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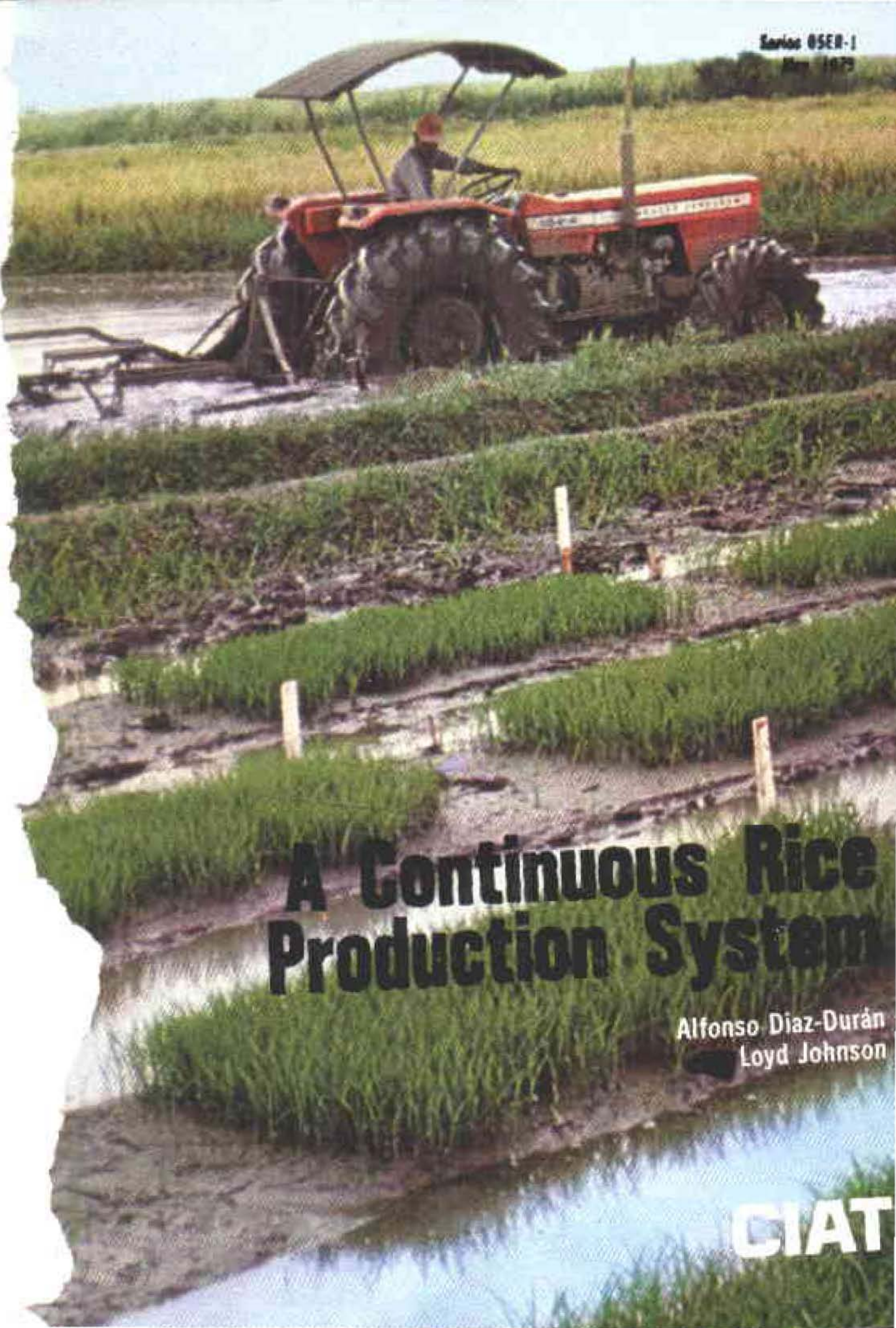

A Continuous Rice Production System

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CIAT

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CIAT is a nonprofit organization devoted to the agricultural and economic development of the lowland tropics. The Government of Colombia provides support as host country for CIAT and furnishes a 522-hectare farm near Cali for CIAT's headquarters. In addition, the Fundación para la Educación Superior (FES) makes available to CIAT the 184 hectare substation of Quilichao, situated near Santander de Quilichao, *Departamento del Cauca. Collaborative work with the* Instituto Colombiano Agropecuario (ICA) is carried out on several of its experimental stations and similar work is done with national agricultural agencies in other Latin American countries. CIAT is financed by a number of donors represented in the Consultative Group for International Agricultural Research (CGIAR). During 1979 these donors are: the United States Agency for International Development (USAID), the Rockefeller Foundation, the Ford Foundation, the W.K. Kellogg Foundation, the Canadian International Development Agency (CIDA), the International Bank for *Reconstruction and Development* (IBRD) through the International Development Association (IDA) the Inter-American Development Bank (IDB), the European Economic Community (EEC) and the governments of Australia, Belgium, the Federal Republic of Germany, Japan, the Netherlands, Norway, Switzerland and the United Kingdom. In addition, special project funds are supplied by various of the aforementioned entities plus the International *Development Research* Centre (IDRC) of Canada and the United Nations Development Programme (UNDP). Information and conclusions reported herein do not necessarily reflect the position of any of the aforementioned agencies, foundations or governments.

A CONTINUOUS RICE PRODUCTION SYSTEM

Alfonso Díaz-Durán
and Loyd Johnson*

Rice may be planted, harvested and immediately replanted where favorable conditions of water, temperature, soils, equipment and skills exist. Since much of the American lowland tropics is wet, poorly drained and has little value for normal dryland agriculture, a modified Asian wetland culture, with rice planted and harvested weekly throughout the year, will convert these lands into food factories. The steady utilization of labor, land, and equipment can provide an attractive income while production cost and capital investment remain low. If crop diversification is desired, one or two rice crops level the land so that row crops may be grown on beds and irrigated easily during the dry season.

This bulletin is intended for farmers and students interested in the authors' experience and suggestions on continuous rice production, especially on: (1) selection of the farm; (2) selection and operation of equipment; (3) farm layout and development; and (4) cultural practices. The ideas and methods presented here are only suggestions as techniques may improve with additional experience. Field observations and results of future experiments will be included in future publications.

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Selection of the farm

A farm for continuous rice production should meet the following conditions:

Water control

Water level must be permanently controlled throughout the year to maintain a water level of 0-10cm above the soil surface. Irrigation water should be pumped at a rate of 2 lits./sec/ha for soil preparation and 1 lit/sec/ha to keep water on the fields.

Water may be obtained either by gravity or a pump system, whenever the latter is economical. Irrigation and drainage districts offer favorable conditions for this type of rice production. Heavy clay soils with an average slope of less than 3m/km are best. Heavy clays are easy to prepare wet as they give better support to tractor tires, cause less wear to the rototiller blades, and produce a mud which levels more easily and hardens more slowly. Loams and sandy soils cause excessive bogging of tractors, require more water and fertilizer. In general these soils are better suited for other crops.

Land which has an average slope of 3/1000 or less i.e., equal to or less than a drop of 3m/km are appropriate for continuous rice production. Land with bigger slopes (from 4-7/1000) can also be prepared. However, the cost will be proportionately higher as more land must be moved, the paddies must be smaller and a proportionately greater number of dikes must be constructed.

The internal and surface drainage must be taken into account as well as the drainage canals. A good paddy should drain easily and rapidly to meet the plant requirements. When a combine is used, sun-drying of the paddy is important to facilitate harvesting. Swamp lands can be puddled whenever they have been previously well drained.

Land clearing

Land free of stumps, roots and logs should be selected when possible. Low areas planted to corn, upland rice, bananas, and pastures are available and are easy to develop. Forested areas may be cleared by traditional methods, burned and planted to rice, corn and pasture for two to three years while the stumps and logs decompose.

Farm size

The farm size for continuous rice production ranges from two hectares to more than 100 hectares. The smallest economic unit would be one man with two hectares. Farms larger than 2-4 hectares require hired labor for crop care and harvesting. The maximum size of the farm depends upon managerial capabilities and operating capital for labor and equipment services. An experienced farmer can manage 40-400 hectares on a fulltime basis. Cooperative or corporate farms could be developed on a continuous rice production basis for areas from 100 to more than 1,000 hectares. Special consideration must be given to training for the farmer and for the technician, use of capital, distribution of profit and the socio-political objectives of the country.

Selection and operation of the equipment

The most critical factor relevant to the continuous rice production system is the modification of the existing equipment and the training of the tractor operators for this type of field work.

Tractors

The authors have used medium-sized 60-80hp tractors such as the John Deere 2120, Ford 5000, Massey-Ferguson MF178, International IH856 and Same Leone 70*. Other tractors with the same horsepowers and weights may be used.

Important tractor features to consider are:

Acquisition of the tractor

It is very important to check on the reliability of the agent or dealer representing the make of tractor which has been chosen, the quality of the technical service which the vendor offers to the farmer, availability of replacements, and his interest in the production method which the farmer has chosen.

Three point lift

A category II lift able to sustain a heavy rototiller at all times should be chosen. Because the soil is too soft for depth control devices, all forces must be supported by the three-point lift.

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* Mention of any product by commercial brand name does not constitute a recommendation by CIAT.

Power take off

A power take off capable of continuous use with a rototiller with the rated horsepower of the tractor, without excessive repairs is ideal. The standard rated speed of 540 RPM is acceptable but the additional ability to drive in ground speed at 9 revolutions/m and at 1000 RPM is preferable. Be careful to check the length of the telescopic PTO drive shaft for the individual tractor and rototiller models so that the shaft functions safely as the implement is raised and lowered over the entire range. Too short a shaft will slip apart and too long a shaft will break the PTO.

Brakes

There are some tractors whose brake systems operate in a continuous oil bath and are completely sealed. This is a fundamental characteristic of a machine which must work in mud and water.

Tires

Working in mud requires high lug rice and cane tires either 23.1" x 26" or 23.1" x 30". These tires are not normally used on medium-size tractors as the tires have a greater load capacity than is essential. Since they are not standard equipment the farmer must purchase 20" x 26" or 20" x 30" rims and have the tires mounted. The tires are inflated to five psi and the tractor operates without additional weights and without water in the tires for increased mobility in the mud. The oversized tire is used only for flotation work in wet rice fields. The manufacturer's design criteria would be exceeded if the tires were used on dry soils with water and ballast. These tires give acceptable mobility in more than 90 percent of the fields. The remaining fields demand tractors with four wheel drive and 23.1" x 26" tires or dual tires of 23.1" x 26".

Weights, chains and pullpoints

Weights are added to hold down and stabilize the front end. These weights should be added to a sturdy frame on the front of the tractor. This frame should contain holes or hooks for attaching a heavy-duty 20-30 meter chain for disengaging the tractor when bogged down. The same frame when not in use, can also serve to store the chain (see photo 1).

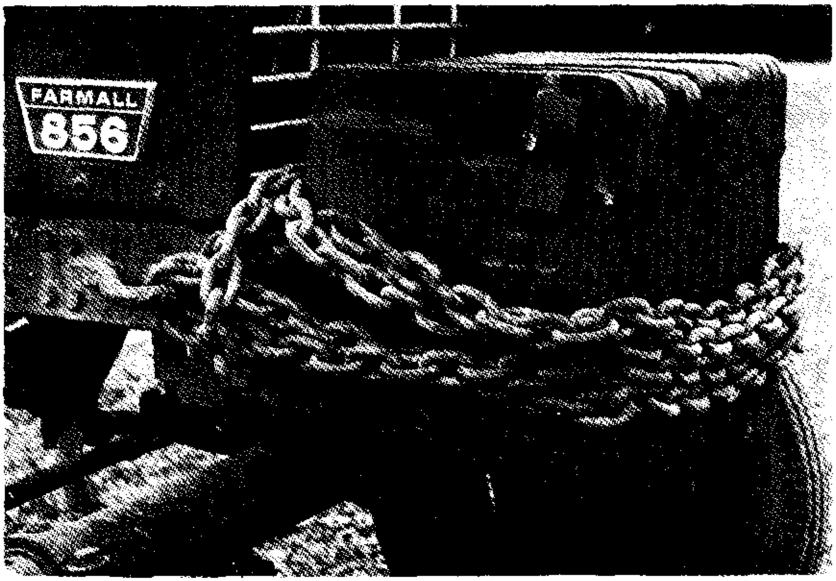

Photo 1: Front weights, chain and pull points to stabilize the tractor and for pulling when stuck in the mud.

Four wheel drive

When the same tires are used, four wheel drive tractors with a normal clearance and turning radius perform better under all soil conditions than two-wheel drive tractors. For best performance, use 23.1" x 30" or 23.1" x 26" rice and cane tires on the four wheel drive.

Rototillers

Rototillers developed for use in muddy rice fields are preferred over models designed for general dryland agriculture. The authors have used the Maletti Model 200R rototiller satisfactorily and have fabricated and used their own prototypes. Sturdy construction, well-sealed bearings and transmission, and light weight are important features. Rototillers can be locally built using imported transmissions, bearings, shaft, seals, high strength steel and high strength welding rods (see photo 2).

Levee and bed makers

A levee and bed maker designed and built at CIAT can form levees in

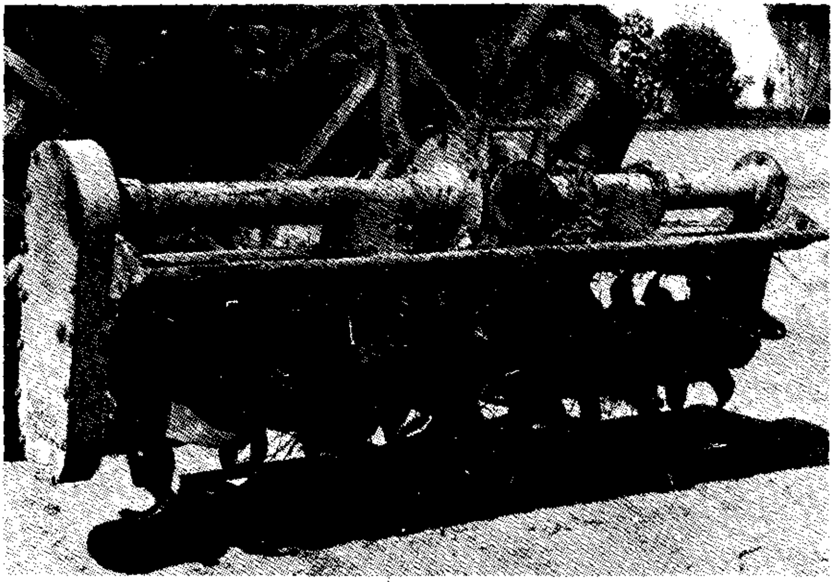

Photo 2: Rototiller designed for both wet and dry fields.

both dry or wet soils, or beds in dry soils (see photo 3). Drawings are available upon request.

Blades for soil movement

A three point mounted blade is used for rough leveling. It requires considerable draft and it is difficult to control the depth of cut.

Spike tooth or comb harrow

A spike tooth or comb harrow buries the vegetation under the mud and provides a clean, level field surface. A standard spike tooth dryland section harrow suspended from a three- point mounted tool bar gives excellent service. Many U.S. and European manufacturers produce this harrow; local shops can also build it (see photo 4).

Seeding, fertilizing and spraying equipment

At the present wage rates, equipment to replace hand broadcast seed, fertilizers, granular insecticides, or granular herbicides are not economical in the developing countries. When insecticides and herbicides are not available in granular form, knapsack sprayers or

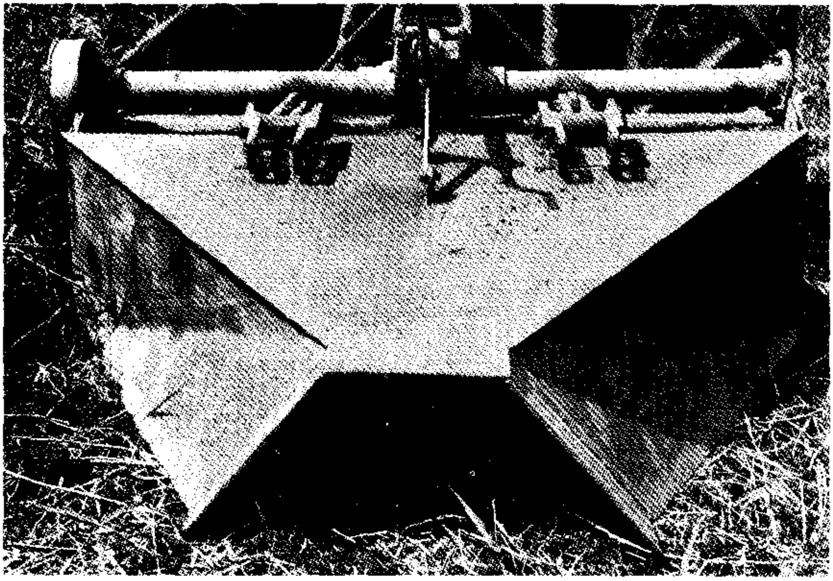

Photo 3: Levee maker designed and fabricated by CIAT personnel.

Photo 4: Spike tooth harrow for leveling and final smoothing of field. Note the boards which aid in moving mud.

contract aerial spray services are used. To permit uniform application, the knapsack sprayer should be equipped with a 3-5 meter wooden boom, quality calibrated spray nozzles, and a pressure gauge (see photo 5). These adaptations can be made locally.

Harvesting equipment

The rice combine with rice tires or half tracks is suited to large areas and satisfactory weather conditions. The average farmer cannot afford a combine but must depend upon custom services or upon hand harvest. CIAT has developed a portable thresher (see photo 6) which permits two men to cut, thresh, clean, and bag 500 kilograms of paddy daily of the variety CICA 4 or any other variety with similar threshing characteristics. At current wage rates (or less than US$ 3 per day) hand harvest is economicaly feasible. IRRI has also designed several types of stationary threshers.

Drying equipment

The freshly harvested paddy is usually sold on a wet basis to avoid drying and storage problems. In low wage areas, if a market is not immediately available, sun drying on a concrete patio and storage in

Photo 5: Back pack sprayers and 6 meter boom built in CIAT shops.

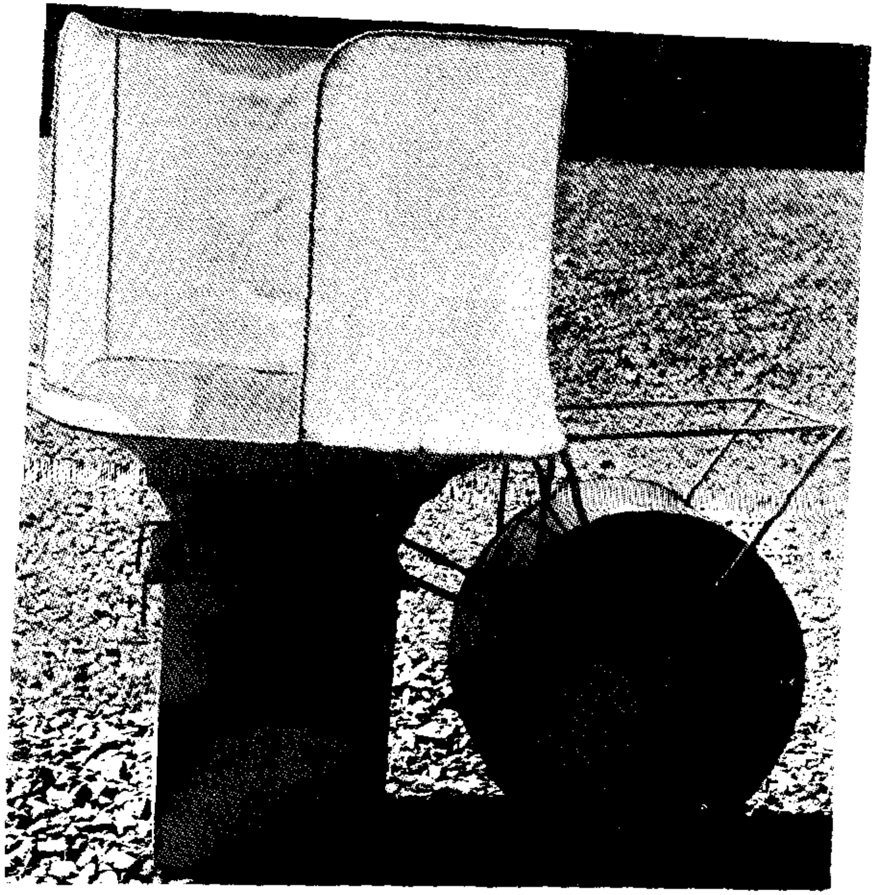

Photo 6: Portable rice thresher designed and fabricated by CIAT personnel.

sacks is feasible. Forced air drying *in bins is* practical if the relative humidity is less than 75 percent for two to three hours per day. The fans are run continuously for grain with over 18 percent moisture content while grain with a moisture content below 18 percent is dried by running the fans when the air has less than 75 percent relative humidity. Normally only skilled personnel should use heated air drying.

Operation and care of equipment

Maintenance and the operators' interest and his skills determine the productivity and durability of the equipment. Some key factors to remember are:

Personnel

Select, motivate, train and supervise the best men available. Pay on an incentive basis when possible and penalize for negligent operation or maintenance.

Manuals

Obtain operator, maintenance, spare parts and service manuals for all equipment. To prevent loss or misplacement, use a record and filing system. These manuals should be read and used by all operators, maintenance, and supervisory personnel.

Records

For each piece of equipment open a record book to register hours of work, work accomplished, materials used, maintenance and repairs performed, and expenses.

Lubricants

Use a high quality water resistant lithium base grease for all equipment. To avoid excessive wear use high quality oils and fuels. Check manufacturers' manuals for recommendations and consult a lubrication engineer through your oil company supplier about standardizing oils and grease. Buy them in drum lots to save money and to assure their constant availability.

Spare parts

Buy genuine manufacturer's spare parts when possible. Other suppliers may furnish quality bearings, belts, hoses, and filters. Always keep a large assortment of high strength nuts, bolts, and pins available.

Shop tools

A complete set of quality wrenches is essential. Careless use of adjustable wrenches damages equipment. Socket and box wrenches are preferable to open end wrenches. Adjustable wrenches and pipe wrenches are unsatisfactory substitutes. Electric or gas welders and high quality welding rods are recommended to prevent excessive down time and extra trips to town. Invest in a high pressure pump and hose to clean muddy equipment.

Field operation suggestions

Survey fields for holes, obstacles and soft spots before entering with equipment. Walk around most rice fields with knee-high rubber boots and two pairs of heavy socks. When the mud is too sticky or deep for the boots, check the area barefoot or back the tractor slowly into the area in order pull out in a forward direction. If the wheels spin stop immediately to avoid digging in up to the axle. Use the differential lock and with a minimum of wheel spin make tentative efforts to pull out. If available, use a second tractor and a long chain or cable for towing from firmer soils. Two tractors are more efficient than one to reduce time loss from bogging. When only one tractor works, the operator should avoid bad spots as well as to put lugs on the wheel rims to attach a pipe in the form of an "I" longer than the tire diameter (see photo 7). Attach an "I" pipe to each tire and back out in reverse to avoid overturning. Keep depth control of the rototiller by using the three-point lift and listening to the engine to prevent overloading and stalling. Beware of areas with stiff, deep mud as these clog the tire lugs, rototiller blades, and give maximum rolling resistance. Work whenever possible in water-covered areas because the water lubricates the tire to prevent mud from sticking.

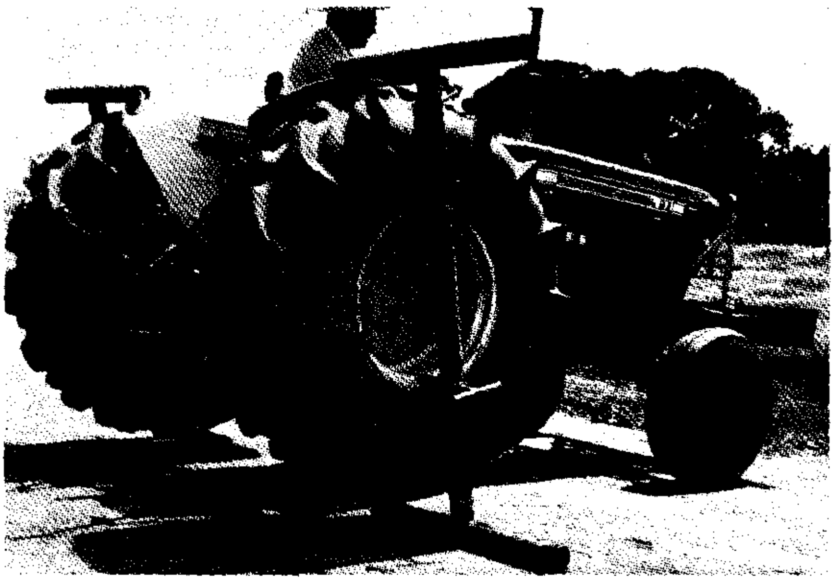

Photo 7: Four-inch pipe attachment in form of "I" designed and built in CIAT to increase traction when bogged. When used always operate tractor in reverse to prevent accidents.

Layout and development of the farm

Careful initial layout and development of the farm for continuous rice production saves equipment, management and time, and reduces future operational costs.

Farm map

The land title should provide a map of the farm boundaries. This can serve as a basis for future survey work. Clean the farm boundaries and markers to clearly expose them in an aerial photograph. An aerial photograph with a negative contact scale of 1:10,000 with a 60 percent overlap should be made. From these aerial photos a scale mosaic can be done and copied on a heliograph machine. These copies will serve as working plans. A topography crew can take elevations on the ground and enter them directly on the working print for future references. These photographs are less expensive, more detailed, and more useful than a normal plane table map.

Roads, irrigation canals, and drains

The existing and future network of roads, irrigation canals, drains, fences, etc. should be drawn on the working print. Since the topography in rice areas usually has a gradient of less than 3m/km, make the main roads and drains in the direction of maximum slope. Raise the base of the roads with the earth from the drains. Use straight and parallel roads, drains, and canals to form uniform fields where the topography permits. This procedure will simplify future work.

Location of levees

The levees are staked out on a 25 x 25m grid which results in easily handled cuts and fills when the land slope is less than 3m/km. One set of well-built levees runs down slope near and parallel to the drains. Additional small interior cross levees are also made parallel to the roads and drains at 25 meter intervals. Well constructed levees are then made every 25 meters either perpendicular to the roads and drains or approximately on the same level (see photo 8). Next, water is introduced to the field. Adjacent plots with similar elevations are joined by removing the smaller cross levees to make 25 x 50, 25 x 75 or 25 x 100 meter plots. Plots longer than 100-150 meters are not recommended because water control is difficult. This method requires no topographic detail and can be carried out in high weeds and over uneven soils such as in pastures with pronounced humps.

Photo 8: Layout of levees in a field in the process of wet land preparation and development.

Other methods of locating levees such as contouring or up grading fields are not recommended unless designed by a skilled topographer or engineer.

Construction of the levees

Permanent field levees for continuous rice production should be about 25cm high, 80cm at the base, and 40cm at the top (see photo 9) which gives about 0.15 cubic meters per inear meter of levee. One man can construct 30-50 liner meters/day.

First wet leveling and land preparation

The first wet leveling and land preparation is the principle undertaking in land development for continuous rice production whereas future land preparation is easier and less expensive. Careful and thorough leveling and land preparation pays for its cost in the first crop through increased yield and reduced fertilizer, water and herbicide expenses.

Once the levees are constructed and the weak sections repaired the fields are flooded leaving only the high spots partially exposed. The

Photo 9: Levee formed by levee maker designed and fabricated in CIAT. The levee dimensions are 80cm base by 25cm height by 40cm top width.

operator loosens the high spots with a tractor and rototiller. This loose earth and mud are moved to deeper water to fill in the low spots. (see photo 10) A blade attached to the rototiller tail flap permits cutting and earth movement in a single operation (see photo 11). A three-point mounted blade may be used but traction and depth control are difficult. After removing the high spots and filling in the low ones the entire field is rototilled to a 15-20cm depth. A three-point mounted spike tooth harrow is then used for the final leveling and to bury the weeds and grass (see photo 12). Average tractor and implement times are as follows:

Rototill high spots:	0.4 ha/hr
Movement of earth to low spots:	0.2 ha/hr
Rototill entire plot:	0.4 ha/hr
Final leveling with harrow:	0.7 ha/hr

When completed the field is level and a layer of water 1-5cm deep covers a weed-free mud surface. Then planting can be done either by hand-broadcasting pregerminated seeds or by transplanting.

Photo 10: Leveling high spots with a blade mounted on the rear of a rototiller.

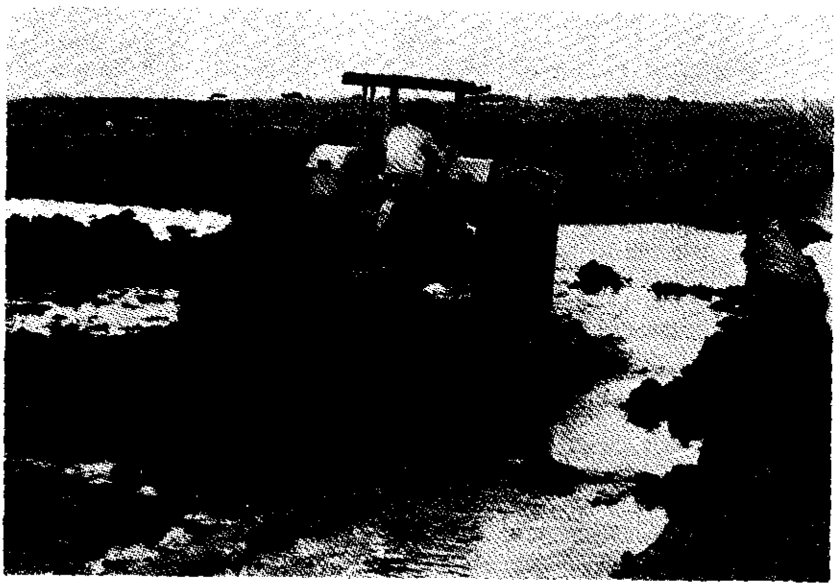

Photo 11: A blade mounted on the three point hitch cutting high spots.

Photo 12: Leveling and finishing of field with the spike tooth harrow

Cultural practices

Planting with pregerminated seed

From 80-120kg of improved variety certified seeds are used per hectare. Seed from certified improved varieties should be used. Seed is pregerminated by placing it into a burlap bag up to about 80 percent of the bag's capacity. Then the bag should be submerged in water for 24 hours. After removing the bag from the water, it should be placed in the shade for 24 hours. During the germination process the unfilled 20 percent of the bag will be used up as the seed swells. The germinated seed will have a root approximately 1 mm long (see photo 13). Seed may be broadcast (see photo 14) and one man can plant one hectare in less than a day. Planting may also be done by plane but this system is not presently economical due to the low cost of hand planting and considering that only 3-6 ha/week will be ready for planting.

Broadcast the seed within 24 hours after the final puddling (see photo 14). Remove the water within 24 hours after sowing to expose the seed to the air for rapid growth. Seed in areas left flooded for several days germinate, grow slowly, and usually die. Small hand-

Photo 13: Pregerminated rice seed.

Photo 14: Hand broadcasting rice seed.

made furrows permit draining most of the field. Occasionally, poorly leveled spots where the seedlings die should be transplanted with excess seedlings from other areas. In some countries like Surinam where the fields are larger, a special V-wheel is used to make drainage ruts in the field.

Transplanting

A seedbed should be prepared some 25-30 days before planting. Preparation of land for a seedbed consists of: construction of seedbeds which are 0.5-0.10cm high by 1 meter wide; the length varies according the amount of seed required for planting. One or more seedbeds with a total surface area of 300-500 meters will take 25-35 kg of seed which are sufficient to plant one hectare. Seeds are taken to the seedbeds after having been pregerminated.

Care should be taken to maintain the seedbeds free of weeds and if nitrogen deficiency symptoms are observed 60-100g of urea/m^2 can be applied. Seedlings should be transplanted when 25-30 days old in the plots which have been prepared by puddling.

Weed control

Wetland preparation gives good weed control for several days and the planting of pregerminated seed gives the seedling the advantage of several days of growth. This difference is much more noticable in transplanted seedlings.

Good weed control can be achieved up through the first 20 days of growth by flooding the rice field until the rice population is submerged for two days. Chemical control of grassy weeds and Cyperaceae can be done with Stam F-34 (Propanil) at 10 lit/ha in one postemergant application of the herbicide when the weeds have 2-3 leaves. Before applying Stam, the paddy should be drained. Two days later the paddy can be flooded again. Other weed-killers have also been tried at CIAT such as Saturno (Benthiocarb) at 6 lit/ha applied five or six days after the rice has germinated. Broad leaf weeds are controlled when necessary with 1.5 lit/ha of 2,4-D amine after the rice starts tillering. Apply herbicides in 320 liters of water/ha with a knapsack sprayer at a rate of one hectare per man-day. Herbicides can also be applied via plane or helicopter. When weed control is done by hand, 15-20 men/day/ha are required on the average. But if the weed invasion is very large, it may be more economical to prepare and plant the paddy again.

Insect control

At CIAT, Furadan 3 percent granulated (2.3 Dihidro-2.2 Dimethil-7 *Benzofuranilmethil carbomate*) is used to control insect attacks. Twenty kg/ha is hand-applied at a rate of 2-2.5 man-days/ha/day. Furadan adequately controls stemborers, leaf miners and suckers. However, precautions should be taken to avoid intoxication of the person applying the insecticide.

Fertilization

When preparing the fields broadcast 100 kg of urea/ha and incorporate it into the mud with the harrow. Forty to fifty days after planting if the plant needs additional nitrogen, apply urea without draining the fields to avoid weed and water problems, and dentrification. One man can hand broadcast 1.5-2 ha/day. Photo 15 shows a well-fertilized, weed-free rice field.

Irrigation

Keep the fields completely flooded at a depth of 1-10cm. Water enters on the high side and passes to adjacent lower fields through notches in the earth levees. Cut notches high enough to maintain the

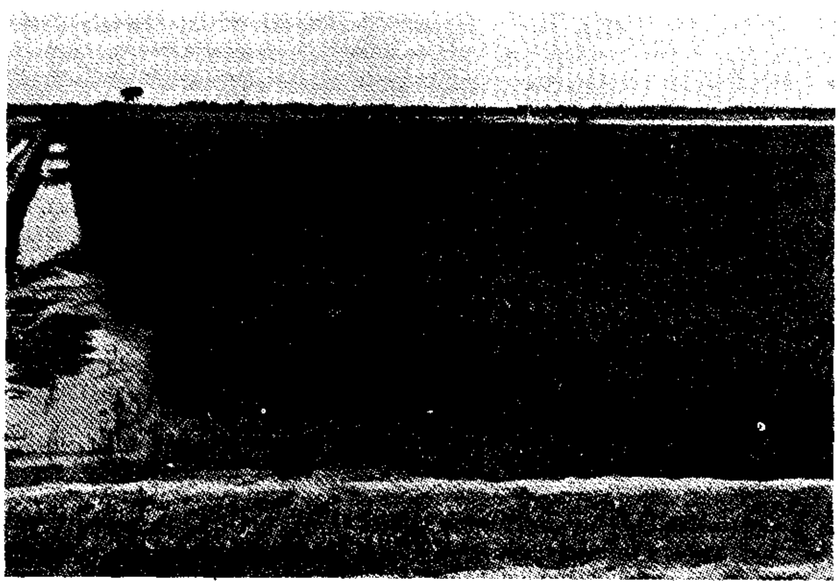

Photo 15: A veiw of a clean, fertile rice field.

field covered with water. Approximately 200mm of water are required for land preparation and 600mm are lost in evaporation. The additional water requirements include losses through levees and canals to drains. Where possible the water entering drains should be reused on lower fields. About 2.0 lit/sec/ha of water are required to flood and prepare rice land and about 0.7-1.3 lit/sec are needed to maintain flooded fields.

Water requirements can vary depending upon losses through filtration. These losses will depend upon the soil characteristics, the dimensions of the levees and the depth of the puddled water. Some losses due to filtration on the order of 20 lit/hr/m for water levels of 8cm can be considered normal whenever there is good irrigation control. When the water levels are higher losses due to filtration may reach 60 lit/hr/m.

The perimeter levees can be constructed using greater dimensions: for example, 100cm at the base, 78cm at the top and 30cm high in order to reduce filtration losses (Valderruten, R. 1977).

Harvesting

Harvesting may be done by hand or by combine. When done by hand, a portable thresher constructed from a 55 galon drum may be used. To use this thresher to advantage, two men harvest the rice for the first few hours, then one man harvests while the other threshes. Under this system, 400kg/day can be harvested by this two-man team (see photo 16). With the combine, 2,400-5,500kg/hr can be harvested with a medium-size or a large combine, respectively. In tropical areas, the amount of rice which is harvested/hr is always slightly less than in temperate climates due to bad weather, soil types or lack of experience on the part of the operator.

Land preparation and subsequent leveling

Once the farm has been largely developed and the second harvest is already in progress, land preparation requires little soil movement, and the machine operation time is reduced to nearly half. Residues from the previous crop may be burned on the surface or incorporated into the soil.

Cleaning and repair of levees

After the first crop is harvested, clean and repair the levees by repassing with the rototiller and levee builder. Remove the center

Photo 16: Hand harvest of rice with CIAT portable thresher

blades from the rototiller so the sides of the levees are chopped and reformed yet the center is left compact. This operation kills the weeds and rats nesting in the levees.

The sequence of operation for the second land preparation consists of plowing the paddies with the rotiller whenever the weather and soil humidity permit this to be done. Then the crop residues and weeds are incorporated into the mud, the paddy is leveled with a harrow-tooth plow. Planting and other cultural practices are as previously described.