Chapter 4. BASIC DESIGN FOR THE ITEMS COVERED BY THE GRANT AID PROGRAMME OF THE GOVERNMENT OF JAPAN

4-1 Basic Design for the National Center

4-1-1 Objectives and Functions

The objectives and functions of the National Center which is the core of the agricultural mechanization network are as follows:

i) To train systematically technical officers concerned with agricultural machinery, and

ii) To establish hiring services and undertake repairing, maintenance and management services for large scale machines at the national level.

The objectives and the functions are supplementarily explained as follows:

i) The advantages for the training of official engineers at the national level are to make the following items possible:

- To provide the Center with high standard facilities and equipments as possible by concentrating the budget in one center.
- To conduct the highest-level-training in Bhutan.
- To invite high class instructors from every corner of Bhutan.
- To equalize the technical level throughout the country by collecting trainees equally from all parts of the country.
- To utilize the limited amount of the Grant Aid Funds to the best advantage.

ii) The reasons for establishing hiring services, repairing, maintenance and management of large scale machines at the national level are as under:

- The prices of large scale machines are expensive and the Grant Aid Funds are limited, then their number is restricted.
- A large scale workshop is absolutely necessary for repairing and maintaining large scale machines.

4-1-2 Planning of Manpower Required for Agricultural Mechanization

As mentioned above, 65 officers are working at present in mechanization in Bhutan, and they are divided into three categories; i.e. mechanical engineers, operators and mechanics. They are equally divided in number into the three categories. Mechanical engineers can fully repair almost all kinds of agricultural machines and earth moving machines, such as bulldozers and excavators, and four-wheel-vehicles. Operators can operate not only power threshers, power tillers and bulldozers but also various kinds of agricultural machinery, and they can also repair and maintain simple machines. These two kinds of engineers have mostly been educated abroad, while mechanics are mostly graduates from the diploma level polytechnic school within the country. They can manufacture simple spare parts, and can fabricate, repair and maintain simple machines.

On the other hand, a training center will be established for mechanization purpose in the Central Agriculture Mechanization Center to train freshmen and to upgrade the existing staff as follows.

Two training courses are to be opened; one is a "Freshman's Course", the other is a "Upgrading Course". In the Freshman's Course 20 trainees will be admitted; i.e. 18 trainees from 18 districts (one from each district) and 2 trainees from the Regional Mechanization Centers. The term of training is one year, and all trainees are required to live in the Center's dormitory. The trainees are mostly graduates from the diploma level polytechnic school.

The "Upgrading Course" is the in-service training of the existing staff, providing new knowledge about mechanization and training them on the operation, repairing, maintenance and management of new agricultural machines. The term of training is 3 to 6 months. The number of trainees in the course is 10; i.e. 8 from districts and 2 from the Regional Mechanization Centers.

Senior engineers in Bhutan will act as teachers in the courses, and additionally one expatriate expert will be invited from abroad as a senior teacher.

4-1-3 Planning of Curriculum

The curriculum for the diploma course training (Freshman's Course) has already been set up by discussion between the officers in charge in Bhutan and the Japanese team and further it was corrected by university professors of agricultural machinery in Japan. The curriculum is shown below.

CURRICULUM FOR THE DIPLOMA COURSE TRAINING

- On Agricultural Machinery and it's Usage
- At National Agricultural Mechanization Center
- For One Year's Course

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SUBJECT-AREA	SUBJECT	LESSON OUTLINE AND TRAINEE COMPETENCE
(I) Personal Development	1. Mathematics	Basic calculation
	2. Book keeping and oral-expression	Accounting, stock-register, log-book, cost-analysis telephone use, writing
	3. Development Policy	Govt. policy and programme Inter-Departmental Cooperation, rural development
	4. Extension Service	Planning, rural survey farming system
(II) Land Management	1. Soil	Soil pattern, chemical & physical character of soil
	2. Soil Management	Manure & compost, fertilizer, pH etc. Rotation, Conservation
(III) Crop Husbandry	1. Agricultural Science	Basic botany, plant physiology
	2. Growth Requirement	Principles and requirement of key crops
	3. Crop & Varieties	"
	4. Cultivation	"
	5. Post Harvest	"
	6. Pest & Disease	"

SUBJECT-AREA	SUBJECT	LESSON OUTLINE AND TRAINEE COMPETENCE
(IV) Material for Agricultural Machinery	1. Iron and Non-ferrous Metal	Kind, property, utility, production
	2. Industrial standard of materials	Quality of material and the standard
	3. Treatment of metals	Method of hardening, heat treatment
	4. Wood	Kind, property, utility
	5. Cement & Concrete	"
	6. Synthetic Material	
(V) Work-shop	1. Element of Machinery	Screw, key, rivet shaft, bearing, power transmission etc.
	2. Tools	Various tools and utility
	3. Heavy Tools and Repairing Equipment	"
	4. Measuring Tools and Equipment	Handling, measurement
	5. Instrumentation	Theory and practice
	6. Machine Works	Drilling, reaming, hack-saw, filing, metal-sheet work
	7. Wedling	Type of welding, gas, arc welding, soldering material
(VI) Engine and Motor	1. Prime mover	Simple theory of engine and miscellaneous powers
	2. Electric Ignition Engine	Simple theory, function, testing
	3. Diesel Engine	"
	4. Auxiliary parts of Engine	"
	5. Electric Motors	"

SUBJECT-AREA	SUBJECT	LESSON OUTLINE AND TRAINEE COMPETENCE
(VII) Agricultural Machinery	1. Specific feature of Agricultural Machinery	Basic and usage of Agricultural Machineries
	2. Utilization of Animal Power	Usage and implements Basics
	3. Tractors	Mechanism, usage, parts 7 function
	4. Tillage Implements	"
	5. Seed and Fertilizer Distribution Implements	"
	6. Crop Protection Equipments	"
	7. Harvesting Implements	"
	8. Crop-processing Implements & Equipments	"
	9. Pumps and Irrigation Equipments	"
	10. Civil Engineering Equipment	"
(VIII) Work-shop Practice		Accordance with class room theoritical study
(IX) Field Practice		
(X) Extension Service Practice		Participating with seasonal agricultural operation and practice, method of Extension Service and Hire Service
(XI) Project Activity Participation		Participating with project operation and study/experience the volume and importance of Nation-Building activities

SUBJECT-AREA	SUBJECT	LESSON OUTLINE AND TRAINEE COMPETENCE
(XII) Study Tour	To visit general important agricultural and developmental activities center, and industrial area	

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4-1-4 Planning of Repairing, Maintenance and Management of Machines

Repairing, maintenance and management are indispensable for mechanization. As has been stated in Par. 3-2-1, the network of repairing, maintenance and management has completely been planned. There are three kinds of workshops in the network, i.e. a large scale workshops in the National Mechanization Center, medium scale workshops in the Regional Mechanization Center, and small scale workshops in the District Mechanization Center. One large scale workshop in the National Center, four medium scale workshops in the Regional Centers, and 18 small scale workshops in the District Centers will be able to carry out considerably all necessary repairing, maintenance and management in Bhutan.

As to the necessary manpower for mechanization, at present 65 officers are engaged in agricultural mechanization in the whole country, and moreover the member of each Regional and each District Mechanization Center will be increased every year or every other year by one graduate from the Freshman's Course and one graduate from the Upgrading Course in the Training Center in National Mechanization Center. Then, the manpower will be able to meet the requirement for agricultural mechanization in Bhutan.

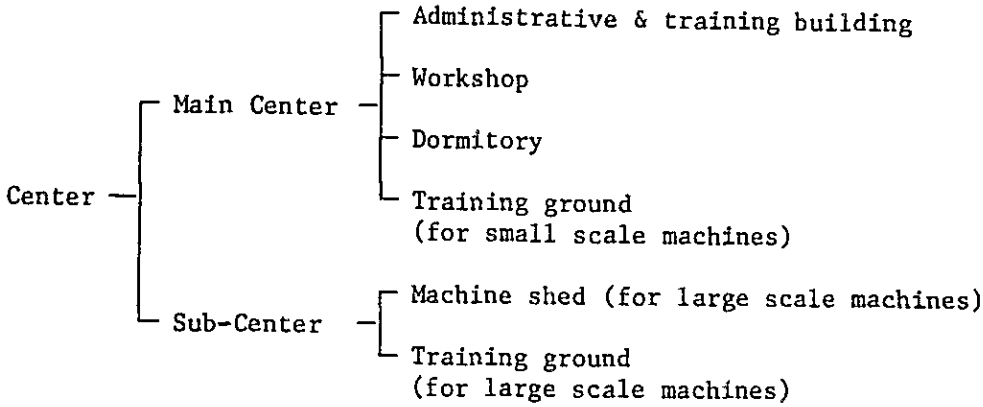
As to spare parts, general spare parts can easily be imported from India and special spare parts are to be introduced from Japan. In fact, however, most spare parts can be manufactured within the country, as it has been done so far in Paro Regional Mechanization Center. Therefore, could the workshops be fully equipped by the Grant Aid Programme of the Government of Japan, much more spare parts would be manufactured within the country. From this viewpoint the realization of the Grant Aid Programme are eagerly expected by the people of Bhutan.

4-1-5 Planning of Building Facilities

(1) Scope of Facilities

The facilities to be incorporated in the National Center are composed of the buildings, appurtenant facilities and outdoor constructions as explained hereunder. Machinery and equipment including autio-visual aids necessary for training, repairing and preparation of textbooks are detailed hereinafter in Clause 4-2.

Since it turned out to be very difficult to acquire a single large land for the National Center because of the topographical conditions of Bhutan, the Center has to be divided into two centers, i.e. the Main Center and the Sub Center, as shown below.



1) Main Center

(a) Buildings (incl. appurtenant facilities)

Administrative & training building: 531.0 m^2

Room	Function
Administrative Office	Administration of hire services, maintenance and extension of large scale machines
Instructor's room Store room	Preparation of textbooks and curriculum
Training room: 3 rooms (for 20 persons each) Multipurpose room (for 30 persons)	Training officials or experts and meeting
Library	Purchase and control of books and data

Workshop: 778.0 m^2

Office Spare parts, tools and material room	— Control of spare parts, materials, repairing equipment and training machinery
Repairing area	— Training of machine operation and repairing
Machine shed	— Storage for small scale machines

Dormitory: 571.0 m^2

Bed room: 10 rooms - 2 storied -	— Lodging for trainees: max. accommodation - 30 persons (3 persons max. in one bed room)
Bed room: 2 rooms (for 2 persons each)	— Lodging for instructors: max. accommodation - 4 persons (2 persons max. in one bed room)
Dining room Kitchen	— Dining for trainees and instructors

(b) Outdoor constructions

- Outdoor power distribution, water supply, drainage
- *Access roads, *compound roads, *gardening, *gate and fence
- *Training ground for small scale machines

Note: Outdoor constructions marked with (*) shall be carried out by the Royal Government of Bhutan.

2) Sub-Center

(a) Building (incl. appurtenant facilities)

Machine shed: 200 m^2 — Storage for large scale machines

(b) Outdoor constructions

- Compound roads, gardening, gate and fence
- Training ground for large scale machines

(2) Construction site

1) Conditions of the proposed sites

(a) The proposed sites will be divided into two places as stated in Paragraph 4-1-5 (1).

The proposed site for the Main Center
- located on a hillock at "Chunda-Dinkha", Paro district, which is about 7 km south of the center of Paro city
- adjoining asphalt paved roads, 5 m wide each, at south and north and being about 3 - 5 m higher than the adjacent roads
- requires to construct access roads and land grading
- having a strip of land measuring 500 m by 100 m

The proposed site for the Sub-Center
- located on the flat area adjacent to "Agri-Horticultural Farm" or "Bondey Farm" in another name which is about 100 m south-east downward of the site for the Main Center
- covered an area of 100 m by 40 m

(b) The top soil and the upper layer of the ground of both sites consist of clayish soil, about 1 m - 1.5 m in thickness and mica slate spreads underneath. Therefore, there would be no problem with respect to the soil bearing capacity if all the foundations of the building facilities are designed to rest on the mica slate layer.

(c) The climatic conditions in Paro district which is situated in the central zone of Bhutan can be characterized as "mild" as the following points demonstrate.

Many fine days : 16 days on monthly average but 25-28 days in November thru March

Little rainfall: 150 mm on monthly average but 670 mm on annual average owing to long dry season

Moderate temperature: annual average ranges from -8°C to 28°C

These climatic conditions are caused by the foehn phenomemon; when the seasonal wind with moisture brings heavy rain and snow to the high mountain ranges. It afterwards becomes dry and blows off clouds over the Paro basin, which is said to have been created in the third post glacier era.

(d) Although no earthquake in Bhutan has been recorded so far, it is recommended in the locally adopted standard that the lateral seismic force by earthquake should basically be applied to buildings of not less than 4 stories, by taking $k = 0.08$ as a lateral seismic force coefficient.

2) Conditions of infrastructures

(a) Power supply

Electric power can be obtained from the terminal of a distribution line of 11 kV located at about 40 m south of the Bondey Farm. It is presently fed from the micro-hydro power station of 400 kW in total capacity. The power station is located at about 10 km far from the proposed site for the Main Center. In this case, a new distribution line needs be extended from the terminal to the Main Center by the Royal Government of Bhutan.

Presently, there are two problems in the electric power supply system in Bhutan as follows:

i) electric power failure is frequent at night and

ii) voltage fluctuated widely.

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These problems, however, will be solved by the new electric supply from the Chukha power station which is scheduled to be completed by the end of 1984.

(b) Water supply and drainage

As there is no public water supply and drainage system around the proposed sites, individual facilities will have to be installed. Water will possibly be obtained from a stream flowing in a valley, 2 km south-west upwards of the site for the Main Center. The result of the field survey showed the amount of the stream discharge would be approximately 15 m^3/hr. As to the drainage system, it is recommended it be designed as follows:

Sewage	:	to be treated in a septic tank and discharged into a soak pit
Storm water and waste water	:	to be conducted into drain ditches and be discharged outside

(c) Gas and fuel

Propane gas for hot water supply and cooking will be supplied in cylinders, and other fuel such as gasoline, kerosene, light oil and heavy oil will be supplied, as the occasion may require, from India.

(3) Basic planning

1) General principles

The basic planning of the Center was made out in accordance with the following principles:

- To fully consider such local conditions as physical environment, conditions of infrastructures, social environment, agricultural conditions and traditional architecture, all of which are characteristic of the mountainous country of Bhutan.
- To incorporate as many building facilities, machinery and equipment as possible so that the operation of the Center might start immediately after its completion.
- To make the building facilities to be operated and maintained as easily as possible.

- To vest as high function as possible with the Center so that it may play the core role in the agricultural mechanization network in Bhutan.

2) Planning of land grading and building arrangement

(a) Land grading (Main Center only)

As the proposed site for the Main Center is located on a hillock, the following works shall be carried out by the Royal Government of Bhutan prior to commencing the construction of the Main Center:

a) Access roads to the site

The most recommendable access to the site will be from the existing asphalt pavement road, 5 m in width, running south of the site. The access road shall be designed with a width of 4 m, a total length of about 100 m and a slope of about 7/100.

b) Land grading

It is required to grade the land since the site has a difference of ground level of about 3 m and a gentle slope from east to west. The volume of grading is assumed to be about 100 m^3.

(b) Planning of building arrangement

a) Main Center

For the building arrangement, it is recommended to apply a patio-architectural-method as used in castle buildings, one of the traditional architecture in Bhutan. That is, surrounding a court yard, the administrative & training building will be located at north-east, the dormitory at north-west and the workshop at south-west respectively. All in all the buildings will be aligned in a L-shape plan.

b) Sub-Center

The location of the machine shed for large scale machines such as bulldozers and excavators was decided in consideration of the access from the front road facing Paro Bondey Farm as well as the training ground.

3) Finishing materials

(a) Administrative & training building (Main Center)

Exterior finishes

Roof : Slate tile on 1-ply asphalt waterproofing

Wall : Stone masonry (up to G.L +1,000)
Hollow concrete block masonry and cement mortar with plaster finish (G.L +1,000 ~ eaves soffit)

Door and window : Wood made and painted in the manner of local method

Interior finishes

[Room]	[Floor]	[Wall]	[Ceiling]
Administrative office, Instructor's room, Library, Training room and Multipurpose room	Terrazzo tile	Cement mortar with plaster fin.	Plywood with paint fin.
Store room	Cement mortar	- do -	- do -
Toilet Kitchenette	Ceramic tile	Ceramic tile	- do -

(b) Workshop (Main Center)

Exterior finishes

Roof : Slate tile on 1-ply asphalt waterproofing

Wall : Stone masonry (up to G.L +1,000),
Hollow concrete block masonry and cement mortar with plaster finish (G.L +1,000 ~ eaves soffit) and chain link mesh (G.L +2,000 ~ eaves soffit)

Door and window : Wood and steel made and painted in the manner of local method

Interior finishes

[Room]	[Floor]	[Wall]	[Ceiling]
Office	Terrazzo tile	Cement mortar with plaster	Plywood with paint fin.
Toilet and Store room	Cement mortar	- do -	- do -
Machine shed Repairing space	Concrete exposed	Exposed concrete block with tooled joint	Exposed

(c) Dormitory (Main Center)

Exterior finishes

Roof : Slate tile on 1-ply asphalt waterproofing

Wall : Stone masonry (up to G.L +1,000)
Hollow concrete block masonry and cement mortar with plaster finish (G.L +1,000 ~ eaves soffit)

Door and window : Wood made and painted in the manner of local method

Interior finishes

[Room]	[Floor]	[Wall]	[Ceiling]
Bedroom	Wood flooring	Cement mortar with plaster fin.	Plywood with paint fin.
Dining room Corridor	Terrazzo tile	- do -	- do -
Washing room Toilet Bathroom	Ceramic tile	Ceramic tile	- do -
Kitchen	Cement mortar	Cement mortar with plaster fin.	- do -

(d) Machine shed (Sub-Center)

Exterior finish: Same as (b) Workshop (Main Center) above

Interior finish:

[Floor]	[Wall]
Concrete exposed	Exposed concrete block with tooled joint

[Ceiling]

Exposed

4) Structural design

Since there is not yet a comprehensive structural design standard in Bhutan, the following standards will be used as a design basis taking good account of local conditions:

(a) Lateral seismic coefficient : k = 0.08

(b) Wind velocity pressure : q = 150 kg/m^2

(c) Compressive strength of concrete at 28 days : Fc = 180 kg/cm^2

(d) Allowable tensile stress of re-bar : 1,600 kg/cm^2

(e) Soil bearing capacity : 100 t/m^2 on top surface of the existing mica slate rock

(f) Assumed live loads (kg/m^2):

[Room]	[Floor, Beam]	[Column, Girder]	[Earthquake]
Bedroom Verandah	180	130	60

(g) Structural specifications in details:

[Building]	[Foundation]	[Superstructure]
Administrative/ training building	Independent reinforced concrete footing	Reinforced concrete block masonry and wood roof truss
Workshop		
Office, machine shed	Continuous stone masonry	- do -
Repairing space	Independent reinforced concrete footing	Reinforced concrete frame and wood roof truss
Dormitory		
Bedroom	Independent reinforced concrete footing	- do -
Dining room, kitchen	Continuous stone masonry	Reinforced concrete block masonry and wood roof truss
Machine shed	Independent reinforced concrete footing	Reinforced concrete frame and wood roof truss

5) Planning of building utility

(a) Design principle

The conditions described in Paragraph 4-1-5 (2) shall duly be considered in the electrical, mechanical and plumbing design. No great constraint is anticipated in the construction stage as almost all building materials and equipment required can be procured in Phuntsholing, a border city between India and Bhutan.

(b) Electrical facilities

a) Power source

Power can be obtained from the terminal of the distribution line, 11 kV, located at about 40 m south of Bondey Farm as described in Paragraph 4-1-5 (2). The incoming power characteristics will be of 11 kV, 3-phase, 3-wire, 50 Hz.

b) Private substation

A private substation will be provided in the Main Center because of the high voltage of the incoming line and large power requirement. The capacity of the substation will be about 100 kVA determined by the following assumed power demand of various facilities, simultaneous power demand factor and rating of standard transformer.

Assumed power demand:

i)	Administrative & training building:	35 kVA
ii)	Workshop :	50
iii)	Dormitory :	30
	Total	115 kVA

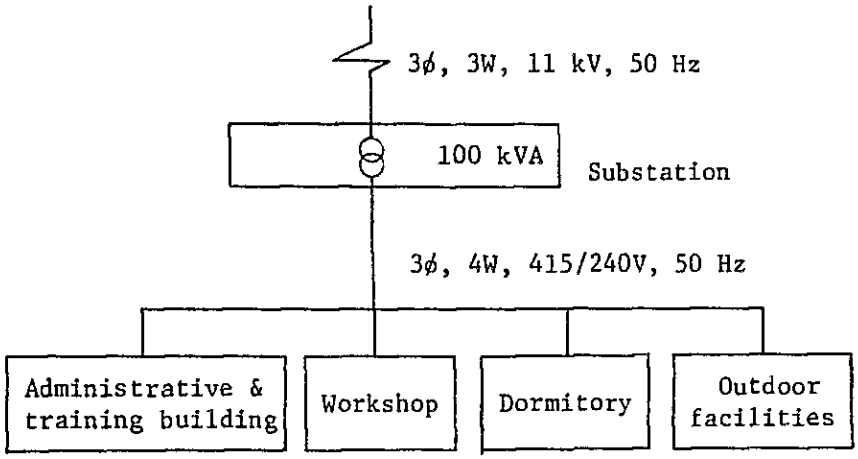
Simultaneous power demand factor: 0.8

Capacity of substation: 115 x 0.8 = 92 → 100 kVA

The substation will be constructed near the workshop as a central power supply station and the electric power therefrom will be distributed to a switch board provided at each building and facility. The outgoing secondary power distribution system will be of 3-phase, 4-wire, 415/240 V, 50 Hz.

Power cables connecting the substation and power switch boards will be of direct-buried underground cable.

The distribution system will be as shown below:



c) Lighting and power receptacles

Lighting will be done mostly by fluorescent lighting fixtures.

The lighting level will be as follows:

Office, Training room, Dining room, Kitchen	:	300 Lx
Toilet, Store room, Repairing space	:	150 Lx
Bedroom	:	80 Lx

Power receptacles will be of single phase, 240 V, grounded type.

(c) Plumbing and sanitary facilities

a) Water source and supply system

Water used in the Main Center will possibly be obtained from a stream flowing in a valley, 2 km south-west upwards of the site for the Main Center as described in Paragraph 4-1-5 (2). The total water demand in the Main Center is estimated to be about 25 m^3/day. Water will be conducted to a water reservoir to be provided in the site for the Main Center through a V-shape water channel and be distributed from there to all buildings in the Main Center. As the result of the field survey, it was found that the stream water is pure and safe for drinking and no water treatment will be required. Water for the Sub-Center will be obtained from the existing water supply line in Paro Bondey farm.

b) Hot water supply

The hot water supply will be arranged to bathrooms and kitchen in the dormitory and other kitchens in the administrative & training building and workshop by providing instantaneous gas water heater using propane gas.

c) Kitchen equipment

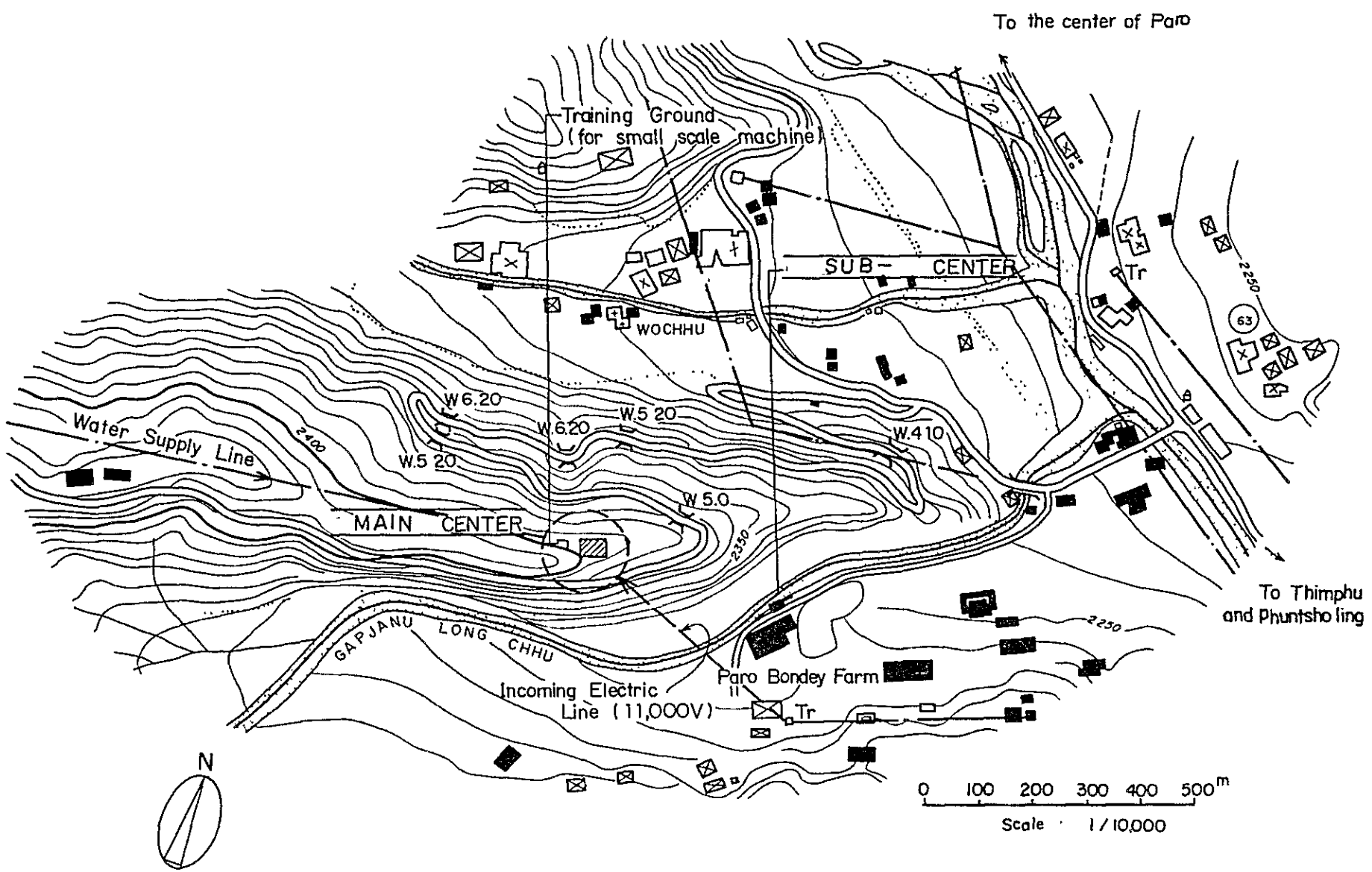
In the kitchen in the dormitory, kitchen equipments catering for about 30 people will be provided.

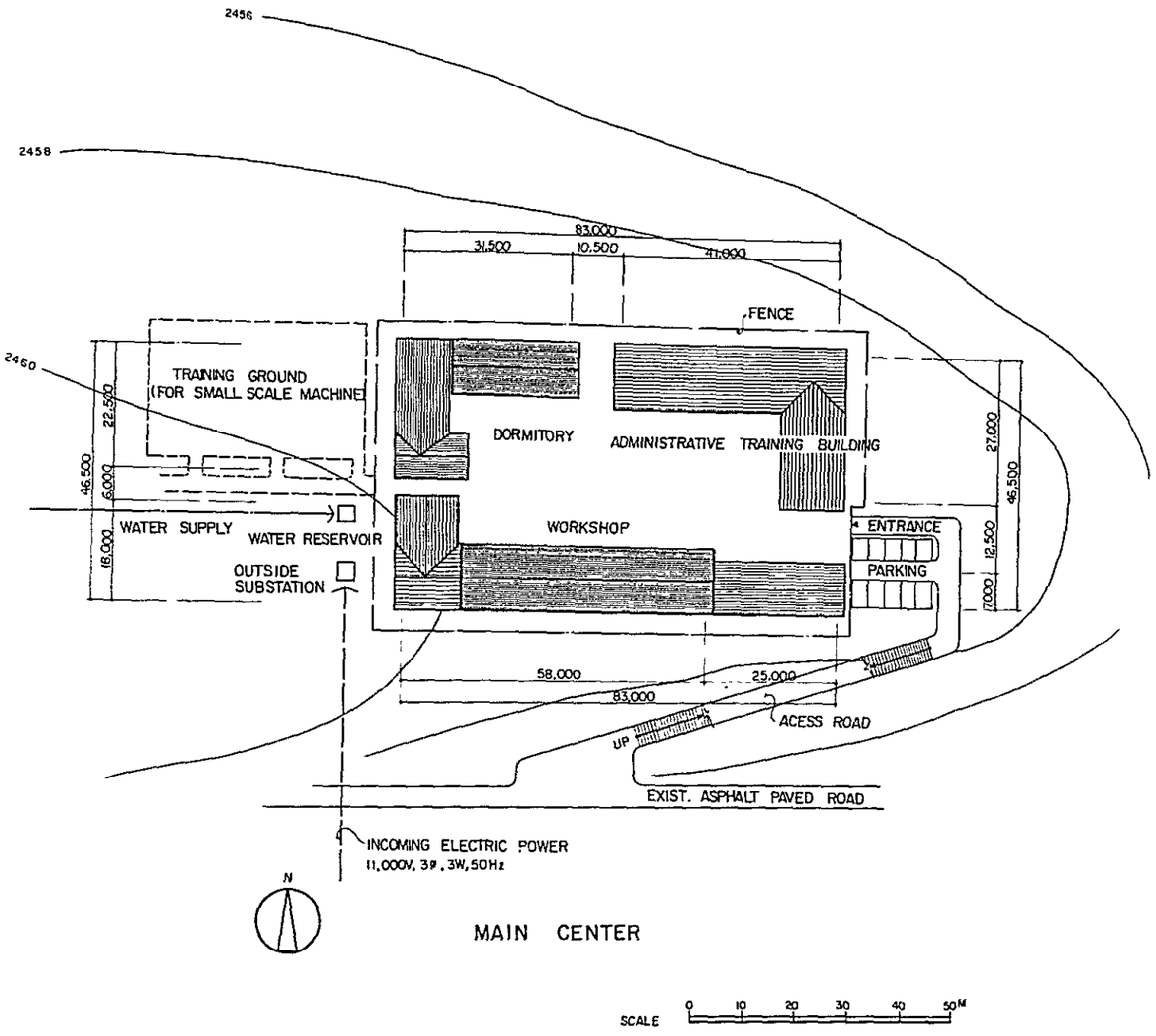
d) Drainage facility

Since there is no city sewerage system around the site, sewage, living waste water and storm water will separately be treated. Living waste water and storm water will be conducted to outdoor drainage ditches and discharged outside. Sewage will be treated in septic tanks and discharged in soak pits.

Fig 4 – 1 LOCATION MAP

NATIONAL AGRICULTURE MECHANIZATION CENTER





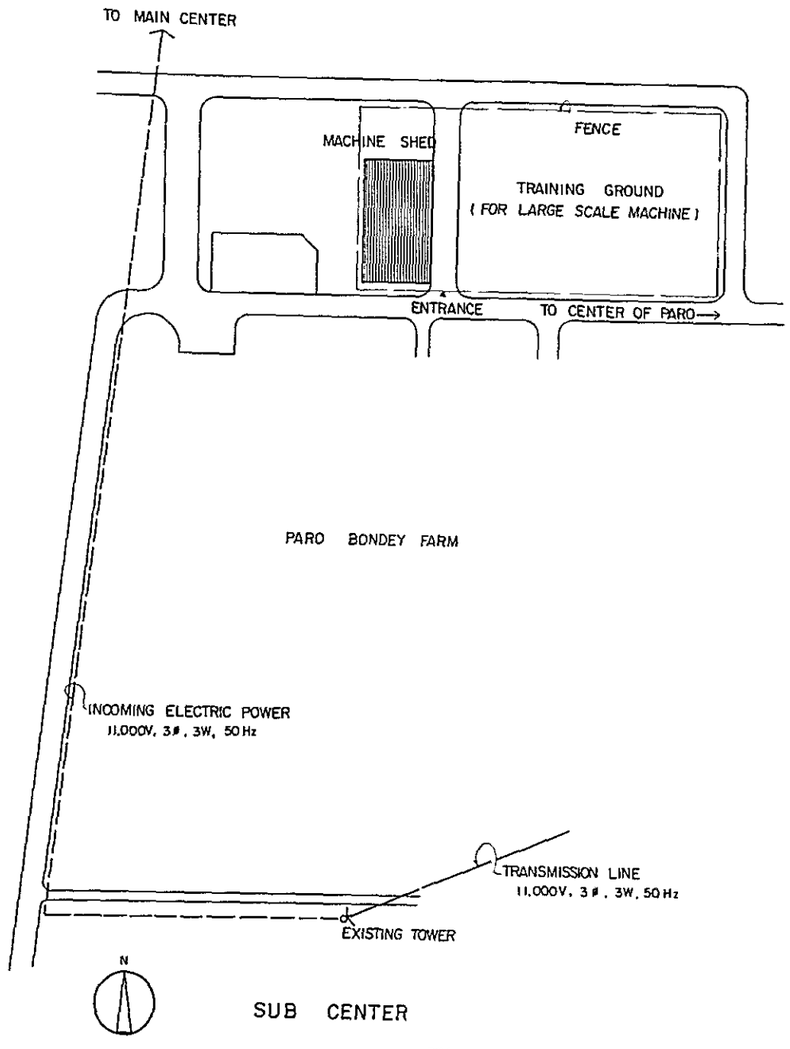
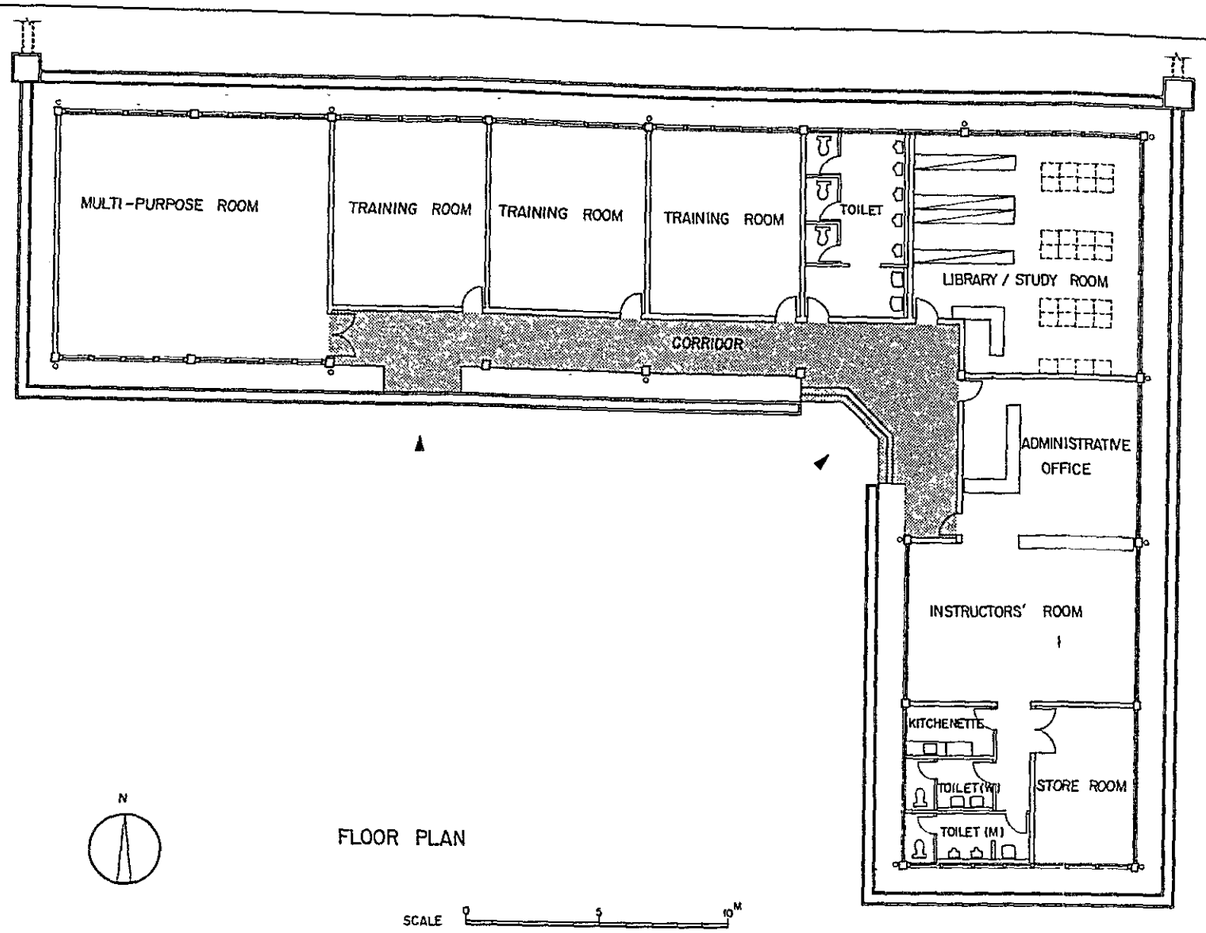
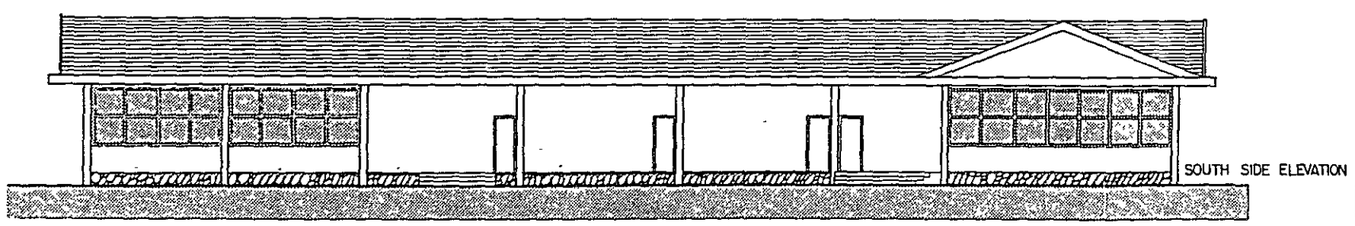


Fig. 4-2 PLOT PLAN





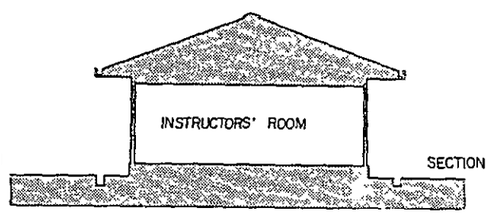
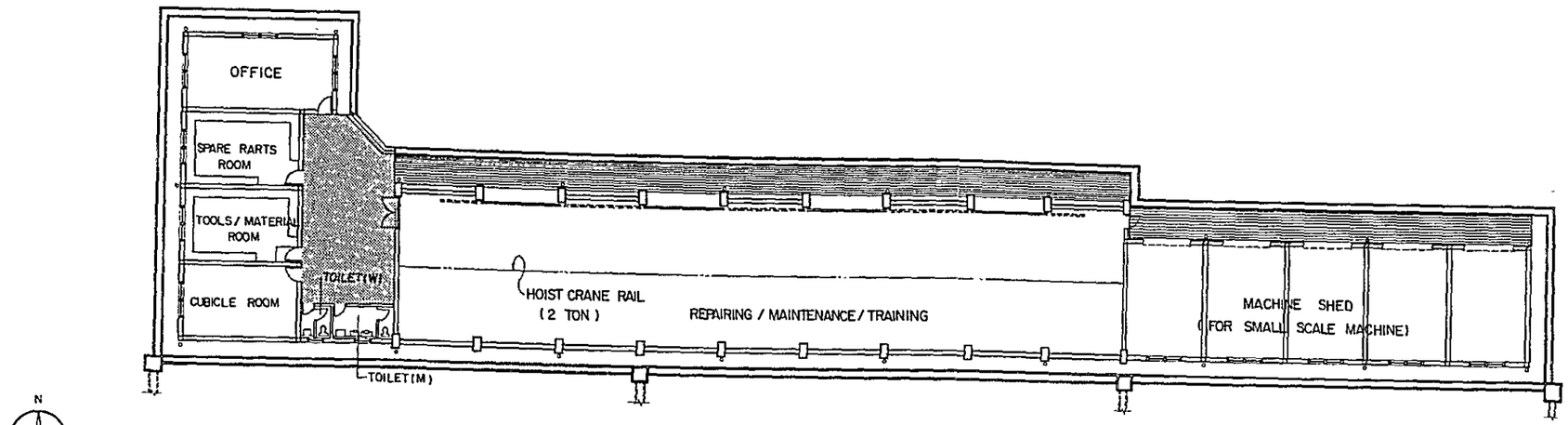
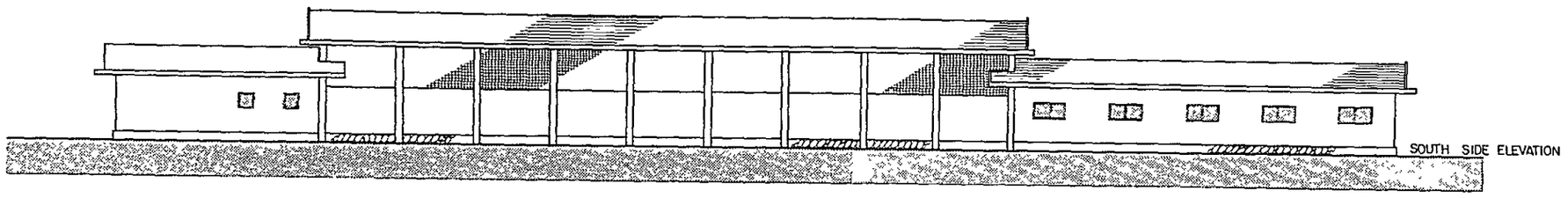


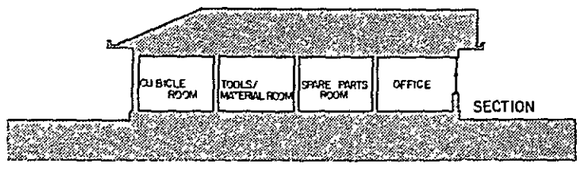
Fig.4-3 ADMINISTRATIVE & TRAINING BUILDING



FLOOR PLAN

SCALE 0 5 10M





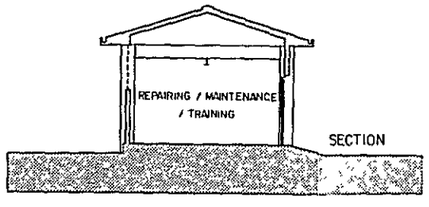
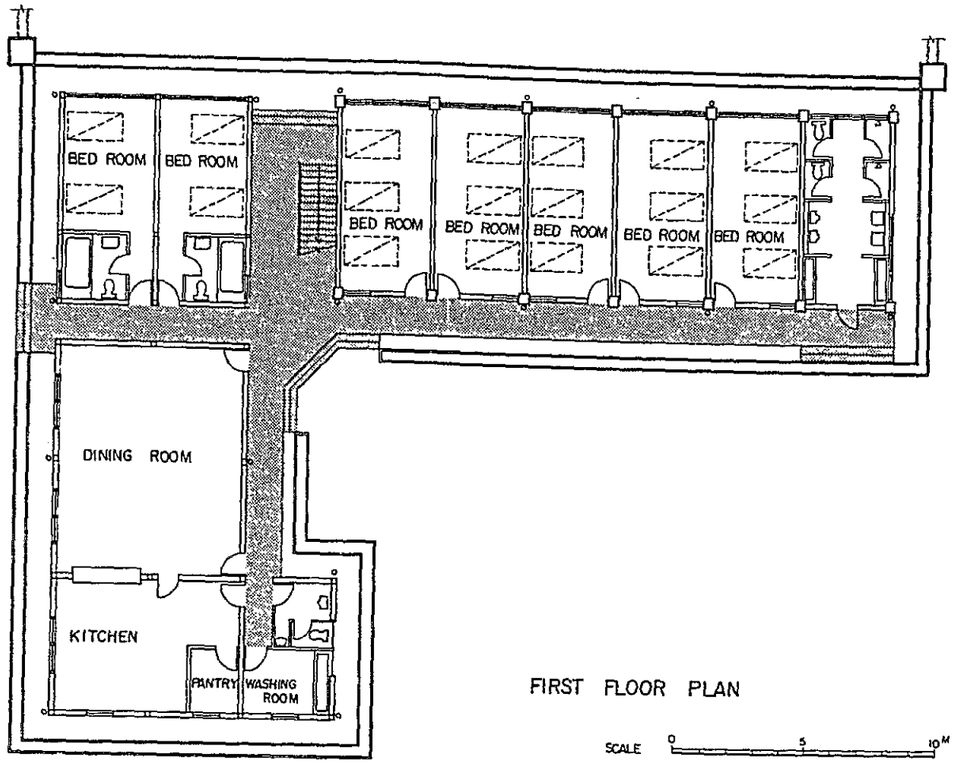
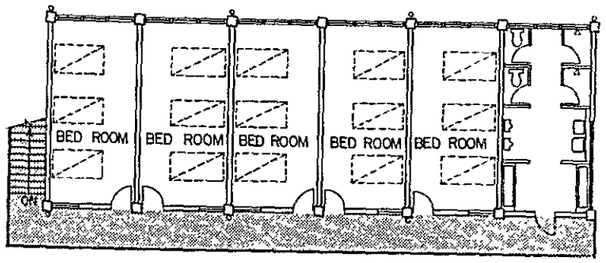


Fig. 4-4 WORKSHOP

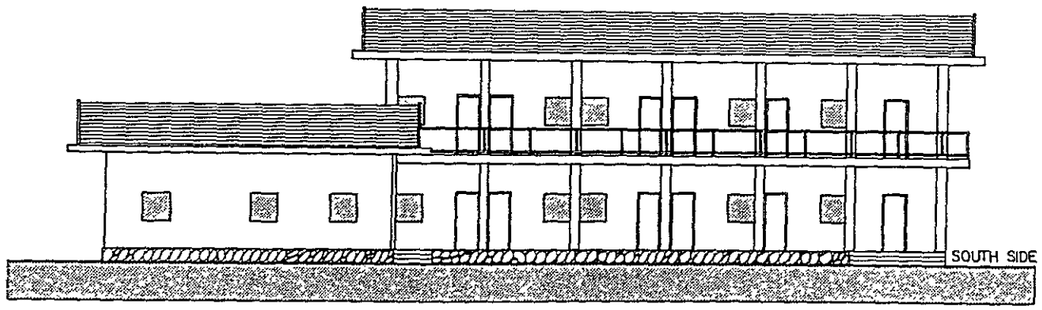


FIRST FLOOR PLAN

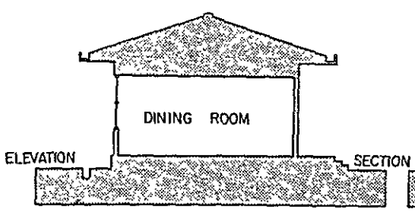
SCALE 0 5 10M



SECOND FLOOR PLAN



SOUTH SIDE ELEVATION



SECTION

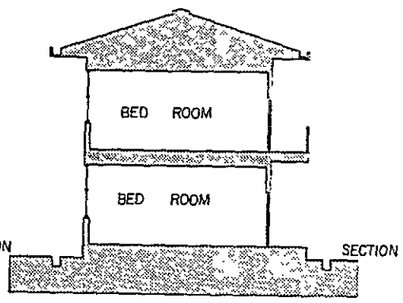


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Fig. 4-5 DORMITORY

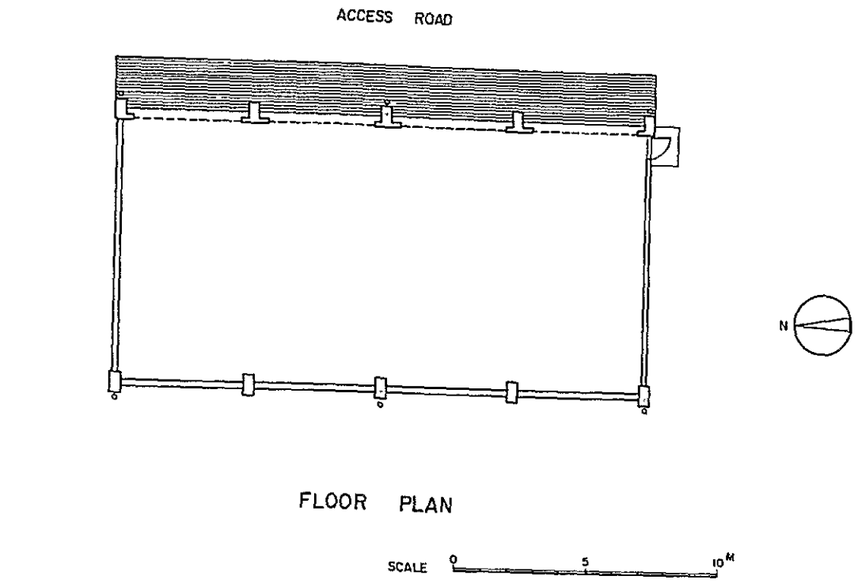


Fig. 4-6 MACHINE SHED

4-2 Basic Design for Strengthening Paro Regional Center

4-2-1 Objectives and Functions

The objectives and functions of Paro Regional Center, which will serve as the model for the other three Regional Centers, are as follows:

i) To train key farmers in Paro Region.

ii) To undertake hire services of agricultural machinery.

iii) To effectuate repairing, maintenance and management for agricultural machinery.

iv) To make improvements of tools and trial manufactures of simple machines.

v) To provide guidance for cottage industries.

4-2-2 Planning for Strengthening Paro Regional Center

One of the most effective means for strengthening the said functions of Paro Regional Center is to introduce proper machines and equipment to the Center. The policy in selecting machines, therefore, was firstly examined, and basal principles in their selecting were laid down, as shown in Par. 4-2-3. Based on the laid principles, the necessary machines and equipment were selected, as shown in Par. 4-2-4.

Another measure for strengthening the Center functions is to increase the number of skillful staff members of the Regional Center. This point has already been mentioned in Par. 4-1-2, "Planning of manpower required for agriculture mechanization".

4-2-3 Planning in Selection of Agricultural Machines

On selecting agricultural machines, in view of steep-sloped upland fields, terraced paddy fields, steep farm roads and paths, and narrow boundaries in the actual conditions in Bhutan, stress was laid on the transfer and movement of machines, and consequently most lightweight machines were selected with the first priority.

On selecting agricultural machines, each actual operation in growing each crop was examined carefully, and then the most suitable machine to each operation was selected. For this purpose, a full technical discussion was made between Bhutan officers in charge and the Japanese team.

In view of the majority of arable fields being distributed over the elevations of 2,000 m in Bhutan and imperfect combustion being apt to occur on account of dilute oxygen at high altitudes, diesel internal combustion engines were preferentially selected. Moreover, such engines will serve to lengthen the life of machines and to decrease the fuel cost.

As mentioned before (Par. 2-3-6), almost all kinds of public works are performed by the labour contribution from farmers, which greatly disturbs their farming works. The labour contribution is a special practice in Bhutan. In view of this special circumstance in Bhutan, it was considered quite necessary to introduce earth moving equipments such as bulldozers, bulldozer shovels and excavators, which would greatly contribute toward saving farmers' labour in Bhutan. A considerable number of earth moving equipments, therefore, were planned to be introduced.

Further, machines and equipments for the cottage industry such as oil expellers, grading machines, starch-sugar processing unit and alcohol processing unit were planned to be introduced. These machines and equipments are not agricultural machinery, but they are quite helpful to the farmers in Bhutan. Because, the farmers produce usually much amount of fruits and vegetables which are not suitable for eating as fresh ones, and also they often over-produce various kinds of agricultural products. These fruits, vegetables and overproduced products can be processed by using machines and equipments mentioned above.

Moreover, rape can be processed into oil, and potato to starch or alcohol by the farmers themselves with the use of machines. Thus, processing of agricultural products will bring about much more cash income to farmers than sold as they are.

Transplanting operation and reaping operation of rice are conducted during the busiest season and they are both the most laborious trudgery. At present in Japan, however, transplanting is carried out by transplanters and reaping by combine-harvesters, releasing farmers completely from the two laborious works. Whereas, the paddy fields in Bhutan being mostly terraced on steep slopes and yet very narrow, these two kinds of machines are difficult to be used in such paddy fields. Moreover, the two kinds of machines having been developed lately and having relatively intricate mechanism, the farmers will have difficulties to use them as the standard of rural education in Bhutan is lower than in Japan. Then, these machines were planned to be introduced in a minimum number just for trials and for training purpose. As an alternative plan for introducing these two machines, apparatuses for easy transplanting as substitute for transplanters, and power reapers and power threshers as substitute for combine-harvesters were planned to be introduced. The apparatus for easy transplanting can be applicable to any mountainous fields and to any terraced fields and its operation efficiency is 10 times as faster as that of the ordinary transplanting method, and further has neither engine trouble nor oil consumption. A reaper is much lighter in weight and easier in movement, and is much faster in reaping than a combine-harvester, then it can be used in any terraced small paddy fields. The combine-harvester, however, not only reaps but also threshes, then for threshing operation a power thresher must additionally be used. The power thresher can be used not only for threshing but also for winnowing just as a combine-harvester, and further it has much less frequent engine troubles and is much less expensive in cost than a combine-harvester. The reaper and the power thresher will nicely be suited to the every field in Bhutan, and they will release the farmers from their painful works.

The other point to be noted is that the kinds (varieties) of machines have been restricted to the minimum so that spare parts of machines may easily be exchanged with one another. The reason for it is that repairing, maintenance and management of machines are not so easy in Bhutan as in the other developed countries. The introduction of the identical kind of machines also makes it possible to simplify the management of spare parts of machines, which is one of the most troublesome works in the workshop.

The importance of workshop facilities can hardly be over-emphasized not only for repairing and maintaining machines but also manufacturing tools, spare parts and trial manufactures of simple machines. In particular, the workshop is of absolute necessity when the necessary spare parts have to be manufactured within the country, because the supply of spare parts is not always easy in Bhutan. Then, considerable amounts of machines and equipments for strengthening the workshop facilities have been planned to be introduced, as seen in Table 4-1.

One of the most important ways for saving farm labour is to improve agricultural tools in general such as sickles, hoes and pruning scissors, etc. Some tools in Bhutan have a low operation efficiency compared to those in Japan. The improvement of these tools will surely increase the operation efficiency of farm works in Bhutan, resulting in saving much farm labour. With this in view, a considerable number of some kinds of tools are to be introduced for making farmers realize the efficiency of these tools and further for manufacturing them from the models. This point appears to have no connection with the agricultural mechanization, but it is of prime importance for increasing the efficiency of farm operation and saving the farm labour in Bhutan. The Royal Government of Bhutan has been putting emphasis on this point, taking it as a link in the chain of the agricultural mechanization programme.

Lastly, the introduction of vehicles will be mentioned. Four kinds of vehicles have been planned to be introduced, i.e. (1) a transport vehicle for carrying workshop equipments and earth moving machines

and equipments, (2) a repair shop truck, (3) a micro bus for trainees and (4) a video car for training and extension purpose. The transport vehicle (1) is a large one and is used for transporting various kinds of workshop equipments and machines and big earth moving equipments and machines such as bulldozers, excavators, bulldozer shovels, etc. The repair shop truck (2) is a kind of a mobile workshop and provides mobility for repairing machines broken on the fields. The micro bus (3) is used for trainees to go on study tours and to go to the job sites. The video car (4) contains a video and is used to show video films to the officers in the regional and district mechanization centers and key-farmers collected in these centers. Taking into consideration the steep, rough roads and further riding capability through the year, front-wheel drive vehicles attached with diesel engines have been selected for Bhutan.

4-2-4 Planning of Introduction of Agricultural Machinery

Based on the above mentioned plan and policy, necessary machines, equipment and tools have concretely been selected. Firstly, machines, equipment and tools necessary for the National Agriculture Mechanization Center have been selected, and then those for Paro Regional Agriculture Mechanization Center have been done, as shown in Table 4-1. All agricultural machines, equipment and tools are selected by crops and by operations according to the policy mentioned in Par. 4-1-6. Other machines, equipment and tools are classified into 5 groups, i.e. (1) earth moving machines and equipment, (2) those for the cottage industry, (3) those for training, (4) workshop equipment and (5) supporting equipment and mobile workshops, and then they are selected one by one carefully. This list of machines, equipment and tools to be introduced to Bhutan is shown in Table 4-1.

Table 4-1 The List of Machines, Equipment and Tools to be Introduced to Bhutan

	National Center	Regional Center
1. Rice Cultivation		
(1) Nursery		
Clod Crusher	3	
Soil Sieving Machine	3	
(2) Main Field		
a. Plowing, Harrowing, Levelling and Puddling Operations		
Reversible Plow	5	55
Power Tiller	5	25
4 Wheel Tractor	2	3
Front Wheel Drive Tractor	2	3
Leveller	5	
b. Irrigation Operation		
Water Pump	2	3
c. Transplanting Operation		
Transplanter	2	
Apparatus for Easy Transplanting		
Type A	1	3
Type D	1	3
d. Disease & Insect Control		
Sprayer (Manual)	10	40
Power Sprayer (Portable)	3	17
e. Harvest Operation		
Combine-Harvester	2	3
Reaper	5	25
f. Processing Operation		
Foot Thresher	5	45
Power Thresher	3	37
Grain Dryer	2	5
Hasking-Polishing Machine	1	2
2. Wheat (Barley) Cultivation		
Seed Drill (Manual)	5	45
Seed Drill (Power Tiller Attachment)	2	5
Flower Mill	1	3

	National Center	Regional Center
3. Cash Crop Cultivation		
Soil Block Machine	1	1
Sollar Cell Powered Water Pump	1	
Pruning Secateur	20	480
Axe & Hoe	100	1900
4. Earth Moving Machines & Equipment		
Bulldozer (Small Model)	1	1
Bulldozer Shovel	1	2
Bulldozer (Swamp Type)	1	
Excavator	1	
Carrier (Crawler Type)	1	3
Well Drilling Machine	1	
5. Machinery & Equipment for Cottage Industry		
Oil Expeller	1	14
Water Turbine	1	9
Belt Hammer	1	2
Grading Machine	1	1
Electric Motor	8	8
Starch Sugar Processing Unit	1	
Alcohol Processing Unit	1	
6. Equipment for Training		
District Level Workshop		3
Regional Level Workshop		1
National Level Workshop	1	
Repairing Equipment for Eath Moving Machines	1	
Electric Discharges	1	
Electric Hand Tools	1	
Gas Cutting Machine	1	
7. Equipment for Training		
Overhead Projector	1	
Slide Projector	1	
Projector (16 mm)	1	
PPC (Dry Type)	1	
Blue Print (A3)	1	
Mimeograph Electric Stencil Cutter	1	
Offset Press (Table Type)	1	
Typewriter (Electric, 27 inch)	1	
Micro Loud Speaker	1	
Video Monitor (26 inch)	1	
Video Player (Coda)	1	
8. Supporting Equipment and Mobile Workshops		
Micro Bus for Trainees	1	
Transport Vehicle for Carrying Workshop and Earth Moving Equipment	1	
Service Truck (Mobile Workshop)	1	
Video Car for Training and Extension	1	

4-2-5 Distribution Density of Machines for Hire-Service

Almost all machines introduced from Japan are to be used for the hire-service except of those for training purpose. The total numbers of the main machines introduced by the previous Grant Aid and that of the present Grant Aid are as follows.

	Previous Grant	Present Grant	Total
Power tiller (Nos.)	30	25	55
Power sprayer (Nos.)	8	17	25
Power thresher (Nos.)	40	37	77

All these machines are to be introduced to Paro Regional Agriculture Mechanization Center. There are six District Agriculture Mechanization Centers in the jurisdiction of Paro Region, as shown in Fig. S-1, and these machines are to be distributed to each District Mechanization Center for the hire-service. According to the distribution plan of these machines, Paro district will be alloted as follows.

Power tiller (Nos.)	25
Power sprayer (Nos.)	10
Power thresher (Nos.)	25

On the other hand, the area of paddy fields in Paro district is 1995 ha and that of upland fields is 2,205 ha as can be seen in Table 2-11. The number of farm families is estimated to be about 3,000, and the average area of paddy fields per family is estimated at approximately 0.6 ha and that of upland fields at 0.81 ha, amounting to 1.41 ha in total per family, which is a little bit larger than that of Japan (1.1 ha). Both two countries are in the same pattern of small land holdings.

Estimating each number of existing machines mentioned above at 5, and adding new machines to be introduced on schedule as above, the number of power tillers and that of power threshers will be both 30, and that of power sprayers 15. Then, the number of power tillers and power threshers per family will be 0.01, and that of power sprayers

0.005. Further, the number of power tillers and power threshers per ha in the total area of paddy fields and upland fields is only 0.007 and that of power sprayers is only 0.0035. In case of Japan, the number of power tillers per farm family is 0.92, and that per ha is 0.78. A surprisingly big difference, therefore, is recognized between the two countries.

Paro district is the most advanced district in agriculture in Bhutan. Taking the case of Paro district and examining the distribution density of the main agricultural machines, the above mentioned results have been obtained. The results have clarified that the number of machines which have already been introduced and are to be introduced is too small to be satisfied by the users of the hire-service. The introduction of agricultural machines, however, will act as a strong stimulant for developing the agricultural mechanization in Bhutan, and then its significance can hardly be overestimated.

4-3 Financial Planning for Agricultural Mechanization Development

Almost all machines, equipment and tools introduced from Japan, except for those to be used for training purpose, will be used for the hire-service. As mentioned before (Par. 2-3-9, 5-1-5), the hire-service in Bhutan proved to be useful and successful, and consequently it was favourably commented by farmers in Bhutan. With an increase in favourable responses by farmers on the hire-service, its users have markedly been increasing year after year. The hire charges in the hire-service are shown in the article of "Agricultural Supporting Service" [Par. 2-3-9(2)]. It has been proved from the actual results in the past that the hire charges make it possible that when the life of durability of a machine is over, not only the new one can be purchased but also all necessary expenses for repairing, maintenance and management can easily be covered, and moreover a fair margin of profit is left. The reason for leaving a fair margin of profit is that the life of durability of machines is surprisingly long, i.e. 3 to 4 times as long as that in other countries. This is mainly due to thorough repairing, careful handling, nice maintenance and good management, especially the repairing is so thorough that no one can imagine it in many other countries.

As mentioned in Par. 2-3-8, it has also been proved that those who have utilized the hire-service can get the benefit of Nu. 20 at the minimum and Nu. 155 at the maximum per acre. The users of hire-service, therefore, have greatly been increasing day by day, and consequently many farmers are complaining of the shortage of machines available, waiting for the introduction of machinery and equipment by the Grant Aid Programme of the Government of Japan.

In short, as stated in Par. 2-3-11, no budgetary measure has been appropriated for the planning of agricultural mechanization, except for Nu. 3,925,000 as the counter cost of the Training Center in the National Agriculture Mechanization Center. All other necessary expenses for the mechanization will depend upon the profit produced by the hire-service. The possibility in realizing this plan, however, has strongly been proved by the actual results in the past several years, which appears to have placed the plan of mechanization on a solid basis.

4-4 Cost Estimate for Construction and Machinery

4-4-1 Conditions for Estimate

The following is the assumed conditions for making a rough estimate of construction costs and machinery costs.

(a) Exchange rate of Japanese yen at the time of the construction assumed at 260 ¥/US$ or 260 ¥ = 10.2 Nu. (Ngultrums).

(b) On the assumption that the construction will be carried out in and around 1984, the cost-up of construction and machinery above the present estimate will be 10% and 5% in Bhutan and Japan respectively.

4-4-2 Works to be Carried Out by the Royal Government of Bhutan

The following are excluded from the estimate for construction and machinery to be included in the present Grant Aid as they are to be carried out or provided by the Royal Government of Bhutan:

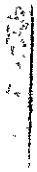
(a) Site preparation works including clearing and grading

(b) Access roads to the site

(c) Installation of electric power supply line and supplying water to the site

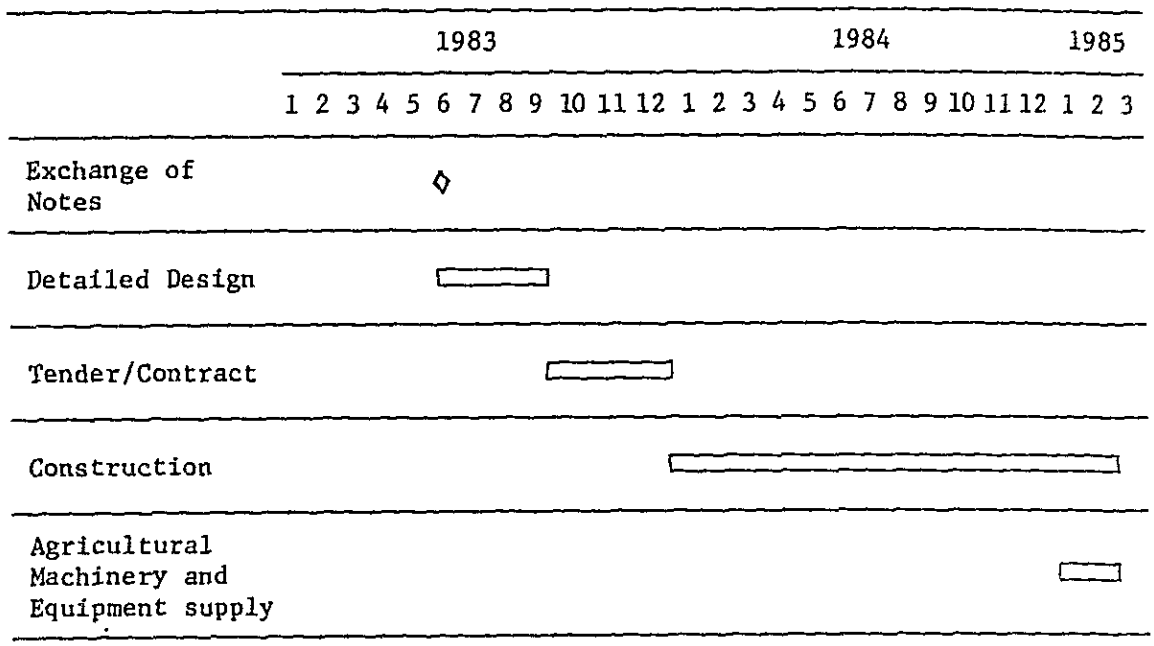
(d) Pavement, gardening and gate and fencing

(e) Furniture, utensils and office stationery



4-5 Execution Time Schedule

(1) Schedule

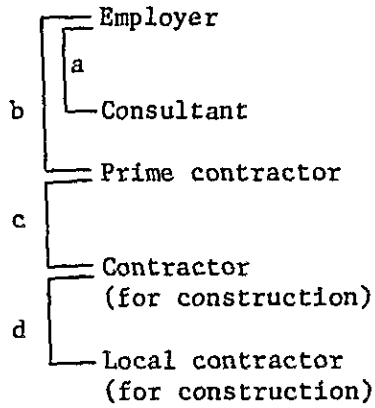


Notes: 1. Date of Exchange of Notes (E/N) is an assumed date.

2. Schedule of detailed design, tender and contract, construction and shipment and delivery shall be adjusted according to the actual date of E/N.

(2) Contract form of construction and design

In order to comply with the special conditions existing in Bhutan, the following contract form for construction and design will be applied should the Project be implemented under the regulations of the Grant Aid Programme of the Government of Japan.



: Ministry of Development
Royal Government of Bhutan

: A Japanese consulting firm

: A Japanese firm having a branch office in Calcutta, India

: Department of Agriculture
Royal Government of Bhutan

: A Bhutanese private firm

a: Engineering contract

b: Prime contract

c: Construction contract

d: Local contract

5. JUSTIFICATION OF THE PROJECT

5-1 Adequacy of the Project

As a result of investigating the actual conditions and analyzing the data collected in Bhutan, the following facts (Par. 5-1-1 ~ 5-1-5) have been clarified. Based on these facts, it has come to light that there is no other way to solve the serious problem of labour shortage in Bhutan than to develop efficiency in agricultural operations, and for this purpose, the agricultural mechanization by introducing improved tools, equipment and machines is of prime necessity in Bhutan. It is strongly believed that the shortest way for realizing mechanization is in the execution of the project, in particular to establish the National Agriculture Mechanization Center and to strengthen a model Regional Agriculture Mechanization Center (Paro) both of which are the core of this project.

Thus, the project subjected to the present Grant Aid Programme of the Government of Japan should be implemented as the most urgent project at the earliest convenience to solve one of the most serious problems in Bhutan.

5-1-1 Actual Conditions of Labour Shortage in Bhutan

Until recent years, Bhutan had closed the door to foreigners, and almost all the people had been depending on agriculture. With the rapid change in its social structure from the closed door policy to the open door policy and from the bartering economy to the monetary economy, the population in the agriculture sector has markedly decreased. Further, almost all development activities such as road construction, building construction of hospital, school and other development institution, building up transport facilities, and other manpower requirement in various kind of level of activities are performed by farmers' labour which are customary and compulsory to the farmers. The labour contribution for these activities from farming communities is so great a burden to the farmers that in some cases the agricultural development activities cannot take shape in the normal process.

Moreover, in view of the fact that the value of export is one third of that of export, the Government of Bhutan has been encouraging farmers to develop village industries (bamboo work, tinning, lacquer ware, handmade paper, mask-making, textile-making, etc.) and to grow cash crops (orange, potato, vegetables, apple, peach, etc.). This has resulted in a labour shortage more serious than before.

5-1-2 Steep Rise in Labour Wage

With the rapid increase of labour shortage in villages, the labour wage in villages started to rise steeply. Farmers therefore are so serious in saving labour in all kinds of farming works that they are reluctant to use the high-yielding varieties, which have been newly introduced, simply because of the varieties being a little bit hard to shatter.

5-1-3 Increase in Imported Labour Force

On account of the serious shortage of farm labour, the number of imported labourers from neighbouring countries (India and Nepal) has inevitably increased. The increase of imported labour force will cause political anxiety in future in Bhutan. The Government of Bhutan, therefore, is paying serious attention to this problem. As stated in Par. 2-1-2, the present status of imported labour force is so serious that nearly 50% employed in the public sector as well as the private sector are of non-nationals, and 96% of the casual labourers are imported from abroad. This fact clearly demonstrates the striking poverty of human resources in Bhutan.

5-1-4 Lack of Necessary Staff in Other Sectors than Agriculture

An another serious problem for Bhutan developing to be a modern state is the lack of necessary staff for consummating national functions, i.e. shortage in number of governmental officers, police officers, military personnel, commercial personnel and service personnel, etc. There is no other way than to fill this gap from the agriculture sector, which gives impetus to the shortage of labour in villages all the more.

5-1-5 High Adaptability of Japanese Agricultural Machinery to the Conditions of Bhutan

Under the above circumstances, small agricultural machines made in Japan were introduced from Japan several years ago under the Grant Aid Programme of the Government of Japan. As a result of tests made in various places in Bhutan, they proved to be useful, effective and successful, and consequently they were favourably commented by farmers in Bhutan.

The reason for high adaptability of Japanese machines to Bhutan might be ascribed to the fact that the two countries, Bhutan and Japan, resemble each other in small land holding patterns, mountainous conditions and terraced fields. With an increase of the farmers' favourable comments on Japanese small scale and light-type machines, those farmers who wish to hire them increased steadily. The Government therefore started a hire service with due charge tentatively. The service proved useful and effective and was hailed widely by farmers in various parts in Bhutan, resulting in a sharp increase in number of hire-applications. Then, the Government extended the hire-service permanently, including the repair service and maintenance service, which also gained public favour. The hire-service placed the agricultural mechanization in Bhutan on a firm basis.

5-2 Effectiveness of the Project

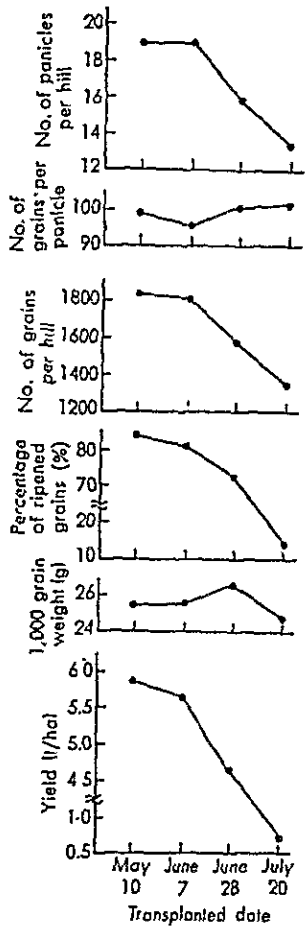
The mechanization not only makes it possible to solve the labour shortage problem, but also directly play an important role in increasing agricultural production and in improving the living conditions of farmers, as shown below.

5-2-1 Timely Seasonal Operation Can Be Done

It has been customary in many cases to avoid the optimum time for farm operation on account of the labour shortage and primitive farming operation, not being able to do timely operation. This causes a marked reduction in yield in various croppings. By mechanizing the operations, every operation can be done rapidly and every work is done in much shorter time than before. Then, farmers are not pressed for time and they can do their practices at the most appropriate farming time, which is one of the largest advantage in mechanization.

In what follows, using the experimental results of the effect of different transplanting dates on the grain yield and its components in rice, an example of an importance of timely operation will be shown.

Fig. 5-1 Effect of Different Transplanting Dates on the Grain Yield and Its Components



Source: S. Matsushima's "High-Yielding Rice Cultivation"

According to Fig. 5-1, as the transplanting date delays, comparing with the values at the optimum transplanting date, May 10, the values of the number of panicles, the number of grains per panicle and the percentage of ripened grains clearly decrease, resulting in a marked increase in yield. The yield on July 20 is nearly one tenth of that on May 10. From this example the importance of timely operation can fully be understood.

In fact, the optimal transplanting time in the center area of rice cultivation in Bhutan is estimated on May 10, but the actual transplanting dates range from late May to early July due to the labour shortage, as stated in Par. 2-2-10. Should the transplanting be conducted on June 28, the reduction in yield would be as much as 22%, taking the yield on May 10 as 100%, as can be seen in Fig. 5-1.

5-2-2 Soil Productivity Can Be Increased

By using power tillers, deep tillage can easily be done, and further harrowing (soil crushing) and levelling can also be effectively practised, which usually increases the soil productivity. The deeper the top soil, the higher the soil productivity becomes in general. In what follows, by using the results of two experiments of rice and wheat, two examples of the yield increase by deep tillage will be shown in Tables 5-1 and 5-2.

Table 5-1 Effect of Deep Tillage on the Grain Yield (Brown Rice)

Depth of Tillage	Normally Fertilized		Heavily Fertilized	
	Yield (ton/ha)	(%)	Yield (ton/ha)	(%)
9.1 cm	4.60	100	4.82	105
15.2 cm	4.82	105	4.94	108
21.2 cm	5.05	110	5.10	111

Source: Matsushima's "Crop Science in Rice" p. 325.

Table 5-2 Effect of Deep Tillage on the Grain Yield of Wheat

Depth of Tillage	Standard Fertilizer		50% Increased Fertilizer		100% Increased Fertilizer	
	Yield ton/ha	%	Yield ton/ha	%	Yield ton/ha	%
12 cm	3.04	100	3.27	108	3.50	115
18 cm	3.20	106	3.41	112	3.63	120
24 cm	3.34	110	3.57	118	3.87	128

Source: Takegami's "Increasing Yield in Wheat and Barley Cultivation", p. 84.

The tables clearly show that with an increase in the depth of tillage, the soil productivity increases, resulting in an increase in yield, at any different dosages of applied fertilizers.

Further, in cases of upland crops, it has generally been recommended that the harrowing should be done carefully so that the diameter of a clod should be less than 2 cm, otherwise satisfactory germination of the seed can never be expected. Such harrowing, however, takes much labour and a long time in general, but the use of a harrow driven by a power tiller makes it possible with ease.

5-2-3 Double Cropping Can Be Promoted

One of the nearest ways for increasing agricultural production is to encourage farmers to grow winter crops. Then, the Government of Bhutan has long been promoting the double cropping strongly. In fact, however, farmers cannot afford to expand the winter cropping on account of their being pressed for time. The percentage of winter cropping area is only 30% of the net cultivated area, and therefore there is left much room for expanding the area of winter cropping.

By using machines, every farm operation can be performed much easier and in much shorter time than before, then farmers can produce surplus labour to grow more winter crops. Thus, the area of winter cropping can definitely be increased. From this viewpoint, the effectiveness of mechanization can hardly be overestimated.

5-2-4 Farmers Can Be Released from Drudgery

The operations of transplanting, weeding and reaping have long been conducted manually, and each of them is a quite painful drudgery. By using machines or newly invested apparatuses, farmers can surely be released from these drudgery, which will definitely improve the farmers' living conditions.

5-2-5 Development of Cash Crops and Cottage Industry Can Be Promoted

The Royal Government of Bhutan has long been encouraging farmers to grow cash crops and to develop cottage industry, but farmers have had little time for them. However, once the farm operation efficiency will be much improved by mechanization, farmers can surely afford to undertake these activities. Thus, the development of cash crop growing (potato, orange, vegetables, apple, pear, etc.) and cottage industry (handicrafts, hand-made carpets, hand-made paper, hand printed Buddhistic scrolls, basket ware, wood carvings, stone carvings, traditional masks, silver-ware, textile, canning, bottling, starch, sugar and alcohol making) will definitely be promoted by the farm mechanization, which will bring about a considerable increase in cash income to farmers, too.

5-2-6 Mechanization Is Commercially Practicable

Using machines which have been purchased actually, monetary balance sheets were worked out. The test-results proved the profitability of mechanization as follows.

Table 5-3 shows the results of a test in which a thresher with a diesel engine (5 H.P.) was used as an example.

The table clearly demonstrates that mechanization is commercially practicable. Any other instance proved the same as above. From this commercial viewpoint the present mechanization project can be taken as a promising project to be realized.

Table 5-3 A Balance Sheet in Using a Motor-driven Thresher

Initial Cost ..... Nu. 10,000 (Thresher ..... Nu. 5,000,
Engine ..... Nu. 5,000)

Running Cost	Per Year 105 Working Days	Per Life of 4 Years	Remarks
Fuel cost	2,250 Nu.	9,000 Nu.	Diesel oil
Lubricant cost	700	2,800	Gear, Mobile oil
Spare parts cost	2,000	8,000	
Repairing & maintenance	300	1,200	Cost of mechanic Nu. 20/day
Operator cost	2,100	8,400	Nu. 600/month
Depreciation	2,500	10,000	Life span 4 years
Total	9,850	39,400	
Benefit			
Actual working hours	630 hrs.	2,520 hrs.	6 hrs. working/day or 105 working days/ year
Benefit	690 man/day or Nu. 10,395	2,772 man/day or Nu. 41,850	In every 3 hours operation or one acre's field work, saving of 3.3 man/ day or Nu. 50

Balance

Total cost of life time	Nu. 39,400
Total output of machinery	41,850
Net benefit in 4 years	2,450

An important point to be noted here is that the number of working days might be increased by 50%, which was proved by the other experimental data, and further in fact the labour cost per day is Nu. 25 with 3 meals instead of Nu. 15. If, therefore, calculation could be worked out on the basis of the labour cost per day being Nu. 25 and the number of working days being 153, the net benefit in 4 years would amount to as much as Nu. 49,850. This might be more realistic than that in Table 5-3. Moreover, in the table the durability of the machine is taken as 4 years, but actually it is much longer than 4 years in Bhutan, as mentioned in Par. 4-3. Taking the durability into account, the net benefit mentioned above will much more be expanded than Nu. 49,850.

Thus, mechanization is not only commercially practicable, but also makes it possible to make an expansive reproduction.

5-3 Justification on the Selection of Kinds (Varieties) of Machines

5-3-1 Selection of Lightweight Machines

In view of the topography in Bhutan, i.e. mountainous fields, steep sloped fields, terraced paddy fields, steep narrow farm roads and footpaths, and putting emphasis on the transportation and movement, lightweight machines were carefully selected with first priority, which is a noteworthy point in selecting machines.

5-3-2 Selection of the Most Suitable Cultivating Machine to Each Operation

Examining each actual operation in cultivating each crop, the most suitable machine to each operation was selected, which is supposed to be quite important. In Table 3-1 the agricultural machines were classified and listed according to the progress of farm operations.

5-3-3 Selection of Machines with Diesel Internal Combustion Engines

It appears to be worth noticing that machines attached with diesel internal combustion engines were preferentially selected for lengthening the life of machines, for decreasing the fuel cost and for making perfect combustion under dilute oxygen concentration.

5-3-4 Introduction of Earth Moving Machines and Equipment

In view of the fact that almost all kinds of public works are performed by the labour contribution by farmers, which is compulsory for farmers as stated in Par. 5-1-1, a considerable number of earth moving machines and equipment were planned to be introduced. The machines and equipment will serve to reduce largely the labour contribution from farming communities, which is noteworthy.

5-3-5 Introduction of Machinery and Equipment Based on Cottage Industry

There are some machines and equipment which cannot be called as agricultural ones in the list of the introducing plan, i.e. oil expeller, starch-sugar processing unit, alcohol processing unit, grading machine, etc. These machines and equipment are to be used for processing fruits and vegetables which are not suitable for eating as fresh ones and for processing surplus agricultural products, to enable farmers to get cash income and elevate their living standard. The introduction of these machines and equipment might also be highly evaluated.

5-3-6 Saving Labour in the Transplanting Operation and the Reaping Operation

The transplanting operation and reaping operation are practised during the busiest farming season and both are the most painful drudgery. In Japan, transplanting has been carried out by transplanters and reaping by combine-harvesters, then the farmers in Japan have completely been released from these painful drudgery. In view of the topography and educational standard of farmers in Bhutan, the direct introduction of these machines is believed to be quite risky. They therefore are to be introduced in a minimum number, as shown in Table 3-1, but in compensation of their quantitative restriction, the following apparatus and machines are to be introduced. For saving labour for transplanting, apparatuses for easy transplanting, which can be applicable to any mountainous and terraced fields, will be used. By using the apparatuses, farmers can transplant rice seedlings 10 times as faster as the ordinary transplanting, and further the apparatuses will have neither engine troubles nor oil consumption. For saving labour for reaping and threshing, power reapers and power threshers will be used. The reapers and the threshers are light in weight and easy in movement, and further much less in engine trouble than the combine-harvesters. These apparatuses and machines, therefore, will be much more suitable to the conditions of Bhutan than transplanters and combine-harvesters.

5-3-7 Restriction of Kinds (Varieties) of Machines

The kinds of machines are restricted to the minimum, so that parts of the machines may easily be exchanged with one another. This will serve to make repairing and maintenance easy and further to simplify the management of parts.

5-3-8 Introduction of Workshop Equipments

A considerable emphasis is placed on introducing workshop equipments, which are necessary not only for repairing agricultural machines but also for manufacturing simple machines and improved tools and spare parts. Manufacturing of simple machines and improved tools has been initiated at Bondey farm in Paro, and it has favourably been noticed by farmers. Machines and tools manufactured by Bondey farm have proved useful and helpful to the farmers in Bhutan. Then, the introduction of workshop equipments will play a strikingly important role in repairing and in manufacturing useful machines, tools and spare parts in Bhutan.

5-3-9 Introduction of Improved Tools

Some tools such as sickles, hoes and pruning scissors in Bhutan are much lower in operation efficiency than those of Japan. Improvement of these tools is of prime importance for increasing the operation efficiency in general farm works in Bhutan. A considerable number are to be introduced in order to make farmers realize the efficiency of these tools by using them actually, and further to manufacture them from the models.

5-3-10 Selection of Vehicles Suitable for Steep and Rough Roads

In view of steep, rough roads and the capability for riding through the year, front-wheel drive vehicles attached with diesel engines are to be selected.

5-4 Justification on the Planning of Repairing, Maintenance and Management

5-4-1 Network of Repairing, Maintenance and Management

The network of repairing, maintenance and management consists of three levels of the workshops, i.e. national level, regional level and district level. The national level workshop is in the National Mechanization Center, and the regional level workshops are in the Regional Mechanization Centers which are located in four regions, each region having one, and moreover each regional level workshop has three to six district level workshops which are distributed to all the districts in each region, each district having one district level workshop.

Thus, all kinds of repairing, maintenance and management will smoothly be carried out by the three level workshops. The plan can be highly evaluated. This network, however, has just started and is not functioning yet. There is hope that, the mechanization project will be realized at the earliest convenience and it will give a strong impetus on the complete functioning of the network.

5-4-2 Actual Practices of Repairing, Maintenance and Management

At present, four regional workshops and other two workshops (Wangdiphodrang, Bumthang) are beginning to function. Among them the workshop in Paro Regional Mechanization Center is most active. The knowledge, technique and accuracy of mechanical engineers are mostly adequate for the performance of their duties. Moreover, should the more precise and higher level workshop equipments be introduced, the function of the workshop would sharply increase. With this in view, the realization of the project is eagerly waited for. Special parts of machines cannot help being imported from abroad, but, once the precision workshop equipments will be introduced from Japan, the manufacture of some kind of spare parts will become possible in Bhutan.

5-5 Justification on the National Mechanization Center

First, it is quite reasonable that the National Mechanization Center has been determined to be established in Paro which is the center of agriculture in Bhutan.

Second, it appears reasonable from the viewpoint of actual circumstances in Bhutan that the National Mechanization Center consists of three centers, i.e. Training Center, Workshop Center and Hire Service Center (dealing with only large scale machines).

Third, it is also reasonable in the present situation of Bhutan that the training course is divided into two courses; i.e. Freshman's course and Upgrading course. At present, 65 agricultural mechanical engineers have been stationed in the country. It is of an absolute necessity for these mechanical engineers to be retrained with the up-to-date knowledge and the recent advanced machines. The training term for 3 months to 6 months appears to be adequate. The freshman's course admits 20 trainees, one from each district and two from the Regional Centers, which seems to be properly planned. The curriculum of the training courses has already been made, which is considerably satisfactory and has also been proved to be reasonable by the professors of Tokyo University.

On carrying out the plan of training, each district will have an increase of one graduate from the Freshman's course every year, and further one graduate from the upgrading course nearly every year. Each Regional Center will have an increase of one graduate from the freshman's course every other year and one graduate from the upgrading course every year. Thus, the newly trained engineers will surely help to develop agricultural mechanization in Bhutan in cooperation with the existing 65 engineers without any hindrance.

The Royal Government of Bhutan itself has proved its great enthusiasm for the training center in having already provided the budget amounting to Nu. 3,925,000 for its running cost in the Fifth Five Year Plan, which also appears to be well-timed.

5-6 Justification on the Regional Mechanization Center

As mentioned before, the Regional Mechanization Centers will be established in the four regions covering the whole country, each controlling 3 to 6 district mechanization centers, and will repair damaged machines which cannot be repaired at the district workshop level. Further the Regional Centers will improve simple agricultural machines and tools, will train farmers and also will carry out the hire-service of machines and tools. Such functions, however, are not realized yet at present, except at Paro Regional Mechanization Center, in which all these functions have already been performed to some extent.

On planning the Project which will be included in the present Grant Aid Programme of the Government of Japan, Paro (Bondey) farm has been selected as a pilot model of the Regional Mechanization Centers to be fully equipped by the Grant Aid. The Plan left the other three Regional Centers untouched, expecting that they will be fully equipped by the Government of Bhutan on the model of Paro. The Plan might be considered best for utilizing the limited amount of the Grant Aid from Japan to the maximum advantage of Bhutan.

Thus, the present Grant Aid Programme of the Japanese Government will be focussed on the establishment of the National Mechanization Center and on strengthening Paro Regional Mechanization Center as a pilot model of the regional mechanization centers. Taking this aid as an initiator, the Royal Government of Bhutan will strengthen on its own effort the other three regional mechanization centers and 18 district mechanization centers. On the basis of this network, the agricultural mechanization in Bhutan will be fully performed without any difficulty. From this viewpoint, the strengthening of Paro (Bondey) farm as a pilot model of the regional mechanization centers is of deep significance.

Chapter 6. CONCLUSION AND RECOMMENDATION

6-1 Conclusion

With the rapid change from a closed-door-country to a modern country, the Kingdom of Bhutan has been forced to face various kinds of national difficulties. One of the most serious difficulties is the labour shortage combined with the low agricultural productivity (Labour efficiency and land production), as mentioned in the foregoing chapters.

The one and only way to solve the problem of the labour shortage combined with the low agricultural productivity is likely to mechanize farming practices, which appears to be the most direct and the most effective means.

As a result of examining the problem along this line, the necessity of formulating a plan of the nation-wide mechanization network was clearly pointed out. Then, the plan was drawn up, and moreover the adequacy and the effectiveness of the plan have considerably been proved, as can be seen in the Chapter 5.

Therefore, a considerable discussion was made on the ways for realizing the plan, attaining to the following conclusion. The urgent measure to be taken up is to establish the National Agriculture Mechanization Center at the national level, which is the core of the mechanization network in Bhutan, and to strengthen Paro Regional Agriculture Mechanization Center as a model case for other Regional Agriculture Mechanization Centers. It is further concluded that the Grant Aid Programme of the Government of Japan should be concentrated on these two centers (National Center and Paro Regional Center) and, making these two centers as an initiator for completing the nation-wide mechanization network, the remaining Regional Agriculture Mechanization Centers and District Centers should be completed by the self-efforts of the Royal Government of Bhutan.

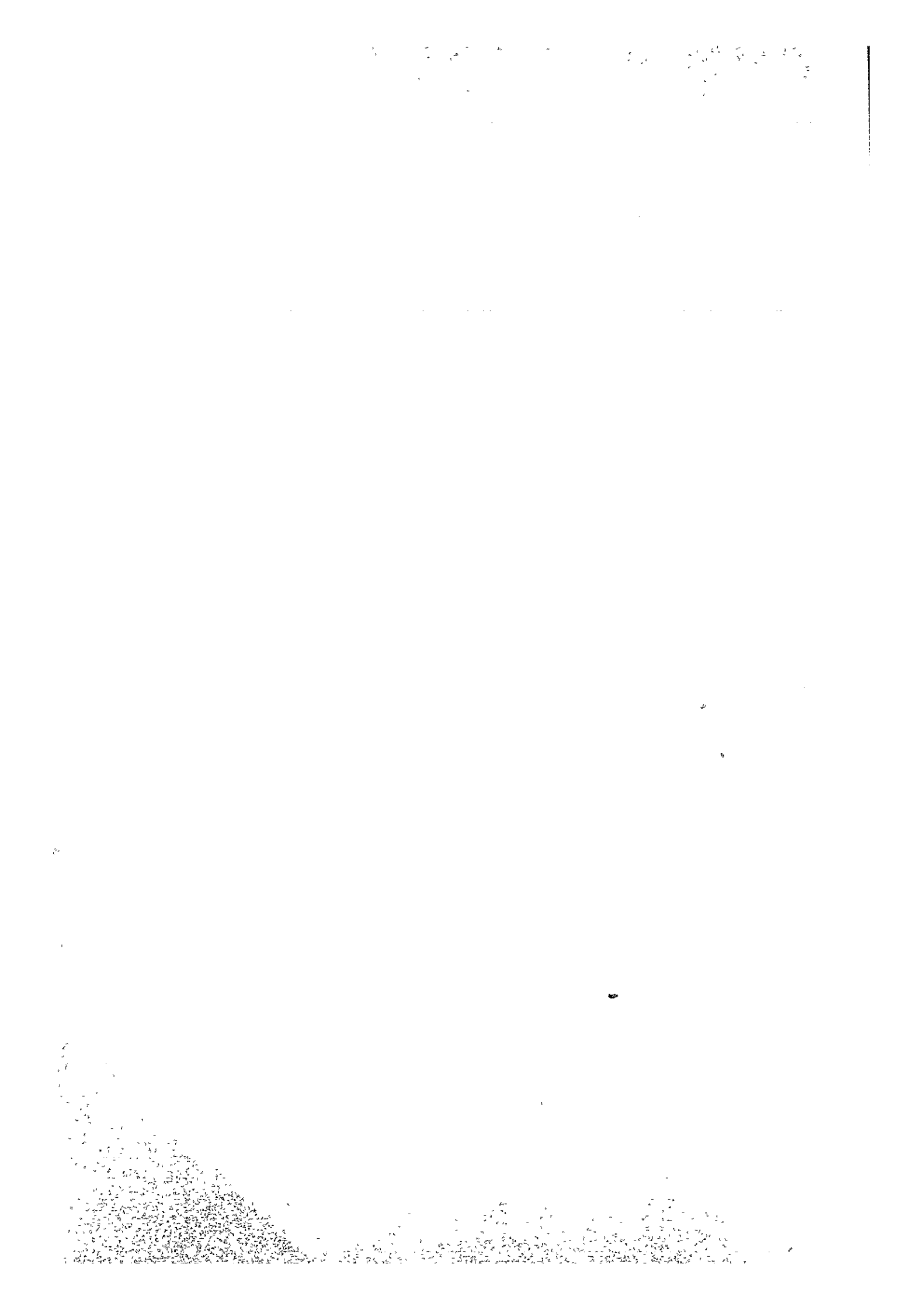
6-2 Recommendation

(1) Every effort should be concentrated on realizing the nation-wide Agricultural Mechanization Plan at the eariest convenience to solve the problems of the labour shortage and the low agriculture productivity in Bhutan.

(2) The Royal Government of Bhutan should take all budgetary and other means necessary for realizing the mechanization plan with priority, besides the running cost of Nu. 3,925,000 for the Training Center in the National Mechanization Center, which has already been earmarked for the Fifth Five Year Plan.

(3) The Royal Government of Bhutan should give priority on making a steering committee and on assigning staff necessary for the agricultural mechanization.

(4) For carrying on the mechanization plan smoothly, the Royal Government of Bhutan should invite a senior expatriate expert on agricultural machinery from abroad, and, at the same time, should send the Government staff concerned to advanced countries for training.



ANNEX 1

DISPATCH OF THE BASIC STUDY TEAM

1-1 Members of the Basic Study Team

. Leader	Mr. Tadashi Shinoura	Chief of Grant Aid Department Japan International Cooperation Agency
. Member	Mr. Senichi Kimura	Coordinator Grant Aid Department Japan International Cooperation Agency
. Member	Dr. Seizo Matsushima	Agricultural Engineer Agricultural Department Nippon Koei Co., Ltd.
. Member	Mr. Keitaro Wakatsuki	Architectural Engineer Architectural Department Nippon Koei Co., Ltd.

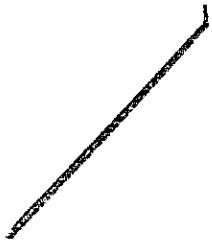
1-2 Itinerary of the Basic Study Team

Date	Day	Activities
Sept. 12	Sunday	Tokyo to Delhi by JL 461
Sept. 13	Monday	Courtesy call to Embassy of Japan and Embassy of Bhutan in New Delhi
Sept. 14	Tuesday	Delhi to Bagdogra by IC 489 Bagdogra to Phuntsholing by car
Sept. 15	Wednesday	Phuntsholing to Thimphu by car
Sept. 16	Thursday	Courtesy call to Ministry of Foreign Affairs, Ministry of Development and Planning Commission
Sept. 17	Friday	Discussion with the officials concerned
Sept. 18	Saturday	Inspection of Bondey farm, rural houses, mini hydro power station, Paro castle in Paro district Reconnaissance in the proposed construction sites

Date	Day	Activities
Sept. 19	Sunday	Reconnaissance in the proposed construction sites
		Discussion with the officials of Department of Agriculture on the project for agricultural mechanization
Sept. 20	Monday	Planning a basic design of the national mechanization center (the National Center) and studying the network for agricultural mechanization
Sept. 21	Tuesday	Discussion with officials of the Department of Agriculture on Minutes of Discussion
Sept. 22	Wednesday	- do -
Sept. 23	Thursday	- do -
Sept. 24	Friday	Signing on Minutes of Discussion
		*(A-group) Left Thimphu for Tokyo
		*(B-group) Field survey
Sept. 25	Saturday	Successive field survey
		Planning the National Center and agricultural machinery and equipment
Sept. 26 thru Oct. 2	Sunday thru Saturday	- do -
Oct. 3	Sunday	Field survey on the rural agricultural circumstances
		Field survey on conditions of infrastructures around the proposed sites
Oct. 4 thru Oct. 8	Monday thru Friday	- do -
Oct. 9	Saturday	Left Phuntsholing for Delhi
Oct. 10	Sunday	Left Delhi for Tokyo

*A-Group: Mr. T. Shinoura and Mr. S. Kimura

*B-Group: Dr. S. Matsushima and Mr. K. Wakatsuki



1-3 Bhutan Authorities and Officials Concerned

Embassy of Bhutan in India	
Dr. T. Tobgel	Ambassador
Mr. Hari K. Chhetri	Secretary
Planning Commission	
Dasho Lam Penjor	Deputy Minister
Mr. Pema Wangdi	Deputy Secretary
Mr. Ugen Tshering	Under Secretary
Ministry of Foreign Affairs	
Dasho Sangay Penjure	Secretary
Mr. D. K. Chetri	Director of Economic Division
Mr. Sonan Tobden Rabgay	Under Secretary
Ministry of Finance	
Mr. M. P. Sharma	Deputy Director
Ministry of Development	
Dasho Thinley Dorji	Director of Department of Development
Mr. Dorji Norbu	Director of Department of Public Works
Dasho Pema Wangchuk	Director of Department of Agriculture
Dasho Rinchen Tshering	Governor of Paro District
Dasho Kyoji Nishioka	Colombo Plan Expert
Region and District Staff concerned	
Mr. P. M. Pradhan	Head, Agri. Research Center, Wangdiphodrang
Mr. Manbahadut Gurung	District Agriculture Officer, Wangdiphodrang
Mr. Dilliram Kharel	Head, Pelela Agri. Farm
Dasho Maj Passang	Commissioner, Tongsa
Mr. H. N. Shukla	District Agriculture Officer, Tongsa
Mr. D. Tamang	Project Manager, Area Development Project, Gayleyphug
Mr. Passuram Shama	Administrator, Shemgang
Mr. S. C. Balva	District Agriculture Officer, Shemgang
Dasho Nim Sangey	Commissioner, Shemgang
Mr. R. Kujwe	District Agriculture Officer, Gayleyphug

Mr. M. D. Yadan	Agriculture Officer, Gayleyphug
Mr. A. N. Praelhen	Manager, Agriculture Farm, Bhur
Dasho H. K. Humagai	Commissioner, Chirang
Mr. C. D. T. Namclue	District Agriculture Officer, Chivang

1-4 Japanese Officials in Delhi

Embassy of Japan in India

Mr. A. Hara	Ambassador
Mr. K. Yano	First Secretary
Mr. M. Murakami	New Delhi Office Japan International Cooperation Agency

ANNEX 2

MINUTES OF DISCUSSION
OF
THE PROJECT FOR MECHANIZATION OF AGRICULTURE
IN THE KINGDOM OF BHUTAN

In response to the request by the Royal Government of Bhutan, the Government of Japan sent, through the Japan International Cooperation Agency (hereinafter referred to as "JICA"), a team headed by Mr. Tadashi SHINOURA to conduct a basic design study of the project for mechanization of agriculture in Bhutan (hereinafter referred to as "the Project") for 15 days from 12th September, 1982.

The team has conducted the field survey and held a series of discussion and exchanged views with the officials concerned of the Royal Government of Bhutan.

Both parties have agreed to recommend their respective Governments and the authorities concerned to examine the result of the study attached herewith toward the realization of the Project.

24th September, 1982

TADASHI SHINOURA
Team Leader, Japanese Study Team
JAPAN INTERNATIONAL COOPERATION AGENCY

PEMA WANGORHUK
Director of Agriculture
Ministry of Development
Royal Government of Bhutan

ATTACHEMENTS

1. The objective of the Project is the mechanization of agriculture in the Kingdom of Bhutan which establishes the National Agriculture Mechanization Centre (hereinafter referred to as "the Centre") and regional and district level workshops for the purposes of creating training/repair/maintenance and hire services network, and introduces wide range of agricultural machineries, small scale earth moving equipment and agricultural cottage industry equipment.

2. The Japanese study team will convey the desires and efforts of Royal Government of Bhutan to the Government of Japan that the latter will take necessary measures to cooperate in implementation of the Project of the Royal Government of Bhutan on providing items as listed in Annex-I within the scope of Japanese economic Cooperation in grant form.

3. The Royal Government of Bhutan will take the following necessary measures on condition that the grant assistance by the Government of Japan is extended to the Project;

   1) To provide data and information necessary for the project.

   2) To secure necessary land for the construction.

   3) To clear, fill and level the site of the Centre as needed before the start of the construction.

   4) To provide the items listed in Annex-II before the start of the construction.

   5) To ensure prompt unloading and customs clearance at ports of disembarkation in India and prompt inland transportation therefrom of imported materials and equipment for the construction, and machineries and equipment purchased under the grant.

6) To exempt Japanese nationals from custom duties, internal taxes and other fiscal levies which may be imposed in recipient country with respect to the supply of materials for the construction machineries, equipment and services under the verified contracts.

7) To accord Japanese nationals whose services may be required in connection with the supply of materials for the construction, machineries, equipment and services under the verified contracts such facilities as may be necessary for their entry into recipient country and stay therein for the performance of their work.

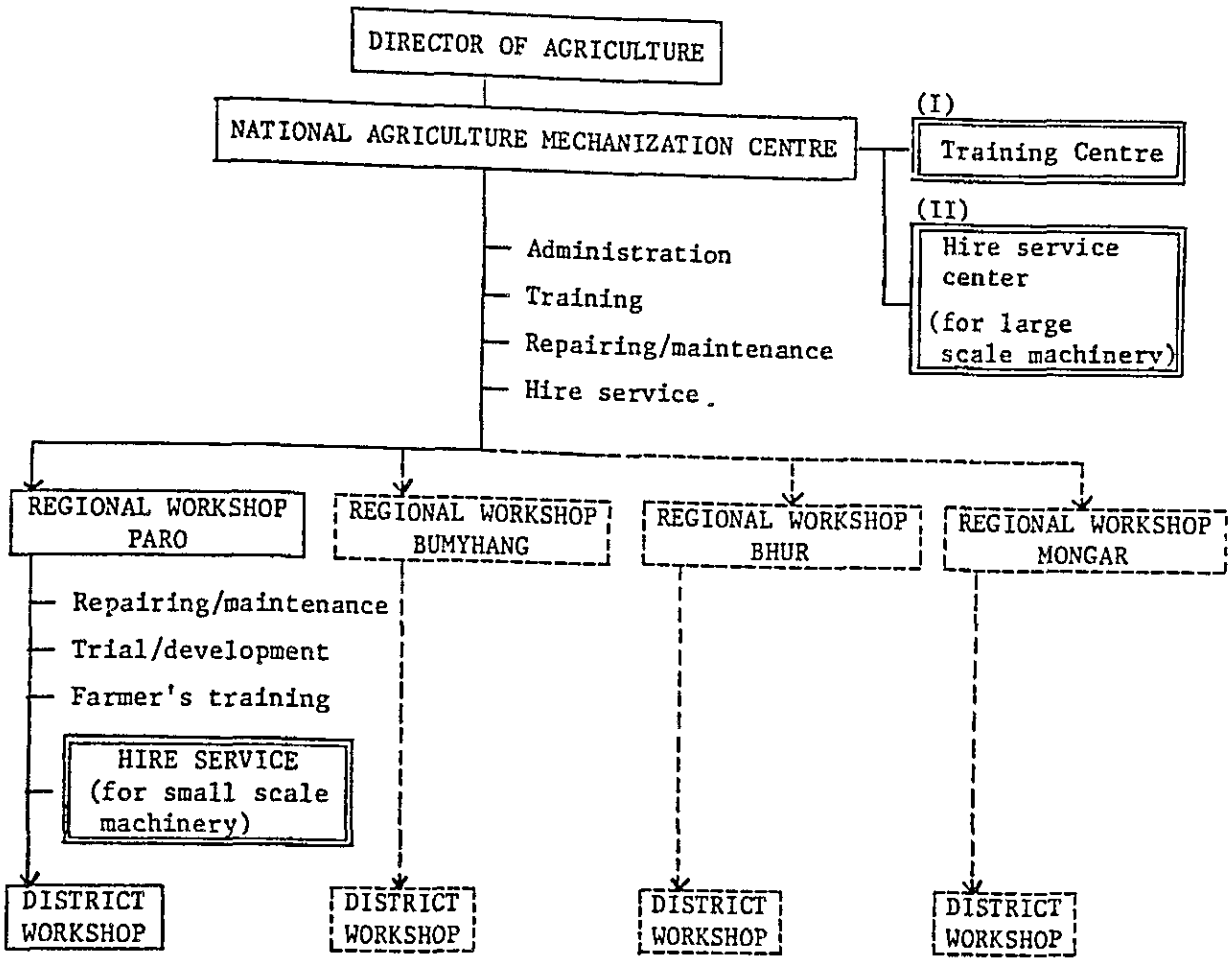
8) To maintain and use properly and effectively that the facilities constructed and equipment purchased under the grant.

9) To bear all the expenses, other than those to be borne by the grant, necessary for construction of the facilities as well as for the transportation and the installation of the equipment.

ANNEX-I

AGRICULTURAL MECHANIZATION NETWORK

TO BE PROPOSED UNDER THE STUDY



LEGENDS

——→ : Model of Agricultural Mechanization Network

▭ : To be proposed for the grant aid assistance of Japanese Government

- - → : Prospective network in Agricultural Mechanization

NOTE: The proposed site of the National Agriculture Mechanization Centre is the land acquired by the Royal Government of Bhutan in Paro.

(I) TRAINING CENTER (for 30 trainees)

1. ADMINISTRATIVE AND TRAINING BUILDING: 1 or 2 storied

Administration (1 FL)	- Teachers' room, administrative office, reception, kitchen, storeroom and toilet
Training (2 FL)	- Training rooms, multi-purpose room, library, store room and toilet

2. WORKSHOP: 1 storied

Workshop	- Repairing/maintenance space, materials, tools and spare parts store rooms, office and toilet
Machine shed	- for small scale machine for training

3. DORMITORY: 1 or 2 storied

Bed room	- Bedrooms, bathrooms
Canteen	- Dining rooms, kitchen, washing rooms, and toilet

4. TRAINING GROUND: for small scale machine

5. OUTDOOR FACILITY: Substation, elevated water tank, street lamps, water supply system, drainage system, electric distribution

6. OTHER FACILITY: Grading, fence and gate, interior and access road

(II) HIRE SERVICE CENTER

1.	MACHINE SHED:	for large scale machine for training and hiring
*2.	TRAINING GROUND:	for large scale machines

NOTE: * Works to be carried out by the Royal Government of Bhutan before the start of the construction.

(III) Agricultural Machine and Equipment to be provided for the National Agriculture Mechanization Center and Paro Regional Mechanication Center

1. Rice Cultivation

(a) Nursery
Clod crusher
Soil sieving machine

(b) Main field
Reversible plow
Power tiller
4-wheel tractor
Front wheel drive tractor
Leveller
Transplanter
Apparatus for easy transplanting (Type A)
" (Type D)
Sprayer (Manual)
Power sprayer (Portable)
Combine harvester
Reaper
Food thresher
Power thresher
Grain dryer
Husking-polishing machine
Water pump

2. Wheat (Barley) Cultivation

Seed drill (Manual)
Seed drill (Power tiller attachment)
Flour mill

3. Cash Crop Cultivation

Soil block machine
Solar cell powered water pumping unit
Pruning secateur

4. Earth Moving Equipment

Bulldozer (Small model)
Bulldozer shovel
Bulldozer (Swamp type)
Excavator (Hydraulic)
Carrier (Crawler type)
Well drilling machine

5. Machinery and Equipment for Cottage Industry

Oil expeller
Water turbine
Belt hammer
Grading machine
Gravity separator
Electric motor
Starch sugar processing unit
Alcohol processing unit

6. Equipment for Training

Overhead projector
Slide projector
Projector (16 mm)
PPC (Dry type)
Blue print (A 3)
Mimeograph and electric stencil cutter
Offset press (Table type)
Typewriter (Electro-motive) (27 inch)
Microphone, Loudspeaker, Amplitude modulation apparatus
Video monitor (26 inch)
Video player

7. Workshop Equipment

Workshop (Small type)
Workshop (Medium type)
National level workshop (Large type)
Repairing equipment for earth moving machines
Electric discharge machine
Electric hand tools
Gas cutting equipment

8. Supporting Equipment and Mobile Workshop

Transport vehicle for carrying mobile workshop, service unit and earth moving equipment.

Service - track (4 x 4)
Video car (4 x 4, Station wagon)

ANNEX-II

MEASURES TO BE TAKEN BY THE ROYAL GOVERNMENT OF BHUTAN

a) Acquisition of the land of the National Agriculture Mechanization Center and clearing and grading thereof (the center)

b) Supply of electric power, water to the site of the center

c) Access road to the site of the Center

d) Interior road in the site of the Center

e) Surrounding fence and gate

ANNEX 3

A YIELD DIAGNOSIS AND ITS PRESCRIPTION FOR IMPROVING RICE CULTIVATION IN BHUTAN

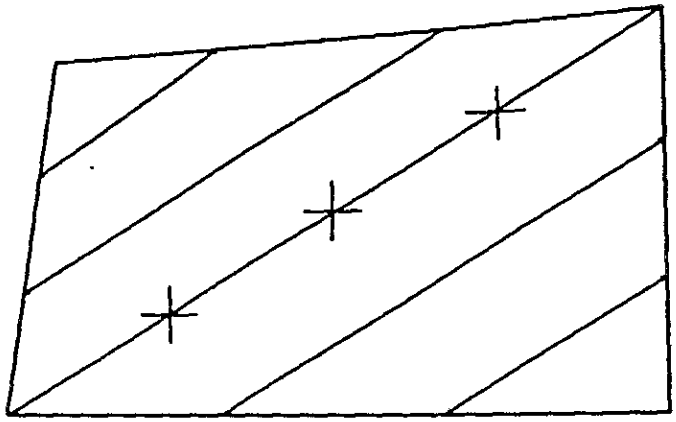
To identify the characteristics, in particular the defects, in the rice cultivation in Bhutan, and, basing upon it, to find out the key points for its improvement, a yield-diagnosis was carried out in paddy fields in Paro in late September, 1982.

For increasing the yield of a given paddy field, the defects in the paddy field must first be diagnosed. To diagnose the defects, it is convenient to examine the process of yield determination by investigating the hills of rice. The method of investigating the hills is to select the "average" or "representative" hills from the field and then to examine their yields analytically.

3-1 Method of Yield-Diagnosis

Four paddy fields differing in yield from high to low were selected in the Paro area. In each field under investigation 75 to 150 hills were sampled at a definite interval along the five lines parallel to a diagonal, as shown in Fig. 3-1. Three hills which have nearly an average number of panicles as well as an average weight of panicles per hill for the sampled hills were selected from each field under investigation. These selected hills are referred as "representative hills". Using the representative hills, yield-diagnoses were carried out as follows. As to the details of the investigation method and its theoretical bases, refer to Matsushima's "Crop Science in Rice" and "Rice Cultivation for the Million".

Fig. 3-1 A Method of Sampling Hills along Five Lines Parallel to a Diagonal



Note: Crosses indicate the spots at which the longitudinal and horizontal distances between rows are measured for determining the number of hills per m^2.

3-2 Results of Diagnoses

The results of the diagnoses are shown in Table 3-1. Taking into account the number of hills per m^2, the number of panicles per hill is considerably small. The number of hills per m^2 is larger than that of northern parts of Japan, except for No. 2 field. The number of panicles per m^2, which is the product of the above two components, is 240 - 328, while that of Japan is 350 - 500 in general. The number of grains per panicle can be taken as nearly the same as that of Japan. The number of grains per m^2 is one of the most important yield-components which is the product of the number of panicles per m^2 and the number of grains per panicle, and its value is quite small, which is believed to be a characteristic in the rice cultivation in Bhutan. How low is the value of the number of grains per m^2 can easily be understood by referring the values of Japan which range from 30,000 to 50,000 in general in Japan. The percentage of ripened grains is also one of the most important components. The values of the percentage of ripened grains are generally high enough, except for No. 2 field. The value of No. 4 field attains as high as 90%. The value of the weight of 1,000 grains is primarily characterized by the varieties, but there is found a difference of 2 grains at the maximum among the same three varieties. The product of 4 components, i.e. Number of panicles/m^2 x Number of grains/panicle x Percentage of ripened grains x 1,000 grain weight, is the yield of grains. In this case, however, sampled grains were dried by using a drying machine, then the grains were dried up excessively. The yields of grains, therefore, were corrected on the basis of 14% in water content in grains. The grain yield ranges from 3.53 ton/ha (1.45 ton/ac) to 6.13 ton/ha (2.51 ton/ac). Taking that the yield in the Paro area is by far the highest in Bhutan, these values of grain yields appear to be much higher than the average in Bhutan. (Incidentally, the average yield of the whole country in Japan is nearly 6.5 ton/ha, and the highest one attains 13 ton/ha.)

Table 3-1 Results of Rice-Yield Diagnoses in Paro

Sample No. of Field	Names of Varieties	No. of Panicles /hill	No. of Hills /m^2	No. of Panicles /m^2	No. of Grains /panicle	No. of Grains /m^2	Percent. of Ripened Grains	1,000 Grain Weight	Yield	Yield 14% water basis	Degenerated rachis-branches/panicle		Percent. of Unfertilized Grains
											Primary	Secondary	
							%	g	ton/ha	ton/ha			%
No. 1	Takanenishiki	10.04	24.0	241	59.2	14,267	83.9	28.6	3.42	3.52	0.5	0.8	6.5
No. 2	Takenenishiki	8.44	28.4	240	94.0	22,560	61.5	27.6	3.83	3.94	0.5	3.2	23.5
No. 3	Jya NAK	9.63	32.0	308	86.3	26,580	77.3	21.6	4.44	4.57	0.3	4.0	11.8
No. 4	Takanenishiki	11.3	29.0	328	76.4	25,095	89.6	26.5	5.95	6.13	0	2.2	5.9

Note: Locations of samples are as follows:

No. 1 ..... Bondey Farm
No. 2 ..... Shari Village
No. 3 and 4 ..... Bondey Village

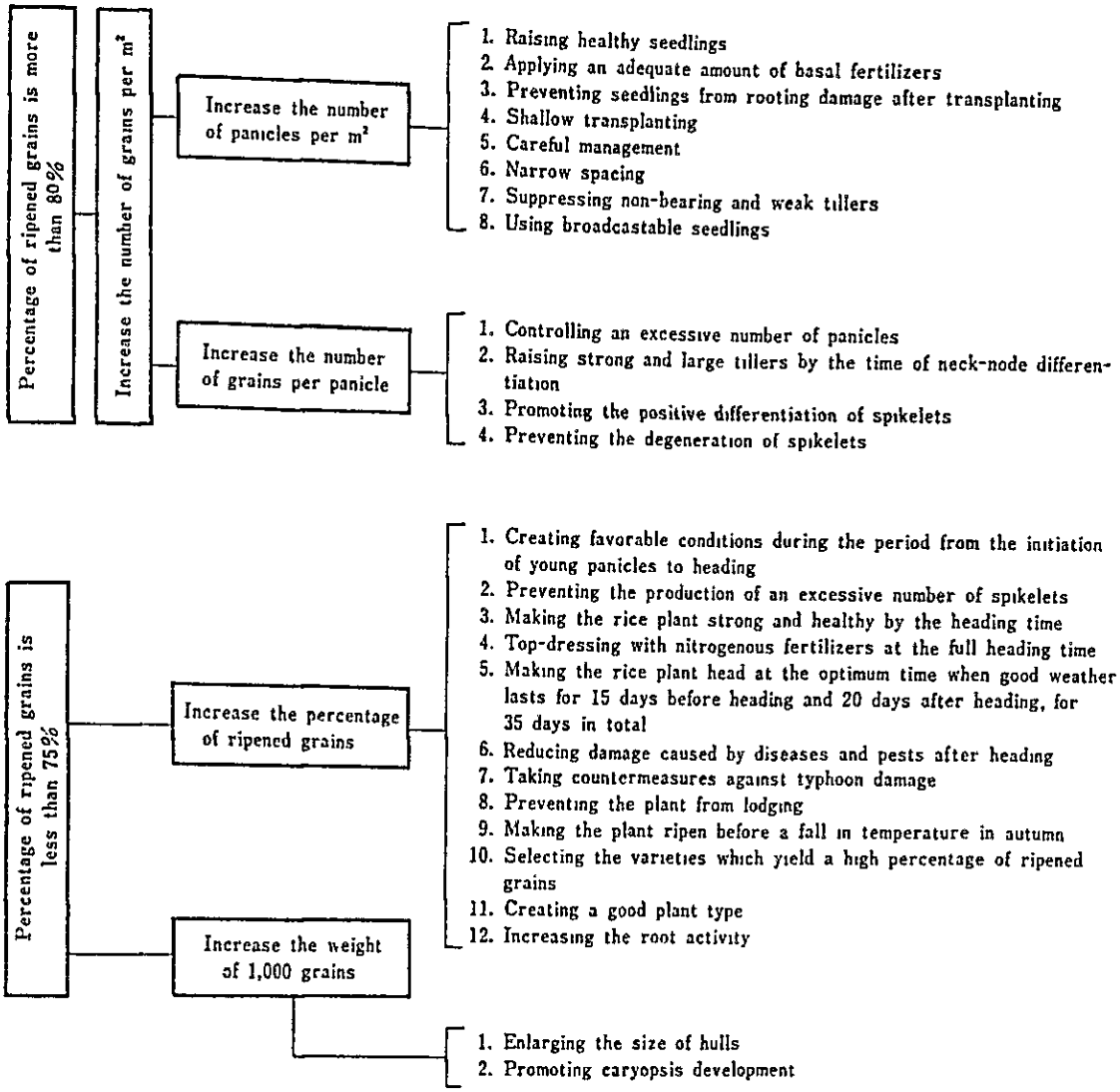
3-3 Prescriptions for the Results of Diagnoses

The prescription for the results of diagnosis in each paddy field is shown in the following.

A glimpse at Table 3-2 makes it possible to understand the guiding principle in prescription. As shown in the table, the percentage of ripened grains is by far the most important for the prescription. In case of the percentage of ripened grains being less than 75%, the percentage of ripened grains is the limiting component for increasing yield. Because, however hard one may work to increase the number of panicles per m^2 as well as the number of grains per panicle, one will never be able to increase the yield without increasing the percentage of ripened grains. On the contrary, when the percentage of ripened grains is more than 85% or 80%, however hard one may work to increase the percentage of ripened grains, one will hardly be able to increase the yield without increasing the number of panicles per m^2 as well as the number of grains per panicle. Without this basic knowledge, however hard one may try to increase the yield, his efforts will be in vain.

The prescription for improving rice cultivation, therefore, differs entirely between the cases of the percentage of ripened grains being more than 80% and less than 75%, as shown in Table 3-2. (In the case when the percentage of ripened grains is between 75% and 80%, it is necessary to increase both components of the number of grains per m^2 and the percentage of ripened grains.)

Table 3-2 Prescription Based on Yield-Diagnosis for Improving Rice Cultivation



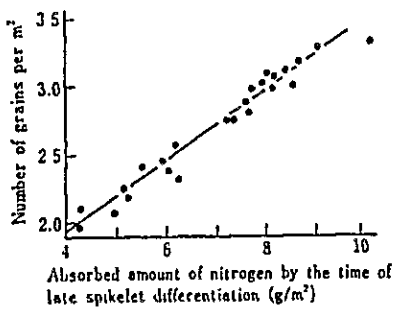
The field of No. 2 was located near a brook and cold water was continuously flowing into the field in large quantity. As a result, rice plants near the water inlet were lately matured and straight-headed, showing the damage caused by cold water. These facts could be taken as enough evidence to estimate that the low percentage of ripened grains in No. 2 field could be ascribed to the high percentage of unfertilized grains due to imperfect reproductive organs damaged by cold water. In fact, this estimation can fully be supported by the high percentage of unfertilized grains in No. 2 field which is shown in the last column in Table 3-1. (The percentage of unfertilized grains is nearly 5% under normal conditions.) The prescription for No. 2 field, therefore, is to raise the irrigation

water temperature, in particular to raise it during the period from the initial stage of panicle formation (32 days before heading) to the reduction division stage of pollen mother cells (10 days before heading). There are several methods for raising the temperature of irrigation water as written in Matsushima's "Crop Science in Rice" (pp. 58). Among them the simplest and the most efficient way for raising water temperature in the fields like No. 2 is a "night-time irrigation method". In this method the inflow of irrigation water is cut off at 6 or 7 o'clock in the morning and no more is added to the field until 7 o'clock in the evening, accordingly no water comes in during the daytime. By using this method, the percentage of ripened grains will surely be improved, resulting in a marked increase in yield. (In the paddy fields, in which late-maturing and straight-heading phenomena of rice plants are observed at the vicinity of the water inlet, the same prescription as above will successfully be applied. The late-maturing and straight-heading phenomena, however, were found in only a few fields during the trip from Thimphu to Gaylegphug, passing through Punakha, Wangdiphodrang, Tongsa, Shemgang and Chirang. The reason for only a few examples of cold water damage being observed in spite of cold water being irrigated is that the amount of inflow water into fields is in small quantity on account of a rotational irrigation method with intervals of 5 to 12 days being widely practised in general.)

As to the other paddy fields under investigation, the values of the percentage of ripened grains can be taken as more than 80%, except for No. 3 field which is less by only 2% than 80%. In Bhutan it appears that there are very few paddy fields to which much amount of cold water is continuously irrigated like No. 2 field, then the percentage of ripened grains is estimated to be more than 80% in general under the normal weather conditions, except for the cases when the rice plant is subjected to low air temperature or a drought at its critical growth stages (the panicle initiation stage, the reduction division stage and the flowering stage). The prescription, therefore, for the paddy fields in general in Bhutan will be prepared according to the case of the percentage of ripened grains being more

than 80% in Table 3-2. In this case the point is to increase the number of grains per m^2. There are two ways for increasing the number of grains per m^2, as can be seen in Table 3-2. One is to increase the number of panicles per m^2, the other is to increase the number of grains per panicle. Examining the correlations between the yield and its constitutional components, the number of panicles per m^2 showed the highest coefficient against the yield among the four components. Accordingly, an increase in the number of panicles per m^2 appears to be the secret for increasing the yield of rice in Bhutan. There are eight concrete methods for increasing the number of panicles per m^2, as can be seen in Table 3-2. Among these eight methods, the most effective ones in Bhutan seem to be the second one "Applying an adequate amount of basal fertilizers" and the fifth one "Careful management". As to "An adequate amount of basal fertilizers", as mentioned in Par. 2-3-10, the amount of basal fertilizers (in particular the amount of nitrogen) in Bhutan is too little to get the enough number of panicles per m^2. Further, the most important practice in the management after transplanting is the top-dressing of nitrogen. The amount of nitrogen in top-dressing in Bhutan is also in small quantity in general. There is a definite relation between the absorbed amount of nitrogen by the rice plants and the number of grains per m^2, as shown in Fig. 3-2. Namely, the number of grains per m^2 is nearly in direct proportion to the absorbed amount of nitrogen by the rice plants per m^2 by the time of late spikelet differentiation, as can be seen in Fig. 3-2.

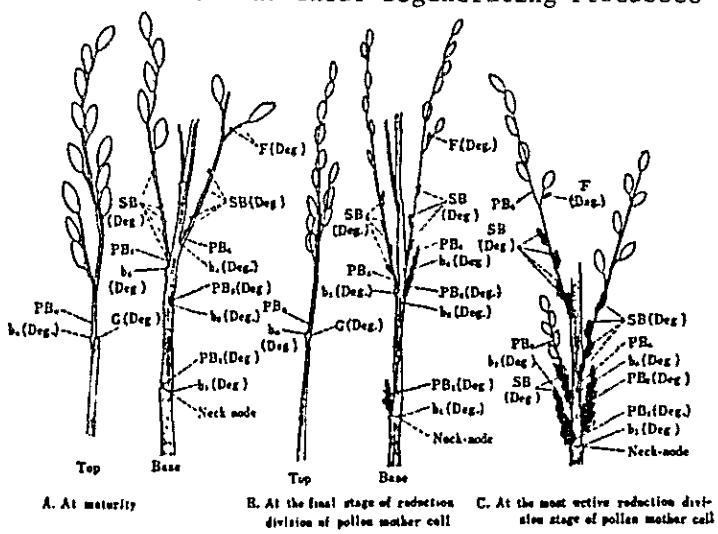
Fig. 3-2 Relation Between the Absorbed Amount of Nitrogen by the Time of Late Spikelet Differentiation and the Number of Grains per m^2



Accordingly, the most effective means for increasing the number of grains per m^2 is to apply as much as nitrogen to the rice plants by the time of late spikelet differentiation (20 days before heading). For the purpose, the amount of basal fertilizers as well as that of top-dressing must be much increased. Here likely exists an important secret for improving the rice cultivation in Bhutan.

Moreover, there is another method for increasing the number of grains per m^2, i.e. an increase of the number of grains per panicle, as can be seen in Table 3-2. Four methods are presented for increasing the number of grains per panicle in the table. Among the four methods, the most effective one will be the fourth "Preventing the degeneration of spikelets" in Bhutan. The degeneration of spikelets occurs with the degeneration of primary and secondary rachis-branches caused by the nutrient deficiency of the rice plant or unfavourable circumstances such as unfavourable weather conditions, drought conditions, flooding conditions, etc. at the reduction division stage, as illustrated in Fig. 3-3. One of the most common causes, however, for the degeneration of spikelets is the lack of nitrogen in the rice plant during the reduction division stage.

Fig. 4-3 Vestiges of Degenerated Organs on an Adult Panicle and Their Degenerating Processes



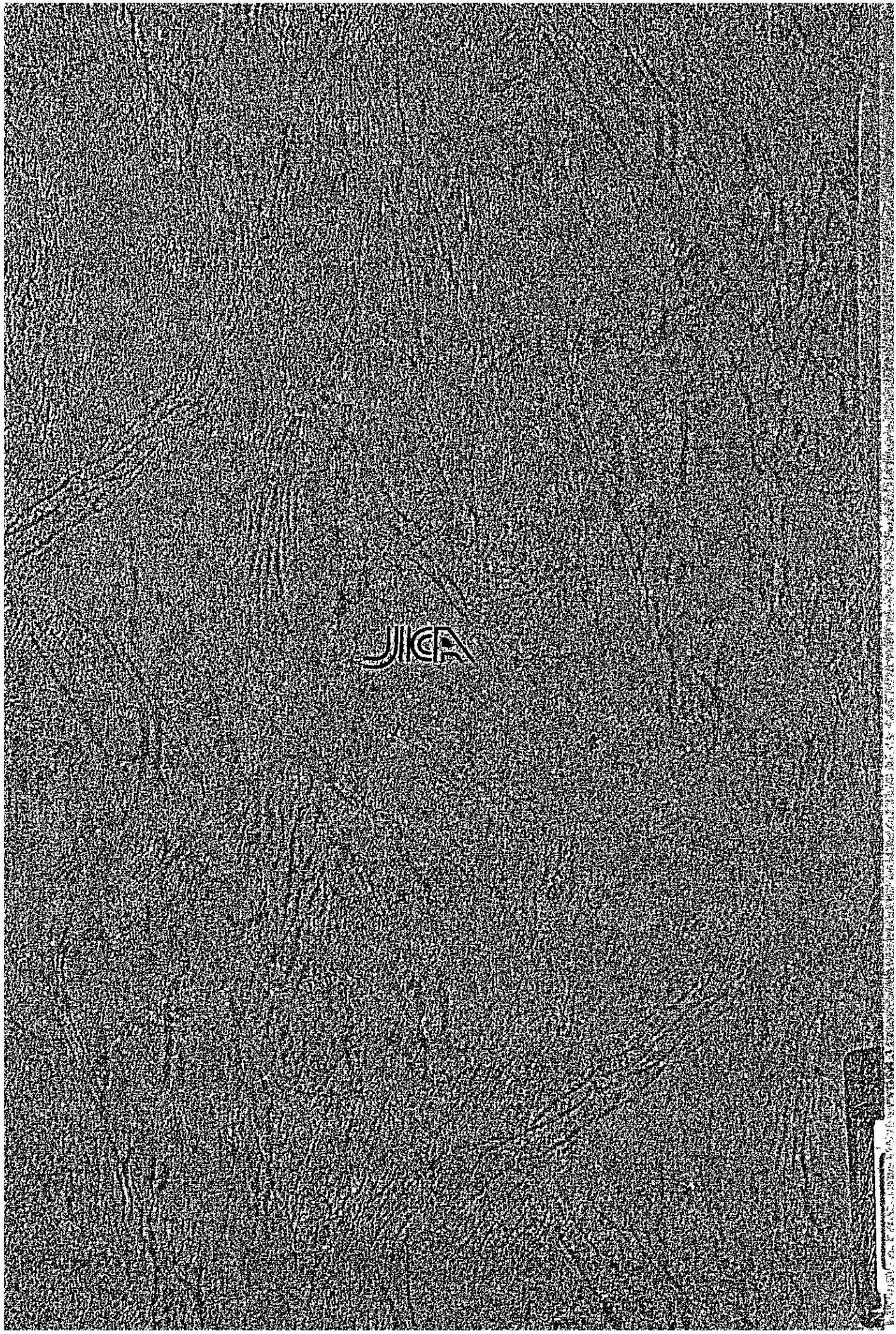
NOTES: 1. b_1, b_2, b_3 1st, 2nd and 3rd bract.
PB_1, PB_2, PB_3 1st, 2nd and 3rd primary rachis-branch.
SB. Secondary rachis-branch.
F. Flower.
G. Growth point.
Deg. Degenerated.
2. In the picture A, five kinds of vestiges of the degenerated organs can be seen.
3. In the picture B, as the degenerating organs stop their growth, they are found to be remarkably small in size as compared with normal ones.
4. In the picture C, the difference between normal organs and those commencing to degenerate begins to be seen.

In the second last column of Table 3-1, the results of investigations on the number of degenerated primary and secondary rachis-branches per panicle are presented. The degeneration of one primary rachis-branch means the degeneration of 11 grains (spikelets) at least, because 11 grains (spikelets) are born at least on the lowest primary rachis-branch. Likewise, the degeneration of one secondary rachis-branch means the degeneration of 3 grains (spikelets). Accordingly, the number of degenerated grains per panicle ranges from 7 in No. 4 field to 16 in No. 2 field, and the percentages of degenerated grains per panicle ranges from 9% to 17%, with an average of 15%. These values can be taken as the minimum values. These facts suggested that the percentage of degenerated grains will come to 20% or more in most fields in the Paro area. Further, taking into consideration that these fields under investigation were nicely managed and relatively high in soil fertility, it can be estimated that the percentage of degenerated grains might be 30% in general in Bhutan. This estimation was confirmed by an inspection trip from Paro to Gaylegphung. Namely, as many as 30% of grains which were once borne have degenerated due to the nutrient (mainly nitrogen) deficiency during the reduction division stage. This fact is worth noticing and attention should be focussed on it hereafter in the rice cultivation in Bhutan.

The countermeasure for preventing the degeneration of grains (spikelets) from the rice plant is simple in general, except for those under unfavourable conditions. The most common and most effective method is to top-dress with nitrogen just before the reduction division stage (18 or 20 days before heading). Generally speaking, the amount of nitrogen to be top-dressed is 30 to 40 kg/ha in element. Besides the nitrogen deficiency, there are other causes for the degeneration of grains such as the low air temperature, the low water temperature, the unfavourable weather conditions and the lack of water, then the countermeasures against the causes must be taken.

The above-mentioned are the results of yield-diagnoses and the prescriptions for improving the rice cultivation in Bhutan. For the details for the methods of diagnosis and prescription, refer to Matsushima's "Crop Science in Rice" and "Rice Cultivation for the Million".

Incidentally, a member of the Japanese team had an opportunity to make an inspection trip from Thimphu to Gaylegphug passing through Punakha, Wangdiphodrang, Tongsa, Shemgang and Chirang. In this trip he deeply felt that one of the most important constraints for increasing the yield of rice in Bhutan is the lack of water due to poor facilities of irrigation. In many places the rotational irrigation method was adopted on account of the shortage of irrigation water, and, as a result, in not a few places it was clearly observed that the yield of rice was markedly decreased by the lack of irrigation water at the critical growth stages such as the initiation stage of young panicles, the reduction division stage, the heading stage and the most active ripening stage. One of the most important countermeasures, therefore, for improving the rice cultivation in Bhutan should be the development of irrigation facilities, without which any rapid progress in the rice cultivation in Bhutan will never be achieved.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