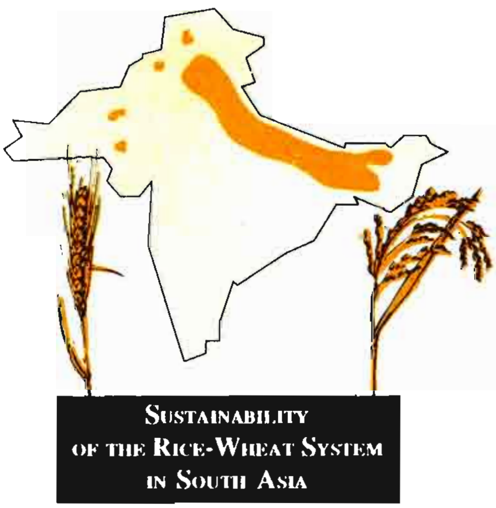
Rice-Wheat Cropping Systems in Faizabad District of Uttar Pradesh, India

Exploratory Surveys of Farmers' Practices and Problems, and Needs for Further Research

2-9 April and 21-27 September, 1991



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CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on improving the productivity of agricultural resources in developing countries. It is one of 16 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of a combination of 40 donor countries, international and regional organizations, and private foundations.

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CONTENTS

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INTRODUCTION

The rice-wheat (R-W) cropping pattern is very important in eastern Uttar Pradesh (U.P.), India (Figure 1). Of the 18 Districts (three divisions) in this part of the State under the responsibility of the Narendra Deva University of Agriculture and Technology (NDUAT), there are 2.944 million (m) hectares of rice and 1.983 m hectares of wheat (*Triticum aestivum*) grown. About 90% of the wheat is planted after rice (*Oryza sativa* L.) so, although statistics are not collected by cropping pattern, it would appear that there are approximately 1.80 m hectares of the R-W cropping pattern in this area.

This region under the jurisdiction of NDUAT was selected to be one of three sites in India as part of a collaborative South Asian regional endeavor of National Agricultural Research Systems (NARSs), the International Maize and Wheat Improvement Center (CIMMYT), and the International Rice Research Institute (IRRI). This effort will evaluate the productivity, profitability, and sustainability of the R-W system in a particular area and identify possible solutions (practices or techniques) for near-term productivity issues and longer-term sustainability problems.

The other two Indian sites are at G.B. Pant University of Agriculture and Technology (Pantnagar) in Western Uttar Pradesh (see Hobbs et al. 1991) and at Karnal in Haryana State. The Faizabad site was selected to represent the lower productivity, traditional R-W systems of the Eastern Plain Zone of India where farm size is small and rice is often grown as a rainfed crop. Mechanization is less developed than at the other two sites and many farmers depend on bullock power for land preparation.

This report presents the results of two exploratory surveys conducted 2-9 April 1991 during the end of the wheat season and 21-27 September during the middle of the rice season. The western half of Faizabad District was chosen for these surveys because of its representativeness and convenience to the University campus and Masodha Research Farm. Appendix I lists the participants in these surveys.

METHODS

The exploratory survey is a first step in evaluation of the R-W cropping systems and the development of a research agenda. The method is qualitative in nature although some secondary data sources are used to provide some quantification.

Objectives

- To better understand the local cropping systems, particularly R-W, and identify key interactions between rice and wheat and between rice, wheat, and other subsystems.

- To define and prioritize near- and longer-term problems in this system and understand their causes.

- To improve the definition of poorly defined problems.

- To identify possible solutions for well defined problems.

- To identify and prioritize further research needs, both biophysical and socioeconomic.

Figure 1. Districts of eastern Uttar Pradesh under the responsibility of NDUAT, Narendranagar (Kumarganj), Faizabad.

Procedures

Participants, who were senior professors and researchers in agronomy, pathology, soils, production economics, entomology, agricultural engineering, and breeding (Appendix I), were divided into four subgroups each day for field surveys and farmer interviews. Two groups started from the University campus at Kumarganj and surveyed the areas on both sides of the roads from Kumarganj to Faizabad, and from Kumarganj to Kurebhar and north to the Masodha Station (Figure 2). The other two groups left from Masodha and surveyed the areas from Faizabad to Kurebhar and from Faizabad to Akbarpur. Morning interviews with farmers were followed by structured discussions back at the Masodha Farm following lunch.

As in past surveys, semi-structured guidelines rather than formal questionnaires were used to guide the discussions with farmers and other respondents. Using a sequential approach, these guidelines were redefined daily, in accord with the consensus of the whole group and after analysis of newly obtained information and identification of remaining data gaps. A running account of findings was maintained in order to ready a draft report immediately after each fieldwork period. Methods are further described in Tripp and Woolley (1989) and Fujisaka (1991). Respondents included small- and medium-scale farmers from the medium and lower-lying areas of the above described area.

General topics included:

- Farmer classification of land types, soil types, and water regimes, and how these classifications are used by farmers when deciding which crops and cultivars to grow and where to grow them.

- Reliability of irrigation and interactions with variability in annual rainfall.

- Farm size and links to mechanization and crop management decisions.

- Farmers' rice and wheat production practices and interactions between them.

- Farmers' organic matter (OM) management, including use of crop residues and farm yard manure (FYM) and the interaction with farmers' fuel needs.

- Seasonal labor scarcity and its effects on rice and wheat production problems.

- The role of sugarcane (*Saccharum officinarum*) in the system and interactions with rice and wheat.

- Mixed cropping of mustard with wheat.

- Problems of crop production as perceived by farmers.

- Longer-term sustainability problems.

Wheat and R-W system problems were identified, prioritized, and then discussed in terms of interacting components of problem complexes. Where possible, these were diagrammed for easier assimilation. Research to address the priority problems was identified and further prioritized. A collaborative work plan was suggested.

During the rice survey in September 1991, a severe drought was in progress. As can be seen in the section on Exploratory Survey Findings, considerable effort was made to ascertain the effects of this drought on crop management and system problems.

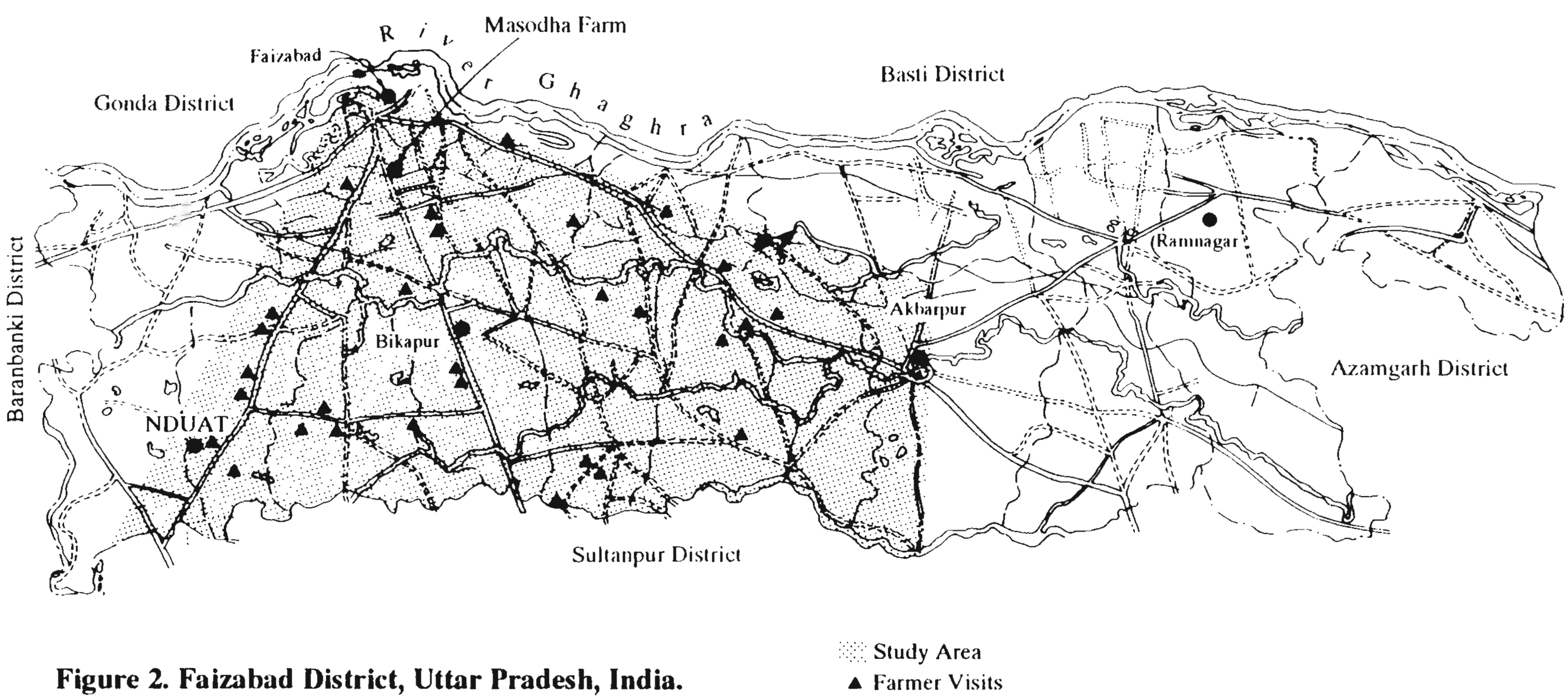

Figure 2. Faizabad District, Uttar Pradesh, India.

DESCRIPTION OF THE STUDY AREA

Location

NDUAT at Kumarganj in Faizabad District is situated at 26° 32'N latitude and 82° E longitude, 42 km southwest of Faizabad town (Figure 2). Kumarganj and Faizabad represent the north-south boundaries of the study area. The study area's western boundary is the western border of Faizabad District and a north-south line going through Akbarpur roughly represents the eastern boundary.

Climate

The climate of the area is subtropical and semi-arid with an average annual rainfall of around 1200 mm (Chauhan and Singh 1990). There is some variation in rainfall in the study area from north to south, i.e., Masodha Agricultural Farm near Faizabad averages 1208 mm/year and Kumarganj averages 1056 mm (Appendix IIA,B). Nearly 90% of the total rainfall is received from the southeast monsoon during the months of July to September (Figure 3).

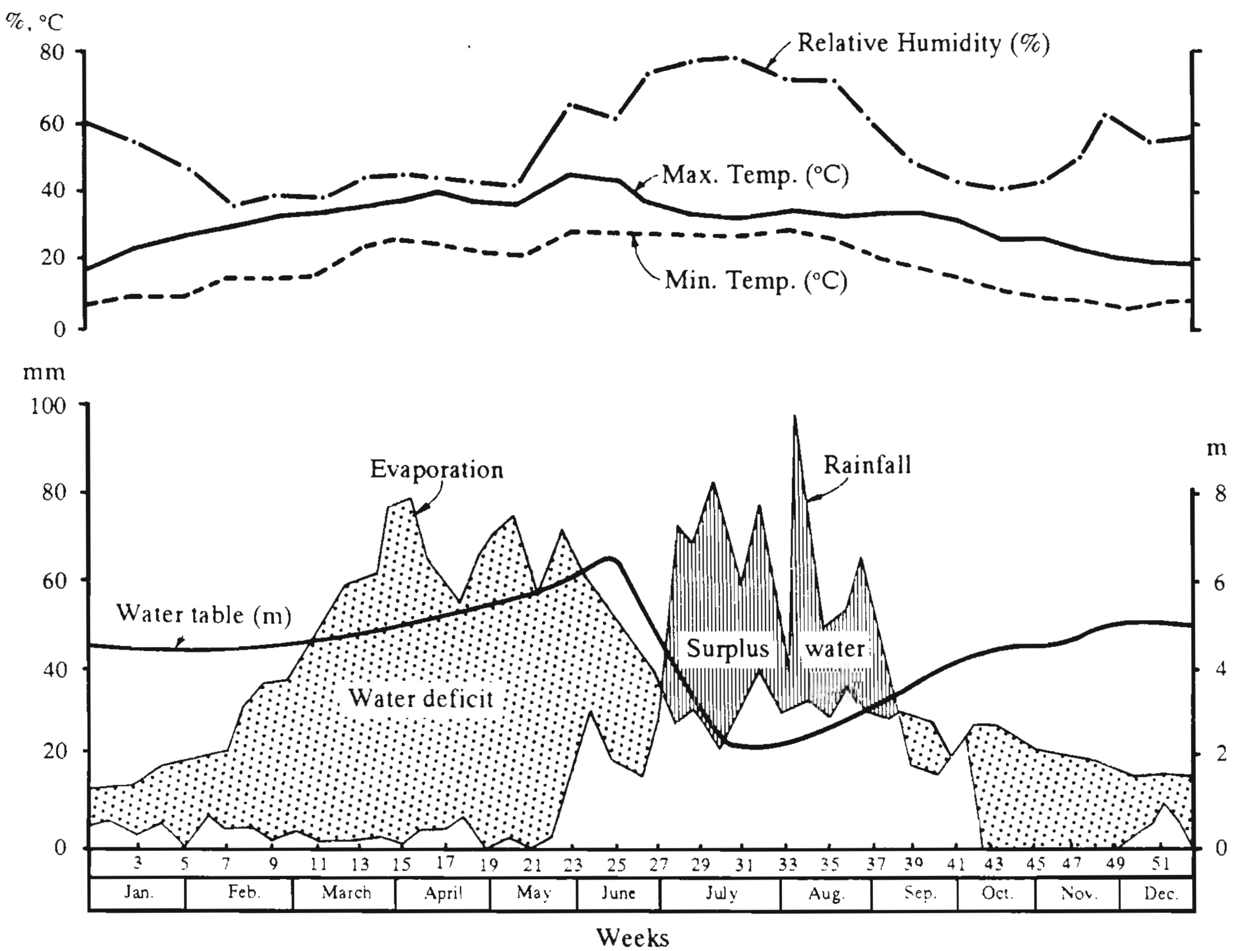

Figure 3. Weekly mean temperature (°C), relative humidity (%), and hydrology (mm) at Kumarganj, Faizabad (Mean of 5 years).

The maximum and minimum temperatures at Kumarganj range from 18.7-38.2°C and 7.8-27.5°C, respectively (Figure 3 and Appendix IIB). The temperatures begin to rise from February onwards until the summer maximums, often exceeding 40°C, are reached in the months of May and June. During these extremely hot months, desiccating winds blow from west to east and dust storms are frequently observed. With the onset of the southeast monsoon, temperatures tend to fall until monthly minimums are reached during December and January.

Potential Evapotranspiration (PET) rises steeply with the rise in temperature and leads to a decline in relative humidity from February to June. Relative humidity rises during the monsoon period, which leads to low evaporative demand. Low temperatures during the winter also result in low PET. Figure 3 shows an annual water balance graph for Kumarganj, which depicts the total evaporative demand for this area as approximately 2900 mm compared to the total annual precipitation of about 1200 mm resulting in a net annual deficit of 1700 mm. Only in July and August is there no absolute moisture deficit for soil profile recharge.

Soils

The soils of the survey area have developed from the deep alluvium deposited by the Ghaghra and Gomti Rivers and their tributaries. The alluvial material owes its origin to the soft dolomitic rocks of the Himalayas. The soils are Inceptisols (aquepts) and Alfisols (aqualfs and udalfs) with considerable variation depending upon the toposequence. They are basic in character and developed from mild or strongly calcareous parent material. The area has a slope gradient of about 1% from northwest to southeast.

Based on toposequence, the area has three distinct land types—uplands, medium lands, and lowlands. Not all the villages surveyed had all three situations. However, farmers still refer to higher and lower situations in relative terms and have local terminology for identification of their different land types.

Uplands

Soils of this land type occupy about 15% of the total area surveyed. These are well drained, light textured soils (sandy loam) where R-W is not common, but can be grown if irrigation is available. In local parlance, they are termed as *Bhitki, Dodh, Bhur, Dand, Dihawa, Dom, Som, Goper, Unchas, Dandwa*, and *Uparhar*. The soils are alkaline (pH 8.5) and have very low organic carbon content (<0.4%). They are very low in available N (<150 kg/ha) and P_2O_5 (<15 kg/ha) and high in K_20 (>350 kg/ha). They are highly responsive to fertilizer and irrigation management. In no part of the year does the water table depth rise to within 4 m from the surface.

Medium lands

These occupy the largest proportion (>75%) of the cultivated land in the surveyed area and, hence, it is the major land type representative of the district in terms of area and importance for the R-W system. Different textural classes are met within this land type—the major being loam, silty loam, sandy loam, silty clay loam, and clay loam depending upon location, topography, and hydrology. The local textural equivalents are *Baluwar, Domat,* and *Matiyar* for sandy loams, loams, and clay loams to clays, respectively.

Local farmer names for the soils in the medium lands are:

- *Khet*, a cultivated field and uniform, level land.

- *Uparhar / Dhand*, well drained soils between upland and medium land.
- *Chauras / Samtal*, well leveled land.
- *Dhanao*, most suited to rice.
- *Hemwar*, well leveled fertile soils.

These soils are neutral to alkaline in reaction (pH>7.0-8.5) and have a comparatively higher content of organic carbon (<0.7%) than uplands. The soils test low in available N (<130 kg/ha) and P_2O_5 (<20 kg/ha) and high in K_20 (>350 kg/h) and respond well to fertilizer application (Appendix III). Response to zinc application is commonly observed, particularly in the case of rice. The soils are fairly permeable and have 0.5-2.0% $CaCO_3$. The water table fluctuates from between 1 and 7 m from the surface during the course of the year. Temporary flooding generally occurs in depressed pockets for a few days following heavy rains. The soils are heavier in lower toposequences, due to washing and deposition of finer material transported from nearby uplands. The physicochemical properties of medium land soil at three locations in the District are shown in Appendix III.

Lowlands

Lowlands occupy nearly 8% of the total area surveyed, particularly in the villages along the Faizabad-Kumarganj, Kumarganj-Kurebhar, and Faizabad-Akbarpur (Gosaiganj area) roads. These soils are black and have a high content of organic carbon (>0.75%). They are heavy in texture and are locally called *Matiyar*. The use of this land for growing rice depends upon rainfall and depth and rate of flooding on them.

The management of rice and wheat in this land type is different from that in the medium lands because of the heavier soil type and the slower drainage. The rice crop can be lost entirely in some years due to flooding and because farmers do not grow rice varieties adapted to these situations. The lowlands can be planted to wheat and pulses, like lentil, gram, and lathyrus, when moisture recedes making the soil suitable to start land preparation in November and December.

Local farmer names for the soils in the lowlands are:

- *Khal / Khala / Khalar*, higher lowlands where cropping is possible although they are susceptible to submergence.
- *Jhil / Tal / Jhilkat / Jhilar*, soils with permanent water stagnation and where cropping is not possible.
- *Soti / Nala*, soils along the seasonal natural drains that have light texture (sandy or sandy loam) and are not generally cropped.
- *Jarahania*, lowlands most suited to wild and traditional species of rice.

Water stagnation is due to poor drainage. Drainage has been affected by blockage of natural drainage systems through development and expansion of roads and infrastructure, seepage in canal command areas, shallow water tables, and natural depressions of the topography. So far, less attention has been given to improve the productivity of this land type in the area. These soils have potential for both rice and wheat if suitable technology and varieties can be developed. This may require land shaping to various degrees.

Recommendation Domains

The study area can conveniently be divided into two land types for technological recommendations for R-W:

- Medium lands with better drained, loamy soils.
- Medium to lower lands with heavier, clay-loam to clay soil and susceptible to occasional flooding.

Another key factor for dividing the area into recommendation domains is the access to irrigation water—near canals or where tubewell water is not a constraint and land where water availability is a constraint.

Within each land type, a further division might be made on farm size for some recommendations:

- Small-scale farmers with few resources (<1 ha).
- Medium size farmers with more abundant resources (1-4 ha).

More work is needed on the relative importance of land type, irrigation, farm size, and caste or domain identification.

Statistical Trends over the Past 10 Years in Faizabad District

Appendix IV (Tables 1-7) summarizes the trends in various factors in Faizabad District over the past 10 years. The national census is presently being tabulated and analyzed for the 1981-91 period. The population growth from 1971 to 1981 was 2.36%/year and rose from 1.93 to 2.38 million. Assuming a similar growth rate in the 1980s, the present population in the selected District is close to 2.95 million.

The net cultivated area has dropped from 307,000 ha to 293,000 ha in the 10 years from 1977-78 to 1987-88 with a present 0.1 ha of cultivated land per person. The net irrigated area increased from 180,000 ha (59% of net cultivated area) to 206,000 ha (71%) in the same period. Irrigation is by tubewell (74%) and canal (24%).

Percentage of cropped area to rice and wheat increased during the 1978-88 period by 2.4 and 12.5%, respectively, while that for sugarcane dropped by 1.3% (Appendix IV, Table 4). Over the same 10-year period, yields of rice, wheat, and sugarcane increased by 80, 28, and 44%, respectively (Appendix IV, Table 5). This was partly associated with 57, 213, and 29% increases in N, P, K applications, respectively. Total nutrient use increased from 53 to 92 kg nutrients/ha (Appendix IV, Table 6).

Mechanization showed a marked increase from 1977 to 1987. Thresher numbers increased from 6306 to 27,425 (a 335% increase). Similar increases occurred for sprayers, seed drills, and tractors (Appendix IV, Table 7). Numbers of tractors per 1000 ha increased from 3 to 17.

EXPLORATORY SURVEY FINDINGS

Major Crops

Rice and wheat are the major crops grown on the medium lands. Although, as indicated earlier, the area under sugarcane had dropped somewhat during the 1978-88 period, since 1988, the area under sugarcane has begun to grow, especially for the medium- and larger-scale farmers. Various vegetables, potatoes, peas, and oilseeds are replacing some wheat in the *rabi* (winter) season on lighter-textured soils. Mustard (*Brassica alba*) is another important *rabi* crop, but it is mostly grown mixed with wheat rather than as a pure crop. Farmers indicated this is because the mixed combination is less risky than a pure crop of mustard. Some farmers grow berseem (*Trifolium alexandrinum*) and gram for fodder and domestic use. A few farmers grow short-duration summer pulses after wheat and before rice. Where early maturing rice varieties are grown, lahi (*Brassica campestris*) and potato (*Solanum tuberosum*) are grown followed by very late-sown wheat. In the *kharif* (monsoon) season, rice and sugarcane are the major crops, but fodder crops (Sorghum—*Sorghum bicolar* (L.) Moench), pulses (pigeon pea—*Cajanus cajan* (L.) Millsp.), and fiber crops (sunn hemp—*Crotalaria juncea* L.) are also found on better drained land. Two thirds of the medium lands are irrigated, but many crops only receive supplemental irrigation.

On the lowlands, rice is the major *kharif* crop and can be followed by wheat if the water level recedes in time. Some pulses like lentil, gram, and lathyrus may be grown instead of wheat. In deep water areas, no *kharif* crop is grown and wheat is planted after the water recedes. In some of the low lying river bed areas, sugarcane is one of the common crops. Farmers have specific varieties that tolerate flooding for this situation.

Under rainfed conditions, pigeon pea mixed with sorghum or pulses is the common pattern in the uplands. In some areas, maize is an important crop on the uplands. Where irrigation is available, the crops grown on the uplands are similar to those on the medium land, but with more of the wheat replaced by potato, oilseed (lahi), or vegetables.

Cropping Patterns

R-W is the major pattern in the area with continuous R-W common on the medium land, especially for farmers with small land holdings. Sugarcane sometimes breaks the monotony of continuous R-W. A sugarcane crop and up to three ratoons (one ratoon is the most common practice) are harvested before growing R-W again. Some farmers reported a better yield of wheat after sugarcane, but did not specify the cause.

The common rotations followed in this area are:

- Continuous R-W (predominant).
- Rice-wheat-sugarcane-ratoon-wheat or rice.
- Early rice-lahi-wheat-rice.
- Early rice-lahi or potatoes-sugarcane-ratoon-wheat.
- Rice-wheat-summer pulses-rice.

The rotations with sugarcane cover a period of 4 to 5 years, depending on the number of ratoons. The others are 1-year rotations.

Irrigation from low-lift diesel pump sets influences cropping patterns in the medium and uplands. More cash crops like vegetables, potato, and sugarcane could be grown if there was better availability and rational distribution of the available water resources.

R-W is also common on the lowlands but, where flooding occurs, the rice crop can be lost and only wheat harvested. At times, pulses and linseed replace wheat.

Calendar for Major Rotations

- **Rice-wheat**

Rice:	
Nursery sowing:	End-May to 1st week July
Transplanting:	End-June to end-August
Harvesting:	Mid-September to mid-November
Wheat:	
Sowing:	Mid-November to mid-January
Harvesting:	April to early-May

- **Rice-wheat-sugarcane-ratoon-wheat**

Rice and wheat as above.

Sugarcane:	
Planting:	February to April
Harvesting:	End November to April
Ratoon:	1-3 years
Wheat after sugarcane:	
Sowing:	Mid-December to mid-January
Harvesting:	Mid-April to early-May

- **Rice-lahi/potato-sugarcane-ratoon-wheat**

Rice (short duration varieties like Saket-4, Prasad, Pusa-33, Narendra-80 and Narendra-118):

Nursery sowing:	End-May to mid-June
Transplanting:	End-June to mid-July
Harvesting:	Mid-September
Direct seeding:	End-June to early July
Lahi/potato:	
Sowing:	End-September to early-October
Harvesting:	End-December to early-January

Sugarcane, ratoon, and wheat as above.

- **Rice-lahi/potato-wheat-rice**

Rice, lahi and potato as above.

Wheat:	
Sowing:	Early-January
Harvesting:	End-April to early-May

Sugarcane

This crop competes for land with R-W in the medium lands. Farmers with medium and large land holdings are more likely to grow sugarcane. Farmers with small holdings indicated problems with obtaining indents and getting the cane to the collection points or mills as the most common reasons for not growing the crop. Sugarcane markets in this part of UP are less developed compared to those in the western part of the state.

As much as 60% of the land is under sugarcane in some villages close to the sugar mills. However, only from 5 to 10% of the District is grown to sugarcane according to official statistics. The main reasons given for its increase in popularity since 1988 are:

- Good returns because of the present favorable market price and assured cash returns.

- Sugarcane tops provide fodder for animals.

- Labor profiles are more favorable than R-W.

- Sugarcane mills provide good extension, and arrange for supply and services including sets and other inputs.

- Increase in irrigation facilities.

An increase in the number of sugar mills and small crusher units would likely stimulate an expansion in area for this crop. Farmers complain about the time required to get the crop registered at the mill or collection points.

Mixed Cropping

The most common mixed cropping combination, wheat and mustard, is practiced by almost 95% of the farmers in the area. This traditional practice provides the oil needs of the household in the form of a bonus crop.

Most of the farmers sow the mustard by broadcasting it at the time of wheat sowing. Some farmers plant it in rows behind the plow after the main crop of wheat is broadcast-sown. The amount (5-10%) of mustard grown in the mixture is relatively low.

The following reasons were presented for this practice:

- Oil requirements—this helps farmers provide for their home oil needs.

- Risk reduction—if farmers grow a sole crop of mustard and a severe aphid attack occurs because of favorable climatic conditions or late planting, then the whole crop can be lost. In mixed cropping, although aphids attack the mustard, there is still the wheat crop.

- Fodder/vegetable—early in the season, some farmers remove the mustard as a fodder crop for their animals or as a vegetable for home consumption.

Large-scale farmers are more likely to grow pure stands of mustard or wheat as they feel that there are chances of yield reduction in wheat when grown mixed and also because of the damage done to wheat during mustard harvest.

Obviously, this topic needs to be discussed when developing a research agenda for the area.

Farm Yard Manure (FYM) Interactions

The survey found FYM availability to be increasing in some villages but decreasing in others. In villages where FYM is increasing, it is usually associated with increases in numbers of bullocks and milk cows kept by lower caste farmers. Decreases are associated with the higher caste farmers, who are shifting land preparation from animal to tractor power.

FYM is said to be applied preferentially to sugarcane, potatoes, and other higher value cash crops and is commonly used on rice seedbeds. It may also be applied to rice or wheat, depending on availability. Less FYM is being used on crops than in earlier times. Before, fields would receive dung for every crop, but today fields receive dung on a rotational basis varying from 1 to 5 years. Its use is affected by decreasing availability, mainly due to decreasing numbers of cattle and bullocks and to increased fuel use. On average, 67% of the dung is being used as a fuel and 33% is being added to crops. In the 4 months of the monsoon season, dung is collected and composted. During the rest of the year, it is collected, dried, and made into "dung cakes" for cooking purposes. Trees are found around many villages in upland areas, but it is illegal to use live trees for fuel. This law is being enforced and reduces the availability of fuelwood.

Many farmers indicated that livestock numbers, in general, are decreasing due to partial mechanization of land preparation and threshing. At present, 80% or more farmers use bullocks for land preparation and the rest use tractors. Farm families having smaller holdings (<0.5 ha), especially the higher castes, often prefer to hire tractors rather than maintain a pair of bullocks. However, more than 50% of smallholders still have bullocks and, in some cases, try to keep at least one bullock so they can prepare their land by sharing with other one-bullock farmers. Some farmers have also sold off their bullocks because it has become difficult to find laborers willing to tend them. An interesting social problem is developing in the area—low caste laborers who used to herd and tend the animals in the village are now finding alternative job opportunities. Higher caste farmers cannot tend animals because of their social status in the village. Part of the decline in bullock numbers is offset by an upward trend in numbers of dairy animals, especially buffalo.

Availability of suitable caste labor to transport FYM to the fields is also affecting its use. Because of this problem, fields closer to the homestead receive more FYM while those farther away from the house may not receive any. The increase in cropping intensity and the lack of access through planted fields for the bullock carts that carry most of the FYM to the fields are also affecting application distant from the homestead.

Some farmers reported that a combination of FYM and chemical fertilizer is best for crop production and that the use of chemical fertilizers alone may have unfavorable effects on soil fertility over the long term. Several farmers also believed that yields of rice and wheat are going up because of increased inputs (fertilizer). The effects of reduction in FYM applications are being confounded by increased use of purchased inputs.

Fuel sources are mostly dung, but other sources include pigeon pea and fiber crop sticks, sugarcane waste, and fuelwood. New sources might be biogas and kerosene, but at the moment these sources are rare.

Management Practices for Rice

Land preparation and tillage

The majority of the rice is transplanted including all major improved varieties grown on medium lands. Direct seeding was mentioned by farmers and was seen in some fields. In the uplands, at most 10% of the rice is direct-seeded and in the lowlands, mostly in the lower *khala* areas, up to 30% of the area is direct-seeded to local varieties. This proportion varies from village to village. The decision to direct seed or not hinges on several factors:

- Adaptability of the local variety to direct seeding.
- Late rains may not allow enough time for seedbed preparation.
- Light soils in the uplands do not allow puddling.
- Local lowland varieties are adapted to direct seeding.

Timing of seedbed land preparation and sowing varies from the end of May to mid-June, depending on water availability. Land preparation for the transplanted field usually occurs 1 month later (late June through July). However, in 1991, the monsoon rains were late and many fields were prepared 2 to 3 weeks later than normal and, in some villages, up to 50% of the rice fields were not prepared at all. Farmers tend to think of rice as a rainfed crop in the District and are reluctant to use irrigation to help prepare the fields. They assume it will soon rain. Even when irrigation is available, it is often not used to overcome the problem of late rains. As soon as the rains do fall, farmers know it is important to plow as soon as possible. Plowing before the rains start is not common. Dry or preparatory tillage refers to those operations done after the rains begin but prior to flooding the fields and puddling the soils.

Tractors are increasing in use and are commonly used for dry tillage. Several farmers said they prefer tractors for the dry tillage, especially when fields are weedy and have heavier textured soils, because they are faster than animals. Animals are preferred for the puddling operations and tractors are only used for this operation if the owners have cage wheels. Farmers said that bullocks are better for puddling, but that tractors with cage wheels are faster. Plankings are also done mostly with animals.

Tractor owners indicated they do more dry tillage than nonowners. Tillage operations seem to be influenced by machinery ownership as follows:

- Tractor owners—Three or four dry plowings with tractor, flooding, and then one or two wet plowings by tractor if cage wheels are available or bullocks if not. Plankings occur after plowing and are usually done by bullocks.
- Bullock owners, no tractor—Two or three dry plowings with the country plow, flooding, and then two plowings by bullock.
- Hired tractors—Two cultivations with tractor, flooding, and then one plowing by bullock.

The only tractor tillage implement available in the District is the tined cultivator and the "plowings" referred to above are actually cultivations. Some farmers have improved moldboard plows for their bullocks made locally out of old plowshares. Farmers indicated that these give better tillage than the traditional country plow.

In many villages, tractors are available for rental plowing and the average rental rate is Rs (rupees) 350-400/ha (US$13.58-15.52/ha)[1] for two plowings and Rs400 (US$15.52)/ha for wet plowing or puddling. Bullock hiring rates are Rs300 (US$11.64)/ha for both dry and wet plowing. This is equivalent to Rs60 (US$2.32)/pair per day, including labor. Labor was not mentioned as a constraint for land preparation and mechanization does not appear to affect labor markets.

Seeding and transplanting

Direct seeding only covers 30% of the lowlands, 10% of the uplands, and practically none of the medium land. When practiced, direct seeding can be done in dry soil with early maturing local varieties or in puddled soil if sufficient moisture is available. During the 1991 drought year, some farmers dry seeded (usually on the uplands) and others direct-seeded on puddled soils because of the time delay due to the drought. Seed is usually soaked before being broadcast in both dry or puddled soil conditions. Seed rates for direct seeding range from 80 to 100 kg/ha. After dry seeding, the field is plowed, sometimes in both directions, and planked to cover and compact the seed. There tends to be more stand problems in direct-seeded rice and termites, birds and weeds are more of a problem as well.

Seedbed sowing of medium-maturity varieties is usually earlier than for early maturing varieties. In transplanted rice, seedbed seed rates are around 40-60 kg/ha. Normally, 80% of the rice is transplanted in July. In 1991, however, transplanting was delayed on many fields because of the late monsoon, even up to the end of August.

Farmers with assured irrigation transplant earlier; with canal irrigation a little later, depending on the release of canal water. Those depending on rainfall typically plant last, especially if the rains are late.

Smallholders mostly use family labor for transplanting, but many largeholders use contract or daily wage labor for this operation. In contract transplanting, plant stands tend to be poorer because the laborers are paid on an area basis and tend to use wider spacing to speed up the operation. For this reason, contract arrangements are less common. There appears to be no gender differential in wages for transplanting. Wages range from Rs8-15 (US$0.31-0.58)/day with somewhere between 80-120 person-days (reported by farmers) required to transplant 1 ha. The contract system rates are Rs1000-1200 (US$38.81-46.57)/ha with 50-60 person-days to transplant 1 ha. This results in an implicit wage of around Rs20 (US$0.77)/day in the contract system.

Labor is scarce at the time of rice transplanting. Some villages reported that, in a normal year, labor scarcity delays transplanting and reduces yields. In 1991, drought was an overriding factor in determining the transplanting date and compounded the labor problem even more since, when the rains finally came, everyone wanted to transplant at the same time. In the 1991 survey, scarcity of labor was found to delay rice transplanting by 15-20 days on 25-30% of the surveyed area (even more in some areas). Some lands were not transplanted at all in 1991 because of the drought and labor scarcity. Delayed transplanting was common in some villages and farms, even though irrigation was available. The high cost of diesel fuel, the unreliability of the electricity supply for tubewells, and uncertainties regarding the timing of water release from canals restricted the use of irrigation. Moreover, many farmers prefer to wait to see if rains will fall, rather than invest money in irrigation that may prove unnecessary and they do not want to start paying for irrigation that they would then have to continue until the onset of rains.

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[1] Rupee to US$ Market Exchange Rate on Sept. 30, 1991 = 25.763.

Farmers usually transplant rice seedlings that are from 20 to 30 days old. In 1991, seedling age was older by 2 to 3 weeks, resulting in less tillering and reduced yields.

Varieties
Farmers like early varieties on the uplands (local, 90-day maturity) so that they can grow a crop of *lahi* (Brassica) between rice and wheat. In the uplands, rice varieties include:

- Improved: ND118, Saket-4, and Prasad.

- Local: Kalkatia; Bagari, safed (white) and kali (black); Dehula; and Mutmuri; a variety called "90-days"; and Basahwa (a 110-day variety for special purposes).

The local varieties can be direct-seeded.

Varieties for medium land types include:

- Improved: Sarju-52, Indrasan, Pant Dhan-4, Saket-4, Sita, IR36, Jaya, Mahsuri, Narendra-80, Kasturi, Pusa-2-21, and China-4.

- Local quality rice: Bilaspuri.

Most of these varieties except Saket-4 are medium in duration and harvested in mid- to late October. The varieties seen predominantly in the field are Sarju-52, Pant Dhan 4, Mahsuri, Indrasan, and Narendra-80.

Lowland varieties include:

- Improved: Mahsuri, China-4, Sarju-52, and Pant Dhan-4.

- Local: Jarhan, Dularva, Lalmati, Kanakjeer, and Bilaspuri.

Mahsuri is the most important lowland variety, but where deeper flooding occurs, local varieties are used. Some of the local varieties are also preferred for their aromatic quality.

Farmers do not appear to match varieties for the R-W pattern and use mostly the medium-duration varieties. They reported using short-duration rice varieties when growing rice-potato or lahi-wheat patterns.

Fertilizer use
Fertilizer rates reported by farmers in the survey are definitely high and reflect a maximum dose used by farmers rather than average doses. A more quantitative survey is needed to get a better picture on this issue. Fertilizer use is related to water availability with farmers having assured irrigation using higher rates than those with water constraints.

Fertilizer use reported by farmers in middle land types is surprisingly high and well above recommendations. Rates of fertilizer for the main field were commonly reported as: 100-150 kg urea/ha basal (applied within 1 week of transplanting to avoid injury to laborers' feet as happens when fertilizer is applied before transplanting) plus 100-200 kg urea/ha as a topdress; 50-250 kg SSP as basal; rarely any potash use; 10-20 kg zinc sulfate according to need (10-20% of the farmers). If available, some farmers apply from 1 to 25 t FYM/ha. In addition, 1 to 50 t FYM, 80-250 kg urea, and a little SSP are applied per hectare to the rice nurseries.

It is not clear whether fertilizer application varies according to farm size, caste, or other factors. Definitely less fertilizer is used where irrigation is not reliable or not used. Farmers of all types gave fertilizer rates indicated above, although some resource-poor farmers indicated they use lower rates. Fertilizer prices increased in 1991 because of the reduction of the government subsidy. Urea increased from Rs115 to 165 (US$4.46-6.40)/50 kg; SSP increased from Rs48 to 55 (US$1.86-2.13)/kg, and zinc was Rs16 (US$0.62)/kg. Some farmers reported a 25-30% reduction in fertilizer use because of price increases.

Some farmers reported that when they applied zinc to affected fields there was no response. When they then applied sodium chloride they did get a response. This may indicate that potassium may be a limiting nutrient in some areas and this issue should be further explored.

As already mentioned above, some farmers do not apply their fertilizer before transplanting because transplanting laborers complain about injury to their feet. Some laborers will even refuse to transplant fields where basal doses are used. As a result, farmers mostly reported that both N and P are applied after transplanting.

Most farmers considered yields higher now than 5 or 10 years ago because of higher fertilizer use and better varieties. Reduction in FYM applications is being masked by increased use of other inputs. However, some farmers reported that a combination of FYM and chemical fertilizer is best. They reported that the use of chemical fertilizers alone had unfavorable effects on soil fertility over the long term. Some other farmers also reported that fertilizer rates have to increase by 5-10% per year just to maintain rice yields.

Farmers reported that *Khaira*, the local term for a brown leaf discoloration, is a common, widespread problem that, if not controlled, can cause severe rice losses every year. Most probably attributable to inadequate availability of zinc, the discoloration is observed in nurseries and main fields and in direct-seeded fields as well. Farmers are not always able to distinguish zinc deficiency symptoms from other leaf firing and leaf diseases and they use the term *Khaira* for all these rice leaf symptoms. Fortunately, farmers are aware of zinc deficiency and treat their fields with zinc sulfate as they see the problem develop. Some varieties like Saket-4 are more susceptible to zinc deficiency than others.

Fertilizer rates for direct-seeded rice is lower than for transplanted rice. From 80 to 150 kg urea/ha and 100-200 kg SSP/ha were commonly reported.

Irrigation

Statistics for the District show that 65% of the area has irrigation facilities. Irrigation is largely from diesel tubewells and shallow bores using mobile pumpsets. Canal irrigation and public and private electric tubewells are also available. The potential for more tubewells is high, but farmers are constrained by availability of loans and resources to invest in this technology. Electric tubewells are preferred because of the lower cost per unit of water, but electricity supply is unreliable, which restricts their use. Diesel is expensive and often scarce. Diesel tubewell operation costs about Rs360-440 (US$13.97-17.07)/ha per irrigation; electric tubewell costs only Rs150 (US$5.82)/ha.

The survey area can be most accurately described as a rainfed rice area with some supplemental irrigation. Depending on the village, rice area irrigated can vary from none to 50-90% of the total. Supplemental irrigation is more common than full irrigation. Irrigation was used more in 1991 because of the late rains, although many farmers with irrigation still waited for the rains. Some villages visited do have assured irrigation and these definitely can be defined as irrigated rice villages. Many of these villages also were at the head end of irrigation canals, but even so they often supplemented their canal water with tubewell water.

Some reported and observed drainage problems are associated with obstruction of natural drains and seepage from canals. Usually, two thirds of the lowland is not planted because of excessive water. Because of the 1991 drought, up to 50% of the area may have been cropped.

Diseases

No farmers reported using any measures to control diseases on rice. However, the following diseases in the rice crop were either observed by or reported to survey participants.[2]

- Sheath blight (*Rhizoctonia solani*)—This fungal disease was observed under both irrigated and nonirrigated situations, being more severe in the latter. Blighting of sheaths is the first symptom, but infection can spread to the panicles. The disease is widespread and occurs every year. It causes severe damage under nonirrigated conditions and under irrigated conditions where high nitrogen doses are used and if lodging occurs.

- Bacterial leaf blight (*Xanthomonas campestris*)—This disease is reported to be a problem in the area, but the survey was too early for observation in the field. Farmers reported losses of from 1 to 45%, especially when high doses of nitrogen are used and crop growth is luxuriant. It is more important under irrigated conditions. Its incidence and severity vary with varieties.

- Brown spot (*Helminthosporium oryzeae*)—This disease was commonly observed on the variety Bagari in direct-seeded fields. Losses of from 1 to 25% have been recorded. Though the disease is widespread, yield losses are mostly found under late planted conditions. Very poor or high application of fertilizers increases incidence of the disease.

- Sheath rot (*Sarocladium oryzeae*)—This fungal disease can cause losses from 1 to 10% and is aggravated by drought, heavy rains, or attack of sucking insect pests. Infection occurs on the upper leaf sheath at late booting with poor panicle exertion occurring in severe infections. Saket-4 and Jaya are particularly susceptible.

- False smut (*Ustilaginoidea virens*)—This disease occurs more often when rice is given heavy nitrogen fertilizer doses. Usually, a few spikelets in the panicle are affected transforming the seed into a mass of yellow orange spores. Kalkatia and Pant Dhan 4 are susceptible.

- Bacterial leaf streak (*Xanthomonas campestris*)—Symptoms of this disease are on leaf blades where streaks are formed and bear an amber colored bacterial ooze. The bacteria enter the leaves through mechanical injuries or natural cell openings.

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[2] Much of the data presented here is from secondary data provided by the pathologists on the survey team.

Pests

Farmers reported the following insect pests in rice, although as with most of the diseases it was too early to observe damage in the field:

- Armyworm (*Mythimna separata*)—These pests can appear in large numbers at the end of the season and reduce yields by defoliating the crop. It is a major problem later in the season, especially in the lowlands.

- Rice bug (*Leptocorisa oratorius*)—This insect feeds on the rice grains during the milk stages, reducing grain set and grain quality.

Although farmers did not mention stemborer as a problem, it was observed in the fields during the survey.

Farmers reported using Folidol (methyl parathion), BHC dust, and malathion for insect control. They are typically used after the damage occurs and with no protective safety measures.

Most farmers reported rats to be problems in the field and in storage. Some use zinc phosphide baits for control, but this is not always effective and there are no communal rat control programs.

Weeds

Weeding for transplanted rice usually occurs in August to mid-September. Farmers do not consider labor scarcity to be a problem for weeding. Smallholders use their own labor and largeholders use hired labor costing Rs6-10 (US$0.23-0.39)/day plus food. There is no gender differential in weeding labor costs even though women do a substantial part of this task. Unfortunately, since many weeds are fed to animals, they are often removed after damage has already been done to the rice crop.

Most farmers in the middle land types do not use herbicides. Only a couple of largeholders were found using *Butachlor* 2 to 3 days after transplanting.

Weeding is usually started 15-20 days after transplanting and 20-30 days after direct seeding. There are more weeds in direct-seeded fields where control methods include *"Bushening"* or *"Bideni"*, which involves bullock-plowing and planking up to 30 days after seeding, depending on rains, and hand weeding 10-15 days later.

Weeds observed in the middle land types include a wide array of grasses, sedges, and broadleaf weeds. They are listed in the following by scientific name with local name when applicable in parentheses:

- Grasses—*Echinochloa colonum* (Sanwai), *Echinochloa crus-gali* (Daura), *Dactyloctenium aegyptium* (Makra), *Setaria glauca* (Jhunsa), *Cynodon dactylon* (Dubegrass), and *Eleusine indica* (Kodo).

- Sedges—*Cyperus rotundus* (Motha), *Cyperus iria* (Motha), *Cyperus haspan* (Motha), *Fimbristylis littoralis / dichotoma*, and *Scirpus erectus*.

- Broadleaves—*Eclipta alba* (Bhangra), *Ageratum conyzoides, Monochoria* spp., *Ammannia baccifera, Euphorbia hirta* (Dudhi), *Phyllanthus niruri* (Hazardana), and *Convolvulus arvensis* (Hirankhuri).

Harvesting and threshing

Rice harvest takes place from mid-September to mid-November. The early direct-seeded, local rice varieties are harvested first in September. This provides farm families with food during a time of scarcity. The medium-duration, improved varieties are harvested from mid-October on, depending on the transplanting date. In 1991, the harvest in many of these fields was delayed because of delayed transplanting. Mahsuri and the local photo-sensitive varieties grown in the medium and lowlands are harvested last, but usually not later than mid-November. Some largeholders stack their rice and delay threshing until after wheat tillage and planting are completed. The effect of this practice on yield losses needs to be assessed.

A labor scarcity peak occurs at rice harvest and is reported to delay harvesting by around 15 days on about 25% of the area surveyed. This delay is independent of transplanting delays. Thus, late rice harvest is a factor for delayed wheat planting.

Labor for harvesting and threshing commonly follows a sharing or contract system except for lower castes and smallholders, who use family labor. Typically, those who conduct harvesting and threshing receive 1/8 to 1/10 of the harvest. This includes hauling, cleaning, and bagging. Harvesting and threshing are paid at 1/16 of the harvest with additional grain in kind given for hauling from the field to the threshing floor and after cleaning and bagging from there to the house. The proportion of grain given in kind depends on the labor scarcity in a given season.

Mechanical threshers are rarely used for several reasons including:

- Farmers want the rice straw for their cattle.
- There is no suitable thresher for rice and wheat threshers are unsuitable.
- The contract system in the District includes the cost of threshing.

Yields

Farmers reported rice yields to be around 4-5 t/ha when irrigation is available and used with good management of inputs. Medium-duration rice varieties yield more than the early, improved varieties and much more than the local direct-seeded varieties. Yields in 1991 will be lower than normal where delayed planting of older seedlings occurred because of the drought. Also because of the drought, the area planted to rice in 1991 was 20-25% below average.

Official recommendations

See Appendix VA for the official recommendations of the State Government for growing rice.

Management Practices for Wheat

Land preparation for medium lands

Farmers reported doing the first plowing just after the rice crop is harvested and removed. The number of plowings for this first operation varies by soil type and whether tractors or bullocks are used for this operation. With tractors, one cross plowing is usually done; with bullocks, two to four plowings are done. Some farmers then leave the field open for 7 to 15 days and some irrigate if moisture is not sufficient. (If moisture is sufficient or rains occur, this irrigation is not done.) After irrigation, when soil moisture is correct, two to four more plowings are done.

The seed is then sown, typically by broadcasting, although a few respondents said they plant in lines behind the plow. After broadcasting, the field is plowed once or twice cross-wise and then planked.

Planking, done mainly with bullock power, is used after the plowing that follows seeding to:

- Help cover the seed.
- Level the land to facilitate irrigation.
- Cover the seed to avoid bird damage.
- Conserve moisture.
- Improve germination.

Tractors are mainly used for preparatory tillage. Most farmers do subsequent plowings with bullocks. Power, in the form of tractors or bullocks, is not a serious constraint for land preparation. Tractor availability is on the increase and is substituting for declining bullock numbers. Some smaller farmers prefer to keep a pair of bullocks rather than look for a tractor during peak periods of farm operations, while others find it more convenient to hire a tractor than to look after a pair of bullocks, provide feed, and pay a person to tend them. At the time of the survey, tractor hire rates were Rs150-180 (US$5.82-6.98)/ha. (It takes about 3 hours to plow 1 ha.) The only implement used is the cultivator; there are no other implements for deeper tillage. Despite ready availability of draught power, turnaround time from rice to wheat is in the range of 20-45 days, depending on moisture conditions and soil types.

Land preparation for lowlands
Usually, lowlands have excess moisture and/or standing water that must drain away before land preparation can begin. In these situations, two to three plowings are given when moisture levels are favorable followed by seeding, plowing, and planking. No irrigation is necessary before seeding. Turnaround time depends on soil moisture status and the rate at which excess moisture recedes to allow tillage.

Tractors are the preferred means of power for land preparation. Time is more of a factor in these areas and tractors can prepare these heavier soils much faster than can animals. Tractor tillage reduces turnaround time by 10 days compared to bullocks.

Seeding rates and varieties
Varieties used include UP262, HUW 234, HD2285, UP2003, Shekhar (K7410), and RR21. K68, an old quality variety with a premium price, is grown by a few farmers. In some villages, UP262 predominates while, in others, RR21 and others are more common. Farmers have no obvious selection criteria and appear to use whatever seed they have available. Varieties recommended for late planting are planted early and vice versa. Most use varieties that have the highest yield potential, regardless of maturity or planting date.

Seed rates vary from 130-160 kg/ha with more seed being used when planting is late. Some farmers use 70 kg/ha seed when they plant in lines and use newly bought seed. The general feeling is that the seed should be replaced at least once every 3-4 years because of declining productivity when seed is kept for longer periods. However, many farmers continue to use their own seed beyond this period due to cash shortage or low availability of new seed.

Seeding date
Seeding date was observed to be variable in the study area. Dates given by farmers ranged from November through January. Researchers consider November to be timely. Early planting was associated mainly with soils of lighter texture and late planting with lower lying, heavier textured soils. The main reasons given by farmers for late wheat planting are:

- Labor constraints that delay rice harvest.
- Planting of lahi, potatoes, and other crops after rice harvest, but before wheat.
- Late harvest of sugarcane.
- Lack of irrigation water.
- Late drainage of water from the lowlands.

Farmers do not see a perceptible yield decline up to a 15 December planting. In some villages, the first week of December is, in fact, the preferred planting date. Farmers do perceive a yield loss (10-15%) after mid-December and a drastic yield loss (50%) in January plantings. Lowlands have later plantings than medium lands. From 10-30% of the lowland is late planted (after 25 December).

Farmers compensate for late planting by using more seed, fertilizer, and irrigation.

Fertilizer use
Virtually all farmers use chemical fertilizers, especially nitrogen. Most farmers also use phosphate, but few reported using potash. Fertilizer rates and combinations are variable, but two primary mixes can be discerned. DAP (diammonium phosphate) mixed with urea is frequently applied basally, with a subsequent urea topdressing. The second mixture—single super phosphate with urea, followed by a urea topdressing—is also common. When potash is used MOP (muriate of potash) is typically the source.

Basal fertilizer rates, equivalent nutrient application rates, and rates of nutrients applied by topdressing are shown in Table 1. These estimates should be used with care as they are most likely somewhat high. Note that fertilizer offtake in the District for wheat is only 76-18-2 NPK, well below the fertilizer application rates indicated in Table 1.

Potash use is not common. In one area farmers complained of poor grain filling, which might be due to potash deficiency. A few farmers reported plumper grains when potash was used. This issue warrants further study.

Urea is typically topdressed at the first irrigation, rarely at the second, and occasionally at the third.

A few farmers reported using zinc on wheat and in one village pyrites (iron sulfide) is used. Many farmers pointed out that a major constraint to zinc use is the poor availability of unadulterated supplies of nutrient. In addition, the price of zinc sulfate has been high in recent years.

Manure use varies. Some farmers said they give rice preference to wheat while other indicated the reverse. All agreed that sugarcane and potatoes receive preference over wheat. Manure availability seems to be declining and this may be affecting yields.

Table 1. Fertilizer management practices for wheat.

Practice	Mixture 1	(kg/ha)	Mixture 2
Basal fertilizer rates (range):			
DAP (Diammonium phosphate)	75-150		0
Single super phosphate	0		120-250
Urea	50-200		50-200
Muriate of potash	20-100		20-100
Basal nutrient rates (average):			
Nitrogen	64		69
Phosphate	48		24
Potash	0		0
Topdress nutrient rates (average):			
Urea	100		100
Nitrogen	46		46
Total nutrient rates (average):			
Nitrogen	110		115
Phosphate	48		24

Inorganic fertilizers may not entirely compensate for reduced manure application—indeed, it seems likely that a combination of FYM and inorganic fertilizers may be best. When FYM is used, farmers reported rates that varied from 1 to 10 t/ha.

Irrigation

In some areas visited, wheat is not irrigated—mainly in the lowlands where wheat production is dependent on residual moisture. In the medium lands, wheat is usually irrigated. From one to four irrigations are given, not counting the pre-sowing irrigation. Many farmers give a pre-sowing irrigation to provide good moisture for seed germination. The average number of irrigations is two (three with pre-sowing) with the first given at 20-25 days and the second at 50-55 days or close to heading.

Sources of irrigation water include canals, tubewells, low lift pumps, and other surface water sources like tanks. Canal irrigation is dependent on release of water at pre-arranged timings and is used for both rice and wheat cultivation. Tubewells and pumps may be either electric or diesel powered and have significantly increased in numbers over the past few years. The use of diesel pump sets in shallow bores with the pumps moved from bore to bore is rapidly increasing. The availability of low lift pumps is helping farmers become more flexible in their cropping and substituting potatoes, sugarcane, and vegetables as cash crops for wheat. Power supply for pumps is a constraint due to a total lack of electricity (or its erratic supply) and the high cost of diesel fuel.

Diseases

The following diseases were observed during the survey or were reported by researchers:

- Foliar blight caused by *Helminthosporium* and *Alternaria* sp.—Farmers are not able to distinguish the cause of this disease and tend to include it in a group of foliar problems that result in yellowing and leaf firing. There is an increasing trend toward infection on most commonly grown varieties in the area like RR-21, UP-2003, and UP-262. During the survey, the crop was too mature to observe foliar blight.

- Karnal bunt (*Tilletia indica* syn. *Neovossia indica*)—This is reported to be a serious problem in some pockets of the survey area in the Faizabad and Gosaiganj areas. Varieties found to be infected with Karnal bunt were mainly UP-262, UP2003, and Shekhar (K7410) with a high percentage and RR-21 with much less.

- Loose smut (*Ustiligo tritici*)—Farmers reported incidence of loose smut to be increasing, but it was not found during the survey at more than 3% infection, even in the susceptible variety RR-21.

- Leaf rust (*Puccinia recondita*)—This can be a problem in late-sown wheat, especially on varieties RR-21 and HD-1553.

- Ear cockle (*Anguina tritici*)—In some pockets, farmers reported an increasing trend of this nematode gall in wheat grains.

- Yellowing of wheat—This is known to be a major problem in the area, but farmers are not aware of its cause and bulk it together with general leaf firing and yellowing. Possible causes are deficiency of nitrogen, sulfur, or zinc; alkalinity or even a genetic expression of the variety. It is also commonly observed following the first irrigation. This problem needs further assessment in terms of yield loss, and work to identify the cause or causes.

Pests
The following pests were observed during the survey:

- Rats—A common problem in some of the areas surveyed, some farmers reported up to 30% damage by rats. Zinc phosphide is used for control, but without much success because the effort is not coordinated. There is a need for a community approach for effective rat control.

- Termites—Farmers reported that this pest contributes to reduced germination in some areas surveyed, especially where soil is mainly saline, alkaline, sandy, or dry. Farmers use BHC (10%) dust and Aldrin (30 EC) for control.

- Rice weevil and grain borer—A considerable portion of the wheat stored for seed and consumption in the area is damaged rice weevil and, to a lesser degree, the grain borer. Some farmers mix BHC dust with the seed and store the grain in the wheat straw. A few farmers have started using aluminum phosphide for the control of these pests in storage containers. Farmers in the area use various indigenous storage systems.

Weeds
Phalaris minor is the major weed reported in the survey area. Others are *Avena fatua* (wild oats), *Lathyrus aphaca*, and *Chenopodium album*. During the survey, there were more wild oats along the road between Kumarganj and Faizabad. A few farmers use herbicides for control of *P. minor.* Isoproturon and 2,4-D are the two most common

herbicides mentioned, but sometimes farmers do not know what product they are using. Some farmers use sprayers, while others mix the herbicide with urea and topdress just after the first irrigation. According to farmers, control results are variable, but some say that herbicides are effective. Isoproturon costs Rs350 (US$13.58)/kg, but it is subsidized by 50% in the area to promote use.

Some farmers hand weed their fields late, often to provide fodder for their animals. Another control method is to allow the weeds to germinate after the pre-sowing irrigation and then kill them with a tillage operation prior to planting.

Harvesting and threshing
All harvesting is done by hand since there are no combines in the area. Smaller families use family labor to harvest, whereas medium and larger farms use hired labor. Labor scarcity is a major constraint in the area and is delaying harvest and exposing the crop to possible damage from the weather, birds, and rats. Payment for harvesting is usually in kind—1/20th of the crop is reported as the rate, but farmers complain that the labor bundle is always larger and, as such, 1/4 to 1/6th of the crop is often paid for harvesting. Other rates are 1/12 to 1/16th for cutting, bundling, and threshing.

Threshing is mostly done by machines powered by electric motors, tractors, or diesel engines. The charges are Rs15, 60, and 35 (US$0.58, 2.32, and 1.36)/hour, respectively, for the three methods. Charges for threshing with diesel engines varies from Rs25-40 (US$0.97-1.55)/hour depending on engine size. From 150 to 250 kg of seed can be threshed per hour, depending on thresher size. In addition, there is a charge for the labor to operate the thresher. Some smaller farmers thresh their grain with bullocks. There does not appear to be a threshing constraint.

Yields
Yields are variable, but average about 2-2.5 t/ha. The lowlands have lower yields than the medium lands. Some of the late planted wheat does not yield well. Some fields observed during the survey had good stands, but grain filling was poor. This is due to lack of irrigation, lodging, and possibly potash deficiency in some observed fields.

Official recommendations
See Appendix VB for the official recommendations of the State Government for growing wheat.

Gender Issues

During the rice survey in September, two female scientists in the survey group interviewed women in the villages visited. The following is a brief summary of their findings.

Women, who belong to upper castes on farms of either large- or smallholders, do not participate in any crop production activities in the field in order to maintain their social status. By contrast, women who belong to lower castes are involved in almost all operations of wheat and rice production activities except land preparation.

In rice production, all tasks are performed jointly by both men and women, however, the contribution of women to transplanting, weeding, harvesting, and threshing is always higher than men's contribution. Table 2 shows the relative contributions of men and women to various rice production activities.

Table 2. Contribution of men and women to various rice production activities in Faizabad District, September 1991.[a]

Rice activity	% Male	% Female
Land preparation	100	0
Seeding	95	5
Transplanting	5-30	70-85
Weeding	20	80
Harvesting	20-30	70-80
Post harvest	10-20	60-90

[a] Based on interviews with 50 women belonging to medium and low caste categories of farmers in 12 villages visited during the rice survey.

In animal production, women play an important role in the collection of fodder for the animals, making dung cakes for fuel, and tending the grazing animals in the fields. Because of the lack of fodder within the village, they have to go fairly long distances every day and thus spend most of their time with this task. Weeds become the most important source of animal fodder in September because of their availability in rice fields. The application of herbicides would reduce the availability of the weed component of the fodder and would force women to locate alternate fodder sources unless alternate fodder crops could be introduced into the system. Some women are paid less for weeding because they collect the weeds for their animals.

Rice threshing, done by 80% women, is a manual activity that requires considerable energy. During peak periods, this activity has to be completed before the next crop of wheat, potato, or Lahi is planted. A light mechanical thresher, which could be operated by a group of women, would be very useful in the system.

Because of the greater job opportunities outside of agriculture, many young men are migrating seasonally or even permanently from the villages. This is increasing even more the women's responsibilities for farm and household maintenance.

PROBLEMS, CAUSES, AND POSSIBLE SOLUTIONS

Discussions held after the completion of the field visits on problems affecting R-W productivity were based on farmers' perceptions, but included some secondary data available at NDUAT (compilation of further data is needed). As in the Pantnagar survey (Hobbs et al. 1991), these problems are grouped into near-term ones that can be quickly assessed and long-term ones (sustainability issues) that will require more surveys and research to better define the problem and a much longer time frame for assessment.

Problems were prioritized by using a simple scoring model. Group consensus scores were elicited (for each problem identified) for the extent of the problem (% of farms affected and productivity loss) (Table 3). Frequency of occurrence was not included in the table because all problems occurred every year. Hypothesized causes of major problems and interactions among problems are diagrammed; and research activities to address problems or problem complexes are suggested. Where similar problems exist for both rice and wheat, the causes are combined into one diagram. The following is a summary of the discussions held on rice and wheat problems.

In Faizabad, the ranking of the causes of late planting is different from those outlined in the Pantnagar area (Hobbs et al. 1991), although many of the problems identified are the same. This is partly due to the lighter texture of the soils in Faizabad District in the higher levels of the medium land, which enable easier land preparation following rice harvest. In the lower lands and lower levels of the medium lands, soil texture is heavier (clay loams) and land preparation becomes more difficult and time consuming.

Table 3. Ranking[a] of near-term wheat problems in the rice-wheat rotation in medium land type, NDUAT, Faizabad, India.

Problem	Yield loss	Area affected	Total score	Rank
Near-term problems				
Late wheat planting	2	2-3	4.5	I
Inadequate water:				
wheat	2	2	4.0	I
rice	2	2	4.0	I
Weeds:				
wheat	1	2	3.0	II
rice	1	1-2	2.5	II
Plant stand:				
wheat	1-2	1-2	3.0	II
rice	1-2	1-2	3.0	II
Rat losses:				
wheat	1-2	1-2	3.0	II
rice	1-2	1-2	3.0	II
Field losses:				
wheat	1	2	3.0	III
rice	1	2	3.0	II
Late rice transplanting:	1	1-2	2.5	II
Zinc: rice	?	?	?	?
Technical inefficiency:				
wheat	?	1-2	?	?
rice	?	1-2	?	?
Pests: rice	1	1	2.0	III
Diseases: rice	0-1	1-2	2.0	III
Longer term R-W problems				
Nutrient mining	?	2	?	I

[a] Scoring system: 0 = 0-5%; 1 = 6-15%; 2 = 16-50%; 3 = >50%; ? = more research needed to describe the problem.

Near-Term Issues and Problems in Rice and Wheat

Late planting of wheat

This issue is a universal problem in the R-W rotation with a set of common causes. Farmers in the survey area perceive this as a problem, but differently than may be the case based on experimental data. Most data on planting date by yield in the region indicate that mid-November is the optimum date for planting wheat, although this shifts toward late November in warmer areas. Yields then decline linearly after these dates with a 1% loss per day a common yardstick for yield loss, based on research data from regional on-station date-of-planting studies. Farmers, however, only perceive a yield loss after the middle of December plantings (10-15%) and a drastic yield loss from January plantings (50%). Many prefer the first week of December for planting.

In the lowlands, drainage of excess water and the availability of land at the proper moisture condition for land preparation are major determinants of the wheat planting date. There is probably very little that can be done to improve this situation at present and farmers must accept December and January planting dates as the norm for these situations. As such, yield potential, input efficiency, and profitability will be lower (Figure 4).

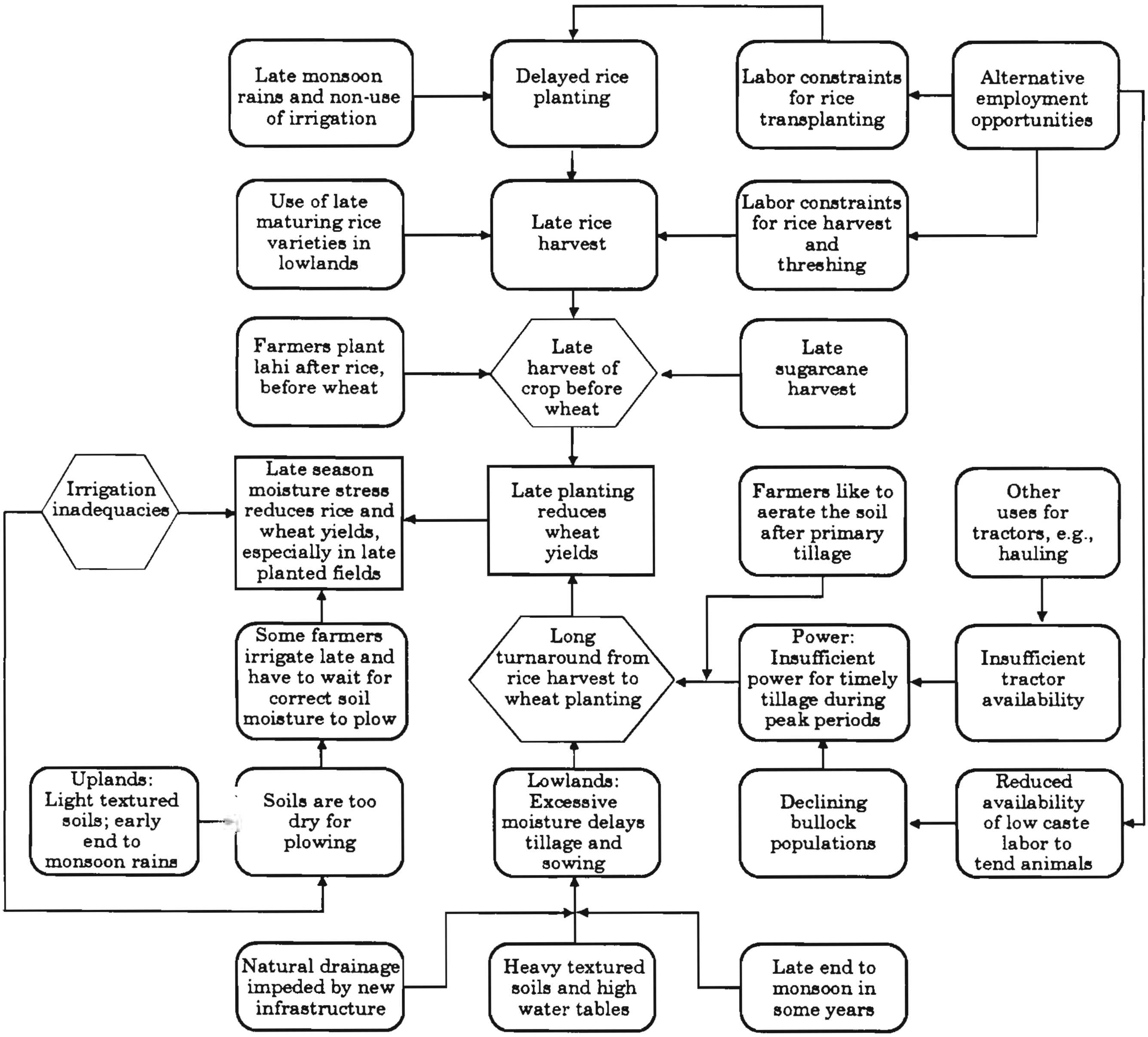
In Faizabad, except in the lowlands, long turnaround from rice to wheat is less of a problem than found at Pantnagar. More important is the set of causes associated with the late harvest of a previous crop (Figure 4).

Despite a high population density, this area of India suffers from peak labor shortages during key rice and wheat operations, evidenced by increased wages and delayed operations. The three major labor constraint periods are at the transplanting time of rice and at the times of rice and wheat harvests. Rice remains in the field long past maturity, and this not only delays land preparation for wheat, but also results in yield losses for rice (shattering and rats). Labor constraints at transplanting also result in delayed rice planting into August with subsequent late rice harvest in November. In the Pantnagar area, most rice is harvested by the end of October. The main reason for the labor shortage at Faizabad is the availability of alternative job opportunities, mostly not related to agricultural production. Farmers said that even available labor demands higher daily rates for transplanting and harvest than in previous years and this affects the profitability of wheat and rice.

On some of the higher levels of the medium lands where irrigation is available, farmers grow a short-duration crop of rice and follow this with an additional crop of *Lahi* (*Brassica campestris*), potatoes, or vegetables before planting wheat. This is one of the major causes for January wheat planting. Farmers are obviously willing to sacrifice wheat for the more profitable crops sown after rice.

Sugarcane is also becoming more prevalent, mainly because the seasonal labor demands are more uniformly distributed and present sugarcane prices are high. This is a relatively new area for sugarcane in India and the lower number of available crushing mills and mills giving late delivery indents to farmers to procure the cane result in late harvest and subsequent late planting of the next crop. However, much of the sugarcane is ratooned two or more times so the area of wheat affected by this problem is small.

The lack of irrigation water, the second problem for wheat production and discussed in detail later, delays wheat planting since in the light textured soils of the area, pre-irrigation is a preferred practice before final land preparation and seeding.



Key: Rectangles represent "problems", hexagons represent "primary causes" and ovals represent "secondary causes".

Figure 4. Problems and primary and secondary causes of late wheat planting.

Bullock populations are declining both as a result of more mechanization, but also because the low caste laborers that look after the animals of higher caste farmers now have alternative job opportunities. At the same time, tractor numbers are low and are often purchased for transport rather than agricultural management. These two factors can delay wheat planting, however, in time tractor numbers should increase (they have increased by 3 times from 1972-1982, Appendix IV, Table 7) and substitute for animal power.

One last factor that delays wheat planting is the farmers' perception that, in order to obtain high yields, it is important to leave the soil open 7-15 days following the primary tillage for aeration before doing final land preparation.

Suggested research issues include:

- Obtaining a better quantification of the extent of the problem in the area through a formal survey.

- Analyzing any research data pertaining to date of planting in the zone to allow evaluation of farmers' perceptions that yield decline is small if wheat is planted before 15 December and to quantify the optimum date of planting and yield loss per day beyond this date.

- Tillage research to:

  a) Study the effect of primary tillage and leaving the soil open for aeration on soil physical and chemical properties.

  b) Investigate reduced and zero-tillage practices to:
  1) determine the minimal land preparation requirement for wheat after rice.
  2) study different implements and seeding methods for improved establishment.
  3) look at the effect of land preparation and stubble management on carry over of pests and diseases.

  c) Make a comparison of different power sources—4-wheel versus 2-wheel tractors—to meet the needs of small farmers.

  d) Study the interaction of rice tillage intensity and methods on wheat establishment, especially on the heavier soils and the lowlands. In this connection, do more detailed work on direct seeding of rice by identifying varieties having greater establishment, initial growth vigor, better root penetration and proliferation, increased culm strength, medium tillering, increased nutrient uptake, and greater panicle weight.

  e) Study irrigation timing in rice as a way to provide good moisture conditions for wheat following rice harvest.

The solution to the labor problem of late rice harvest is more a policy issue. One route to take is introducing mechanization for harvest either in the form of reapers or combines. The use of a small reaper, powered by a 2-wheel tractor, and part of a set of implements for this power source, may be a feasible solution for small- and medium-size farmers.

Late transplanting of rice

Drought was a major factor in 1991 for late transplanting of rice. The effect of irrigation problems is discussed next. Other causes of late transplanting are shown in Figure 5 and are related to labor scarcity.

Suggested research issues include:

- Reviewing data on effects of transplanting date on yield loss. This should be collected, if available, where seedling age is kept constant in order to measure the direct effects of date and, also where seedling age increases as transplanting is delayed. If these data are not available, suitable experiments should be planned to obtain this yield loss information.

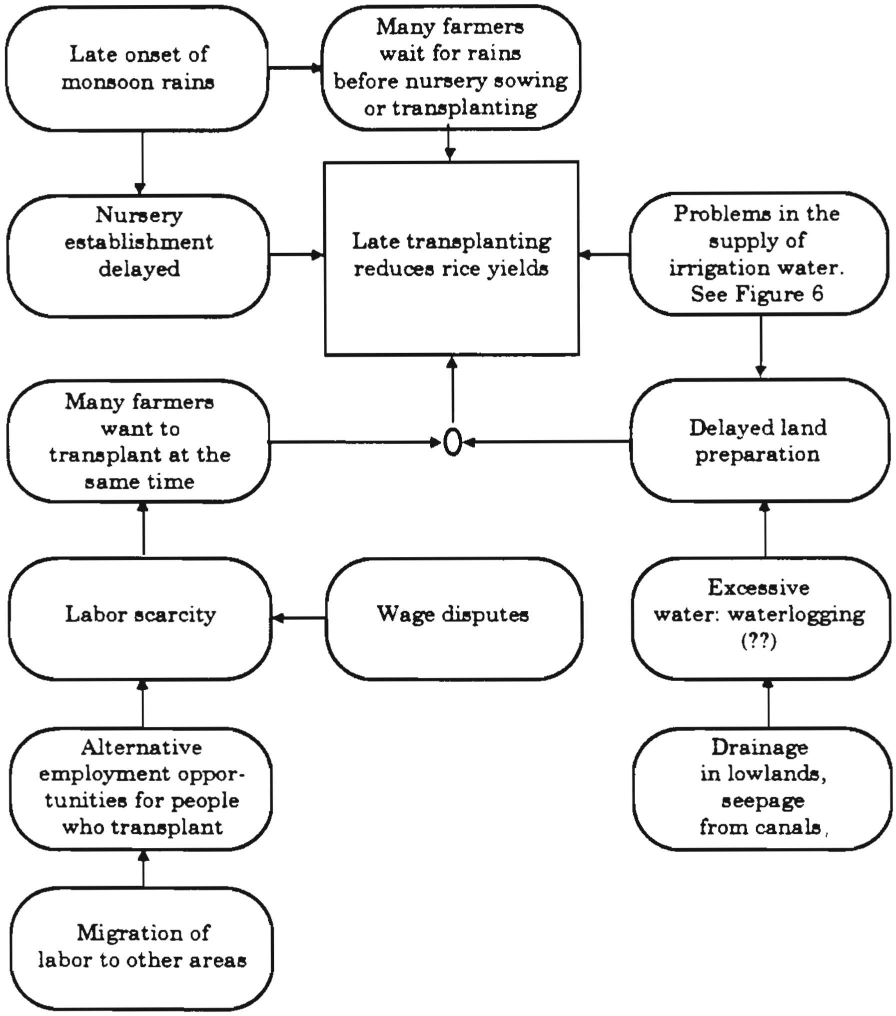


Figure 5. The problems and causes of late rice transplanting.

- Researching alternatives to transplanting and development of machinery for both direct and dry seeding, planting, and weeding.

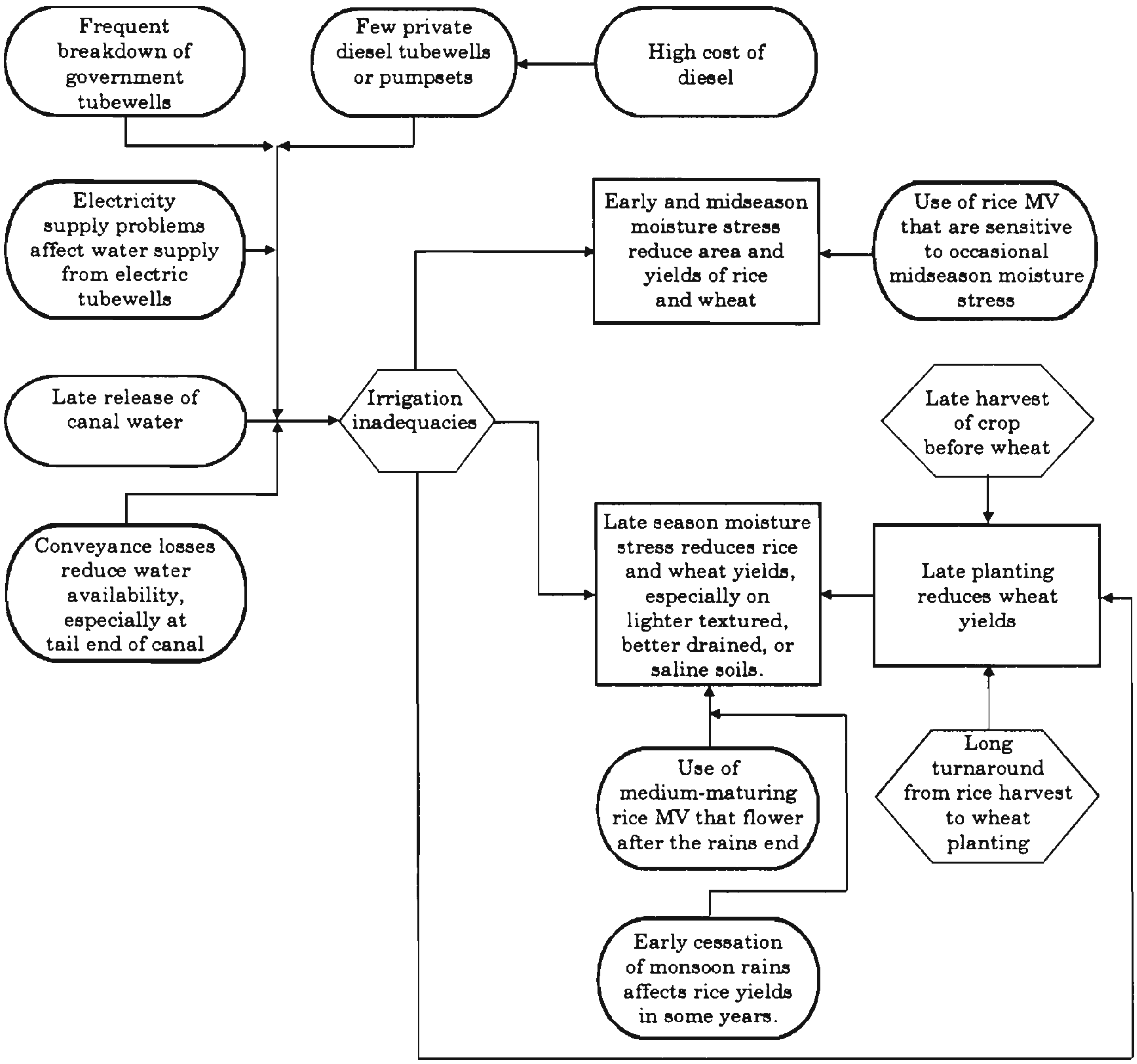
- Developing management practices that will minimize the losses due to late transplanting.

- Reviewing weather data to assess whether droughts like the one in 1991 are a common occurrence.

Inadequate water or soil moisture

Lack of water at the proper time is a major factor that constrains increased productivity in this area. Where irrigation facilities are used, yields are as good as in western UP. However, irrigation water is not always used when available for many of the reasons outlined in Figure 6.

Farmers perceive this problem as either insufficient water when needed or the lack of cash to pay for the diesel fuel or electricity to pump the water. This was a major problem in 1991 for the rice crop. The monsoon rains arrived very late and, because of drought, rice area was reduced by up to 75% in the uplands and 30-40% in the medium



Key: Rectangles refer to "problems", hexagons to "primary causes" and ovals to "secondary causes".

Figure 6. Problems and primary and secondary causes of moisture stress (early-, mid-, and late-season) for rice and wheat.

lands. In the lowlands, only about 1/3 of the land is typically cropped in the rice season because of excessive water. In 1991, the proportion of lowland planted to wheat may have increased to around 50% because of the drought. As mentioned earlier, farmers prefer to wait for rain rather than invest money in irrigation that may not be needed. Apart from the area reduction, the drought will also have an impact on rice production because farmers planted older seedlings later. If the monsoon rains finish early, this late-planted rice will also be affected by late season moisture stress.

Figure 6 outlines the causes and interactions for this problem. Availability of canal water is influenced by the timing of water release by the authorities, conveyance losses through seepage in the canals and channels, and the distance from the canal. Tubewell water is influenced by the number of tubewells available, credit for farmers to purchase and install low lift pumps and cash to pay for diesel or electricity. Electric tubewells are also affected by the unreliable supply of power. However, farmers prefer the electric tubewells because they are cheaper per unit of land irrigated—Rs150 (US$5.82)/ha for electric versus Rs400 (US$15.52)/ha for diesel tubewells. Conveyance losses from tubewell water would also be similar to that for canals, especially for the larger irrigation systems.

The inadequate supply of water can have a direct effect on yield. Data from experiments show that from four to six irrigations are required on the medium lands for maximum wheat yield, whereas farmers are averaging only two. Inadequate water for land preparation can also delay planting and reduce yield potential as already discussed. This has a direct effect on yield when late planting coincides with late season moisture stress in years when the monsoon rains finish early. Medium-duration varieties presently available suffer severely if moisture stress occurs during flowering and grain filling. One response of the farmers to the drought will be to plant more *Lahi* on land not planted to rice.

Many of the water supply issues have policy implications and require management decisions for solution. Other issues are related to soil physical and water management disciplines and so suggested research issues include:

- Conducting a more formal survey to quantify farmer irrigation practices to help answer the question of whether the area is rainfed with some facilities for supplemental irrigation or fully irrigated.

- Collecting technical information on the water balance statement for major land types in the area, which includes studies on:

  a) Moisture depletion and moisture recession.
  b) Water availability index for major soil types.
  c) Hydrological and groundwater mapping for the area and research soil profile characteristics.
  d) Atmospheric-evaporative demands and water requirements for wheat and rice.

- Conducting tillage trials to look at optimum moisture conditions for tillage and tilth, changes in bulk density, compaction and clod formation and/or hard pan development and possible influences on root growth and rooting density.

- Reviewing the literature and past research on the above topics to identify known information and determining research and knowledge gaps.

- Reviewing secondary data on weather and climate to determine if drought similar to the one in 1991 is a frequent problem. Collect secondary data from irrigation departments on the status of irrigation in the District.

Weeds reduce rice and wheat yields

Farmers consistently mention this problem in wheat and rice, but in rice nearly all farmers do at least one hand weeding. Weeds are more of a problem in direct-seeded rice than transplanted rice. Only a very few farmers use herbicides for control of weeds in either crop. Scarcity of labor for hand weeding in rice was not mentioned by farmers as a constraint, however, they did mention it for wheat.

The major weed for wheat is *Phalaris minor* (a winter season grassy weed), which has been found proliferating in many of the regions' R-W areas. Wild oats, *Avena fatua*, is the other grassy weed found in a few areas, particularly near Faizabad, on the Kumarganj Road. Many farmers believe the weed is spread by wheat seed contaminated with weed seed. Rice weeds (grasses, sedges and broadleaves) were listed earlier in the section on Management Practices for Rice.

As shown in Figure 7, the causes of yield loss attributed to weeds vary by crop. In wheat, the major cause of the grassy weed problem is probably the ineffectiveness of the control measures farmers use. Hand weeding is difficult, particularly with *P. minor*, and as mentioned earlier, labor availability is a constraint. Herbicides can be effective, but they are management-sensitive, particularly the substituted urea herbicides such as Isoproturon, which require good soil moisture for activation. Knowledge on the proper use of these chemicals on the part of farmers and, in many instances, of extension staff as well is also deficient. Thus, success with herbicides is variable. Despite a 50% subsidy to help promote Isoproturon's use in some areas, the cost may still be too high for resource-poor farmers. This results in a dosage below that recommended or non-use of herbicides. Other factors such as availability of herbicides, adulteration of products, and lack of sprayers all contribute to the problem.

P. minor and *A. fatua* are *rabi* season wheat weeds that only germinate when temperatures drop to critical levels in November. They germinate at the time wheat is planted. One effective control measure is to pre-irrigate, allow the weeds to germinate, and then destroy them through tillage. However, the benefit from this procedure has to be balanced against the losses incurred by late planting.

In rice, levels of irrigation water are often inadequate to control weeds because of previously mentioned irrigation problems. Transplanted rice is mostly done in a random manner making it difficult to mechanize the operation, although suitable machinery is not available anyway. Many weeds are introduced into the soil with FYM. And as already mentioned, weeding in rice is often done late after the weeds have already done their yield-reducing damage. Continuous R-W also promotes the buildup of problem weeds.

In addition to the direct effect of weed competition on yield, weeds also influence yields through lowering fertilizer efficiency and fostering pests and diseases (Figure 7).

Suggested research issues include:

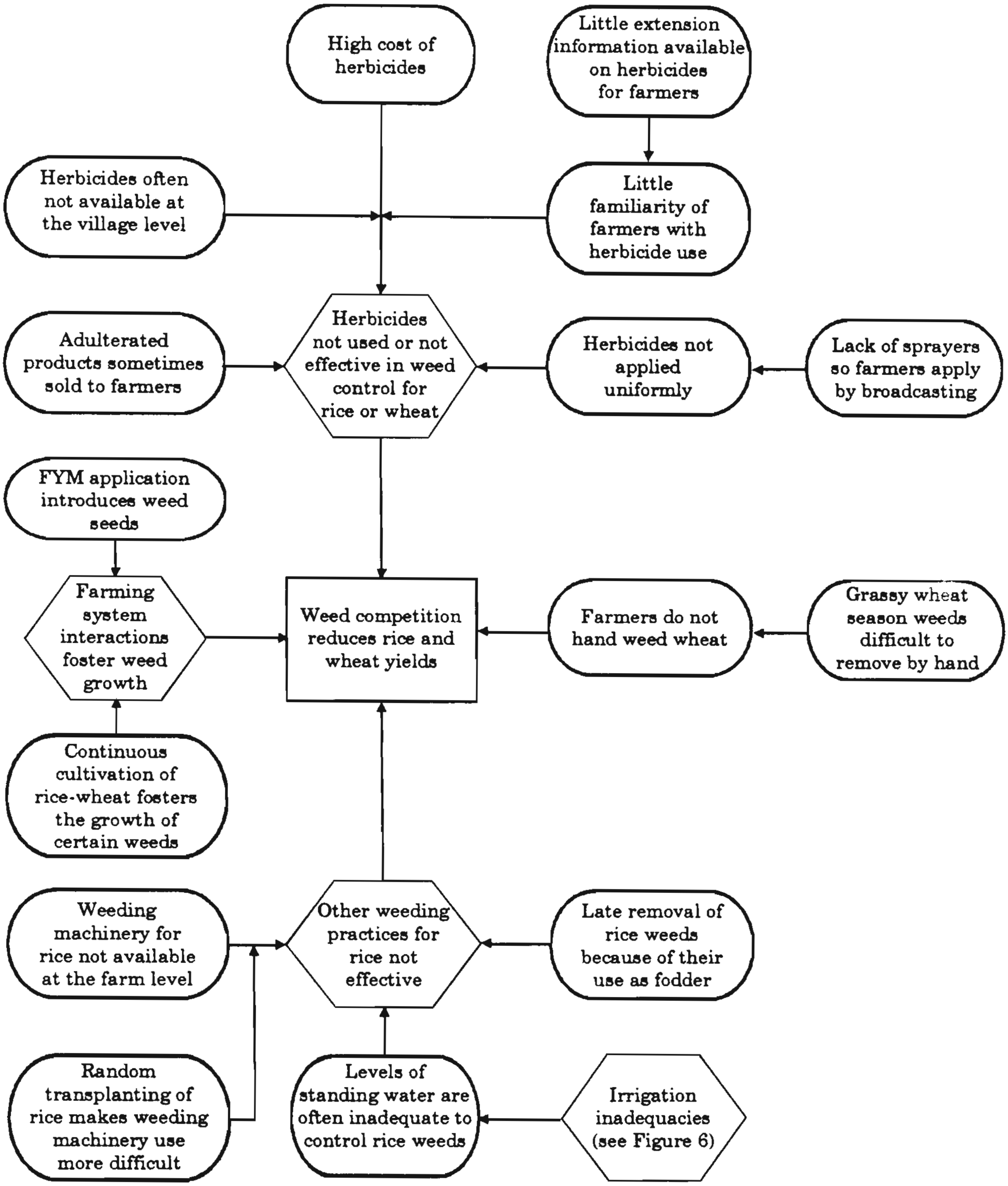
- Conducting a survey of the area at the correct time to assess the extent of the problem—what areas are affected, what species and populations are present, and what control measures farmers take to control the weed.

- Studying the mechanisms responsible for spread and proliferation of *P. minor* in the R-W system. Look at the role of water, wind, FYM use, and contaminated seed on its spread.

- Studying application methods, timings, and rates of herbicides used by farmers, and assessing in relation to control in the field and recommendations.

- Monitoring selected fields to determine why some fields are infested and others clean and relating this to the management system of the farmer. Look at the dynamics of weed buildup in R-W rotations.

- Looking at rotations as an alternative means for controlling weeds. In Pantnagar, sugarcane is used effectively for this purpose. More work on



Key: Rectangles are "problems", hexagons are "primary causes" and ovals are "secondary causes".

Figure 7. Problems and primary and secondary causes of weed competition for rice and wheat.

developing viable options for farmers on crop sequences to break the R-W monotony, and for supplying supplementary income for the subsistence rice farmers of the area.

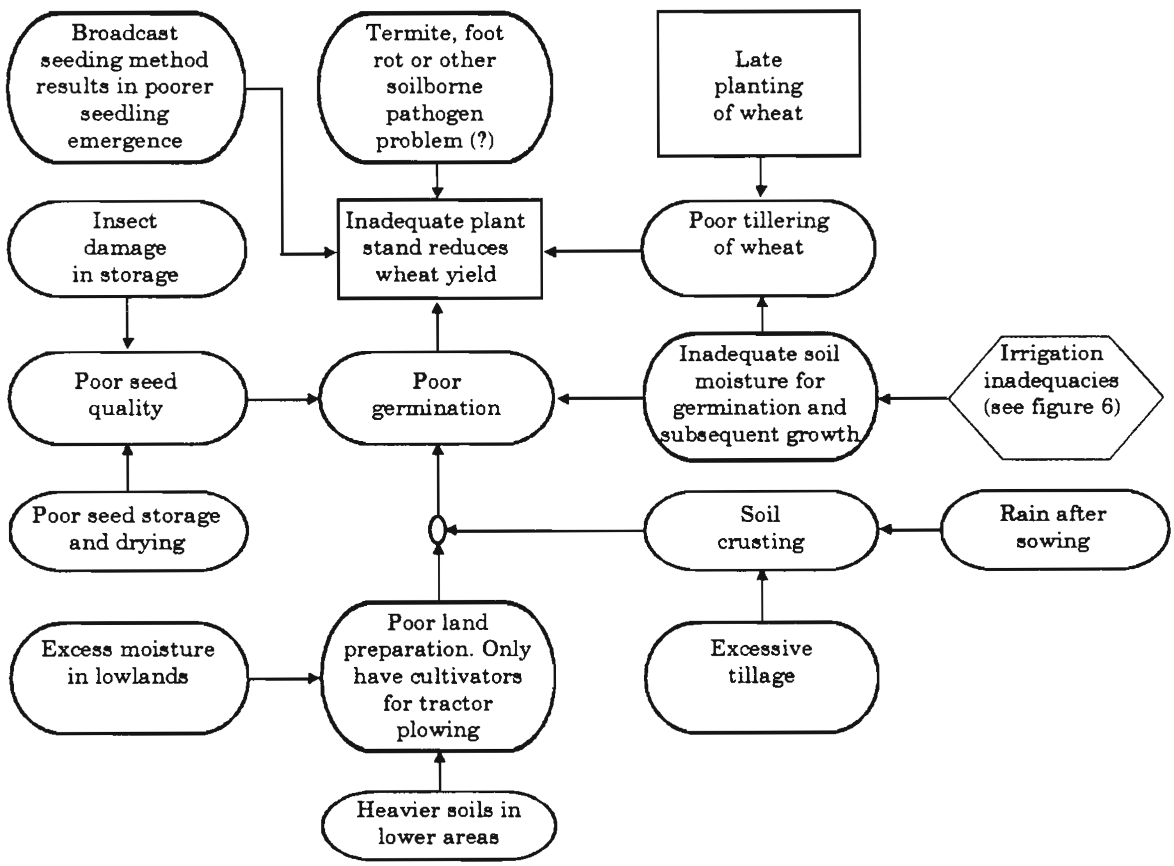
• Conducting loss assessment studies to develop the threshold levels for economic control of weeds in relation to weed populations.

• Studying alternative rice and wheat herbicides that are less management-sensitive and effective.

• Using machinery for direct seeding rice in rows (e.g., drum seeder) and using improved implements for weeding.

There is a large set of literature available on many of these topics that should be reviewed so that research can be focused on topics where knowledge is scanty. Where knowledge is available, it should be tested extensively in on-farm trials with the active participation of the farmer.

Inadequate plant stands reduce rice and wheat yields
This is an issue not commonly mentioned by wheat farmers, but is a concern of rice farmers, especially those that used contract labor for transplanting. Figures 8 and 9 outline the causes of this problem for wheat and rice, respectively.



Key: Rectangles refer to "problems", hexagons to "primary causes" and ovals to "secondary causes".

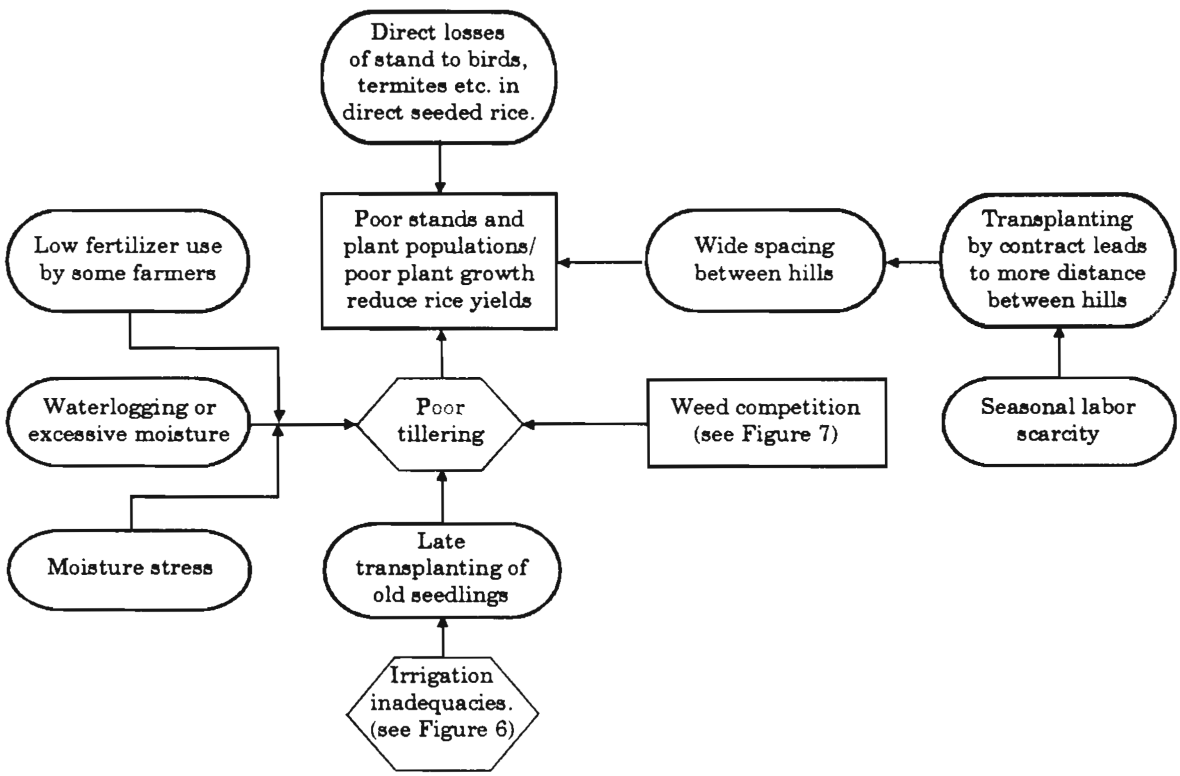
Figure 8. Problems and primary and secondary causes of inadequate plant stand in wheat.

Many survey participants observed a stand problem in wheat fields. Poor germination and poor tillering are the main causes (Figure 8). Poor germination can result from poor seed quality (due to storage problems), soil crusting, low soil moisture, and pest and disease problems. Poor tillering, on the other hand, can be caused by late planting and moisture stress.

Some scientists hypothesized that the broadcasting method of seeding causes poor plant stand because a) farmers do not broadcast seed uniformly and b) seed depth and emergence are variable. This needs further study, but may have to be an accepted constraint since alternative seeding methods are neither available nor economically competitive with broadcasting. Farmers do increase seed rates for broadcasting, which probably compensates for some seed not germinating.

For rice, the major farmer complaint about stand is related to the inadequate plant spacing that results when contract labor is used for transplanting (Figure 9). As mentioned earlier, contract labor for transplanting is paid on an area basis and this promotes wide spacing between hills. Stands in transplanted fields are also affected by drought, which directly affects tillering and through its effect on delayed planting and the use of old seedlings.

There are more stand problems in direct-seeded rice because farmers broadcast the seed. There are also more problems with termites,and birds. Weeds are also more competitive in direct-seeded rice and directly affect plant growth. Weeding methods used in direct-seeded rice like *Bushening* and *Bideni* also result in poorer plant stands.



Key: Rectangles refer to "problems", hexagons to "primary causes" and ovals to "secondary causes".

Figure 9. Problems and primary and secondary causes of inadequate plant stand in rice.

Suggested research issues include:

- Surveying the extent of the problem and relating it to farmer management practices.

- As mentioned under late planting problems, studying the effect of tillage systems, seeding methods, and soil properties on plant stand.

- Determining if any soilborne pathogens/insects affect germination and, if so, assessing the importance. Various foot rots and fungi have been postulated to influence germination of wheat in other parts of South Asia.

Rats reduce rice and wheat productivity
Farmers mention this problem widely, although it was too early for participants in the rice survey to observe rat problems in the field. The major cause (Figure 10) is obviously the lack of adequate control measures—especially at the community level. Other factors include the nearness of alternative habitats for rats (canals, bunds, sugarcane, woods) and a possible decline in the predator populations in the area. Rats are also responsible for considerable yield losses after the crop is harvested either before or after threshing. Many farmers stack their rice and prepare their land for wheat before rice threshing. These stacks of unthreshed grain are ideal habitats for rats. Storage losses can also be a factor because of inadequate farmer storage facilities.

Apart from assessing the yield loss and damage in farmers' fields as related to nearby rat habitats, other research issues include:

- Improving storage systems at the farm level.

- Promoting community habitat management and synchronized poisoning.

- Improving baits and finding alternative ones.

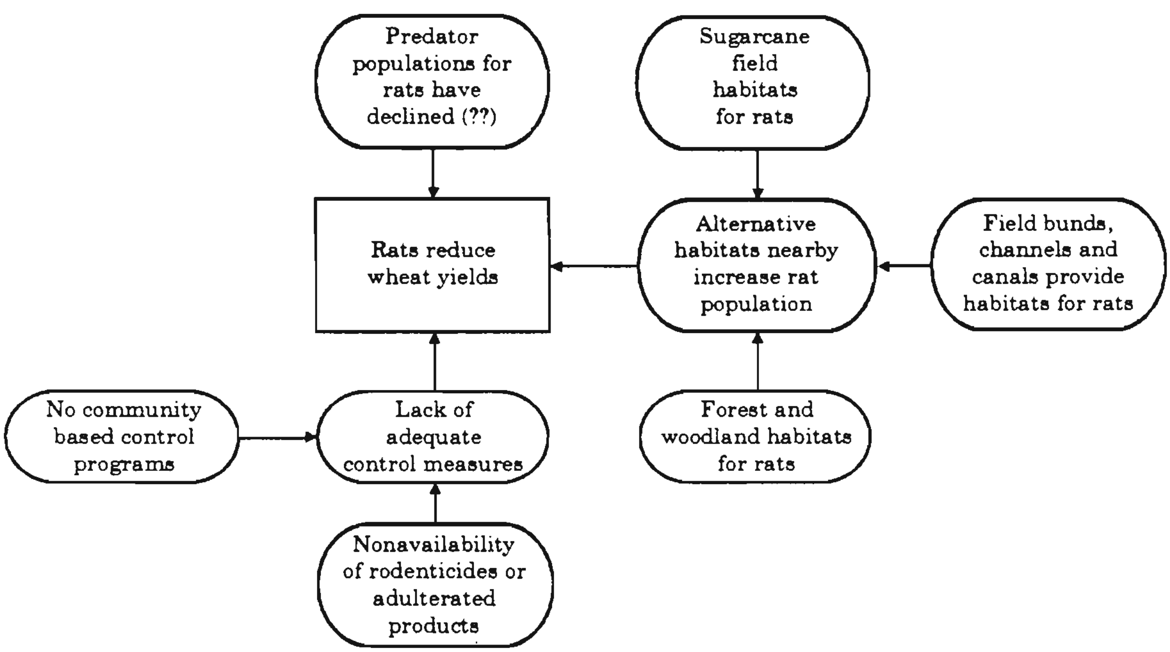


Figure 10. The problems and causes of rats in wheat.

Pre-harvest field losses reduce effective wheat yields
Although not specifically identified by the farmers, survey participants observed this problem in wheat fields. The rice survey was too early to observe this problem, but farmers said this was a problem due to labor problems at harvest (Figure 11). As mentioned earlier, labor scarcity in the area results from other job opportunities for agricultural labor. There is also competition at this wheat harvest time for sugarcane-related labor, i.e., harvesting, cultivating, preparing land, and planting. There are no combines or reapers in the area to help with timely harvest of either rice or wheat.

The climate at wheat harvest time is very changeable, i.e., strong winds, hail, and rain from pre-monsoon storms can cause considerable damage such as grain shattering. This is particularly critical with some of the shattering-susceptible varieties such as Shekhar. Delayed harvest also gives the rats and birds more time to do damage.

In addition to the harvest delay, the labor shortage is causing an increase in harvesting and threshing costs, thus making wheat less profitable. This will be discussed later.

Suggested research issues include:

- Conducting a survey to measure the extent of late harvest and relate it to loss assessment in terms of shattering or rodent damage.

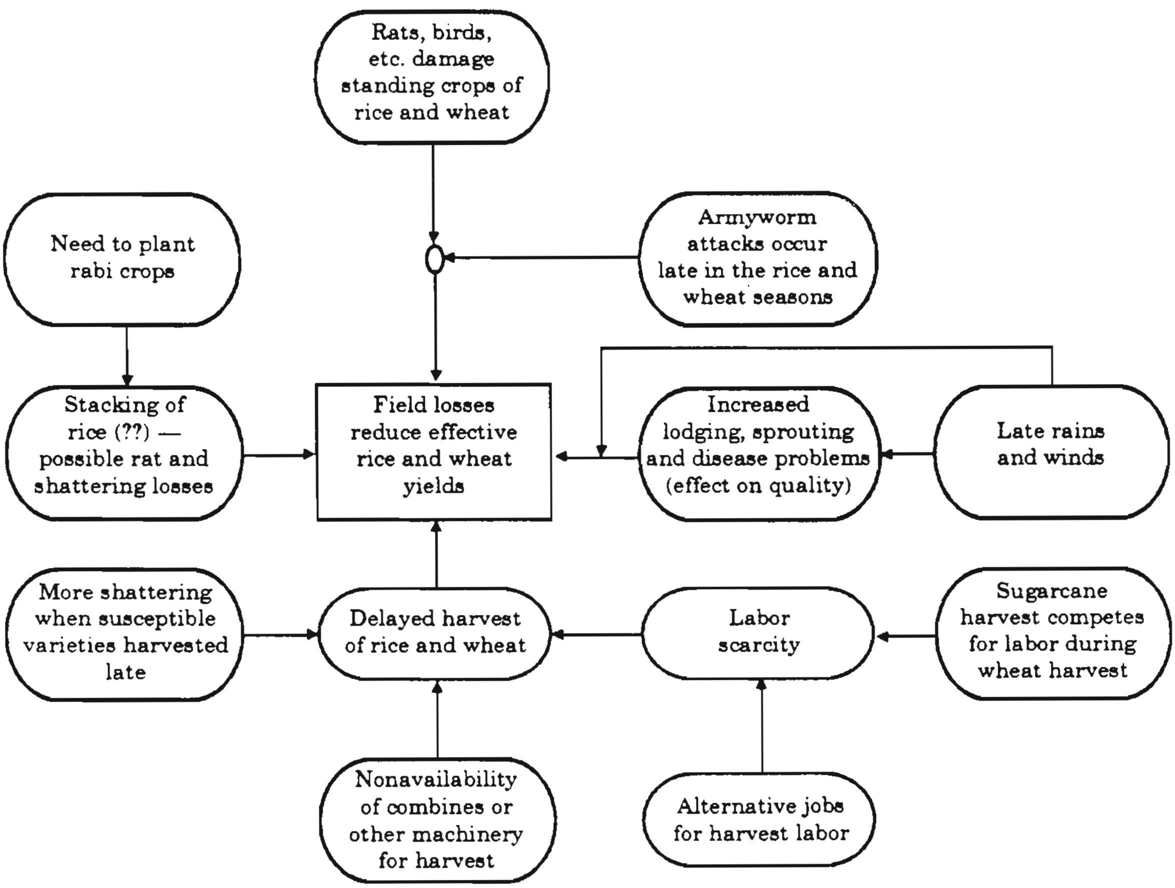


Figure 11. Field loss problems and causes for rice and wheat.

• Evaluating some form of mechanization suitable for small farm holdings in the area. Various equipment is available for cutting and binding wheat and rice in other parts of India. Combines are gaining popularity. The use of a cutter bar on a two-wheel tractor, however, may be more appropriate for the small field sizes in the area. This attachment should be evaluated along with other implements for the two-wheeled tractors.

Zinc deficiency reduces rice yields

This was mentioned as a problem during the rice survey, but not the wheat survey. Figure 12 diagrams the various causes of this problem. The light textured, alkaline reaction soils of the District are known to be zinc deficient, especially where intensive cropping such as R-W is practiced and crop residues are not returned to the soil. As mentioned earlier, FYM use is declining in the area.

The other cause of zinc deficiency is the nonuse or late application of zinc, which is available locally as zinc sulfate. Many farmers mentioned they used zinc as part of their fertilizer package, but many fields were observed with this problem. It is difficult for farmers to observe and distinguish the symptoms of zinc deficiency from other foliar problems. Several farmers reported no response to applied zinc when they suspected this problem. They may have been looking at some other nutrient or disease problem or used an adulterated zinc product. Potash deficiency was hypothesized for some wheat fields and may be a problem in rice.

Suggested research issues include:

- Characterizing zinc-deficient areas by soil type, moisture regime, and other soil chemical properties.

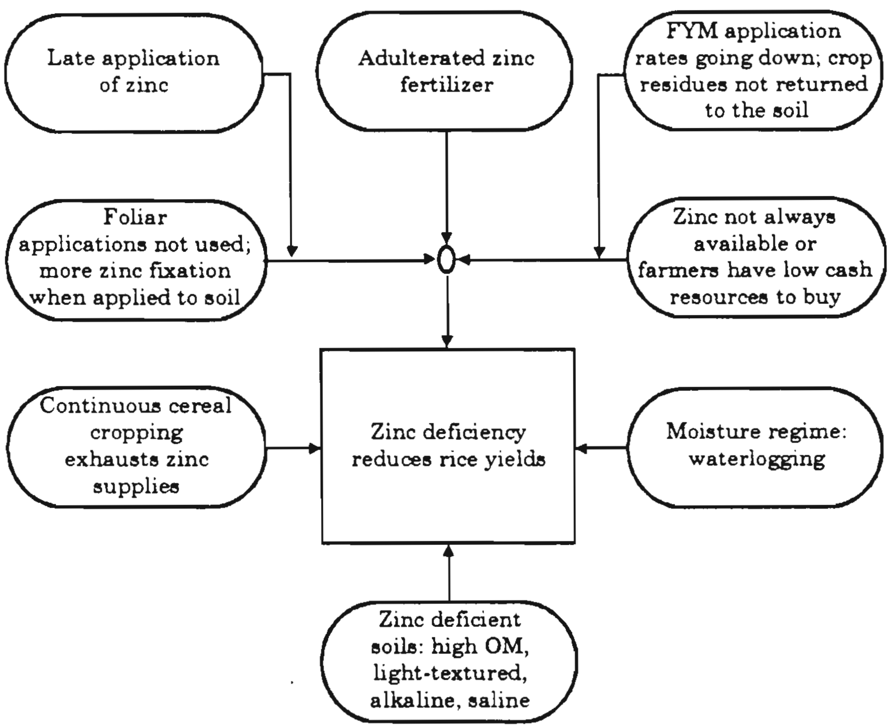


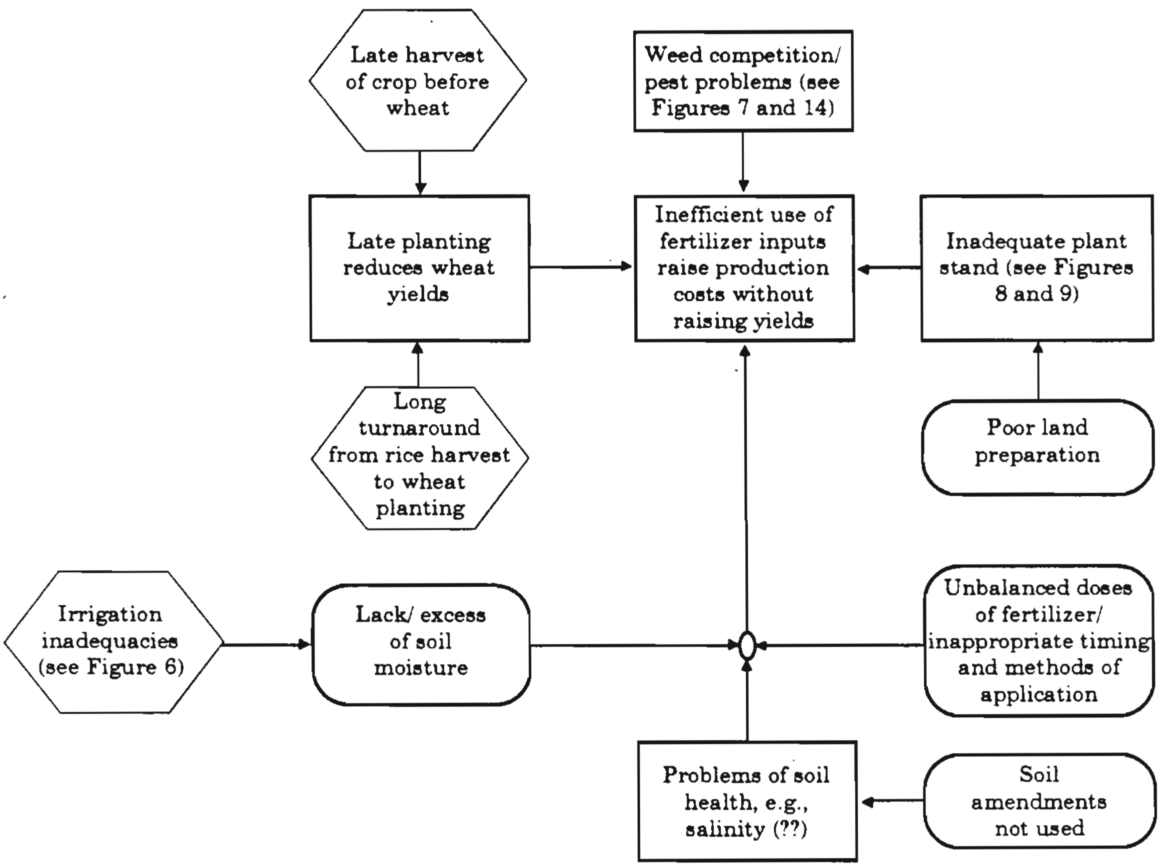
Figure 12. The problems and causes of zinc deficiency in rice.

• Reviewing available information from other institutions in the District. A Hindi publication entitled "Rice Production Program for Faizabad Division" has maps of areas identified as having zinc deficiency in the District.

Inefficient use of inputs

It may be possible to reduce input levels and increase profits through more efficient management. Farmers reported using surprisingly high fertilizer rates. Pest management practices are also low in efficiency. Figure 13 diagrams these problems of inefficient input use. Many of the causes of this problem are ones that have been outlined earlier. Late planting dates, incidences of pests and inappropriate timing, and methods of input application all reduce efficiency. Possible micronutrient and other macronutrient deficiencies together with moisture constraints will also lower input efficiency.

Although farmers did not refer to low profits as a problem, they did complain about the high costs of inputs for rice and wheat production. Cash is not readily available, especially to the resource-poor, smallholders of the area. Based on data obtained by the University economists, Appendix VI presents the costs and returns of recommended



Key: Rectangles represent "problems", hexagons represent "primary causes" and ovals represent "secondary causes".

Figure 13. Problems and primary and secondary causes of inefficient use of fertilizer.

technology for a 4-t/ha wheat crop (a good crop for which recommended levels of inputs are used). Similar data for rice and sugarcane, presented in Appendices VII and VIII, show income from rice—Rs1955 (US$75.95)/ha—to be less than wheat—Rs3257 (US$126.50)/ha—and income from sugarcane—Rs17,030 (US$661.11)/ha—to be substantially more than wheat and rice.

The average wheat yield for rainfed, partially irrigated, and fully irrigated crops combined in Faizabad District is 2.05 t/ha. This average also includes crops of those farmers who do not use recommended practices. The data in Appendix VI are for a wheat crop receiving five irrigations and the recommended inputs. Similar situations apply to the data for rice and sugarcane in Appendices VII and VIII, respectively. The high returns from sugarcane, at the present prices, will obviously influence farmer decisions on crop selection in the future.

Obviously, the problem of inefficient use of inputs relates directly to crop profitability and as such the following research is suggested:

- Reviewing and determining the need for further study of costs and returns to rice and wheat cultivation for different land types and farm sizes.

- Researching the role of cost reducing technology to help improve profitability. Activities include:

    a) mechanization of harvest and threshing—more emphasis on small farm machinery to speed up these practices.
    b) reduced tillage to obtain timely planting.
    c) increased efficiency of applied fertilizers.
    d) identification of nutrient deficiencies, e.g., potash.

- Organizing work on wheat-toria/mustard systems and on crop sequences involving other cash crops to break the R-W monotony and to supply supplementary income for subsistence farmers in the area.

Pests reduce rice yields

The survey was too early to see much insect damage on rice and so only farmers' opinions could be obtained. Figure 14 outlines the various interactions for pest problems in rice. Different insects are affected by different management situations, but farmers only referred to armyworm and rice bug as problems. Later in the 1991 rice growing season, armyworm was to be a problem in the lowlands, and in the medium lands as well. Improper use of broad spectrum insecticides could be shifting the balance of insects towards rice pests. Continuous R-W, staggered rice planting, and late planting all foster pest buildup.

Suggested research issues include:

- Studying the effect of the R-W system on insect buildup, e.g., population dynamics of armyworm.

- Researching population shifts in insects in R-W systems through a system of monitoring surveys over time.

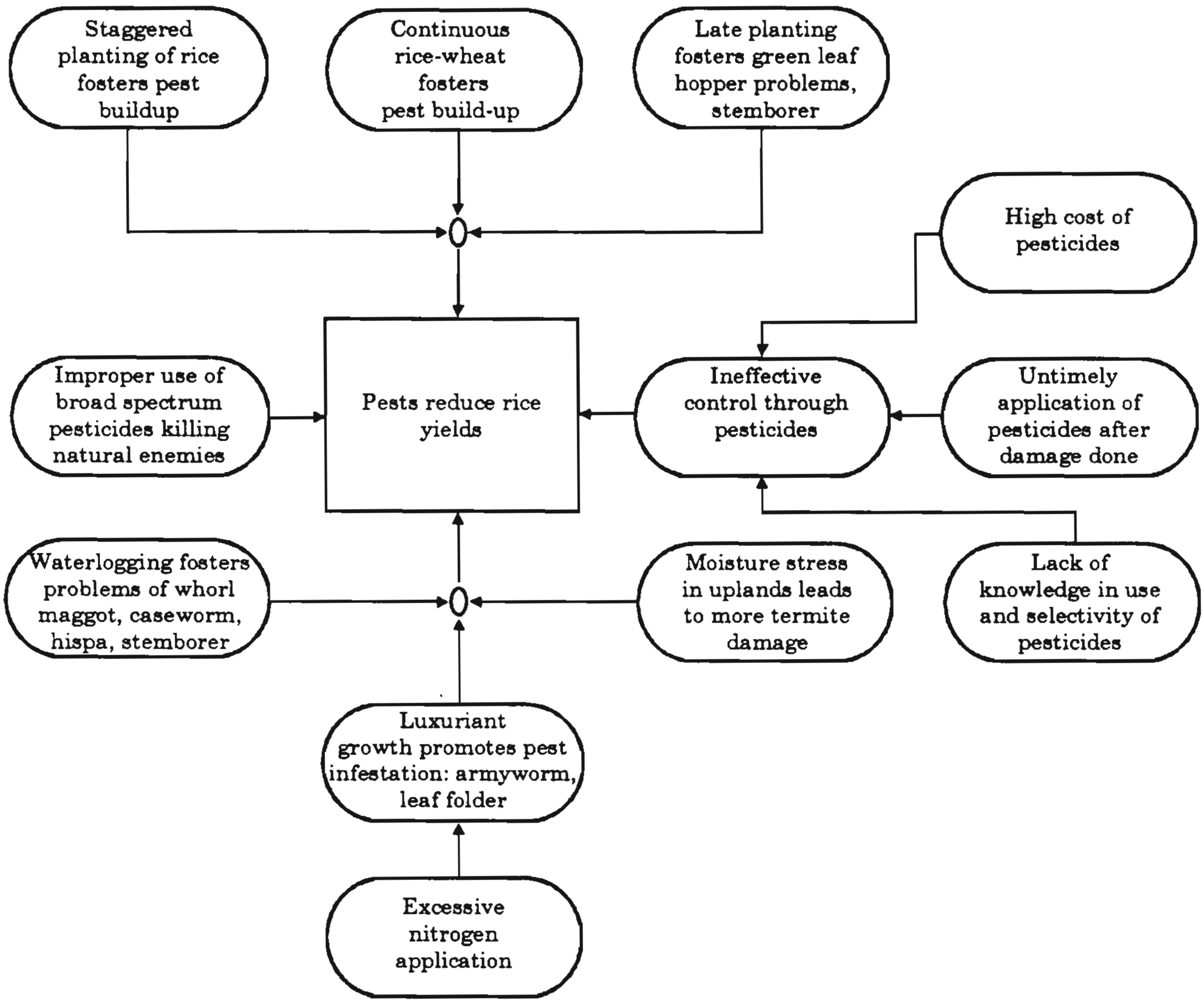


Figure 14. Pest problems and causes in rice.

Diseases reduce rice yields
In this dry year rice, diseases were less prominent than reported by farmers in previous years. At the time of the survey, few diseases were found. Farmers reported that foliar diseases cause the most problems. Like the insects, each disease has a different environment in which it proliferates (Figure 15).

Suggested research issues include:

- Assessing losses due to foliar diseases in R-W versus alternative systems.
- Continuing with the development of resistant varieties.
- Studying shifts in disease complexes over time in different systems.
- Developing more efficient IPM systems for disease, insect and weed control.

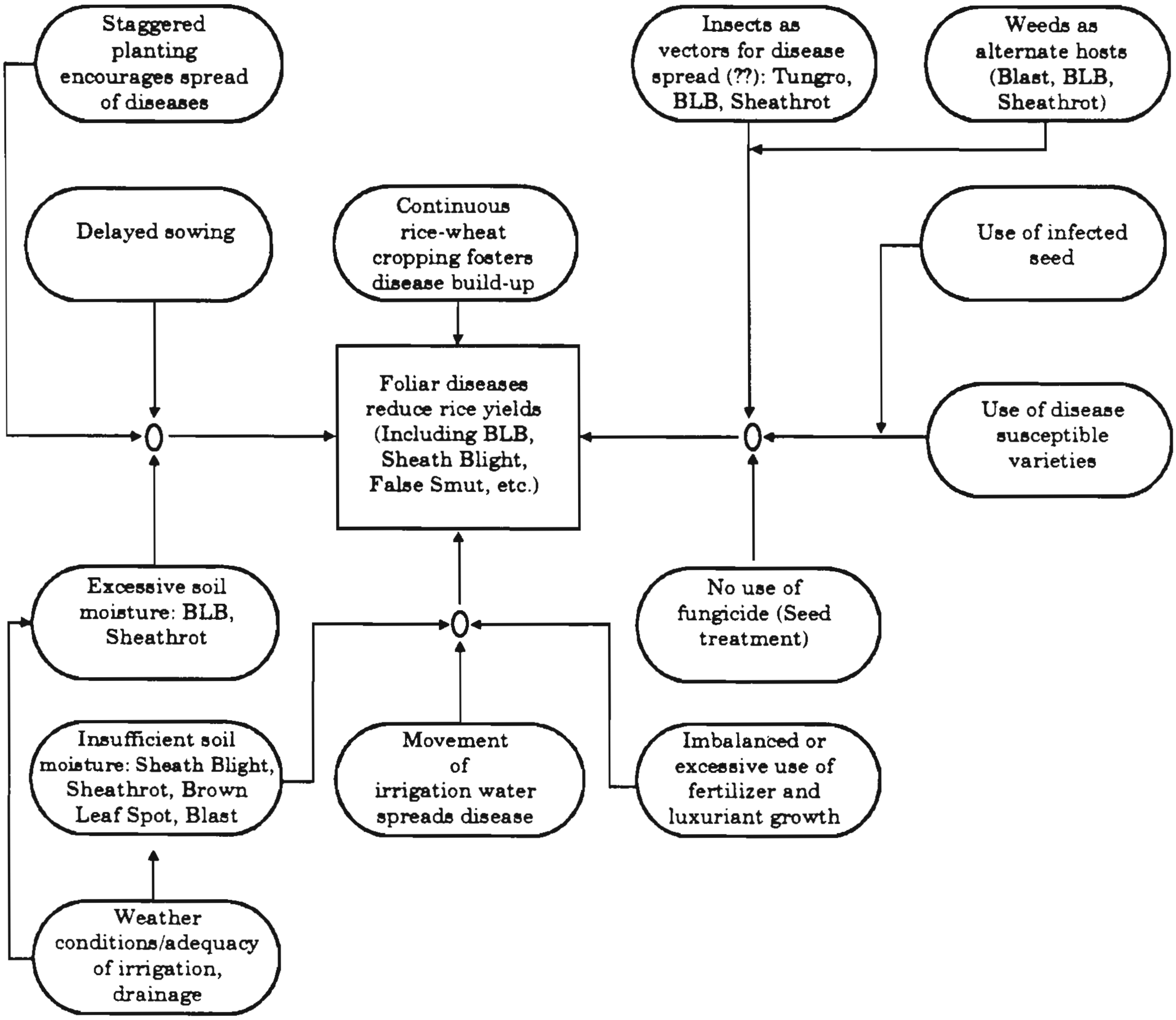


Figure 15. Disease problems and causes in rice.

Sustainability Issues in the Longer Term

The more complex issues of sustainability are not easily identified in this type of survey and are not identified as problems by farmers. Farmers when asked about production trends in wheat usually indicated that yields are increasing with time. Some farmers said that in order to maintain yields more fertilizer is needed. One farmer estimated the need for 10% more fertilizer per year just to maintain the same yields. However, it is difficult to separate the confounding effects of increased use of fertilizer, improved varieties, and irrigation from yield trends. One safe conclusion is that productivity (yield per unit of input) is declining over time. Fertilizer and nutrient use and the question of pest management are two topics related to sustainability issues.

Nutrient mining and fertilizer use

Fertilizer use in the area has increased over the past 10 years (Appendix IV, Table 6) from 43 kg nutrients/ha in 1979-80 to 96 kg/ha in 1989-90. Nitrogen use has more than doubled over this period and presently averages almost 80 kg/ha. Phosphorus use has also tripled, but rates per hectare are below the recommendation of 18 kg/ha. Potash use is low and has declined since 1979-80. All fertilizers are broadcast. Nitrogen, phosphorus, and potash are applied basally; nitrogen is also applied as a topdress.

The Faizabad surveys indicate that all farmers use nitrogen, most use phosphorus, and a few use potash. Where potash is used, farmers reported a response in the form of larger grains. Potash deficiency is suspected in one location visited by the survey participants.

Zinc use in rice is variable because of availability. More would be used if it were available in the market. There are also some questions raised about substitution of zinc sulfate with salt and other adulterations. Farmers are able to identify zinc problems in rice and apply zinc sulfate when the problem is observed. Farmers still use single super phosphate. The calcium sulfate in this product probably helps provide the sulfur needs of the two cereal crops. With a shift to urea and diammonium phosphate, this situation could change with sulfur becoming a deficient element. Sulfur has been reported as deficient in other parts of the region.

Many farmers mentioned that organic manure for crop production was less available for rice and wheat production. Green manures are not important and farmers are not willing to sacrifice a crop or use irrigation for improving land quality. This seems to be common throughout the region. Much of the above ground crop residues are removed and used for animal fodder or fuel and not plowed into the soil.

Since wheat and rice are exhaustive crops and remove considerable quantities of nutrients per year, long-term soil nutrient depletion on future productivity must be a central issue for the R-W work. Figure 16 diagrams all of these nutrient mining factors.

Suggested research issues include:

- Surveying or monitoring the extent of the problem and relating farmer management and input use to soil test data.

- Compiling, computerizing, and analyzing the data from various long-term soil fertility trials to determine whether yield declines are observable.

- Studying nutrient use efficiency rates, methods, sources, and organic and inorganic combinations and identifying deficiencies.

- Studying rotational use of organic manures in conjunction with need based on inorganic fertilization and prioritization of crops in terms of crop requirements and long-term soil productivity and sustainability.

- Identifying nutritional imbalances and monitoring new and emerging problems in this exhaustive cropping system.

- Mapping of nutrient deficient areas.

- Estimating long-term fertility status focusing on use of green manures, legume crops, crop residues, and other farm by-products.

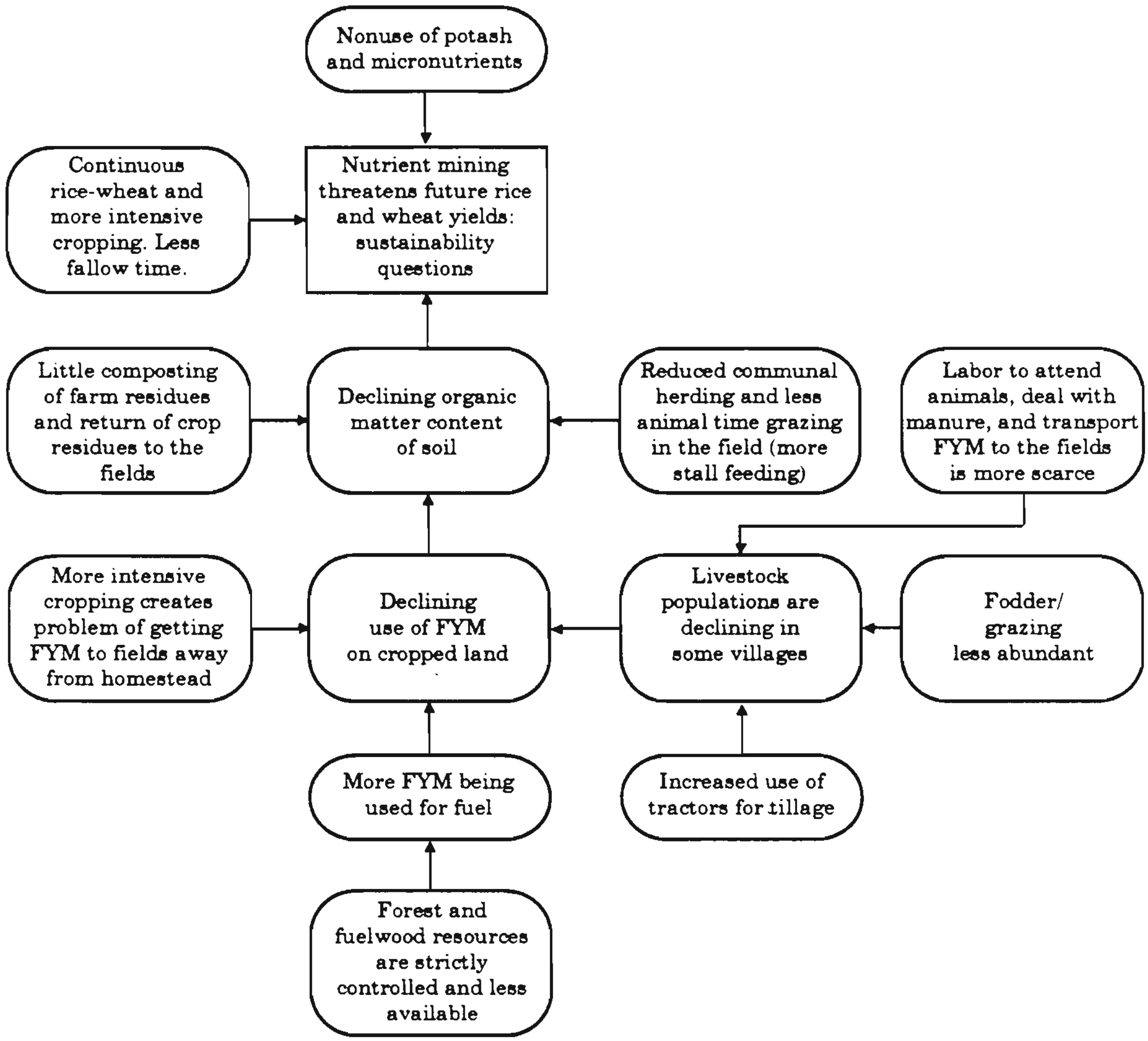


Figure 16. Problems and causes of nutrient mining.

Pest management

Farmers identify rats, weeds, insects (rice), and diseases as the major pest problems. Rats and *P. minor* have already been discussed, but do need to be researched in terms of longer-term trends in severity of the problem.

Farmers are less able to identify specific diseases such as foliar blights and tend to bulk all leaf diseases under the heading of leaf yellowing and firing. This common symptom can be caused by foliar blight, zinc deficiency (mostly rice), waterlogging, nitrogen deficiency, sulfur deficiency, or alkalinity; it can also be a genetic expression in some varieties. Obviously, much more research is needed on unraveling the causes and quantifying effect on yield.

Farmers are able to identify loose smut and Karnal bunt of wheat and false smut of rice. Currently, they do not use any control measures for any of these diseases. Loose smut is reportedly increasing, especially on RR-21 and Shekhar (K7410).

Karnal bunt was reported in eastern U.P. in 1983-84 following the collection and analysis of wheat grain samples from different commercial varieties. Initial data from 1983-84 to 1985-86 showed low levels of infection up to 0.15%. In 1986-87, 1988-89, and in 1989-90, maximum levels of 54, 21, and 30%, respectively, were recorded. UP2003, UP262, and Shekhar are the most susceptible commercial varieties. The disease is increasing and requires further monitoring.

Leaf rust is mostly a problem on RR-21 and mainly when it is planted late.

The following pest interactions in the R-W system are of concern:

- The role of *Helminthosporium sativum* in the system.
- The buildup of armyworm (rice cut worm, *Mythimna*).
- Increased incidence of bunt in rice and Karnal bunt in wheat.
- Soilborne pathogens (fungi and nematodes).
- Stubble management and rice stemborer populations.

Suggested research issues include:

- Surveying and monitoring severity, incidence, and trends of important pest complexes.
- Conducting loss assessment and researching the causes of leaf firing and yellowing.
- Reviewing past literature from the region and identification of knowledge gaps.
- Collecting pest, disease, and weed data from various agronomic and long-term trials by respective scientists together with agronomists.

Gender Issues

Appendix IX lists some of the main problems and constraints related to women in the District and some potential solutions.

FOLLOW-UP RESEARCH FOR NEAR- AND LONGER-TERM ISSUES

Many problems and researchable issues are listed in the previous sections. Some of these issues are commodity-oriented and can be pursued by the respective wheat and rice programs. What is needed in the R-W work is an identification of those issues that would benefit from integrated efforts across disciplines and commodities. The following are some activities that could be started immediately.

Compilation of Secondary Data

Before and during the diagnostic surveys, considerable secondary data were gathered on, for example, climate and soil characteristics. However, much remains to be done.

Like many areas of India, the study area is rich in relevant published information. This should be synthesized and used in research planning. The following are some suggested areas for initial concentration:[3]

- Statistics on trends over time (e.g., the last 10 to 15 years) in area, production, yields, input use, production technology.

- Estimates of costs and returns for important crops.

- Data from long-term experiments in the study area that can be analyzed for trends and/or identification of possible problems of sustainability.

- Data from wheat and rice agronomy trials, especially data on date of planting, fertilizer response, and weed control. Data from on-farm trials would be especially useful.

- Data from crop rotation or cropping pattern trials, or from trials that examine the management of crop residue or organic fertilizer.

- Data on effects of rice puddling on wheat establishment and growth.

- Information from field surveys of the incidence of pests, diseases, and weeds.

- Data on soil nutrient problems, such as zinc or potash deficiencies.

- Information on irrigation systems and farmers' irrigation practices.

- Training in the use of computers for database management and statistical analysis would be useful.

In-Depth Studies

The following are some suggestions for in-depth studies put forth by the survey teams:

Tillage research
This appears to be a major area for research for both rice and wheat. In rice, research is needed on the effect of soil puddling on the water needs of the rice crop, soil physical and chemical changes, root restricting soil layers, and problems with land preparation for wheat. Such research should take account of the different soil and land types in the District. In wheat, more research is needed on reduced tillage systems to allow earlier planting and reduced production costs. This research should include in-depth soil physical and soil chemical studies related to rice and wheat establishment and subsequent growth, including rooting.

Farm equipment
Another suggested research area is evaluating small farm equipment for land preparation, seeding, and harvesting and threshing. Comparisons are needed between 2-wheel and 4-wheel traction and between animal and mechanical power. Because of labor constraints at transplanting, practices to either accelerate transplanting or eliminate it (e.g., improved methods of direct seeding) are needed.

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[3] Secondary data should be screened for relevance to the District and the study area. Less attention should be given to data from other districts unless they are clearly pertinent.

Effects of the rice crop on wheat
Research is needed on the effects of rice variety and rice planting method (and especially the interactions between these) on rice and wheat productivity. For example, fruitful research might be conducted on different rice establishment methods (dry vs puddled; direct-seeded vs transplanted) and rice varieties better-adapted to these new alternative planting methods. In addition, the development of rice varieties suitable for late planting (photosensitive, high yielding) would be useful. Idle land in lowland areas could be brought into cultivation through the development of rice varieties with flooding tolerance and elongation abilities.

Water management
Water management research should look at the water balance equation for different land and soil types in the District, the possibility of root restricting layers, and more efficient use of available water. Other studies might involve 1) looking at the water-reducing characteristics and contributions of groundwater to evapotranspiration and 2) the timing and amount of irrigation in wheat in relation to water availability and soil types.

Mixed cropping
There are opportunities for fruitful research on mixed cropping of wheat and mustard (and other oilseeds). However, these themes are probably not of the highest priority given the low proportion of oilseeds in the crop mixture (usually 5-7% of the stand). Research themes include:

- Mixed cropping vs. monocropping.
- Proportion of mustard seed to wheat seed.
- Varietal matching of wheat and mustard for mixed cropping.
- Effect of crop mixtures vs. monoculture on pest populations.
- Effect of planting date on farmers' mixed cropping practices.
- Mixed cropping and weed control.
- Role of mustard as a fodder crop.

Longer-term research trials
Although there is widespread suspicion that sustainability issues might be important in the study area, these issues are not very well defined. FYM use may be declining while inorganic fertilizer use increases, but the effects of this process over extended periods of time are not clear. Long-term trials can help identify sustainability problems and define their properties and causes. Any program of long-term trials should be preceded, of course, by a thorough analysis of available data on trends in productivity and resource quality (soil characteristics, land degradation) in the study area.

Opportunities for research featuring long-term trials include the following:

- Trials to ascertain the sequence with which different nutrients (N, P, K, S, Zn) become limiting, given soil test information for different land types and soil types. A simple design that allows nutrient deficiencies to develop on large main plots, followed by splitting of these main plots into subplots to examine residual effects on alternative measures, would be an efficient way to proceed. In such trials, residue management alternatives can be combined with nutrient treatments.

- Trials to examine integrated fertility management in the R-W system, including dynamic (carryover) effects associated with inorganic and organic fertilizer use, in the context of alternating flooding and drying of the soil.

- Long-term cropping pattern trials comparing continuous R-W with alternative systems that include sugarcane, pulses, or green manures. These long-term trials would feature analysis of carryover and changes in soil quality over time.

Monitoring Research

It is apparent from the diagnostic surveys that there is a need for more quantitative data on farming systems in the study area. To assess sustainability questions, information is needed on the quality of farmers' land, water, and livestock assets and changes in these over time. In addition, an understanding is needed on how farmers' rice and wheat management practices affect trends in resource quality.

In order to collect this type of data, and at the same time develop a database for future evaluation of trends, it may be useful to start a monitoring research project. Such a project would study, for a random sample of farmers and intensive data plots, the following:

- Farmers' *current* practices, land and resource quality, and system productivity over time.

- Causes of productivity change, including associated changes in input levels, changes in technology (e.g., adoption of new varieties), and changes in resource quality (e.g., soil nutrient mining).

Such research would require cooperation of scientists from several disciplines, commodity study groups, extension staff, and farmers and would help foster integration of R-W research activities. Occasional resurveys would be needed over several years (one might think in terms of a 10-20 year time horizon), although it would not be necessary to survey all farmers in all years. Themes to be studied in some detail might include:

- Farmer assets (farm size, land fragmentation, family size, labor sources and availability, animal stocks, machinery availability and extent of mechanization, cooking fuel sources, and irrigation facilities).

- Physical measures from intensive data plots of soil chemical and physical measures (e.g., OM, pH, salinity and sodicity, macro- and micronutrient status, compaction, water table depth, infiltration, and bulk density) and biotic problems (e.g., pest, disease, and weed incidence).

- Farmers' production practices for rice, wheat, and selected other crops (stand establishment, varietal selection, soil fertility management, irrigation, weed and pest control, and harvest and post-harvest) and relevant interactions affecting rice or wheat.

- Input supply and markets for purchased inputs, including labor and machinery markets.

- Yield measurements.

- Estimates of costs and returns, including total factor productivity.

The development of the sampling frame for this monitoring study must be done carefully, given the long time associated with this type of research. Monitoring will require training of enumerators in data collection, editing, and analysis. Computer use will be an important aspect of this research because of the large amount of data to be handled. An upgrading of the computer skills of collaborating scientists may be necessary.

Finally, additional work is needed on the conceptual framework, given the central importance of methods for measuring sustainability in the monitoring program. A regional workshop on this theme is expected to be held in the near future. Training in estimation of total factor productivity may be combined with training in computer use and the economic analysis of agronomic data (including data from long-term trials).

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APPENDIX I. PARTICIPANTS IN THE EXPLORATORY SURVEYS HELD 2-9 APRIL AND 21-27 SEPTEMBER 1991 AT FAIZABAD, UTTAR PRADESH, INDIA.

R.K. Singh[b]	Director, Research	NDUAT
K.G. Pillai[b]	P.S. Rice Agronomy	Dir. Rice Res.
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D.S. Yadav[a]	Agronomist	NDUAT
C.H. Mishra[a]	Rice breeder	NDUAT
R.V. Singh[a]	Wheat pathologist	NDUAT
H.P. Singh[b]	Agronomist	NDUAT
V. Pandey[a]	Entomologist	NDUAT
B.N. Singh[a]	Production economist	NDUAT
T.P.S. Katiyar[a]	Soil physicist	NDUAT
R.P.S. Chauhan[b]	Soil scientist	NDUAT
J.P. Singh[b]	Agronomist	MODIPURAM
N.D. Shukla[b]	Agric. Economics	MODIPURAM
H.M. Singh[b]	Entomologist	NDUAT
B.N. Singh[a]	Asst. breeder	NDUAT
R.A. Singh[a]	Economics	NDUAT
M. Gufran[a]	Agric. engineer	NDUAT
S.P. Singh[a]	Wheat agronomist	NDUAT
A.K. Singh[a]	Pathologist	NDUAT
R.N. Singh[c]	Pathologist	NDUAT
H.M. Singh[c]	Entomologist	NDUAT
S.B. Singh[c]	Agronomist	NDUAT
M.R. Varma[c]	Agric. engineer	NDUAT
A. Singh[c]	Social scientist	NDUAT
P.R. Hobbs[a]	Wheat agronomist	CIMMYT
V.P. Singh[a]	IRRI Rice agronomist	IRRI
T.R. Paris[c]	Social scientist	IRRI
L.W. Harrington[c]	Economist	CIMMYT
T. Woodhead[c]	Soil scientist	IRRI

[a] Participated in both surveys.

[b] Participated in April wheat survey only.

[c] Participated in September rice survey only.

APPENDIX IIA. MEAN WEATHER RECORDS FOR 19 YEARS AT CROP RESEARCH STATION MASODHA, FAIZABAD.

Month	Mean Temp. (°C) Max.	Mean Temp. (°C) Min.	Relative humidity %	Vapor pressure (mm)	Rainfall (mm)
Jan.	21.5	8.2	80.2	7.2	15.1
Feb.	25.2	9.3	83.7	7.8	11.4
March	32.2	14.5	73.7	9.8	6.1
April	36.9	19.7	72.0	13.4	9.4
May	39.1	19.8	70.4	16.0	17.8
June	37.5	20.9	73.1	20.5	131.4
July	34.5	20.7	90.9	23.2	352.6
Aug.	31.2	19.3	81.1	23.5	293.5
Sept.	31.6	17.5	89.3	23.5	282.3
Oct.	31.8	14.0	87.3	19.2	70.5
Nov.	28.8	11.5	86.8	11.5	4.6
Dec.	25.3	9.1	87.0	7.9	13.6
Annual or Mean	31.3	15.4	81.3	15.3	1208.3

APPENDIX IIB. MEAN WEATHER RECORDS FOR 7 YEARS AT KUMARGANJ (NDUAT).

Month	Mean Temp (°C) Max	Mean Temp (°C) Min	Relative humidity %	Vapor pressure (mm)	Rainfall (mm)
Jan.	18.7	7.8	85.9	6.2	12.6
Feb.	23.7	8.8	77.0	7.5	11.8
March	29.2	11.7	72.3	11.5	7.7
April	36.7	16.5	68.6	11.7	11.3
May	38.2	25.3	59.2	15.3	8.7
June	36.0	25.7	81.6	23.0	123.7
July	32.8	27.5	90.4	25.7	337.4
Aug.	31.5	26.6	87.7	24.8	275.5
Sept.	33.2	26.2	87.0	24.7	204.0
Oct.	30.3	18.4	83.1	16.1	49.2
Nov.	29.2	13.8	89.7	14.6	2.1
Dec.	25.3	9.9	84.9	8.9	12.1
Annual or Mean	30.4	18.2	80.6	5.8	1056.2

APPENDIX III. PHYSICO-CHEMICAL PROPERTIES OF THE SOILS AT MASODHA, KUMARGANJ, AND THE VILLAGE ANJRAULI.

Properties	Masodha	Kumarganj	Anjrauli
Sand %	35.2	21.2	15.2
Silt %	48.6	56.2	54.2
Clay %	16.2	22.6	30.6
Field capacity, % v/v	39.6	32.4	31.7
P.W.P., % v/v	9.8	15.9	11.2
Sat. Hydr. Cond. (mm/hr)	4.23	2.78	2.82
Infiltration rate (mm/hr)	3.87	2.12	2.46
Bulk density g/cm^3	1.33	1.48	1.46
pH	7.4	8.2	7.8
ECe (ds/m)	0.21	0.35	0.38
Organic carbon, %	0.34	0.32	0.36
Available N (kg/ha)	128.40	80.00	82.00
Available P_2O_5 (kg/ha)	13.5	14.8	15.22
Available K_20 (kg/ha)	355.70	353.02	358.50

APPENDIX IV. TABLES OF STATISTICAL DATA FROM FAIZABAD DISTRICT SAMPLED FOR THE PAST 10 YEARS*.

Table 1. Population growth.

1971	1981	% increase/y over 1971
1,927,281	2,382,515	2.36

Table 2. Land use and irrigation.

Net cultivated area (000 ha)		Net irrigated area (000 ha)		Percentage irrigated area	
77-78	87-88	77-78	87-88	77-78	87-88
307	293	180	206	59	70

Table 3. Percentage irrigated area by source.

Canal		Tubewell		Others	
77-78	87-88	77-78	87-88	77-78	87-88
23.60	24.00	68.02	74.00	8.38	2.00

Table 4. Percentage cropped area to various crops.

1977-78			1987-88		
Rice	Wheat	Sugarcane	Rice	Wheat	Sugarcane
37.23	26.67	5.73	39.61	39.23	4.45

Table 5. Yield of major crops (t/ha).

1977-78			1987-88		
Rice	Wheat	Sugarcane	Rice	Wheat	Sugarcane
0.85	1.53	34.05	1.53	1.96	49.02

Table 6. Fertilizer use intensity (kg element per hectare gross cropped area).

1977 - 78				1987 -88			
N	P	K	Total	N	P	K	Total
44	6	3	53	69	19	4	92

Table 7. Improved farm implements.

Particular	1977	1982	1987
Thresher	6,306	11,371	27,425
Sprayers	411	3,197	3,611
Seed Drill	43	600	1,039
Tractor	939	1,825	4,895
No. of tractors/000 ha	(3.05)	_	(16.73)

* All the data were collected from the District Statistical Bulletin 1979 and 1989.

APPENDIX VA. RECOMMENDED PACKAGE OF PRACTICES FOR RICE.

- **Land Preparation**

  One summer plowing by soil-turning plow followed by two or three plowings by a country (deshi) plow.

- **Fertilizer**

Irrigated transplanted:	N	P	K
Short-duration variety	100	50	50
Medium-Late variety	120	60	60
Local variety	60	30	30
Direct seeding:			
High yielding variety	100-120	50-60	50-60
Local variety	60	30	30
Rainfed	60	40	30

  50% N and all P and K as basal. Rest N at tillering and panicle initiation. In the case of rainfed, all fertilizers should be placed in furrows at sowing.

- **Nursery**

  Seedrate: 30-40 kg/ha planted.
  Area: 1/15th ha for every hectare planted.
  Fertilizer: 100 kg N + 50 kg P_2O_5/ha.

  Spray 5 kg $ZnsO_4$ + 0.25% ferrous sulfate + 2% urea; spray the insecticide Phosphamidan 1—14 days after sowing.

  Direct seeding: 80- to 110-day varieties should be selected.
  Sowing time: mid-June through first week of July.
  Seed rate: 75-80 kg/ha.
  Row spacing: 20 cm.

  Under puddled conditions: Use 100-110 kg seed/ha. Soak seed for 12-48 hours before sowing.

- **Transplanting**

  Time: Third week of June through mid-July.
  Spacing: 20 x 10 cm.
  Depth: 3-4 cm.
  Age of seedlings: 21-25 days; 30-34 days for long duration varieties; 35 days for saline soils.

- **Irrigation**

  Irrigate 1 week after transplanting, during active tillering stage, and critical stages with 2.5-cm water depth maintained each time.

- **Crop Protection**

  For insects: Indosulphan (35 E.C.), BNE, malathion, and folidal.
  Khaira diseases: 20 kg $ZnSO_4$/ha or spray 5 kg $ZnSO_4$ + 2% urea.

- **Weeds**

  Use Khurpe or Paddy weeder. 400-500 g 2,4-D (sodium salt) 1 week after transplanting and 20 days after direct seeding.

Butachlor: 3-4 L/ha (50 E.C.) or 30-40 kg 5% granules or 15 kg 10% granules/ha.
Thiobencarb: 3 L/ha (50 E.C.).
Pendmenthalin: 3.3 L/ha (30 E.C.) should be applied within 3-4 days after transplanting.

- **Harvest**

At 90% maturity.

- **Varieties**

Direct seeding: Ngina 22, Caveri, Thona 349, Saket 4, Govind, and Narendra.
Transplanted irrigated: Saket 4, Ratna, Pusa 33, Govind, and Narenda.
Short duration: Saket 4, Ratna, Pusa 33, Govind, Manhar.
Medium late: Jaya, IR8, IR24, Saryu 52, T-3, Pant Dhan 4, and Prasad.
Long duration: Cross 11C, T100, T-23, T-9, T-26, and Mahsuri.
Scented varieties: T-3 and T-9.
For saline soils: IR8, Shona 3g, Saket 4, Jaya, Ugar Dhan, and Lakada.
Low lands: Cross 116, T-100, Mahsuri, and T-26.
45-120 cm water: Chakia 59.
Above 20 cm water: Jalmagn.
Flooded areas: Madhukar.

APPENDIX VB. RECOMMENDED PACKAGE OF PRACTICES FOR WHEAT.

- **Land Preparation**

Most farmers are growing rice before wheat and should select a rice variety with a duration that will allow rice to vacate the land in October. Because of puddling for rice, the soil becomes compact in the low lands and two plowings by disk harrow are needed to prepare the soil for the wheat sowing. On the medium lands, two cross plowings are done and the land left open for 7 to 15 days. The land is then plowed once more and the seed sown, followed by two cross plowing and a planking to cover the seed.

- **Seed and Seed Treatment**

For normal seeding, the recommended seed rate is 100 kg/ha. For rainfed and late planting conditions, a seed rate of 125 kg/ha is recommended. If the germination is poor, more seed should be used. The seed should be treated with 2.5 g thiram/ kg seed.

Wheat should be planted in rows 18 to 22 cm apart when soil moisture is good. This can be done either by seed drill or behind the plow. Final head count should be 400-500 spike/m^2.

- **Fertilizer**

After rice: apply 120-60-40 kg N-P_2O_5-K_2O/ha.
After fallow, pulse, or green manure: apply 80-60-40 kg N-P_2O_5-K_2O/ha; for local varieties or old varieties like K-68 use 60-30-30 N-P_2O_5-K_2O/ha.
40-45 DAS: spray 5 kg zinc sulfate + 2% urea mixed with 800 L of water; second spray at 60-65 DAS.
For Domat and Matiyar soils: half the N plus all the P_2O_5 and K_2O is applied at the time of sowing in the furrows 5 cm below the seed. The other half of the N dose should be broadcast at the time of the first irrigation.

For sandy soils: one third of the N plus all of the P_2O_5 and one third of the K_2O is applied at the time of sowing in the furrows below the seed. One third of the N and K_2O is then applied after 20-25 days or at the first irrigation; the rest is applied at the second irrigation.

- **Irrigation**

For light and sandy soils, apply six irrigations at:
1) CRI—20-25 DAS.
2) Tillering—40-45 DAS.
3) Jointing—60-65 DAS.
4) Flowering—80-85 DAS.
5) Milking—100-105 DAS.
6) Dough stage—115-120 DAS.

For Domat or heavy Domat (clay), apply four irrigations at:
1) CRI—20-25 DAS.
2) 30 days after the first irrigation.
3) 30 days after the second irrigation.
4) 20-25 days after the third irrigation.

- **Crop Protection**

For control of Karnal bunt: apply 2.5 g thiram/kg seed and 2 g Captan (75%)/kg seed.
For control of termites: before sowing apply to soil BHC 10% dust @ 30 kg/ha or Aldrin 5% dust @ 25 kg/ha or Heptachlor 5% dust @ 25 kg/ha.

- **Weeds**

For control of *Phalaris minor* use any of the following:
1) Methabenzthiazuron (70% WP) at 1.5 kg/ha.
2) Metoxuron (80% WP) at 1.0 kg/ha.
3) Isoproturon (50% WP) at 1.5 kg/ha.
4) Isoproturon (75% WP) at 1.0 kg/ha.

Spray with a flat tip nozzle any of the above herbicides mixed with 500-700 L of water after the first irrigation or between 30-35 days after seeding

For control of *Chenopodium album*: apply 2,4-D 80% sodium salt at 625 g/ha at 30-35 days after seeding.

- **After a late variety of rice, toria, potato, or sugarcane, wheat should be grown as follows**

1) Select a late sown variety like HD2285 and RR-21.
2) Increase the seed rate by 25%.
3) Apply balanced fertilizer.
4) Soak seed in water overnight before sowing.
5) Give first irrigation 15 DAS; after that give a light irrigation every 15 to 20 days.

- **Varieties**

Recommended: UP262, UP2003, HD2285, RR-21, Shekhar, and HD2329. For late planting: HD2285 and Shekhar.

APPENDIX VI. PER HECTARE COST OF CULTIVATION OF WHEAT USING RECOMMENDED TECHNOLOGY.

S.No.	Particulars	No./Quantity	Cost (Rs)	Cost (US$)[a]
1.	Plowing (Tractor)	6	1,500.00	58.22
2.	Sowing			
	a. Labor	9	162.00	6.29
	b. Bullock pair	3	105.00	4.07
	c. Seed	100 kg	350.00	13.58
3.	Fertilizer			
	a. Nitrogen	120 kg	612.00	23.75
	b. Phosphorus	60 kg	319.20	12.38
	c. Potash	40 kg	80.00	3.10
	d. Labor	2	36.00	1.40
4.	Plotting and bunding (labor)	4	72.00	2.79
5.	Irrigation	5	-	-
	a. Tubewell charge	-	1,125.00	43.66
	b. Labor	12	216.00	8.38
6.	Weeding and Hoeing (labor)	25	450.00	17.46
7.	Pesticides	-	100.00	3.88
8.	Harvesting (labor)	40	720.00	27.95
9.	Threshing			
	a. Thresher charge	-	250.00	9.70
	b. Labor	12	216.00	8.38
10.	Interest on working capital	-	189.40	7.35
11.	Revenue	-	40.00	1.55
12.	Rental value of owned land	-	800.00	31.05
	Total cost		**7,342.60**	**284.94**
	Yield			
	a. Grain	40 Ql	9,000.00	349.34
	b. Bhusa	40 Ql	1,600.00	62.10
	Total income	-	10,600.00	411.44
	Net income	-	3,257.40	126.50
	Input-output ratio	-	1:1.44	

Note:

a. Plowing (Tractor)	Rs. 250/ha	US$ 9.70/ha
b. Labor (8 hours)	Rs. 18/day	US$ 0.70/day
c. Seed	Rs. 350/Ql	US$ 13.58/Ql
d. Irrigation (Tubewell)	Rs. 225/ha	US$ 8.73/ha
e. Nitrogen	Rs. 5.10/kg	US$ 0.20/kg
f. Phosphorus	Rs. 5.32/kg	US$ 0.20/kg
g. Potash	Rs. 2.00/kg	US$ 0.08/kg
h. Wheat grain	Rs. 225/Ql	US$ 8.73/Ql
i. Bhusa	Rs. 40/Ql	US$ 1.55/Ql

[a] Rupee to US$ exchange rate on Sept. 30, 1991 = 25.763.

APPENDIX VII. PER HECTARE COST OF CULTIVATION OF RICE USING RECOMMENDED TECHNOLOGY.

S.No.	Particulars	No./Quantity	Cost (Rs)	Cost (US$)[a]
1.	Plowing (Tractor)	2	500.00	19.40
2.	Bunding (labor)	10	180.00	6.98
3.	Nursery	-	200.00	7.76
4.	Irrigation (Tubewell)	1	225.00	8.73
	labor	4	72.00	2.79
5.	Fertilizer			
	a. Nitrogen	120 kg	612.00	23.75
	b. Phosphorus	60 kg	319.20	12.98
	c. Potash	40 kg	80.00	3.10
	d. Labor	2	36.00	1.40
6.	Transplanting (labor)	72	1,390.00	53.95
7.	Weeding (labor)	10	180.00	6.98
8.	Pesticides			
	a. B.H.C.	-	100.00	3.88
	b. Labor	2	36.00	1.40
9.	Harvesting (labor)	35	630.00	24.45
10.	Threshing and winowing (labor)	78	1,498.00	58.14
11.	Interest on working capital	-	181.75	7.05
12.	Revenue	-	40.00	1.55
13.	Rental value of owned land	-	800.00	31.05
	Total		**7,079.85**	**274.74**
	Yield			
	a. Grain	42.50 Ql	8,075.00	313.43
	b. Paddy straw	48.00 Ql	960.00	37.26
	Total income	-	9,035.00	350.69
	Net income	-	1,955.15	75.95
	Input-output ratio	-	1:1.28	

Note:

a. Plowing (Tractor)	Rs. 250/ha	US$ 9.70/ha
b. Labor (8 hours)	Rs. 18/day	US$ 0.70/day
c. Irrigation (Tubewell)	Rs. 225/ha	US$ 8.73/ha
d. Nitrogen per kg nutrient	Rs. 5.10/kg	US$ 0.20/kg
e. Phosphorus per kg nutrient	Rs. 5.32/kg	US$ 0.20/kg
f. Potash per kg nutrient	Rs. 2.00/kg	US$ 0.08/kg
g. Paddy	Rs. 190/Ql	US$ 7.73/Ql
h. Paddy straw	Rs. 20/Ql	US$ 0.78/Ql

[a] Rupee to US$ exchange rate on Sept. 30, 1991 = 25.763.

APPENDIX VIII. PER HECTARE COST OF CULTIVATION OF SUGARCANE USING RECOMMENDED TECHNOLOGY.

S.No.	Particulars	No./Quantity	Cost (Rs)	Cost (US$)[a]
1.	Preparation of land			
	a. Irrigation	1	225.00	8.73
	b. Plowing (Tractor)	4	1,000.00	38.81
	c. Labor	4	72.00	2.79
2.	Sowing			
	a. Seed	60 Ql	2,400.00	93.15
	b. Tractor	1	250.00	9.70
	c. Labor	35	630.00	24.45
3.	Fertilizers			
	a. Nitrogen	150 kg	765.00	29.69
	b. Phosphorus	40 kg	213.00	8.27
	c. Potash	60 kg	120.00	4.66
4.	Weeding - Hoeing	3	-	-
	Labor	120	2,160.00	83.84
5.	Irrigation (Total expenditure)	4	900.00	34.93
6.	Pesticides	-	500.00	19.40
	Labor	6	108.00	4.19
7.	Harvesting and Transportation			
	a. Labor	80	1,440.00	55.89
	b. Transportation by tractor	-	2,000.00	77.63
8.	Interest on working capital	-	636.15	24.69
9.	Revenue	-	50.00	1.94
10.	Rental value of owned land	-	1,500.00	58.22
	Total cost		**14,969.15**	**580.98**
	Yield	800 Ql	-	-
	Total income	-	32,000.00	1242.09
	Net income	-	17,030.85	661.11
	Input-output ratio	-	1:2.15	

Note:

a. Plowing (Tractor)	Rs. 250/ha	US$ 9.70/ha
b. Labor (8 hours)	Rs. 18/day	US$ 0.70/day
c. Seed and Sugarcane	Rs. 40/Ql	US$ 1.55/Ql
d. Irrigation (Tubewell)	Rs. 225/ha	US$ 8.73/ha
e. Nitrogen	Rs. 5.10/kg	US$ 0.20/kg
f. Phosphorus	Rs. 5.32/kg	US$ 0.20/kg
g. Potash	Rs. 2.00/kg	US$ 0.08/kg

[a] Rupee to US$ exchange rate on Sept. 30, 1991 = 25.763.

APPENDIX IX. MAIN PROBLEMS AND CONSTRAINTS RELATED TO WOMEN IN THE DISTRICT AND POTENTIAL SOLUTIONS.

Problem	Constraint	Potential Solution
Crops		
Selection of seeds	Lack of knowledge about varietal selection	Provide information regarding new varieties
Weeding	Drudgery and lower wages	Develop improved tools for weeding
Post harvest activities	Drudgery and low wages (12:1, 16:1, & 20% of whole grains)	Introduce light machinery for threshing like the pedal thresher
Livestock		
Collection of animal fodder	Lack of access to animal fodder, long hours spent every day in fodder collection which competes with other crop management and domestic responsibilities	Introduce forage within the homestead
Fuel procurement	Competition of FYM as fuel and organic matter for crops	Introduce dual purpose trees for fuel and fodder

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