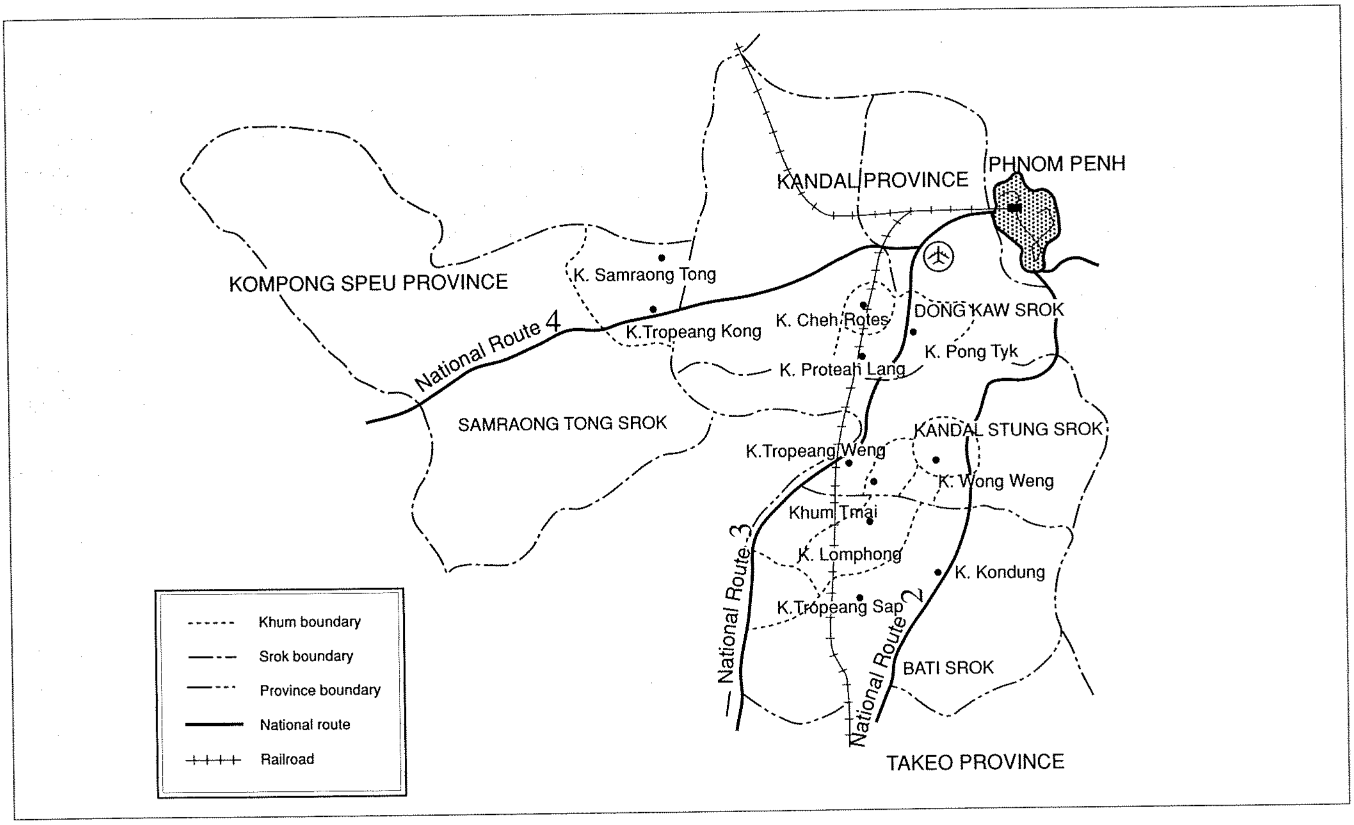
**Table 2. Research sites, basic statistics, and cultivated area, 1989 RLR crop, Cambodia.**

| Province | District | No. of village clusters | Total population | No. of households | Agricultural land area (ha) | Cultivated area (ha) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1989 dry season | | 1989 wet season | | | | |
| | | | | | | Total | IR varieties | Early varieties | Medium varieties | Late varieties | IR varieties | Total |
| Kandal | Dong Kaw | 15 | 49,035 | 8,960 | 8,917 | 350 | 320 | 385 | 2,180 | 6,035 | No data | 8,600 |
| Kompong Speu | Samraong Tong | 15 | 85,491 | 16,147 | 13,521 | 391 | No data | 2,709 | 6,443 | 4,321 | No data | 13,473 |
| Takeo | Bati | 15 | 87,856 | 16,255 | 27,636 | 3,740 | 3,740 | 4,872 | 11,520 | 4,003 | 3,550 | 20,395 |

**Table 3. Interview sites for the RLR baseline survey, Cambodia.**

| Province | District | Village cluster | Village |
|---|---|---|---|
| Kandal | Dong Kaw | Proteah Lang | Ang Kong Ksaich |
| Kompong Speu | Samraong Tong | Samraong Tong | Ang Thum Loab |
| | | | Robong Chhros |
| | | | Kaew Munin |
| Takeo | Bati | Lomphong | Krang Thom |
| | | | Bak Ronos |

Because of Proteah Lang's proximity to Phnom Penh, its farmers have greater opportunity for nonagricultural economic activities than do the farmers at the other research sites: 47% of the farmers sampled in Proteah Lang but only 21% of the farmers at the other two sites had nonfarm employment. However, the village cluster's economy is based primarily on rice agriculture. Few cash crops are raised, and few sources of alternative agricultural income are available, other than tapping sugar palms to produce sugar.




**1.** Research survey area.

cluster, Proteah Lang, which has only five villages, is approximately 20 km southwest of Phnom Penh. Rice cultivation in the cluster is entirely rainfed. A parcel of land within the cluster has been proposed as the site of the Cambodian Rice Research and Development Institute, which is still being planned.

Ricefields in Proteah Lang slope gradually upward, away from the main road. Soils are primarily light sand, subject to heavy compaction after land preparation. In the low terraces, some soils are sandy loam and silt loam mixed with sand.

**Kompong Speu Province**

Samraong Tong, a large district chosen in Kompong Speu Province, is situated on Route 4, approximately 30 km west of Phnom Penh. The village cluster of the same name also is large, comprising 18 villages, and is approximately 8 km north of Route 4 on an unpaved road. The local economy is based almost entirely on RLR cultivation. Farmers in the cluster grow few cash crops and depend largely on palm-sugar production for income. Ricefields in Samraong Tong are flat, and light sandy soils predominate.

**Takeo Province**

Bati is a large district between National Routes 2 and 3, about 40 km south of Phnom Penh in Takeo Province. The district is agriculturally diverse, and some village clusters have irrigation systems. The district has a community development center, under the direction of the Department of Agronomy, which provides training and extension advice to farmers.

Lomphong, the village cluster chosen in Bati, is medium sized, comprising 12 villages. It is unlike other village clusters in Bati in that its rice production is entirely rainfed and few of its farmers engage in wet-season cash cropping. Lomphong's farmers depend largely on palm-sugar production for cash income, although some villagers own large numbers of cattle. Some villages have low-lying fields. A small chain of foothills bisects the village cluster, and fields that are close to them have steeper slopes and poor, sandy soils.

## SURVEY SUBJECTS

Data gathered in four categories—family composition, farm assets (including domestic animals), sources of agricultural labor, and proportions of agricultural production geared toward subsistence vs cash income—were used to characterize the farmers who participated in this study. Households were selected randomly for interviewing.

**Family composition**

Although the Pol Pot times and military conscription for the civil war had taken their toll of the adult male population, each family surveyed had a male head of household. The average age of the heads of household was 41 yr. Eighteen of the heads of household (40%) had no formal education. Of the rest, 3 (7%) had attained some literacy with the monks at the local Buddhist temple, 22 (49%) had attended elementary school, and 2 (4%) had attended secondary school.

All heads of household were actively engaged in farming, but 18 (40%) had a source of nonagricultural income. Of the 17 Kandal households surveyed, 8 (47%) had some source of outside income. Only 6 farmers (21%) of the 28 surveyed in Kompong Speu and Takeo had outside employment or another source of income: four sold goods from small household stores, and two were civil servants.

The average age of the wives of the heads of household was 37 yr. Twenty-five (56%) of the wives had no education; the remaining 20 (44%) had attended but not completed elementary school.

The families surveyed had an average of four to five children. Only 11 (24%) of the families had children who assisted regularly in agricultural work and of these, the number who helped was only one or two. The rest were too young or in school.

Eight households had resident individuals other than the nuclear family of the head of household. Only in four cases did any of these people assist in agricultural labor.

The average number of individuals who participated regularly in agricultural labor in the households sampled was four to five.

**Farm assets**

Most households sampled had some domestic animals but did not derive much income from them. Two-thirds of the households surveyed kept pigs. Ducks and chickens were raised primarily for domestic consumption.

Across the total sample, farmers owned an average of 3.4 cattle; however, the distribution of these animals was uneven. Only six households (13%), three each in Kandal and Kompong Speu, owned no cattle.

Despite the figure of 3.4 cattle per household, 11 (29%) of the households sampled did not own plow animals. They had to pay cash or exchange labor for having their fields plowed. The distribution of the households lacking draft animals also was uneven: 7 (41%) of the households in Kandal, 5 (35%) in Kompong Speu, and only 1 (7%) in cattle-rich Takeo.

Some residents of the villages surveyed plowed for hire, but the survey participants who owned plow animals said they seldom offered this service. Only one of the 32 draft-animal owners plowed for cash, and 13 others plowed in return for labor.

Interview subjects owned few farm assets (Table 4). The most common farm implements were carts, plows, and harrows.

**Sources of agricultural labor**

The primary source of agricultural labor outside the household is exchange labor, despite the difficulty of scheduling labor exchanges for RLR cropping operations. The importance of exchange labor increased radically with the drastic increase in farm wages between the 1989-90 and 1990-91 cropping seasons. Of the households surveyed, 43 (96%) exchanged labor.

From 1982 to 1989, farmers were forced to farm collectively in production groups called *krom sammaki*. These groups had an average of 15-20 member families who farmed the group's riceland jointly and divided the produce according to shares based on size of family and relative ages of the members.

Though the krom sammaki have been officially disbanded, the government now calls them *krom prowas dai* (exchange labor groups). The continuing influence of these groups is

**Table 4. Number of households having important means of agricultural production, Cambodia.**[a]

| Province | Total no. of samples | Plow animals | Mean | Cart | Plow | Harrow | Rohat[b] | Snaich[c] |
|---|---|---|---|---|---|---|---|---|
| Kandal | 17 | 10 | 1.3 | 9 | 12 | 9 | 0 | 0 |
| Kompong Speu | 14 | 9 | 1.4 | 9 | 10 | 6 | 0 | 2 |
| Takeo | 14 | 13 | 1.7 | 12 | 12 | 11 | 1 | 1 |
| Total | 45 | 32 | 1.5 | 30 | 34 | 26 | 1 | 3 |
| Percent | | 71 | | 67 | 76 | 58 | 2 | 7 |

[a]No household owned a thresher or a pump. [b]Pedal-driven irrigation wheel. [c]Manually operated water shovel used primarily for irrigating nursery beds in RLR production.

shown by the fact that 37 (87%) of the households that exchanged labor did so primarily with former members of their krom sammaki. Only six families (13%) exchanged labor primarily with extended family, kin, and neighbors.

### Production for subsistence vs cash income

Most farmers said they could grow only enough rice for subsistence— with a small surplus for sale in good years— because their landholdings are small and RLR yields are poor. Nine households did not grow enough rice for subsistence and had to buy rice for some portion of the year. Farmers frequently mentioned this marginal subsistence production as a reason for favoring varieties that have good volume expansion.

Farmers were obligated to sell small amounts of rice— seldom exceeding 100-200 kg—to the government. The official government prices for the 1989-90 harvest were 16.50 riels/kg (US$0.05/kg) for TVs and 19 riels/kg (US$0.06/kg) for IR varieties. Private traders purchased paddy of the varieties prized for their eating quality, such as *Phka Khnyai* or *Chma Phrom* for as much as 35-40 riels/kg (US$0.13-0.14/kg) during the same period.

Palm-sugar production was one of the few sources of cash income for the families sampled. Quotas varied, but the village headmen generally granted applicants exclusive exploitation rights for 20-25 mature trees, regardless of where they grew. Sixteen households (36%) in the interview sample were engaged in palm-sugar production.

The palm-sugar season extends from late October or early November to late April or early May. Men engaged in this activity work 6-8 h/d, setting and collecting the bamboo containers that catch the palm sap twice daily and boiling the sap down for sugar.

The seasons for palm-sugar production and RLR harvest overlap. Thus, men who are engaged in producing palm sugar are not available to provide labor for the rice harvest. Households prefer to thresh rice at night, when men can assist, so they can complete the task quickly.

Income derived from palm sugar varied widely, but sugar tappers said they could earn 30,000-40,000 riels (US$95-125) during the 5- to 6-mo season.

## LAND ALLOCATION

RLR farmers sampled in the three sites are constrained by the sizes of their landholdings, which average only 1.1 ha per family, and the fragmentation of their fields, which are distributed in tiny plots among three field levels. Farmers' land allocations were divided into an average of seven plots (Table 5).

As the krom sammaki (collectives) devolved toward private production, farmers received individual land allocations. When the collectively held land was divided, holdings of each field level were distributed to the member families evenly. Each family received an allocation of high, middle, and low fields in proportion to its shares in the collective, however small. This strict, even division was intended to prevent any family from receiving a disproportionate allocation of either desirable or undesirable field types.

As a result, most of the farmers sampled had land allocations that were divided into small plots throughout the areas formerly cultivated by their collectives. As families grew, they occasionally received additional parcels from village reserve land; but their plots remained small and dispersed.

**Table 5. Average landholdings, by field level and province, Cambodia.**

| Province | Total holdings | | High fields | | | | Middle fields | | | | Low fields | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of plots | Area (ha) | No. of plots | Area (ha) | Reported maximum standing water (cm) | % of total holdings | No. of plots | Area (ha) | Reported maximum standing water (cm) | % of total holdings | No. of plots | Area (ha) | Reported maximum standing water (cm) | % of total holdings |
| Kandal | 6.4 | 1.1 | 3.6 | 0.59 | 28.0 | 55 | 1.8 | 0.57 | 63.0 | 25 | 2.4 | 0.31 | 48.0 | 20 |
| Kompong Speu | 6.1 | 1.1 | 4.2 | 0.75 | 24.0 | 54 | 4.0 | 0.53 | 32.5 | 22 | 1.8 | 0.38 | 46.4 | 24 |
| Takeo | 8.1 | 1.2 | 3.8 | 0.48 | 15.6 | 44 | 3.7 | 1.08 | 30.0 | 9 | 4.0 | 0.62 | 38.8 | 47 |
| Mean | 6.9 | 1.1 | 3.9 | 0.61 | 22.5 | 51 | 3.2 | 0.73 | 41.8 | 19 | 2.7 | 0.44 | 44.4 | 30 |

**Field classifications**

Cambodian RLR farmers classify their fields based on the relative levels of the plots, depth of standing water, and other characteristics. Farmers plant RLR varieties of different types and maturities according to field level and other related criteria. (Fujisaka [1988] clearly explained RLR farmers' differentiation of field levels and classified the levels according to landform, water regime, and prevailing soil type. Fujisaka also listed the TVs encountered in each level.)

Farmers interviewed at the research sites used the terms *srai leu* for high fields, *srai kandal* for middle fields, and *srai kraom* for low fields.

In high fields in the research areas, soils were predominantly sandy, and standing water seldom exceeded 15-20 cm in depth. They often were subject to drought. These fields correspond to the "rainfed shallow, drought-prone" classification of Khush (1984).

In middle fields, soils were sandy or sandy loam, the highest standing water was generally 20-40 cm, and occasional drought or flooding occurred less frequently than in high or low fields. In general, fields that farmers classify as middle fields correspond to the "rainfed shallow, unfavorable" classification of Khush (1984) but may have periodic drought or submergence problems.

Low fields present the farmer with a variety of cultivation problems. The fields surveyed had principally silt loam soils with some sand or clay content. Standing water routinely exceeded 30 cm and frequently exceeded 50 cm. Farmers call especially low-lying fields *tropeang* (pond fields). In these depressions or ponds, standing water may exceed 80 cm.

Low fields, as classified by farmers, correspond to "medium deep, waterlogged" fields, as classified by Khush (1984). Some low fields have deep standing water only intermittently. Deep, stagnant water may accumulate in low-lying plots, especially pond fields, for as long as 2 mo or more.

RLR fields in the village do not slope away in a regular stair-step progression. The three field types may be distributed in discrete areas around the village or in a patchwork, with a high field immediately adjacent to a low one. Tichit (1981) described RLR fields: "Each parcel is individually planted without consideration of the level of its neighbor....The ricefields appear like a series of basins juxtaposed at different levels."

**Field-level preferences**

Farmers consider high fields to be the least advantageous to farm of the three field types because these fields are drought prone and tend to have infertile, sandy soils. High fields accounted, however, for 51% of the sampled farmers' overall landholdings.

Middle fields are considered the most desirable because their soils tend to be more fertile and their problems with drought and excess standing water tend to be fewer than those of other field levels. The medium-maturing rice varieties, which are valued by farmers for their eating quality and which command the best sale prices, are best suited to this field level as well. Based on farmers' classifications, middle fields represented only 19% of the landholdings of the farmers sampled; however, this figure may be artificially low because Kompong Speu and Takeo farmers seldom use this classification.

Farmers consider low fields to be desirable because they have higher soil fertility than other field levels; however, high standing water causes problems in rice cultivation (Table 5). Pond fields are especially desirable because their soil is the most fertile. Tall, late-maturing varieties planted in pond fields yield as much as 2 t/ha, despite standing water as high as 80 cm.

## VARIETAL FACTORS

Cambodian farmers plant RLR varieties of different types and maturities according to field level and other related criteria. The following descriptions of scientists' and farmers' classifications of wet-season rice provide a context for understanding the farmers' varietal choices. Varietal constraints also are discussed.

**Scientists' classifications of wet-season rice**

Earlier sources offer a breakdown of Khmer terms and classifications of different cultural types (Table 6). The term *srai* (French transcription *sre*) translates as "field." Farmers more often describe these seasonal divisions and culture types using the word *srao* (rice). They categorize RLR as *srao wossa* (wet-season rice), whether transplanted or direct seeded.

French sources divide Cambodian RLR into "high" and "low" cultivation based on landform and hydrology. High cultivation is entirely rainfed, and sandy soils predominate in the fields. Low cultivation also is rainfed, but the water supply is good and the seasonal riverine flood inundates some fields. Low cultivation predominates in a large area of the low-lying plains of Battambang and Kompong Thom provinces. RLR in this area is usually direct seeded (Delvert 1961, Tichit 1981).

High cultivation is typical of RLR cultivation in Cambodia. Low cultivation is the predominant culture type in the northwest of the country. Tichit (1981) noted: "'High' rice culture is transplanted rice in fields which have the aspect of farm land crisscrossed by hedges, due to the fact that trees are planted on the dikes or along the paths (between fields)....especially the sugar palms which border the parcels and which give a characteristic appearance to the plains of Kandal, Takeo, Kompong Speu, and Kompong Chhnang provinces."

**Table 6. Khmer RLR classification as per season and cultural type, Cambodia (Tichit 1981).**

| | | | |
|---|---|---|---|
| Dry-culture rice (mountain rice) (*chamcar leu*) | | | |
| Wet-culture rice | | | |
| | Rainy-season rice (*sre vossa*) | | |
| | | Ordinary rice, transplanted (*sre vossa stung*) | |
| | | Ordinary rice, direct seeded (*sre vossa prous*) | |
| | | Floating rice (*sre vea*) | |
| | Dry-season rice (*sre prang*) | | |

The high- and low-cultivation classifications are too broad to distinguish sufficiently between the many field types, crop-management methods, and varietal problems that characterize Cambodian RLR farming. Terminologies provided by Khush (1984) and Garrity et al (1986) are precise for global classification of the RLR environment. One Cambodian RLR farmer, however, may manage fields classified as "rainfed shallow, drought prone;" "rainfed shallow, drought and submergence prone;" "rainfed shallow, submergence prone;" and "rainfed medium deep, water-logged"— all within a land allocation not exceeding 2 ha. According to these classifications, he also may manage "deepwater" ricefields; that is, since the depth of standing water in transplanted RLR fields often may exceed 50 cm, such fields fit the deepwater classification (De Datta 1982).

**Farmers' classifications of wet-season rice**

Cambodian RLR farmers use a diversity of local varieties that are adapted to the various soils and drought and standing-water problems of the area. Delvert (1961) noted that the varietal diversity in Cambodian RLR cultivation reduces the risk of a scanty harvest. In selecting a variety, the farmer considers not only the agronomic problems of a particular plot but also the grain and cooking quality of the variety.

The traditional RLR varieties that farmers commonly cultivate in Cambodia are predominantly photoperiod sensitive, but a few are photoperiod insensitive. Rice scientists who classify varieties according to absolute maturity would classify most photoperiod-sensitive varieties as late-maturing cultivars.

Farmers divide all RLR varieties, regardless of photoperiod sensitivity, into three maturity classifications that are based primarily on flowering and harvest dates rather than on absolute duration. Early-maturing varieties are called *srao sral* (light rice); medium-maturing varieties, *srao kandal* (medium rice); and late-maturing varieties, *srao thngon* (heavy rice). Government officials use these classifications in preparing cultivated-area statistics.

Delvert (1961) made note of very early varieties, *srao konlas* or *srao prape*, that are reaped "before the actual harvest" (that is, from late November to mid-January). These generic Khmer terms refer to photoperiod-insensitive varieties that are harvested as early as September to help fill depleted granaries. Variety names frequently indicate photoperiod insensitivity; for example, *Bai Khai* translates as "Three Months." Farmers have included IR varieties in this category since their introduction in 1979.

Early-maturing varieties, srao sral, include photoperiod-sensitive varieties that are harvested from middle or late November to early December and the photoperiod-insensitive varieties. Farmers in the survey area included in this category the most frequently planted early-maturing varieties, Sombok Ongkrong and Lum Ong Ksaich, and most of the commonly grown glutinous varieties (*srao domnawb*).

Each year, farmers plant a small portion of their RLR fields with glutinous rice. This rice is the basic ingredient of sweets and snacks made for weddings and other celebrations, especially the Khmer lunar new year which is celebrated in April. When in seasonal demand, glutinous varieties can command 10-15 riels/kg more than the premium eating rices.

Medium-maturing varieties, srao kandal, are photoperiod sensitive and are harvested in middle to late December—some as late as early January. The varieties most prized for eating quality in the research sites, Phka Khnyai (Ginger Flower) and Chma Phrom (Thin Border), are srao kandal. Delvert (1961) noted that these varieties are characteristic of Cambodian rainfed rice agriculture and accounted for 50-60% of the area cultivated in rice.

Late-maturing varieties, srao thngon, are harvested from early to late January, when deep standing water has receded. Therefore, farmers must consider flood tolerance in choosing varieties for their low fields. Late-maturing varieties that can tolerate deep standing water are planted in low-lying fields (Tichit 1981). Some late varieties, although transplanted, can survive 80 cm or more of standing water.

Grain and cooking quality of RLR varieties strongly influences farmers' varietal preferences and planting strategies. Delvert (1961) and Tichit (1981) noted important aspects of cooking quality, such as volume expansion, that affect farmers' choices but did not mention specific quality distinctions.

Farmers consider not only volume expansion but also grain shape, color, fragrance, and cooked texture in their assessments of the cooking and eating quality of rice. Superior eating rice should have long, slender white grains that are aromatic and soft when cooked.

Nevertheless, volume expansion can be an important consideration. The farmers surveyed said a small amount of rice with good volume expansion can feed a poor man's large family. They consider the eating quality of these varieties to be inferior, however, because the flavor is poor and the grains are hard when cooked.

Cooking and eating quality characteristics, such as grain shape and volume expansion, correspond to maturity and adaptation to field levels.

Farmers think of early-maturing varieties as subsistence rice. These varieties help ward off hunger because they have good volume expansion and they are harvested when the farmers' granaries are nearly empty.

Medium-maturing varieties are thought to have the most desirable cooking and eating quality. Farmers consistently cited widely cultivated varieties such as Phka Khnyai and Chma Phrom as exemplars of good cooking and eating quality. Delvert (1961) noted that the variety Chmar Proum was renowned for its quality.

Farmers generally consider the eating quality of late-maturing varieties to be inferior to that of medium-maturing varieties. Late-maturing varieties more often have undesirable short/bold grains, although some are favored for superior volume expansion.

**Table 7. Traditional RLR varieties, by province, Cambodia.**

| Variety | Duration | Harvest date | Adapted field level | Reported yield (t/ha) | Grain shape and color | Eating quality | Agronomic notes | Farmers' reasons for yearly cultivation |
|---|---|---|---|---|---|---|---|---|
| | | | | *Kandal Province* | | | | |
| Thung Lahong | Srao sral—early | Late Nov | High | 2.2-2.5 | Glutinous | Acceptable | Some drought tolerance | |
| Srao Domnawb | Srao sral—early | Early-mid Dec | High-middle | 2.4 | Glutinous | Good | | |
| Srao Krohom | Srao kandal—medium | Mid-late Dec | High-middle | 1.2-1.7 | Medium/bold-white | Good | Some drought tolerance | Field adaptation, maturity, eating quality |
| Niang Pal | Srao kandal—medium | Late Dec | Middle | 1.3 | Long/short-white | Good | Tolerates standing water to 30-40 cm | Eating quality and good sale price |
| Chma Phrom | Srao kandal—medium | Late Dec | Low | 1.7 | Long/short-white | Excellent, soft cooked grains | Tolerates standing water to 50 cm | Field adaptation, eating quality, sale price |
| Kung Eth | Srao thngon—late | Early Jan | Low | 1.8 | Short/bold-white | Acceptable | Tolerates standing water to 50 cm | Field adaptation, yield, volume expansion |
| Kung Pluk | Srao thngon—late | Early-mid Jan | Low | 1.8-2 | Short/bold-white | Good | Elongation capacity, tolerates water to >50 cm | Field adaptation, yield, eating quality |
| Kung La Eth | Srao thngon—late | Early-mid Jan | Low | 2+ | Short/bold-white | Good | Elongation capacity, tolerates water to >50 cm | Tolerance for deep standing water, eating quality |
| Chma Jongkaom | Srao thngon—late | Early-mid Jan | Low | 1.0-1.5 | Medium/bold-white | Acceptable, good volume expansion | Tolerates stagnant standing water to >50 cm deep | Tolerance for deep standing water, volume expansion |
| Phka Sla | Srao thngon—late | Early-mid Jan | Low | 1.3-1.8 | Short/bold-white | Good | Elongation ability, tolerates water to 80 cm | Adaptation to lowest fields eating quality, |
| Jamraon Pal | Srao thngon—late | Late Jan | Low | 1.4 | Long/short-white | Acceptable, good volume expansion | Strong tillers, resists lodging, tolerates water to 80 cm | Field adaptation and lodging resistance |
| Srao Saw | Srao thngon—late | Late Jan | Low | 1.5 | Short/bold-white | Acceptable | Elongation capacity, tolerates water to >80 cm | Tolerance for deep standing water in fields |
| | | | | *Kompong Speu Province* | | | | |
| Jong Wai Pdau | Srao sral—early | Photoperiod insensitive | High | 2.4 | Medium/bold-white | Acceptable | Drought tolerant, short stature | Short duration and drought tolerance |
| Lum Ong Ksaich | Srao sral—early | Photoperiod insensitive | High | 1.5-2.2 | Short/bold-white | Acceptable | Drought tolerant, short stature | Duration, field adaptation, good volume expansion |
| Aruth | Srao sral—early | Photoperiod insensitive | High | 1.1 | Short/bold-white | Acceptable | Drought tolerant | Short duration and drought tolerance |
| Sombok Ongkrong | Srao kandal—medium | Mid Dec | High-middle | 1.4-1.7 | Short/bold-white | Acceptable | Drought tolerant but less so than early varieties | Field adaptation and good volume expansion |
| Srao Krohom | Srao kandal—medium | Mid-late Dec | High-middle | 1-1.2 | Medium/bold-white | Good | Some drought tolerance | Early duration and eating quality |
| Chma Phrom | Srao kandal—medium-late | Mid-late Dec | Mid-low | 1.5-2 | Short/short-white | Excellent, fragrant | Tall, tolerates standing water to 50 cm | Yield, field adaptation, eating quality, sale price |
| Phka Phnao | Srao kandal—medium-late | Mid-late Dec | Middle-low | 1.8 | Short/bold-white | Good | Tolerates standing water to >50 cm | Field adaptation and good volume expansion |
| Kul | Srao thngon—late | Early-mid Jan | Low | 1.5 | Short/bold-white | Acceptable | Tolerates standing water to >50 cm | Tolerance for deep standing water in fields |
| | | | | *Takeo Province* | | | | |
| Bai Khai | Srao sral—early | Photoperiod insensitive | High | 1.2 | Medium/bold-white | Acceptable | 100 d duration variety with some drought tolerance | Short duration and because they can be planted to bene-fit from late rains (as in 1989) to add to aggregate rice harvest |
| Jantuas Pluk | Srao sral—early | Photoperiod insensitive | High | 1.1-1.3 | Long/short-white | Acceptable | 110-115 d duration variety with some drought tolerance | |

continued on next page

**Table 7 continued.**

| Variety | Duration | Harvest date | Adapted field level | Reported yield (t/ha) | Grain shape and color | Eating quality | Agronomic notes | Farmers' reasons for yearly cultivation |
|---|---|---|---|---|---|---|---|---|
| Aruth | Srao sral—early | Late Nov | High | 1.6 | Long/short-white | Good | Some drought tolerance | Good yield and eating quality |
| Domnawb Chmal | Srao sral—early | Early Dec | High-middle | 2+ | Glutinous | Good | Some drought tolerance | Good yield and early harvest date |
| Phka Khnyai (1) | Srao kandal—medium | Mid-late Dec | High-middle | 1.7 | Long/short-white | Excellent, fragrant | Some drought tolerance | Field adaptation and eating quality/ sale price |
| Srao Krohom | Srao kandal—medium | Late Dec - early Jan | High-middle | 1.4 | Long/short-white | Good | | Medium duration and good eating quality |
| Krojoh Ksaich | Srao kandal—medium | Late Dec - early Jan | High-middle | 2.5-2.8 | Long/short-white | Good | | Yield and eating quality |
| Prambai Kua | Srao kandal—medium | Late Dec - early Jan | High-middle | 1.4 | Long/short-white | Excellent, soft cooked grains | Suited to low fields if standing water not >40 cm | Especially good eating quality |
| Sombok Ongkrong | Srao kandal—medium | Late Dec - early Jan | High-middle | 1.2 | Short/bold-white | Acceptable | Some drought tolerance | Drought tolerance and maturity |
| Niang Manh | Srao thngon—late | Early Jan | Low | 1.7 | Long/short-white | Good, good volume expansion | Tolerates standing water to 40-50 cm | Yield in low fields and cooking and eating quality |
| Srao Saw | Srao thngon—late | Early-mid Jan | Low | 1.9-2.1 | Short/bold-white | Acceptable-good | Tolerates standing water to 50 cm | Field adaptation and yield |
| Kung Kombot | Srao thngon—late | Early-mid Jan | Low | 2.2 | Short/bold-white | Good | Elongation ability, tolerates standing water >50 cm | Good yield and tolerance for deep standing water |
| Phka Khnyai (2) | Srao thngon—late | Mid-late Jan | Low | 1.7 | Long/short-white | Excellent, fragrant | Elongation ability, tolerates standing water >50 cm | Field adaptation, cooking quality, sale price |
| Niang Saw | Srao thngon—late | Late Jan | Low | 1.7-2.2 | Short/bold-white | Acceptable | Tolerates standing water >50 cm | Good yield in low fields and adaptation to standing water |
| Phka Phnao | Srao thngon—late | Early-mid Jan | Low | 1.3 | Medium/bold-white | Good | Tolerates up to 1 m standing water | Tolerance for deep standing water in fields |

## Farmers' varietal choices

Farmers sampled in all three provinces managed a wide variety of traditional RLR cultivars that were suited to the various field types and prevailing hydrological conditions (Table 7).

Data were collected from all three sites on the frequency at which specific TVs were planted (Table 8). The data confirmed farmers' expressed preference for medium-maturing varieties with good cooking and eating quality. At each site, the TV reported as most frequently cultivated was a medium-maturing variety, favored for its eating quality and high sale price. The high-frequency varieties provide at least competitive average yields when compared with other locally grown, medium-maturing varieties and have some advantageous adaptations to local field conditions as well.

All individuals sampled in Kandal province reported growing the variety Srao Krohom, supporting the assertion that farmers prefer to cultivate good eating rice. Srao Krohom was not rated with the varieties that had the best eating and cooking quality; but the farmers interviewed said that it yields well in the infertile sandy soils of high fields and its eating quality is superior to most other medium-maturing varieties. The four farmers sampled who reported growing only one variety during the 1989-90 cropping season all grew Srao Krohom, and each had only high fields in his land allocation.

Most other varieties grown in the Kandal site were tall, lodging-resistant, late-maturing cultivars favored for their tolerance for the deep standing water found in low fields. Farmers said yield and, especially, eating quality were secondary concerns in their decisions to cultivate these varieties each year.

Farmers in Kompong Speu Province similarly placed more emphasis on eating quality than on agronomic adaptation in their choices of varieties. Of the 14 farmers sampled, 11 grew Chma Phrom, which is prized for its eating quality and commercial value—it commands one of the highest sale prices in Phnom Penh markets. The next-most-frequently planted varieties were Lum Ong Ksaich, an early-maturing variety that yields well in drought-prone upper fields with infertile sandy soils, and Phka Phnao, a late-maturing variety that tolerates deeper standing water than Chma Phrom.

The basis of varietal choice was the same in the Takeo Province research site. The variety most frequently grown by

**Table 8. Reported frequency of planting traditional RLR and modern varieties, 1989-90 crop, by province, Cambodia.**

| Kandal Province | | | | | Kompong Speu Province | | | | | Takeo Province | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variety | Reported frequency of cultivation | % of sample | No. of farmers growing | | Variety | Reported frequency of cultivation | % of sample | No. of farmers growing | | Variety | Reported frequency of cultivation | % of sample | No. of farmers growing | |
| Srao Krohom | 17 | 100 | 1 variety | 4 | Chma Phrom | 11 | 79 | 1 variety | 4 | Phkha Khnai | 8 | 57 | 1 variety | 0 |
| Jamraon Pal | 3 | 18 | 2 varieties | 12 | Lum ong Ksaich | 7 | 50 | 2 varieties | 6 | Niang Manh | 6 | 43 | 2 varieties | 9 |
| Phka Sla | 2 | 12 | 3 varieties | 1 | Phka Phnao | 5 | 36 | 3 varieties | 2 | Srao Krohom | 4 | 29 | 3 varieties | 5 |
| Srao Saw | 2 | 12 | 4 varieties | 0 | Sombok Ongkrong | 2 | 14 | 4 varieties | 2 | Srao Saw | 4 | 29 | 4 varieties | 0 |
| Srao Domnawb | 1 | 6 | | | Jong Wai Pdau | 1 | 7 | | | Sombok Ongkrong | 4 | 29 | | |
| Niang Pal | 1 | 6 | | | Aruth | 1 | 7 | | | Phka Phnao | 2 | 14 | | |
| Kung Eth | 1 | 6 | | | IR42 | 1 | 7 | | | Aruth | 1 | 7 | | |
| Chma Phrom | 1 | 6 | | | | | | | | Krojoh Ksaich | 1 | 7 | | |
| Kung Pluk | 1 | 6 | | | | | | | | Prambai Kua | 1 | 7 | | |
| IR36 | 1 | 6 | | | | | | | | Niang Saw | 1 | 7 | | |
| IR42 | 1 | 6 | | | | | | | | Chma Phrom | 1 | 7 | | |
| | | | Total | 17 | | | | Total | 14 | | | | Total | 14 |

the farmers interviewed, Phka Khnyai, is as valued as Chma Phrom for its eating quality and good sale price. The next-most-frequently grown variety, Niang Manh, is thought to have inferior cooking and eating quality but is favored for its tolerance for moderately deep standing water in low fields.

### Varietal constraints

Cambodian RLR farmers are seriously constrained by the low yields of RLR, despite the advantageous agronomic adaptations of some varieties they regularly grow. Yield data do not indicate that currently planted varieties of any duration yield more than 2 t/ha. Glutinous varieties can yield more than 2 t/ha, but they play a small role in household subsistence strategies and have a limited, seasonal market.

Yields of late-maturing cultivars were consistently higher than those of early- or medium-maturing varieties. The low fields to which the varieties are best adapted account for only 30% of the farmers' total landholdings—an average of 0.34 ha per household. The averages for households sampled in Kandal and Kompong Speu provinces were even smaller.

The average RLR yield in Kandal Province was 1.9 t/ha; in Kompong Speu Province, 1.7 t/ha; and in Takeo Province, 1.3 t/ha. With average landholdings of only 1.4 ha, and with low prevailing yields, farmers could hope to produce only enough rice for family subsistence, with perhaps a small surplus for sale in good years. The diverse nature of their landholdings forces them to plant a number of varieties with differing maturities.

## CROPPING OPERATIONS

The cropping operations observed in the survey area can be divided into eight categories: preparing nursery beds, plowing the fields for transplanting, uprooting, transplanting, weeding, harvesting, threshing, and storing seed and paddy. A closely related operation, managing and using fertilizer, also is discussed.

### Preparing nursery beds

Nursery establishment is the first important cropping operation in RLR cultivation.

Farmers must consider the possibility of a delay in the timely performance of cropping operations due to drought or flood throughout the cropping season. Thus, they choose plots for nursery beds that are neither too high, which would risk drought, nor too low, which would risk waterlogging. If possible, nurseries are made near a source of water so mechanical irrigation with the *snaich* (water shovel) can be used.

Nursery beds for the first-transplanted late-maturing varieties often are established as early as May in the low-lying pond fields, depending on the rains. Farmers believe the fertile soil in these fields promotes vigorous early seedling growth and such growth reduces the risks associated with flooding.

Older farmers said a nursery-bed plot of 0.1-0.2 ha was necessary to produce sufficient seedlings to transplant 1 ha. In practice, nursery beds for the 1989-90 season averaged 23% of the total cultivated area. Land preparation for nursery beds begins in mid-May or early June if rainfall is sufficient.

The farmers sampled applied an average of 3.7 t of farmyard manure (FYM), or two-thirds of that available, to the nursery beds for the 1989-90 crop. Older farmers said 4-5 cartloads of FYM (1.2-2.4 t), if available, should be applied to each 0.1 ha of nursery beds. Manure is applied to the nursery bed 5-10 d before the first plowing, distributed evenly in small piles throughout each plot. More manure may be applied to the plot 15 d after sowing.

Land is prepared carefully for nursery beds. Farmers' strategies for the first and second plowings of nursery beds are identical to those for plowing transplanted fields.

The Khmer farmer prepares land using a pair of draft animals to pull a simple moldboard plow, which turns soil to the right, and a rake-like, short-toothed harrow, on which the farmer usually stands to add weight.

The first plowing is called *phchua sdam* (plowing right). This pass turns the soil inward, helping to level the plot by cutting the higher soil, which is near the bunds, toward the center. The farmer, with the plow and team, enters the plot at the center and plows straight across. He then makes a sharp right turn and plows in the opposite direction, parallel and as close to the first cut as possible. Passing the entry point, he turns right again, plowing each succeeding furrow parallel to the previous one (Fig. 2a). Usually, the plot is harrowed in the same direction. Older farmers estimated that one farmer with a pair of draft animals could complete the first plowing and harrowing of the nursery bed in one morning of work, from 0500 h to 1000 or 1100 h (that is, during the standard work period for draft animals).

The nursery bed receives a second plowing and harrowing, usually 1-2 wk after the first, which is called *phchua chweing* (plowing left). The soil is turned in the opposite direction to the first plowing. The farmer enters at a corner of the field with the mold board of the plow angled toward the bund. He plows around the perimeter of the plot as close to the bunds as possible; then he cuts inward, spiraling toward the center, always turning left (Fig. 2b). The plot is harrowed in the same direction, but harrowing may be abbreviated to save time. The second plowing and harrowing, like the first, require one morning of work.

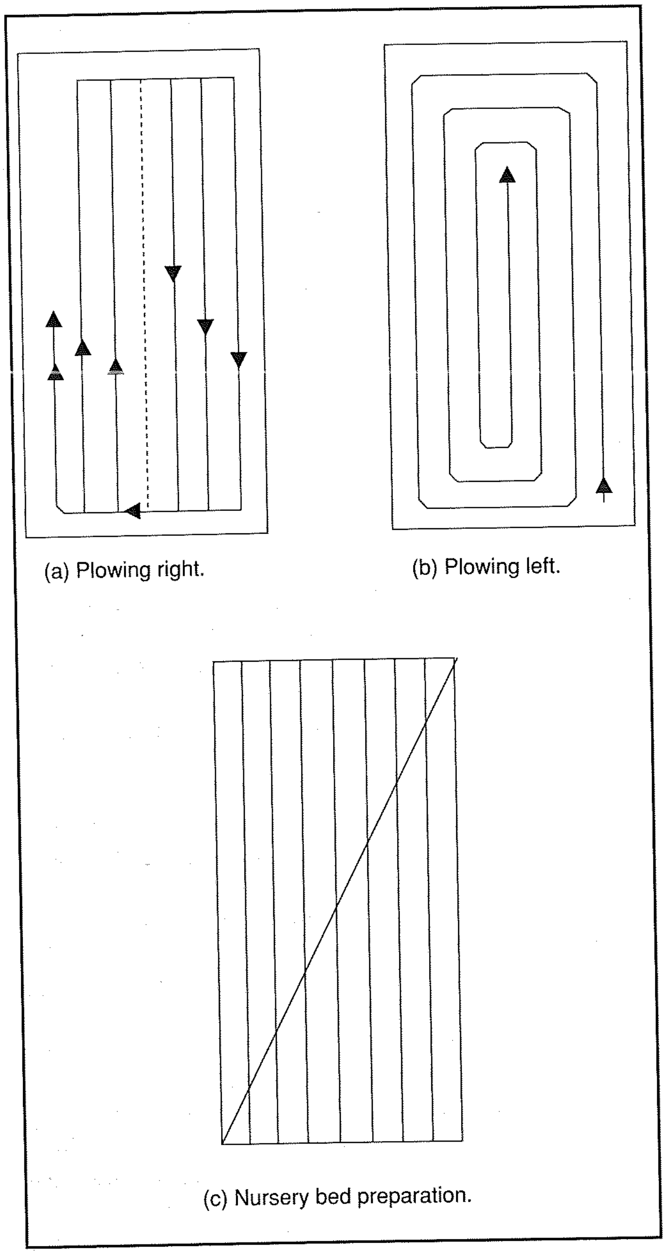
The nursery bed is then prepared for sowing. If standing water is insufficient, the farmer's family may throw water into the bed from neighboring plots. The farmer then plows evenly spaced, parallel, deep furrows across the field to delineate the beds so seed can be sown and to allow for irrigation or drainage. Finally, he cuts a deep furrow diagonally across the parallel furrows (Fig. 2c). (If the plot is oddly shaped, the farmer plows in a deep spiral, leaving 0.7-1 m between the furrows, and then plows a straight furrow diagonally across the spiral.)

The parallel furrows between which the seed is sown are called *jongua nyl* (female furrows), and the diagonal furrow is called the *jongua chmol* (male furrow). The male furrow is positioned to channel irrigation water, introduced with a water shovel, into the plot and to drain the plot of excess water.

Kompong Speu farmers reported that they normally sow five *tao* of seed per 0.1 ha of nursery bed, regardless of field level, soil type, or varietal maturity. The tao is a standard-sized basket used to measure seed and holds about 12 kg of paddy; thus, the seeding rate is 48-60 kg/ha. Delvert (1961) reported a similar seeding rate of 60 kg/ha.

Takeo farmers use a variable seeding rate of 70 kg/ha for medium- and late-maturing varieties sown in the more fertile middle or low fields and 100 kg/ha for early varieties sown in the less fertile, drought-prone high fields. Kandal farmers used a simple sliding formula of 4 tao/ha (48 kg/ha) for late-maturing varieties planted in low fields, 5 tao/ha (60 kg/ha) for medium-maturing varieties, and 6 tao/ha (72 kg/ha) for early-maturing varieties. The mean seeding rate for rice varieties of all maturities was 86 kg/ha for the 1989-90 crop.

Seed is soaked 12-24 h and incubated for a further 36 h (usually 2 nights and 1 day). Kandal farmers usually sow their nursery beds in the morning; once the germinated seed is established on the soil surface, they drain water from the plot in the afternoon. Water is reintroduced into the nursery bed 5-6 d later.




2. Plowing methods.

### Plowing the fields for transplanting

Like the nursery beds, crop fields usually are plowed and harrowed twice before transplanting.

If the early rains have been sufficient, the first plowing usually begins immediately after the nursery beds are prepared. The low fields are plowed first because they are more likely than middle or high fields to contain sufficient standing water for transplanting. Plowing proceeds to the middle fields and then to the high fields.

The farmers sampled used part of their FYM—an average of 1.8 t—on the crop fields, applying it basally before the first plowing. Any FYM remaining after nursery-bed and field preparation was applied either to unproductive upper fields only or to different portions of fields in yearly rotation. Farmers who used chemical fertilizer applied it basally.

Although some 16-20-0 was for sale from the government at subsidized prices for the 1989-90 crop, Soviet ammophos fertilizer (11-42-0) was more often available. Nineteen farmers (42%) applied ammophos to the 1989-90 crop; nine of those farmers applied some part of the fertilizer basally before the first plowing. The average amount applied was 43.4 kg, providing (based on average landholdings) 5.3 kg N/ha and 20.1 kg P/ha. The other 10 farmers who used ammophos applied it in a single topdressing before maximum tillering or in spot topdressings as needed.

Kandal and Takeo farmers generally plow left for the first plowing of crop fields because they need to level the soil of their slightly sloping fields. Kompong Speu farmers plow right for the first plowing because the ricefields in the sampled village cluster are flat and even.

Farmers estimated that one farmer with a pair of draft animals could complete the first plowing of 1 ha in 4-5 mornings. A Kompong Speu farmer said that a farmer and team could plow 0.2 ha per morning in sandy loam or clay loam soil in the middle and low fields but only 0.15 ha/d in the hard-to-plow sandy soils common in the high fields. Based on interview data, the first and second plowings each required 7 d/ha of work (Table 9).

Farmers plow individually or cooperatively, with up to four farmers and their draft animals plowing the same field. Of the farmers interviewed, 19 (42%) plowed alone, 21 (47%) plowed cooperatively, and the remainder hired power for the first plowing. Some Kandal farmers preferred to plow alone because, they said, doing so made it easier to maintain an even depth. Others said that farmers plowing cooperatively could agree on and adequately maintain a uniform depth and that group labor made the arduous task more enjoyable.

Hired plowing was paid for with cash or exchange labor. The wages and labor-exchange rates varied among the provinces (Table 10).

If the rains fall early enough to provide sufficient standing water in the fields, the fields usually receive a second plowing and harrowing just before they are transplanted (that is, 45-60 d after nursery-bed establishment). Tichit (1981) reported that farmers waited 30 d between the first and second plowings of fields that were to be planted in early-maturing varieties and 60 d between plowings of fields that were to be planted in medium- or late-maturing varieties. Farmers estimated that an individual with a pair of draft animals could plow 1 ha in an average of 4-5 mornings of work; interview data indicated that the second plowing required an average of 7 d/ha of work. Within the total sample, 26 (58%) of the farmers plowed cooperatively for the second plowing, 11 (24%) plowed alone, and the remainder hired power.

**Table 9. Comparison of number of workdays/ha for cropping operations in transplanted RLR, Cambodia.**

| Cropping operation | Interview sample | Delvert[a] | Delvert[b] | Tichit[c] |
|---|---|---|---|---|
| Two plowings | 14 | 10 | 16 | 15 |
| Harrowing | 3.5 | 3 | 4 | 3 |
| Uprooting | [d] | 3 | [d] | 5.5 |
| Transplanting | 23.5 | 15 | 20 | 26 |
| Weeding | 6.4 | - | - | - |
| Harvesting | 20.5 | 10 | 20 | 10 |
| Threshing | 10 | 8 | 16 | 5 |
| Total | 77.9 | 49 | 76 | 64.5 |

[a]Delvert (1961). [b]Delvert (1961) citing Baudoin, La Culture du Riz au Cambodge. [c]Tichit (1981) as cited in Lambert (1962). [d]Data for uprooting are included in the number of workdays for transplanting.

**Table 10. Comparative costs of hiring labor for plowing, Cambodia.**

| Province | Wages, 1989-90 crop[a] | | Wages, 1990-91 crop | | Labor repayment |
|---|---|---|---|---|---|
| | Riels | US$ | Riels | US$ | |
| Kandal | 300 | 0.59 | 500 | 0.98 | 2 days transplanting |
| Kompong Speu | 200 | 0.39 | 250 | 0.49 | 2 mornings transplanting or uprooting 80 bundles of seedlings |
| Takeo | 100 | 0.20 | 250 | 0.49 | Uprooting 1 morning and transplanting 1 afternoon |

[a]In 1989-90, the official exchange rate was 510 riels to US$1.00.

Fields usually are harrowed in the same direction that they have been plowed. Takeo farmers routinely harrow their fields after the second plowing. Kompong Speu and Kandal farmers do not harrow plots that have light sandy soils because doing so increases soil compaction. At these two sites, transplanters must follow the plow in such fields during the second plowing if they are to transplant the seedlings easily. If those fields have been harrowed, or if 2 d or more have elapsed since plowing, the transplanters must use the *cheu jaran*, a tool made of sharpened bamboo, to drill holes to receive the seedlings.

## Uprooting

Uprooting seedlings is the first cropping operation in which farmers use cooperative labor. The family whose fields first have sufficient standing water for transplanting is the first to receive exchange labor; then the labor group rotates through the fields of the members, spending 1 d per farm. Of the farmers sampled, 36 (80%) completed this operation with exchange labor for the 1989-90 cropping season. Wages and labor-exchange rates varied among the three sites, but all were based, as piece work, on the number of bundles of seedlings uprooted, bound, and topped. Workers were expected to produce 40 bundles/d.

In Kandal and Kompong Speu, uprooting is a full-day operation. Work begins between 0600 h and 0700 h and ends at about 1700 h with a break from about 1100 h to 1400 h to eat lunch and avoid the midday heat. Uprooted seedlings are left in the fields a maximum of 2 d before they are transported to the fields for transplanting. At both of these sites, each laborer is expected to uproot 40 bundles/d. In Kandal, hired laborers were paid 100 riels (US$0.31) per 40 bundles during the 1989-90 cropping season and 200 riels (US$0.62) per 40 bundles during the 1990-91 season. In Kompong Speu, wages were 100 riels and 150 riels (US$0.47) for the two seasons. Exchange laborers at both sites are expected to participate in a full day's work, but the bundles of seedlings they uproot are not counted as carefully as those of hired laborers.

Takeo farmers prefer to uproot seedlings in the morning and transplant them that afternoon. Each exchange laborer is expected to uproot 40 bundles of seedlings, working at his or her own pace, and may return home as soon as that quota is met. Hired laborers in Takeo received 100 riels (US$0.31) for uprooting 40 bundles or 250 riels (US$0.79) for both uprooting and transplanting 40 bundles during the 1989-90 cropping season.

Farmers interviewed about cropping practices estimated that it took 25-35 d to uproot, bind, and top enough seedlings to transplant 1 ha. The reported time was 15.5 workdays with little variation among the three sites.

If the rains are on time, farmers prefer to uproot seedlings of photoperiod-sensitive varieties 45-60 d after sowing and those of photoperiod-insensitive TVs or IR varieties 20-25 d after sowing.

### Transplanting

Transplanting, like all RLR cropping operations, depends on the timely arrival of sufficient rainfall to ensure crop establishment. If the rains are late or insufficient, then inadequate water is available for proper land preparation and seedlings in the nursery beds are overaged and drought affected.

Under these conditions, farmers often are forced to plow a field only once, as well as the soil moisture allows. Transplanters then must follow the plow, using the cheu jaran to drill holes into which seedlings can be transplanted. If the water shortage is dire, one group advances in a line across a dry plowed field, drilling holes, and another group follows, transplanting seedlings and filling the holes with soil. In either case, the farmers must hope for sufficient late rains to make the best of an already desperate situation.

Transplanting made the greatest use of cooperative labor. Only five farmers (11%) hired labor for transplanting the 1989-90 crop. The remaining 40 (89%) used family and cooperative labor. The exchange rate for 1 d of transplanting in Kandal was set at one-half the cost of one morning of plowing; that is, 2 d of transplanting repaid one morning of plowing. The wage rate was 150 riels/d (US$0.49/d) for the 1989-90 crop and 250 riels/d (US$0.79/d) for the 1990-91 crop. In Kompong Speu, wages were 100 riels (US$0.34) and 200 riels (US$0.68) for the two seasons. Transplanting was included in the all-day uprooting-and-transplanting wage in Takeo.

Older farmers among the interview subjects estimated that it took 20-25 workdays to transplant 1 ha. The actual average labor requirement for the 1989-90 crop was 24 d/ha, ranging from 34 d/ha in Kandal to only 18 d/ha in Takeo. Transplanting is a full-day operation in Kandal and Kompong Speu; the hours worked correspond to those for uprooting. Families whose fields first have sufficient standing water receive first priority in scheduling cooperative labor.

In general, late-maturing varieties are transplanted first in low and pond fields, which are more likely than middle and high fields to have sufficient standing water. Medium-maturing varieties are then transplanted in middle fields if the rains have been timely, and early-maturing varieties are transplanted last into the high fields.

However, due to rainfall irregularities and the dispersal of most farmers' land allocations, transplanting seldom follows such an orderly progression at the study sites. Some plots of any level of land may have sufficient standing water for timely transplanting, while others must wait for enough rainfall or must be transplanted dry. Transplanting generally progressed as dictated by the rains and amount of standing water.

Transplanting spacing between hills usually is random, and none of the farmers who were interviewed reported transplanting in rows. The Khmer Rouge enforced row transplanting with a plant population of up to 100 hills/m$^2$ in attempts to increase yields (Martin 1983).

Farmers said there was no typical number of seedlings transplanted per hill. Transplanters gauge the number per hill from the size and vigor of the seedlings: large, vigorous seedlings and old seedlings are transplanted at the rate of 2-3 per hill and smaller, less healthy seedlings at the rate of 4-5 per hill or more.

Elders interviewed about cropping practices said that the average plant population should be 22-25 hills/m$^2$, but the farmer must consider field level, soil type, and varietal maturity in determining the population appropriate to a particular field (Table 11). Reported plant populations in Cambodian RLR

**Table 11. Comparison of number of hills transplanted per m$^2$ from published sources and farmers' recommendations with field observation of plant population, Cambodia.**

| Soil type | No. of hills/m$^2$ | | | |
|---|---|---|---|---|
| | Tichit (1981) | Kandal farmers | Kompong Speu farmers | Takeo farmers |
| Rich soils | 11 | 11 | <22 | 11-14 |
| Medium fertile soils | 16 | 25 | 22 | 25 |
| Sandy soils | 25 | 44 | >22 | 44 |
| Poor soils | 34 | 44 | >22 | 44 |
| *Observed plant population, by varietal maturity* | | | | |
| Early varieties[a] | | 17 | 17 | 18 |
| Medium varieties[b] | | 14 | 19 | - |
| Late varieties[c] | | 15 | 19 | 18 |

[a]Usually planted in infertile upper fields with sandy soils. [b]Usually planted in middle fields with more fertile sandy loam soils. [c]Usually planted in fertile low fields. Range of observed plant population was 10-20 hills/m$^2$ in Kandal, 19 hills/m$^2$ (single observation) in Kompong Speu, and 9-22 hills/m$^2$ in Takeo.

agriculture range from as few as 11 hills/m$^2$ in fields with fertile soils to 34 hills/m$^2$ in fields with infertile soils (Tichit 1981).

In practice, fields observed in both Kandal and Kompong Speu averaged 18 hills/m$^2$. Fields in Takeo had an average plant population of 15 hills/m$^2$ for all varieties. No field observed had a plant population greater than 23 hills/m$^2$. A late-maturing, tall variety, Phka Sla, was observed in a Takeo pond field with a plant population of only 9 hills/m$^2$.

### Weeding

Fields were weeded exclusively with family labor during the 1989-90 cropping season. Usually, farmers weed as necessary when they go to the fields to observe the transplanted crop. They also apply small amounts of FYM to areas that have pallid plants. If the entire holding is weeded, this operation usually takes place 15-20 d after transplanting. Such complete weedings required 6 workdays/ha during the 1989-90 cropping season.

Most of the farmers who used urea fertilizer (46-0-0) applied it after weeding. Of the farmers sampled, 28 (62%) applied an average of 39 kg of urea for the total crop, or an average of 21.1 kg N/ha. Twenty-two farmers applied urea at maximum tillering while weeding; the remainder applied it at panicle initiation or booting.

### Harvesting

The only other cropping operation carried out before harvest is *pongriab srao* (turning back the rice). Tall varieties are sometimes artificially lodged in one direction by dragging a long bamboo pole across the ripening crop approximately 10-15 d before harvest. This operation facilitates harvest and prevents haphazard natural lodging (cf. Delvert 1961, Tichit 1981).

Cooperative labor is used during harvest, but farmers said scheduling this labor is difficult. A majority of farmers in the villages sampled plant varieties that are strongly photoperiod sensitive and, therefore, ripen at the same time; so conflicts in scheduling labor are inevitable.

Farmers usually use only family labor for harvest, following the varieties of different maturities as they serially ripen. A family may need as many as 15 d to harvest a large area planted in one variety. Of the households sampled, 26 (58%) used only family labor for the 1989-90 harvest, 16 (36%) participated in cooperative labor, and only 3 (in Kandal) hired labor.

Like uprooting, harvesting is treated as piece work; wages and exchange-labor rates are based on the number of bundles of rice cut and bound. (Hired laborers are not expected to assist in transporting the rice to the field owner's house.) During the 1989-90 cropping season, hired laborers were paid 200 riels (US$0.64) per 400 bundles of rice in both Kandal and Takeo. In Kompong Speu, hired laborers received 50 riels (US$0.17) per 150 bundles. Farmers at all three sites estimated that wages would more than double for the 1990-91 harvest.

### Threshing

After drying on the stubble for 2-3 d, the rice bundles are transported to the farmer's house and stacked in a circle around the threshing site.

Farmers at all three research sites thresh rice by beating the bundles against a slanted board called *a kda bawk*, which is placed on a large mat to catch the grain. Individual bundles may be beaten against the board by hand, or several bundles may be bound together so they can be threshed at the same time. To thresh several bundles at once, farmers use a *khniab* (flail), which consists of two pieces of wood connected by a piece of twine. The farmer winds the twine around two or three bundles of rice and then, holding the khniab by the wooden handles, beats the combined bundles against the board.

Hand threshing is reported only in the rice-producing areas of Kandal, Kompong Speu, and Takeo provinces. In other areas of Cambodia, farmers use cattle to thresh rice (Delvert 1961).

At all three sites, rice is threshed almost exclusively in the evening, usually by family and cooperative laborers. Of the farmers surveyed, 23 (53%) used cooperative labor, 21 (47%) used family labor, and only one used hired labor for threshing during the 1989-90 season. Ten evenings of 3-4 h work were required to thresh the rice harvested from 1 ha.

### Storing seed and paddy

Most farmers choose and save their seed stock during threshing. The field owner examines the rice at the threshing site and selects 200-300 bundles that have full panicles with well-filled seeds. These bundles are threshed and dried separately. Some Kandal farmers prefer to identify an area of the standing crop in which the rice has desirable characteristics, then harvest and thresh these areas beforethe general harvest begins, saving the yield for seed. Under this method, if varietal mixing occurs in the field, one member of the threshing group (usually a woman) must laboriously separate the seed stock, panicle by panicle, to ensure that pure seed of the desired variety is saved.

Seed is sun dried on mats for 3-4 d and then stored, separated by variety. Some farmers store seed in homemade bags called *khbong*, which are coarsely plaited of sugar palm leaves. Farmers said the coarse plaiting promotes aeration, which is beneficial during seed storage. Others prefer to store seed in gunny bags, which are more resistant than khbong to rat damage.

Seed of any variety is usually disposed of yearly. Any seed that is not planted during the season after it was harvested is added to the family's subsistence rice because farmers recognize that seed stored for 2 yr loses germinability. If a farmer wants to plant a variety for which he does not have fresh seed stock, he must arrange a trade or purchase with a neighbor family.

Methods of storing subsistence rice vary from site to site. Kandal farmers store all nonglutinous varieties in a large khbong under the house or in a *kong srao*—a separate granary, usually made of bamboo with woven cane walls and a thatch

Table 12. Farmyard manure and chemical fertilizer use, by province, Cambodia.

| | Kandal | Kompong Speu | Takeo | Av/ total | % of sample |
|---|---|---|---|---|---|
| Total no. sampled | 17 | 14 | 14 | 45 | |
| *Farmyard manure (FYM)* | | | | | |
| No. of farmers who apply | 13 | 12 | 14 | 39 | 87 |
| To nursery beds | | | | | |
| To fields | 9 | 7 | 4 | 20 | 44 |
| Av no. of cartloads[a] | | | | | |
| To nursery beds | 12.7 | 16.7 | 11.5 | 13.6 | |
| To fields | 6.2 | 8.2 | 5.6 | 6.7 | |
| Total av no. of cartloads | 18.9 | 24.9 | 17.1 | 20.3 | |
| *Ammophos* | | | | | |
| No. of farmers who apply | 7 | 4 | 8 | 19 | 42 |
| Av kg applied/ha | 42.3 | 56.4 | 31.5 | 43.4 | |
| Av kg P/ha | 16 | 24.5 | 19.9 | 20.1 | |
| Av kg N/ha | 4.2 | 6.4 | 5.2 | 5.3 | |
| Number of farmers who apply | | | | | |
| Basally | 2 | 3 | 4 | 9 | |
| At tillering | 5 | 2 | 4 | 11 | |
| *Urea* | | | | | |
| No. of farmers who apply | 11 | 5 | 12 | 28 | 62 |
| Av kg applied/ha | 47 | 36.6 | 33 | 38.9 | |
| Av kg N/ha | 20.4 | 18 | 24.8 | 21.1 | |
| No. of farmers who apply at | | | | | |
| Tillering | 11 | 3 | 8 | 22 | |
| Panicle initiation | 0 | 2 | 4 | 6 | |

[a]One cartload = approx. 275 kg FYM.

roof. As each variety reaches maturity and is harvested, threshed, and dried, it is placed in the bag or granary and covered with a mat. The next variety harvested is placed on top and similarly separated. Thus, if rice of any single variety is needed, access is possible without undue varietal mixing. Glutinous varieties and seed stock are stored separately.

The storage methods of Kompong Speu and Takeo farmers are similar to those of Kandal farmers; however, in these two provinces mats usually are not used to separate the varieties. Varietal mixing is inevitable as the farmer burrows through levels of paddy to reach a variety stored below.

## Managing and using fertilizer

As described above, the farmers surveyed used both FYM and, when it was available, chemical fertilizer (Table 12).

Using FYM is one of the few means available to Cambodian RLR farmers for increasing yields and improving soil fertility. Litzenberger (1963) identified FYM as the most important fertilizer material in the country. Applying FYM adds humus and increases the soil's fertility, aeration, water-holding capacity, and biological activity.

Litzenberger (1963) noted that the benefits derived from FYM depend on its composition and management, and he said Cambodian FYM is well managed. A chemical analysis showed that 100 kg of well-managed manure contained 65 kg moisture, 16 kg organic matter, 1.44 kg available N, 0.19 kg available P, and 0.95 kg available K.

The farmers surveyed were well aware of the importance of applying FYM to rice crops. Those who owned no cattle gathered droppings from the roads in front of their houses and composted that material to provide themselves with some FYM.

The care with which the sampled farmers managed their FYM varied greatly. Takeo farmers were the most careful: they built roofed manure sheds with low wattled walls separate from their houses, or they built walled manure pits under their houses, close to where they kept their cattle. Kandal and Kompong Speu farmers left the manure outside in unshaded piles or placed it in pits dug in the shade of trees near their houses.

Farmers' practices in adding organic material to the composted manure also varied greatly. Takeo farmers were the most industrious, adding small amounts of rice straw, dried leaves, ashes from the kitchen fire, and kitchen scraps to the manure pit. One Kompong Speu farmer broke down termite mounds and incorporated this aerated soil into his manure pit.

Farmers at all three sites reported that they added leaves of the weed *Chromolaena odorata* to their manure pits and that they found this practice beneficial. Tichit's data (1981) indicated that yields increase significantly for rice grown in degraded sand soils when several t/ha of *C. odorata* are applied.

To maximize the use of FYM, which is a scarce commodity, the sampled farmers applied an average of 60% of their total FYM to their nursery beds—an average of 3.7 t to a nursery bed sufficient to plant 1 ha. Based upon a nursery bed of 0.2 ha, this level of application is equivalent to 71 kg N/ha, 9.5 kg P/ha, and 5.0 kg K/ha.

Before 1990, the government provided chemical fertilizer for sale at affordable, subsidized prices through the province or district agricultural office. The subsidized prices were significantly lower than the prevailing market prices (Table 13). The amounts and types of fertilizer available varied from year to year and from province to province. Government import orders for the 1990-91 wet-season crop were not filled, and subsidized fertilizer was unavailable.

Farmers who used chemical fertilizer during the 1989-90 cropping season applied Soviet ammophos (11-42-0) at an

Table 13. Comparison of market and subsidized government fertilizer prices for two cropping seasons, Cambodia.

| Fertilizer | Market price/kg[a] | | Government price/kg | |
|---|---|---|---|---|
| | 1989-90 | 1990-91 | 1989-90 | 1990-91 |
| Ammophos (11-42-0) | R80 $0.16 | R180-200 $0.35-0.39 | R23.50 $0.05 | Fertilizer not available |
| Ammophos (16-20-0) | R85 $0.17 | R190-210 $0.37-0.41 | R21.25 $0.04 | R144 $0.28 |
| Urea (46-0-0) | R65 $0.13 | R200-210 $0.39-0.41 | R19 $0.04 | R90 $0.18 |

[a]Market prices were based on Phnom Penh prices; local market prices varied greatly by province.

average of 43 kg/ha and urea (46-0-0) at an average of 39 kg/ha.

## CONSTRAINTS

The most serious constraints to intensifying RLR production in Cambodia that were revealed or confirmed by this survey and that can be addressed by further research concern rainfall, soils, pests and diseases, traditional varieties, and cash cropping. Some constraints, however, do not impel further research but must be considered as improvements to RLR production are planned. These constraints are mentioned last.

### Rainfall

Rainfall patterns in Cambodia, and the attendant problems, are one of the most serious constraints to intensifying RLR production nationally. Hellei (1970) noted that precipitation is usually sufficient in quantity but is irregularly distributed. Despite farmers' efforts to bund and level their fields to optimize water control, he said, "the excess of water of one period does not compensate for the deficiency of another."

Three periods during the wet season provide the most serious problems in rice culture. Insufficient rains in May and June often delay land preparation. Water for optimum plant growth is frequently lacking in a period of July and August called the *petite saison seche* (small dry season), when rainfall ceases or falls infrequently. Rainfall in September and October can be heavy, causing flooding and waterlogging. If the rains stop too early in November, the strongly photoperiod-sensitive RLR rice varieties that flower in this period can be adversely affected (Delvert 1961)(Table 14).

**Table 14. Four periods of wet season rainfall irregularities and their resulting problems, Cambodia.**

| Rainfall stress | Problems caused |
|---|---|
| Insufficient early rains | Delayed and poor land preparation<br>Poor seedling development in the nursery beds |
| Short dry season | Insufficient water for timely transplanting or delayed transplanting with overaged seedlings<br>Poor seedling recovery after transplanting<br>Heavy weed growth |
| Heavy Sep-Oct rains | Waterlogging, damage from flooding |
| Early cessation of rains in Nov | Drought stress at flowering<br>Unfilled spikelets and yield reduction |

### Soils

Intensified RLR production in the survey area also is constrained by poor soils. Especially difficult are the *dey ksaich* (light sandy soils) that predominate in the high fields and parts of the middle fields. Sandy soils in Cambodia tend to be acidic ($pH < 5.5$) and are deficient in utilizable nutrients. Soil texture and water retention are poor, and the soils compact after plowing or harrowing. Delvert (1961) noted that the alluvial sandy soils of Kompong Speu Province are "mediocre for the cultivation of rice."

*Dey ksaich kandeng* (sandy loam soils), which are among the soils found in middle fields, are slightly more fertile but have most of the problems of sandy soils (Hirano et al 1968). The *dey lbob ksaich* (silt sand soils) and *dey lbay ksaich* (silt or clay loam soils with sand), which are most commonly found in low fields, are generally more fertile than sandy soils. These fertile soils, together with the deep standing water found in most low fields, provide better yields than other soil types; but they are deficient in organic matter, phosphoric acid, and lime. Therefore, these soils are still rated as mediocre (Delvert 1961).

Cambodian rice soils generally lack sufficient nutrients of all kinds for optimum crop growth. Hirano et al (1968) made special note of the severe phosphorus deficiency of Cambodian rice soils as compared with soils in Thailand and Japan.

### Pests and diseases

The farmers sampled did not consider pests and diseases to be a major problem, based on the infrequency of responses to questions concerning pest damage in the crop (Table 15).

Farmers were asked to identify pests and diseases that damaged their RLR crops and the control measures they took. The only pest or disease mentioned by more than three farmers was *kra phloeng* (fire pest). Of unknown etiology, the malady turns leaves orange and stunts the rice plants during the vegetative phase. IRRI scientists have tentatively identified the cause of kra phloeng as phosphorus deficiency in the soil.

An IRRI integrated pest management team conducted a pest, predator, and parasite survey of Cambodia. They reported a wide diversity of pests, but low pest populations. The infrequent use of pesticides throughout Cambodia may have

**Table 15. Problem pests and diseases of RLR and frequency of reporting, by province, Cambodia.**

| Province | Total no. of samples | Kra phloeng[a] | Field rats | Rice caseworms | Field crabs | Stem borers | Green leafhoppers | Rice bugs | Leaffolders | Army worms |
|---|---|---|---|---|---|---|---|---|---|---|
| Kandal | 17 | 7 | | | 1 | 1 | 1 | 1 | | |
| Kompong Speu | 14 | 2 | 2 | 2 | | 1 | | | | 1 |
| Takeo | 14 | 3 | 1 | 1 | 1 | | 1 | | 1 | |
| Total | 45 | 12 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| % of sample | | 27 | 7 | 7 | 4 | 4 | 4 | 2 | 2 | 2 |

[a]Kra phloeng reddens and stunts the plants up to maximum tillering. It has been tentatively identified as a soil problem, probably phosphorus deficiency.

helped to sustain the large observed population of predators and parasites of rice pests (Rapusas et al 1990).

Although a range of insecticides was periodically available at subsidized prices through district agricultural offices, none of the farmers sampled had used any. Some Kandal farmers used botanical field-crab repellents.

### Traditional varieties

Farmers also are constrained in intensifying production by the strong photoperiod sensitivity and low yields of the varieties upon which they rely. They continue to depend on these varieties, however, because they suit the culinary preferences of Cambodians, both for subsistence and for sale: customers pay premium prices for the favored varieties.

Varietal management is complicated by the fragmentation of the typical land allocation of 1 ha or less into as many as three field levels that have different agronomic problems.

### Cash cropping

None of the farmers surveyed practiced any form of cash cropping in the wet season; neither did they plant any crops before or after rice in their fields. Similarly, no farmer surveyed had any cash-crop land. Few alternative sources of income were available to them save producing palm sugar. Farmers need sources of agricultural income beyond rice monocropping.

### Other constraints

Some factors that constrain agricultural production in Cambodia cannot be addressed directly by research recommendations, but they must be considered as recommendations for changes to RLR cultivation are developed. The most important of these is an inadequate supply of agricultural labor, but lack of access to draft power is significant also.

An average of four to five people were engaged full time in agriculture in the households surveyed. Farmers are too cash poor to hire any labor for most cropping operations, especially in light of the rapid rise in wages between the 1989-90 and 1990-91 cropping seasons.

Any new recommended cropping operation or cultural method that requires increased labor input or the use of draft animals will be difficult for farmers to adopt. The cooperative labor system can effectively mobilize large labor groups only for uprooting and transplanting. Men engaged in palm-sugar production are removed from the labor force from the end of October to March or April.

## CONCLUSIONS

The village clusters sampled were chosen because of their complete dependence on RLR culture. Other Cambodian rice farmers may not experience constraints as severe as those of the surveyed farmers; that is, their average landholdings may not be as small, their land allocations may not be limited to RLR land, and they may have greater options for cash cropping. For example, in other village clusters in the same district, farmers have garden land for cash cropping and additional allocations of deepwater rice or irrigated dry-season riceland.

The data presented here highlight the specific problems of managing the Cambodian RLR environment, but they are applicable to other environments as well. Farmers surveyed in Prey Kabas, a district adjacent to Bati in Takeo Province, primarily farmed deepwater rice, but 30-40% of their land allocations were bunded RLR land. They managed their RLR as described here, though their activities were divided between two rice ecosystems. They preferred the rice harvested from their RLR fields for subsistence, and they were more interested in ways to intensify production in their limited RLR holdings than in ways to increase yields in their more extensive deepwater rice holdings.

RLR improvement is the top research priority in Cambodia due to the extent of cultivation and the limited resources available for irrigation development and expansion of dry-season rice cultivation. Cambodia can best be assisted in gaining rice self-sufficiency and producing an exportable surplus by intensifying its RLR production. This goal can be achieved only if farmers' constraints are addressed and a concerted, appropriate research program is implemented.

## RESEARCH RECOMMENDATIONS

Based on the findings of this survey, further research is recommended in the following areas: additional baseline research, soils, soil fertility enhancement, integrated pest management, traditional and improved varieties, and cultural methods.

### Additional baseline research

When security conditions allow access, researchers should do a baseline survey of the direct-seeded RLR cultivation system in Battambang and Kompong Thom provinces. The survey should complete the description of the Cambodian RLR environment, the identification of constraints, and the formulation of appropriate research recommendations to complement those developed in this report.

### Soils

Diagnostic research should identify the principal soil problems, including nutrient and micronutrient deficiencies and toxicity. The research could be a nationwide survey of areas with soil-related problems. Systematic soil sampling and analysis are needed. Information from the survey could help researchers design trials for improving green manure and soils.

### Soil fertility enhancement

Green-manure trials should be formulated to find a low-cost method for improving soil fertility and texture. Trials should identify the best legume crops to use as green manure, address problems of seed multiplication for yearly use, and consider labor and power constraints for cutting and incorporating the green manure.

Researchers should study FYM management and application as part of a research program for improving soil fertility in RLR cultivation. The IRRI-Cambodia Project could coordinate its own efforts with those of organizations involved in extension to include improving FYM management as a component of research. The nutrient content of samples of farmer-managed FYM from various sites should be analyzed. Trials on improved FYM use, application timing, and related factors that would increase RLR yields should be designed.

Researchers should determine the optimum use of rock phosphate to correct the deficiency prevalent in Cambodian RLR soils. They should consider the constraints of cash availability, supply and production, and other factors. Nutrients of available rock phosphate supplies should be analyzed, and the results should be compared with existing data.

Chemical fertilizer trials should seek optimum yields with minimum fertilizer application. The trials should be conducted with popular local cultivars from different areas for short-term improvement and with advanced breeding lines and promising introduced cultivars in conjunction with the varietal research program. Constraints involving cash availability and national supply should be considered.

### Integrated pest management

Crop-damage and yield-loss research should be conducted to assess the damage pests cause. This research, which is needed for other agroecosystems also, should be a priority for RLR. The data gathered and collated should form the foundation for future integrated pest management research.

Researchers should assist in identifying pest and disease problems of unknown etiology (such as kra phloeng) to establish their causes and nature. Extension agencies could disseminate the knowledge gained to farmers and thus deter costly, ineffective prevention or control measures.

### Traditional and improved varieties

Researchers should screen local cultivars that are most likely to be suitable to other areas and introduce new cultivars suited to the Cambodian RLR environment. Varietal trials should be coordinated with trials for cultural methods and soil fertility.

During this survey, other researchers were collecting germplasm of RLR cultivars and screening them in varietal trials. When collecting germplasm, researchers should note the reasons that farmers maintain the varieties and identify their agronomic, grain, and eating qualities. This information should be used to complement data already gathered from crop cuts.

After locally favored RLR varieties are obtained, screened, and identified, multilocational trials should compare the best-performing cultivars. The trials should determine whether some locally favored cultivars could be grown successfully in other parts of the country.

Samples of the varieties most favored for cooking and eating quality from all parts of the country (such as Chma Phrom or Phka Khnyai from the survey area and Somali from Battambang) should be analyzed. The physiochemical characteristics (such as amylose content and water uptake) that make the tested varieties especially desirable to farmers and consumers should be established. The results could help breeders screen local cultivars and experiment with advanced breeding lines and imported cultivars.

The varietal testing and development program must seek new lines and specific breeding priorities to address the problems of periodic drought, flooding, or stagnant deep standing water. Breeders should seek lines whose yields and drought or submergence tolerance are equal to or better than those of present varieties.

### Cultural methods

Optimum plant spacing should be determined to enhance yields from traditional RLR cultivars. Trials should be conducted in the prevalent soil types and should consider water problems while ascertaining the best plant population for different field levels. Proposed solutions must consider farmers' labor constraints. Trial results could be provided to extension workers seeking to adapt optimum plant populations to farmers' transplanting practices.

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