WHEAT AND WHEAT DEVELOPMENT IN BHUTAN

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Southeast Asia and South Asia
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Executive Summary

• This report summarizes the work of two CIMMYT regional scientists who visited Bhutan Oct 18-Nov. 1 1988 to prepare a paper on wheat and wheat development in Bhutan at the request of the government.

• Wheat is the third most important cereal crop in Bhutan, but it is not the preferred staple. As such, it has received little research attention and farmers grow it as a less important subsistence crop. Yields are low compared to other South Asian countries.

• The government of Bhutan wishes to intensify wheat production to help achieve self-sufficiency in food grains and increase small farmer incomes.

• Figures for the acreage and production of wheat for the whole of Bhutan are only available for 1984. In that year, Bhutan produced 11,880 metric tons (MT) of wheat from 26,242 acres (10,620 ha) and a further 4,139 MT of barley from 9,230 acres (3,735 ha). No data are available after 1984 to compare production in 1988 or to predict trends. However, it is believed that the targets set for the Fifth 5-Year Plan were not met. Reasons for this shortfall are not known.

• Bhutan imported 5,519 MT of wheat from India from April 1, 1987 to June 30, 1988. Most of this wheat was distributed as flour to the urban areas of western Bhutan and major development projects in the West.

• Wheat is mainly utilized in Bhutan as subsistence food and prepared to resemble rice. Some is used as chapatis mainly by the foreign workers from India and Nepal. There is a growing demand for bread products in the urban centers. An undetermined amount of wheat and barley is used for production of alcohol and a certain amount is cut as green fodder for animals.

• Wheat is grown in all zones of Bhutan. Mostly, it follows paddy rice or maize but no data are available on percentages. Wheat is irrigated after paddy and rainfed after maize and is always grown as a winter crop. The spring wheat variety Sonalika is predominant up to 2500 masl; local winter wheats are grown at higher elevations.

• Production methods reflect the low importance and subsistence nature of this crop. Very little inorganic fertilizers are used and most nutrients come from applied farm manure. Harvesting and threshing are done by hand. Very little detailed data are available on the production practises for this crop.

• The Centre for Agricultural Research and Development (CARD) at Wangdiphodrang initiated research on wheat in 1982. Work on selection of suitable materials to replace Sonalika has received most attention. Little work has been done on agronomy issues, although an FAO fertilizer project has several years of data on wheat responses to N-P-K in different parts of the country. Stripe rust is the major disease problem and Sonalika is susceptible.

• The economics of wheat production are negative in terms of net returns and returns to labor in the Wangdi-Punakha Valley where labor costs are very high. In three other promotional areas where labor is cheaper, net returns and returns to labor are good assuming the government will procure the excess production at 3 Ngultrums (US$ 0.21)/kg. With the policy of the government to promote wheat,
research must concentrate on technology that reduces the cost of production and use of labor, while at the same time increases yield. Until costs of production can be reduced, wheat production in Bhutan will not be competitive with imports from India.

- Crop management research offers many opportunities for increasing productivity. Improved crop establishment, earlier planting, zero tillage, mechanization, use of fertilizer and irrigation and water management are discussed in technical terms to meet this goal.

- Fertilizer issues especially efficiency, use of organic manures, green manuring, and the problems of sustainability and yield decline are urgent issues for research. This latter problem must receive attention to prevent the productivity of the land from declining with time.

- Varietal development is discussed in relation to five major environments with distinct breeding needs.

- Five stations are described as suitable places for the wheat research needs of the country. Staffing and equipment requirements for these stations are described. It is recommended that wheat not be a separate entity, but be treated as a component of a system. Rice-wheat, maize-wheat, and rainfed winter wheat are the major systems for study.

- The seed supply system available at the National Seed and Plant Program, Paro (NASEPP) will be sufficient to meet the seed needs of the country.

- The recommendations are made assuming that government priority for wheat will remain. This means that procurement, price, and labor policies, import of fertilizer, credit and manpower for research and extension will continue to be favorable for wheat production.

- Recommendations are made to improve the database constraints that exist on most aspects of wheat production in Bhutan. This is a priority issue in the Sixth 5-Year Plan.

- It is recommended that a wheat coordinator be appointed at CARD, under the Chief Research Officer of that station, to coordinate all the activities of research, extension, input supply and training for wheat in Bhutan. Terms of reference for this coordinator are presented.

- There are no scientists specifically trained in wheat doing research on the crop in Bhutan. The wheat coordinator and other wheat staff should be given wheat training, including the short courses offered at CIMMYT. On return they would train other research and extension staff in the country.

- The coordinator should liaise and work closely with the National Agricultural Training Institute at Paro to ensure the curriculum on wheat production is up to date so that the new diploma holders are knowledgeable about this crop.
• Present links of research with extension are good. These must be maintained so that new findings are quickly transferred to farmers.

• There is good technical potential to increase yields of wheat in Bhutan through environment-based research and extension programs. If yields are improved, economic returns will be more encouraging. Efforts on wheat should concentrate on the western side of Bhutan at first, since this is where most imported wheat is distributed.
Wheat and Wheat Development in Bhutan

Introduction

Wheat is the third most important crop in Bhutan in area and production after rice and maize (Table 1). It is grown in rotation with the two staples, but is rarely marketed for cash. As a consequence, it has received much less attention from research and extension compared with rice and important cash crops. Wheat also receives less farmer interest because it is not a preferred food. However, rapidly growing urban centers are utilizing substantial amounts of wheat and wheat products imported from India.

The Royal Government of Bhutan wishes to intensify wheat production for two reasons stated as objectives in the Sixth 5-Year Plan:

- To achieve self-sufficiency in food grains.
- To increase the income of small-scale farmers who form 90% of the population.

In pursuance of these objectives, the Department of Agriculture (DoA) has asked the International Maize and Wheat Improvement Center (CIMMYT) to draw up a master plan outlining possible avenues and necessary steps for wheat intensification that are integrated into existing institutions and development projects. Specifically, this plan should look at:

- The main features of present wheat production.
- The current status of wheat research.
- Ways to strengthen wheat research and extension.
- The micro- and macro-economic framework under which wheat is produced and production can be increased.

Some general restrictions limiting this task need to be mentioned. Countrywide figures on area planted to wheat and production are not available beyond the 1984 general agricultural survey (5). The 1984 data dealt only with production, area, and yield and did not allow differentiation by environment, crop rotation, production methods, varieties, or economic conditions for wheat production. Wheat was separated from barley. More recent surveys have been more detailed and contain some detailed wheat information including economics, but all concentrated on specific areas or crops. None focused on wheat and none could be used to determine trends in area or production. As a result, the database to draw up this report was extremely weak. Every effort should be made to upgrade the statistical database that is necessary for all development and planning efforts of this type, not only for wheat.

A two-member survey team from CIMMYT (regional staff for South and Southeast Asia) visited Bhutan Oct. 18-Nov. 1, 1988 at the request of the DoA which wanted the results as early as possible. This is a time when nearly no wheat is in the ground.

A list of the publications and reports available to the team is included in the references section. Besides these reports, the findings are based on observations during previous visits to Bhutan by one team member and on interviews during a field trip. The two scientists traveled from Thimpu to Wangdiphodrang to Tongsa and Gaylegphug and returned via Dhampu and
Table 1. Area of maize, rice, wheat, and barley and production of wheat and barley by dzongkhags (1984 Baseline Survey, DoA, Thimphu, Bhutan).

<table>
<thead>
<tr>
<th>Dzongkhag</th>
<th>Area in Acres</th>
<th>Production MT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maize</td>
<td>Rice</td>
</tr>
<tr>
<td>Paro</td>
<td>998</td>
<td>5,113</td>
</tr>
<tr>
<td>Tashigang</td>
<td>22,962</td>
<td>8,120</td>
</tr>
<tr>
<td>Samchi</td>
<td>26,691</td>
<td>15,654</td>
</tr>
<tr>
<td>Wangdiphodrang</td>
<td>237</td>
<td>4,520</td>
</tr>
<tr>
<td>Thimphu</td>
<td>1,126</td>
<td>4,399</td>
</tr>
<tr>
<td>Punakha</td>
<td>256</td>
<td>3,589</td>
</tr>
<tr>
<td>Haa</td>
<td>856</td>
<td>285</td>
</tr>
<tr>
<td>Bumthang</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gaylegphug</td>
<td>26,194</td>
<td>10,362</td>
</tr>
<tr>
<td>Shemgang</td>
<td>4,574</td>
<td>2,671</td>
</tr>
<tr>
<td>Chirang</td>
<td>19,239</td>
<td>7,402</td>
</tr>
<tr>
<td>Tongsa</td>
<td>3,176</td>
<td>1,888</td>
</tr>
<tr>
<td>Samdrupjongkhar</td>
<td>15,334</td>
<td>5,020</td>
</tr>
<tr>
<td>Lhuntshi</td>
<td>4,076</td>
<td>2,867</td>
</tr>
<tr>
<td>Mongar</td>
<td>8,641</td>
<td>1,358</td>
</tr>
<tr>
<td>Pemagatshel</td>
<td>5,217</td>
<td>361</td>
</tr>
<tr>
<td>Dagana</td>
<td>4,912</td>
<td>1,807</td>
</tr>
<tr>
<td>Gasa</td>
<td>0</td>
<td>228</td>
</tr>
<tr>
<td>Total</td>
<td>144,489</td>
<td>75,644</td>
</tr>
</tbody>
</table>
Wangdi to Thimpu. They also made a separate trip to the Paro Valley to see The National Seed and Plant Program (NASEPP) and the Agricultural Mechanization Centre (AMC). Scientists, extension workers, project staff, a few farmers, and anyone with a knowledge of the agriculture in these areas were interviewed. A couple of days were also spent in discussions with staff at the DoA in Thimpu. A list of the main contributors is in Appendix I.

The recommendations accept the objectives of achieving cereal self-sufficiency and increasing farmers’ income. Technology recommendations attempt to increase output at reasonable cost and reducing inputs, especially labor, wherever possible. However, with the given topography and infrastructure of Bhutan, it will not be possible to compete with wheat imports from India in the near future.

For additional information on Bhutan and its agriculture, the World Bank report "Bhutan. Development in a Himalayan Kingdom, 1984" (5) is an excellent reference. In the following sections, the survey team presents its findings and recommendations within the limits just described.

**Wheat in Bhutan**

**Production, Imports, and Utilization**

**Production**

The only statistics available on area and production for wheat and barley for the entire country are presented in Table 1. These data were collected by the Planning Division of the DoA as a baseline survey in 1984 (4). It forms the basis for most of the consultancy reports and technical papers written since 1984. Wheat and barley acreages are combined in the official 1985 and 1987 statistics published as the Statistical Yearbook of Bhutan by the Central Statistical Office (15). These statistics show wheat and barley to rank fourth in area and production of cereals behind maize, rice, and buckwheat/millet. The major wheat growing areas are in western Bhutan, but Tashigang Dzongkhag in the eastern part of the country ranks first when wheat and barley areas are combined (Table 1). The data show that wheat is grown in all and barley in all but one of the dzongkhags of Bhutan. The crops are also grown on land from 300 masl in the south to over 3000 masl in the north.

Yields are low and about the same for both crops at 0.45 t/acre (1.1 t/ha). Attempts to obtain data on area and production of wheat since 1984 were unsuccessful. The data in Table 2 provide statistics for 1981 and 1984 and the targeted area and production in the Fifth 5-Year Plan for 1987. The Fifth Plan strategy gave emphasis to the intensification of existing land use rather than the extension of agriculture into new areas. There was common agreement among the people who the team talked to that the wheat/barley target set for 1987 by the Fifth Plan was not met. The rapid adoption of potato as a winter cash crop and its competition for wheat land is one explanation given for the failure. The unavailability of a suitable price and market for excess wheat production is another logical explanation.

Two surveys were initiated in 1987 and preliminary unofficial reports summarizing these data were available (2, 4). An agronomy survey was conducted in western Bhutan by the Central Statistical Office (CSO) and the Planning and Policy Division (PPD) of the DoA. Their data for wheat/barley acreage are presented in
Table 2. Trends in crop area and production of major cereal crops 1981-87.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop area ('000 ac)</th>
<th>Production ('000 MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat/Barley</td>
<td>29.6</td>
<td>35.6</td>
</tr>
<tr>
<td>Rice</td>
<td>69.2</td>
<td>75.6</td>
</tr>
<tr>
<td>Maize</td>
<td>140.3</td>
<td>144.5</td>
</tr>
<tr>
<td>Buckwheat/millet</td>
<td>38.3</td>
<td>50.9</td>
</tr>
<tr>
<td>TOTAL</td>
<td>277.4</td>
<td>306.6</td>
</tr>
</tbody>
</table>

1981 and 1984 data are from surveys undertaken by the Department of Agriculture.

1987 data refer only to targets for the Fifth Plan, not actual acreage or production.

Table 3. Comparison of areas of wheat and barley in 1984 and 1987 in western Bhutan.

<table>
<thead>
<tr>
<th>Dzongkhags</th>
<th>Area in Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1984 Barley</td>
</tr>
<tr>
<td>Thimphu, Paro, Samchi, Chukha</td>
<td>1,719</td>
</tr>
<tr>
<td>Chirang</td>
<td>299</td>
</tr>
<tr>
<td>Haa</td>
<td>70</td>
</tr>
<tr>
<td>Dagana</td>
<td>247</td>
</tr>
<tr>
<td>Punakha</td>
<td>124</td>
</tr>
<tr>
<td>Wangdiphodrang</td>
<td>948</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,407</strong></td>
</tr>
</tbody>
</table>

a 1987 Agronomy survey, Central Statistical Office and Planning Division of Department of Agriculture. Whether figures refer to wheat alone or combine wheat and barley is not known.
Table 3. They used a different sampling frame than in 1984 and unfortunately no comparison can be made between 1984 and 1987 data nor can any conclusions be drawn on possible trends in wheat/barley area over this period.

A second baseline survey, supported by the International Fund for Agricultural Development (IFAD), was conducted in the Tashigang-Mongar districts in February and March 1987 (4). Wheat (6%) and barley (5%) were grown in winter; 71% of the land was left fallow. Yields averaged 400 kg/acre (988 t/ha) for both crops, which is slightly lower than recorded in 1984. However, there were no statistics on area and production for the two districts to compare with the 1984 data.

Obviously, for wheat planning purposes, much more reliable, comparative data on area, crop rotation, elevation stratification, and the economics of production across years is needed. Admittedly, this is a difficult task since most of the wheat/barley is grown for subsistence.

Imports
Nearly all the wheat/barley grown in Bhutan is grown for local consumption and very little is marketed. Any excess produced is used as barter for buying rice, the preferred staple food. The wheat products found in the village stores and urban areas come either from either imports of the Food Corporation of Bhutan (FCB) or imports by local private traders.

Table 4 shows the quantity of wheat and wheat products imported by FCB from 1984-85 to 1987-88. There has been a trend of increasing imports over this period with present imports exceeding 300 MT per month. The figure for 1987-88 in Table 4 was based on 15 months of data from FCB. From April 1, 1987 to June 30, 1988, FCB imported 5519 MT or 368 t/month. Chhukha received a large quantity in 1987-88 probably to feed the laborers at the construction site of the new Hydel dam. Extra wheat was also utilized in Samchi and Sandrupjongkhar for workers at two cement factory development projects.

The distribution of this imported wheat by Dzongkhag is also shown in Table 4. Seventy-five percent went to the four districts of Chhukha, Thimphu, Samchi, and Paro in western Bhutan. If the districts of Ha, Wangdiphodrang, Punakha, and Bumthang are included, more than 87% of the wheat distribution is covered. These eight western dzongkhags are well connected by roads with Phuntsholing on the Indian border. This pattern of distribution should guide the selection and planning of agricultural production areas needed to attain self-sufficiency in cereals as mentioned in the Fifth and Sixth Plans.

In addition to wheat imported by FCB, wheat is also imported by other groups. About 1000 MT of wheat were imported in June 1988 by the Drahla Flour Mill in Phuntsholing. The World Food Program (WFP) imported 750 MT in 1983. An FCB official estimated that WFP presently imports about 100 MT/year for its ‘food for work’ and other programs. An uncertain quantity is imported by local private traders. No figures were available on 1987/88 imports by this group, although privately imported Indian wheat products were abundant in shops at Gaylegphug, indicating imports do occur. A policy paper on food grains prepared in 1983 by FCB indicated 3000 MT/year were imported by the private sector. It would be useful to have reliable figures for 1988.
Table 4. Wheat imported and distribution by the Food Corporation of Bhutan from 1984-85 to 1987-88, by dzongkhag.

<table>
<thead>
<tr>
<th>Dzongkhag</th>
<th>Quantity in MT</th>
<th>% of total imports in 1987-88</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1984-85</td>
<td>1985-86</td>
</tr>
<tr>
<td>Chukha</td>
<td>830</td>
<td>1,168</td>
</tr>
<tr>
<td>Thimphu</td>
<td>1,117</td>
<td>859</td>
</tr>
<tr>
<td>Paro</td>
<td>115</td>
<td>233</td>
</tr>
<tr>
<td>Sub-totala</td>
<td>2,027</td>
<td>2,142</td>
</tr>
<tr>
<td>Haa</td>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>Wangdiphodrang</td>
<td>55</td>
<td>103</td>
</tr>
<tr>
<td>Punakha</td>
<td>26</td>
<td>61</td>
</tr>
<tr>
<td>Bumthang</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Samdrupjongkhar</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Gaylegphug</td>
<td>42</td>
<td>37</td>
</tr>
<tr>
<td>Tashigang</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Chirang</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>Shemgang</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Mongar</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Tongsa</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Pemagatshel</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Lhuntshi</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dagana</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>2,278</td>
<td>2,518</td>
</tr>
</tbody>
</table>

\[a\] Chukha dzongkhag was formed from parts of Paro, Samchi and Thimphu dzonkhags for 1987-88 data.

\[b\] Data available from FCB were from April 1, 1987 to June 6, 1988. Assuming equal distribution per month these data were converted to a 12-month basis for comparison with other data.
The policy of the Royal Government of Bhutan is to increase domestic production of wheat to replace imports. The Government also wants wheat production to expand even more to help substitute for rice imports because attaining self-sufficiency in rice is more difficult. The government proposes to cut rice imports increasing rice prices and decreasing availability, hoping that people will be encouraged to eat the extra wheat produced as a substitute for rice. Similarly, increased maize production is planned.

Utilization
The preferred staple of Bhutan is rice, which is often consumed four times a day. Wheat and barley are less preferred and are usually prepared in dishes resembling rice. Some wheat is eaten as flour in chapatis, mainly by the foreign labor force from India and Nepal. Tourists, foreign consultants, and Bhutanese in urban areas consume most of the wheat as bread.

A certain amount of wheat and barley is used in making alcoholic beverages. There is little information on the percent of wheat/barley used in this way and there were considerable differences of opinion among people interviewed. The draft of an IFAD baseline survey recently completed in Tashigang-Mongar districts indicates that 12 and 26% of the wheat and barley grown in these eastern areas, respectively, are used for alcohol production (14). Respective consumption figures for wheat and barley in that area were 67 and 56%, respectively. In contrast, a number of qualified people interviewed and a survey by the Bhutan National Potato Project (BNPP) of the Bumthang area (16) estimate that at least 50% of the wheat and barley production goes into alcohol production.

Because green fodder becomes limiting in many areas of Bhutan in the dry winter season, an undetermined area of wheat is grazed or cut green as fodder. In Paro District, late-sown wheat is often cut for fodder purposes to provide animal feed, but also to clear land for preparation of dry seedbed rice nurseries. At these higher elevations (environment 2 in Table 5), there is some conflict in land use between the wheat and rice crops.

Almost all wheat and barley is raised for local consumption. Very little is sold as a cash crop. Farmers grow enough to meet their needs and any excess is used as barter for procuring rice. In this respect, Bhutan is self-sufficient in wheat production in the rural areas, but is not self-sufficient in the urban areas.

Agricultural Zones, Wheat Environments, and Weather

Agricultural zones
The policy and planning cell of the DoA proposed the following agricultural zones for planning purposes. Note that the system for wheat environments suggested later follows roughly these agricultural zones.

- Zone 1: High-altitude areas with limited cultivation up to an elevation of 4250 m. These areas are mostly in the northern areas of Gasa, Thimphu, and Tashigang Dzongkhags. They are thinly populated and yak herding is the main occupation. Animal produce is bartered with farmers in rice growing valleys to obtain supplies of rice.

- Zone 2: High-altitude cultivation areas above 2500 m mainly in valley areas of Haa, Paro, Thimphu, Wangdiphodrang, Gasa, and Bumthang Dzongkhags. Animal husbandry and cropping are practiced in these areas.
Table 5. Selected climatic data for the wheat environments of Bhutan.

<table>
<thead>
<tr>
<th>ENVIRONMENT 1: HIGH ALTITUDES</th>
<th>MONTH</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>Total or Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bumthang - Ura, 3052 m</td>
<td></td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>10</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>14</td>
<td>0</td>
<td>7</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Data base: 1985-87</td>
<td></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>28</td>
<td>36</td>
<td>239</td>
<td>177</td>
<td>98</td>
<td>119</td>
<td>220</td>
<td>11</td>
<td>0</td>
<td>931</td>
</tr>
<tr>
<td>Average monthly temperature (°C)</td>
<td></td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>14</td>
<td>17</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>16</td>
<td>14</td>
<td>11</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Average monthly rainfall (mm)</td>
<td></td>
<td>0</td>
<td>5</td>
<td>14</td>
<td>22</td>
<td>31</td>
<td>87</td>
<td>136</td>
<td>134</td>
<td>70</td>
<td>18</td>
<td>5</td>
<td>1</td>
<td>523</td>
</tr>
</tbody>
</table>

| ENVIRONMENT 2: UPPER MID-ALTITUDE |
| RICE GROWING ENVIRONMENTS |
| Paro, 2250 m |
| Data base: Rainfall 1976-87, temp. 1977-87 |
| Average monthly temperature (°C) | 13 | 16 | 18 | 21 | 23 | 26 | 25 | 24 | 24 | 20 | 16 | 14 | 20 |
| Average monthly rainfall (mm) | 1 | 3 | 7 | 25 | 56 | 111 | 146 | 134 | 76 | 46 | 7 | 9 | 620 |

| ENVIRONMENT 3: LOWER MID-ALTITUDE |
| RICE GROWING ENVIRONMENTS |
| Wangdiphodrang, 1374 m |
| Average monthly temperature (°C) | 9 | 12 | 14 | 16 | 17 | 20 | 20 | 20 | 19 | 17 | 13 | 10 | 16 |
| Average monthly rainfall (mm) | 2 | 17 | 72 | 123 | 49 | 119 | 311 | 126 | 185 | 50 | 12 | 12 | 1,078 |

| ENVIRONMENT 4: MID-ALTITUDE MAIZE |
| GROWING ENVIRONMENTS |
| a) Rangthong - Tashigang, 1993 m; low rainfall |
| Data base: 1985-87 |
| Average monthly temperature (°C) | 12 | 13 | 17 | 19 | 21 | 23 | 22 | 23 | 22 | 19 | 16 | 14 | 18 |
| Average monthly rainfall (mm) | 3 | 25 | 29 | 51 | 75 | 413 | 631 | 356 | 291 | 81 | 5 | 16 | 1,984 |

| ENVIRONMENT 4: LOW ALTITUDE |
| TERAI AREAS |
| Bhur Farm 375 m |
| Average monthly temperature (°C) | 18 | 20 | 22 | 24 | 28 | 26 | 26 | 28 | 27 | 25 | 21 | 18 | 22 |
| Average monthly rainfall (mm) | 14 | 25 | 60 | 165 | 384 | 1,060 | 1,483 | 822 | 766 | 224 | 33 | 27 | 5,063 |
The main crops are buckwheat, wheat, barley, and potatoes. Rice cannot be grown, but is the preferred food grain. It is obtained by bartering animal produce or hiring out as seasonal labor.

• Zone 3: Rice growing valleys of western Bhutan. This includes the rice growing valleys of Paro, Thimphu, Punakha, and Wangdiphodrang. The first two are from 2000 to 2500 masl; the other two from 1200 to 2000 masl.

• Zone 4: The maize growing belt of central, eastern, and southern Bhutan from 800 to 2500 masl. Some rice growing pockets occur in this zone where topography and irrigation availability permits.

• A possible fifth zone occurs in the small, lowland Terai land (300-600 masl) that exists in southern Bhutan along the border with India. Soils in these areas are often shallow, rocky, and of poor agricultural quality. Where soils are suitable and irrigation is available, double rice cropping or rice-wheat can be practiced.

According to the 1984 baseline survey, wheat and barley are grown on the following land types in Bhutan:

• Wetland--12,205 acres
• Dryland--17,890 acres
• Tseri land--295 acres
• Total--30,390 acres (12,303 ha)

Each of the above agricultural zones and the wheat environments listed below can include one, two, or all land types.

The wetland represents the irrigated, terraced paddy soils where wheat follows rice. Irrigation is available on a proportion of this land for growing wheat. Not all the land after rice harvest is planted to winter crops such as wheat. Lack of irrigation, problems with stray cattle, decline in soil fertility because of double cropping, and lack of markets for surplus production are possible reasons for limiting the winter crop.

Dryland is the nonterraced rainfed areas in zones 2 and 4. Wheat or barley grow mostly as single crops in zone 2. In zone 4 maize-wheat is the major cropping pattern on dryland closely followed by maize-millet. The draft of the Tashigang-Mongar baseline survey (4) provides some information on the dryland cropping in these districts. Seventy-one percent of the land is kept fallow in the winter because of lack of moisture, unsuitability of land, crop damage by cattle, and labor shortage. Women, who play a major labor role in crop production from planting and weeding to harvest and threshing, weave to earn cash during the winter and, as a result, are less available for winter cropping. Only land preparation is solely done by men. The cropping intensity in the above area was 127% with wheat (6%), barley (5%), buckwheat (9%) and potato (4%) as the major winter crops. Potato has probably replaced some of the wheat and barley land over the past few years because of its popularity as a cash crop in the region. Potato has also rendered wheat less necessary for food as the cash income is partly used to buy rice. However, in the future, wheat and barley will be necessary crops to be planted in rotation with potatoes since continuous potato cultivation leads to pest and disease build up and yield decline.
**Wheat environments**

Based on the above descriptions, the following distinct environments can be defined for wheat research:

- **Environment 1**: Rainfed winter wheat as grain or fodder in high-altitude areas above 2500 masl. Local winter wheat varieties are sown in September/October and harvested in June/July. Very little is known about the extent, source, production, or performance of these local varieties in this environment. Naked varieties of barley are also grown in this zone as a spring and winter crop, but no data are available on their relative proportion or exact planting or harvesting time.

- **Environment 2**: Irrigated spring wheat for grain or fodder following paddy on higher elevations (2000 to 2500 masl, corresponding to the higher valleys of zone 3 above) where frost occurs and problems of turn-around time in the rice-wheat rotation exist. The spring wheat variety Sonalika is planted in November or December after harvest of rice in the terraced fields with irrigation. Because of the altitude, late planting, fodder scarcity, and conflicts with land for preparing dry seedbeds for rice, up to 50% of this crop will be cut green before maturity. Wheat is harvested in May.

- **Environment 3**: Irrigated spring wheat for grain or fodder following paddy on lower elevations (1200 to 2000 masl, corresponding to the lower valleys of zone 3 above). Sonalika is sown in Nov./Dec. under irrigation and harvested in April to early May. Conflicts between wheat and preparation of seedbeds for rice do not exist in these areas, but wheat is still cut green to provide fodder for animals. The opportunity exists to fit a green manure crop, such as Dhalicha (*Sesbania aculeata*), between the wheat harvest and rice transplanting in these warmer areas. This has important implications for fertility management and will be discussed later.

- **Environment 4**: Rainfed spring wheat on various elevations (800 to 2500 masl, corresponding to zone 4 above) mostly after rainfed maize. Drought stress is limiting to yield. Spring- and autumn-sown barley is also found in this environment. Crop rotations of maize, buckwheat, finger millet, barley, and wheat are more variable than in other environments.

- **Environment 5**: Irrigated spring wheat in low elevation Terai areas (300 to 600 masl, corresponding to the proposed zone 5 above). Sowing time is again in November/December, but because of the warmer climate, harvest is as early as March/April and rice double cropping is possible if water supply is sufficient.

**Climate**

Because of its varied topography, Bhutan is climatically suitable for all types of wheat. Table 5 presents temperature and rainfall data for locations within the various wheat environments listed above. Altitude and temperature play an important role in determining wheat types (spring or winter), cropping patterns (double or single cropping), harvest dates, possible conflicts with succeeding crops, and diseases (rusts, smuts, and leaf blights). Frost can cause damage during flowering at higher elevations.

Winter rainfall varies and can support the growing of rainfed wheat where sufficient soil moisture holding capacity exists. The possible restriction of rooting
by the paddy soil plow pan probably means irrigation is necessary for the paddy-
wheat rotation. The possibility of heavy premonsoon rains in April to May can
cause problems for harvesting and drying the wheat crop, especially in the
southern wetter environments (environment 5) of Bhutan. This increases the risk
of growing wheat in those areas.

The collection of weather data is presently being improved to provide better
information in the future. The data presented in Table 5 are of questionable
reliability and some of the sites only have data available since 1985.

Production Methods
There is very little micro-level data on production practices used by farmers for
wheat. The best data available are in the DoA/International Rice Research
Institute (IRRI) rice-based cropping systems report for the Wangdi-Punakha
Valley (13). This report states that two plowings and one to two plankings are
given for wheat in the 4 weeks from rice harvest to wheat seeding during which
55 kg/acre (136 kg/ha) of seed are broadcast. Organic manure is used on wheat,
but no inorganic fertilizers. More irrigations are given in the lower paddy fields
than the upper fields, up to a maximum of three. About 26% of the higher
elevation fields are weeded compared to only 2% of lower fields. Lower yields are
obtained when sowing is delayed and at higher altitudes probably because of
less moisture. Higher yields are obtained on better soil types and where seeding
rates are higher. Difficulties with land preparation probably result in poor
seedbeds and poor plant stands. This coupled with late planting (Dec.-Jan.) and
low fertilizer rates may account for the low yield (350 kg/acre or 864 kg/ha).
Similar production methods are probably used in other areas and the following
generalizations are made from observations during previous visits to Bhutan,
comments in other reports, and information from interviews.

Land preparation
Land preparation varies from broadcasting seed and plowing once to four to six
plowings before seeding. No data are available on the effect of land preparation
quality or number of plowings on plant stand.

Seed and seedrates
NASEPP data indicate that more than 90% of the farmers must use their own
seed since only 95 MT of seed are distributed by NASEPP. In Gaylegphug area,
problems with seed storage during the wet season require farmers to rely more
on seed from NASEPP than themselves. Seed rates vary from 40 to 55 kg/acre
(99 to 136 kg/ha) and all farmers broadcast and incorporate seed by plowing.
The high percentage of NASEPP seed used by farmers is related to storage
problems and the fact that many farmers do not store seed at all.

Fertilizer use
FAO fertilizer reports (9) indicate that inorganic fertilizer use on wheat is low
despite economic responses to this input. Most farmers who use fertilizer use
organic sources of variable quality. Some suggest that when organic fertilizer is
used on wheat, none is used on the next rice crop. FAO data (9) show that
western Bhutan uses more inorganic fertilizer (57%) than the eastern (19%),
central (17%), or southern parts (7%). However, most of this fertilizer is used on
potato (57%), apples (25%), and paddy (9%). Only 105 MT or 5% was used on
maize, wheat, and buckwheat combined.
Fertilizer prices used by the planning division of DoA for 1988 were as follows:

- Urea—2.32 Nu. (US$ 0.16)/kg
- SSP—1.16 Nu. (US$ 0.08)/kg
- MOP—1.35 Nu. (US$ 0.09)/kg

**Weeds**
Some farmers do handweeding. *Chenopodium album* was recorded as a problem in the south and there were some reports that *Phalaris minor* had been introduced from India. In general, weeds are not a major constraint to production.

**Irrigation**
Wherever possible, wheat after rice is given one to three irrigations. In the Punakha Wangdi Valley, two irrigations, 50 and 90 days after sowing, are common. The first is most probably too late to meet the most critical growth stage at crown root initiation. (CARD is currently investigating this problem.) A pre-irrigation is also needed to have sufficient moisture for germination. After pre-irrigation the farmer waits for the correct moisture for plowing and sowing.

**Harvesting**
Harvesting is done by hand and threshing, either by pounding the wheat ears or trampling by bullocks. Losses using either method have not been assessed. Recently, some Japanese power threshers were introduced in the Punakha, Wangdi, and Paro Valleys and used on contract for threshing. However, their use is limited to valley bottoms and areas accessible by road. The rice paddle thresher is not suitable for wheat, although there was a report that reversing the movement of the paddle thresher improved the threshing of wheat.

Obviously, more detailed micro-level surveys of actual farmer practices in the major wheat growing areas are essential for planning and setting priorities for intensification of wheat production programs. A full understanding of present farmer practices and constraints is needed to focus research on priority problems.

**Varieties**
Most of the wheat in Bhutan is grown during the winter, but the majority of it is spring wheat in technical terms because these varieties do not require specific cold spells or day length in order to flower and set seed.

**Winter wheat**
True winter wheat requiring vernalization for flowering is grown at high elevations above about 2500 m. The exact area is not known—an estimate is 30% of the total area. Winter wheat’s contribution to total production is much lower because it is not irrigated. Average yield of a variety observed in Phubjika Valley in March 1988 was said to be 162 kg/acre (400 kg/ha).

All winter wheat varieties are of local origin and cold tolerant in their juvenile stage down to -10°C without snow. They also have to tolerate drought during the winter months. BNPP has tried several European winter wheats and lines from a CIMMYT winter wheat crossing block. The latter showed promise, but this work could not be continued.

**Spring wheat**
Below 2500 masl Sonalika seems to be only one variety grown, although CARD staff mentioned in 1986 that there may be still some fields planted with
Kalyansona. Sonalika and its sister lines are still widely grown on millions of hectares in India, Bangladesh, Pakistan, and Nepal. It is very early, therefore tolerant to late sowing; has white bold grain of limited yield potential; and is moderately susceptible to leaf rust (Puccinia recondita) and highly susceptible to stripe rust (P. striiformis). Leaf rust is a potential threat in southern Bhutan. Stripe rust did a lot of damage in wheat in the Punakha Valley in 1985 and some in 1986, but occurred too late to cause yield reductions in 1987 and 1988. This dependence on one variety is very risky due to the possibility of substantial crop losses in years favorable to the disease. New races of rust are also continually evolving and the race spectrum can easily change and make the variety even more susceptible.

Barley and rye
Barley was grown on 9230 acres (3737 ha) in 1984 (35% of the wheat area in 1984). The survey team found varieties suitable for spring and winter sowings; however, they are not used in any type of improvement work nor have their characteristics been described properly.

BNPP reports the existence of local rye varieties (8), but nothing is known about their characters nor the existence of commercial production.

Breeding work
CARD started introducing new genetic material during the 1982-83 season and since then has annually received test lines from CIMMYT, IRRI, India, Bangladesh, Pakistan, and most recently Nepal. Statistics of these introductions are given in Table 6. A breeding scheme has been developed (Table 7) and candidate varieties have been tested in Farmers' Field Trials in several locations in the Wangdi Punakha Valley since the 1986-87 season. No new varieties have been released so far. Currently, the most promising lines for release are of Nepali origin. Table 8 lists the varieties in the Advanced Yield Trial for 1988-89. Small nurseries given to the Chirang Hill Irrigation Project (CHIP) and Bhur Farm indicate that Wangdiphodrang selections are of limited use for these distinct environments.

CARD has also worked on durum wheat and barley, but has ceased this work because its station is not in a target area for these crops. A small amount of selection work on triticale is still going on.

Pests
The European Economic Community (EEC) Plant Protection Project within the DoA has identified 26 fungus diseases on wheat and 14 on barley. Of these only a few present a problem, and a few more could become problems with intensification or given favorable weather during a certain year. They are dealt with here according to the wheat environments described earlier.

Septoria nodorum and S. tritici could occur at high elevations (environment 1). One BNPP report mentions S. nodorum, but the severity of the attack is not known. Erysiphe graminis (powdery mildew) might also build up to an epidemic, especially on wheat sown in spring if many cloudy days occur during monsoon season. If selection work is taken up for high elevations, lines with sufficient genetic resistance can be introduced.

On mid-elevation areas (environments 2 and 3), Puccinia striiformis (stripe rust) caused substantial crop losses in 1985 and 1986. This is presently the only
Table 6. Introductions of wheat lines tested at CARD from 1983-84 to 1986-87.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of lines received</th>
<th>No. of lines selected for further tests</th>
<th>Origin of lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983-84</td>
<td></td>
<td>163</td>
<td>CIMMYT, India, Bangladesh, IRRI</td>
</tr>
<tr>
<td>1984-85</td>
<td>444</td>
<td>109</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>1985-86</td>
<td>12</td>
<td>3</td>
<td>IRRI/CIMMYT</td>
</tr>
<tr>
<td>1986-87</td>
<td>502</td>
<td>161</td>
<td>CIMMYT, Pakistan, Nepal, India</td>
</tr>
</tbody>
</table>

Table 7. Germplasm selection system at CARD from Introduction of lines to variety release.

<table>
<thead>
<tr>
<th>Number of entries</th>
<th>Year</th>
<th>Name of nursery or trial and field layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 500</td>
<td>1</td>
<td>Introduction Nurseries: single row or plot, Introduced lines many sources.</td>
</tr>
<tr>
<td>Up to 100</td>
<td>2</td>
<td>CARD Observation Nursery: single plots.</td>
</tr>
<tr>
<td>Up to 50</td>
<td>3</td>
<td>Initial Evaluation Trial: replicated plots, one location.</td>
</tr>
<tr>
<td>20 to 30</td>
<td>4</td>
<td>Advanced Evaluation Trial: replicated plots, different growing conditions like early/late, rainfed/irrigated, high/low fertilizer.</td>
</tr>
<tr>
<td>5 to 10</td>
<td>5</td>
<td>Farmers' Field Trial: replicated plots in several farmer's fields, researcher managed.</td>
</tr>
<tr>
<td>2 to 3</td>
<td>6</td>
<td>Regional Trial: extension/farmer managed, minikits, superimposed management options.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Release of promising lines.</td>
</tr>
</tbody>
</table>

Table 8. Lines in the CARD advanced evaluation trial 1988/89.

<table>
<thead>
<tr>
<th>Line Code</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL 1022</td>
<td>Nepal</td>
</tr>
<tr>
<td>BL 1044</td>
<td>Nepal</td>
</tr>
<tr>
<td>BL 1142</td>
<td>Nepal</td>
</tr>
<tr>
<td>HD 2380</td>
<td>India</td>
</tr>
<tr>
<td>HD 2323</td>
<td>India</td>
</tr>
<tr>
<td>Lyallpur 73</td>
<td>Pakistan</td>
</tr>
<tr>
<td>MN72350/Snb'S</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Chells'</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Vee 5 (Sen)</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Ulc/Pvm/Tan'S</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Turk'S</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Bnc/S/Pvm</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Vee/S/Pvm</td>
<td>CIMMYT</td>
</tr>
<tr>
<td>Celaya</td>
<td>Mexico</td>
</tr>
<tr>
<td>Mexico 82</td>
<td>Mexico</td>
</tr>
</tbody>
</table>
disease in Bhutan known to cause serious epidemics in certain years. *Puccinia recondita* (leaf rust) is observed to appear too late to cause any substantial losses, but an epidemic cannot be ruled out in the Wangdi Punakha Valley (environment 2). Both these diseases are best controlled through genotic resistance. Varieties presently under development at CARD carry suitable resistant genes.

Dryland foot rots caused by various fungi may be a problem for rainfed wheat (environment 4) and kill wheat seedlings soon after emergence. This needs to be investigated in the various rainfed wheat areas of Bhutan because these diseases can have significant affects on plant stand.

At low elevations (environment 5), *Drechslera tritici-repentis* and *D. sorokiniana* syn. *Helminthosporium sativum* (the latter is not mentioned in the EEC project's list of wheat diseases observed in Bhutan) may pose a problem, although no severe incidence is reported. A moderate degree of resistance is available in lines introduced to Bhutan from CIMMYT, Nepal, India, and Bangladesh.

*Ustilago segetum var. tritici* (Loose Smut) is present at all elevations in Bhutan, although usually at low levels of incidence. Seed from NASEPP is treated chemically and is free of this disease. For further control, extension staff should teach the farmers to rogue the infected heads as soon as they appear and feed them to their cattle. This disease as well as stripe rust can also affect barley, but no reports of their severity on this crop exist.

No significant insect pests occur on wheat in Bhutan during growth, but significant damage is caused by storage pest insects, particularly in the warmer and wetter southern areas. No research has been conducted on this issue.

**Economics of Wheat Production in Bhutan**

All of the wheat and barley produced in Bhutan is locally consumed with very little reaching the market. To encourage farmers to intensify wheat production and provide a surplus for marketing, the government must provide facilities to procure the extra production at a price that is favorable to farmers. In addition, services, inputs, and recommendations must be available to technically allow farmers to increase production.

The Planning Cell of the DoA compiled costs of production for growing a 800 kg/acre (1976 kg/ha) crop of wheat in the selected wheat promotional areas of Wangdiphodrang, Chirang, Gaylegphug, and Tashigang (17). These data were modified slightly in this report to include labor costs for plowing under the labor heading and not only under the animal land preparation heading. Our fertilizer and sowing costs also include the time for farmers to purchase their inputs at distribution centers, as well as to apply them to the field. One man-day was added to market the excess production. Table 9 summarizes the data for the four areas and for comparison includes a column for costs of production based on the data available from a DOA/IRRI survey in the Wangdi Punakha Valley (13).

Wheat production in the Wangdi Punakha Valley is not economic in terms of net benefits or returns to labor for either the improved package or the present farmer practice. The high cost of labor in this area accounts for this problem. Even if it is assumed that half of the work can be done outside labor peaks and would therefore cost only 25 Nu. (US$ 1.73)/day, net benefits per kg of wheat are so
Table 9. Cost of production for wheat in the selected wheat promotional areas of Bhutan using recommended practices.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Wangdi</th>
<th>Recommended practice</th>
<th>Gayleghphug</th>
<th>Tashigang</th>
<th>Farmer Practice, Wangdi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nu./ac mdays</td>
<td>Nu./ac mdays</td>
<td>Nu./ac mdays</td>
<td>Nu./ac mdays</td>
<td>Nu./ac mdays</td>
</tr>
<tr>
<td><strong>LABOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landpreparation</td>
<td>490</td>
<td>240</td>
<td>210</td>
<td>173</td>
<td>210</td>
</tr>
<tr>
<td>Manuring</td>
<td>245</td>
<td>120</td>
<td>150</td>
<td>120</td>
<td>280</td>
</tr>
<tr>
<td>Fertilizer applic.</td>
<td>35</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Sowing</td>
<td>35</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Weeding</td>
<td>105</td>
<td>150</td>
<td>150</td>
<td>270</td>
<td>35</td>
</tr>
<tr>
<td>Irrigation</td>
<td>140</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Harvesting</td>
<td>280</td>
<td>150</td>
<td>120</td>
<td>90</td>
<td>140</td>
</tr>
<tr>
<td>Threshing</td>
<td>245</td>
<td>90</td>
<td>150</td>
<td>135</td>
<td>140</td>
</tr>
<tr>
<td>Marketing</td>
<td>35</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL LABOR</strong></td>
<td>1,610</td>
<td>810</td>
<td>855</td>
<td>878</td>
<td>875</td>
</tr>
<tr>
<td><strong>Animal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>350</td>
<td>140</td>
<td>220</td>
<td>360</td>
<td>140</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeds</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>225</td>
<td>200</td>
</tr>
<tr>
<td>Manure</td>
<td>100</td>
<td>125</td>
<td>100</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Fertilizer Urea</td>
<td>125</td>
<td>60</td>
<td>111</td>
<td>112</td>
<td>0</td>
</tr>
<tr>
<td>SSP</td>
<td>110</td>
<td>58</td>
<td>116</td>
<td>116</td>
<td>0</td>
</tr>
<tr>
<td>MOP</td>
<td>23</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL MATERIALS</strong></td>
<td>558</td>
<td>476</td>
<td>527</td>
<td>553</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total mandays</strong></td>
<td>46</td>
<td>54</td>
<td>57</td>
<td>58</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total cost of production</strong></td>
<td>2,518</td>
<td>1,426</td>
<td>1,620</td>
<td>1,791</td>
<td>1,515</td>
</tr>
<tr>
<td>Cost Nu./kg. wheat</td>
<td>3.15</td>
<td>1.78</td>
<td>2.00</td>
<td>2.24</td>
<td>4.32</td>
</tr>
<tr>
<td>Return Nu./manday</td>
<td>32.43</td>
<td>33.04</td>
<td>29.00</td>
<td>25.64</td>
<td>16.40</td>
</tr>
<tr>
<td>Labor rate/day</td>
<td>35</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Yield kg/acre</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>350</td>
</tr>
</tbody>
</table>

1 Nu. = 1 Indian Rupee = 0.089 US$. Sources: 13, 17.
marginal that farmers will hardly be interested in surplus wheat production. Obviously, labor saving or cost reducing technology must be developed if the government is to be successful in this area. Land preparation is a major cost in this valley, but a critical factor in improving plant stands. The biggest cost in the farmers' practice is manuring, which has also benefits for the following rice crop. Ways must be found to reduce this cost. CARD has started to work on fertilizer needs and cost saving methods to be researched are recommended later.

The economics for the other three wheat promotional areas where cost of labor is only 15 Nu. (US$ 1.04)/day is more favorable, both in terms of net returns and returns to labor. However, the cost of labor could rise in these areas due to government policies and cost and labor reducing technology would be necessary then for these areas, too.

Milling of excess production must be considered in these promotional programs. Preferably, this should be done close to the production areas or on the way to the consumption points. Local village mills have neither the capacity nor the quality of product to cater to urban markets. The Dras mill at Phuntsholing was constructed for imports from India. To mill locally produced wheat there would involve significant transportation costs. Construction of small-scale mills near the wheat promotional areas would be more economical.

The FCB imports wheat from India at just over 2 Nu. (US$ 0.14)/kg. This is close to the average cost of production for the three promotional areas in Table 9 where labor costs are 15 Nu. (US$ 1.04)/day. However, the local production costs do not include the subsidies on seed (100% in the first year) or the subsidy on fertilizer transport and the possible losses from less than 100% recovery on credit. There are also hidden subsidies on the seed produced by NASEPP, buying of wheat through FCB, and transportation costs to the mill.

If the government procures the excess wheat at 3 Nu. (US$ 0.21)/kg from farmers, it will cost the government 1 Nu. (US$ 0.07)/kg more than direct import from India plus the subsidies mentioned above. Obviously, the development of cost and labor reducing production methods and technologies to increase wheat yields through wheat research is needed if Bhutan wants to become self-sufficient in wheat.

**Technical Issues for Intensification**

This is a discussion of the various technical issues that are constraining wheat yields in Bhutan. Each issue is discussed in terms of problems and possible solutions.

**Crop Establishment**

A prerequisite for high yields and efficient utilization of inputs is the establishment of a good plant stand. A good yield of wheat (1.2-1.6 t/acre or 3-4 t/ha) requires 300-350 spikes/m². Data taken from trials on farmers' fields by CARD in 1987-88 show figures close to 150 spikes/m² at harvest. This is partly due to poor tillering that results from fertility and moisture interactions, but also suggests that initial establishment was poor.

Sonalika has a 1000 grain weight close to 40 g. With 100% germination and a seadrate of 50 kg/acre (125 kg/ha), 313 plants/m² should be obtained. This number would be influenced by seed quality, depth of seeding, soil moisture
content, quality of land preparation, and some biotic factors. Observations in farmers' fields where land preparation was poor, seeds were placed at variable depths by broadcast seeding, and seed quality may have been below optimum showed that plant emergence is at best 156 plants/m² and in many cases much less. A survey of farmers' plant stands together with information on the factors listed above is a high priority research issue. Factors determined responsible for poor stands should then receive priority for developing solutions. This was suggested to CARD scientists and is on the 1989 research agenda.

The farmer practice of broadcast sowing and plowing in of seed is one factor causing poor germination, especially if soil moisture is insufficient. Broadcast sowing saves time compared to line sowing. Research on pre-irrigation timing and the time from irrigation to sowing is needed to check the effect of soil moisture on emergence. Farmers in other areas of South Asia plow, broadcast seed, and plow and harrow once more to improve plant establishment. Simple germination tests can check seed quality. Soaking of seed from 12 to 24 hours before broadcasting could help water imbibition by seeds and improve emergence. Pathologists need to look at the possibility of root rot organisms affecting plant stands in dryland wheat.

**Date of Sowing**

Late sowing is another factor responsible for reduced yield. Data from South Asia show that delays in sowing past Nov. 20 result in a loss of 1% per hectare per day of delay even when moisture and fertility is optimal. These significant losses can be avoided by encouraging farmers to sow as soon as possible after rice harvest. This is difficult if farmers prefer to thresh and store their rice crop before sowing wheat.

Late sowing is also related to soil moisture in rainfed areas. If rains do not occur, soil moisture declines with time and the later the crop is sown the less moisture is available for germination and plant growth. In rainfed areas sowing as early as possible should be encouraged. However, later maturing varieties may then be needed to avoid frost damage during flowering which would happen with short duration varieties such as Sonalika.

**Zero Tillage**

Zero tillage is becoming a widely accepted practice in developed countries and some countries in South Asia. In Pakistan, this practice has given excellent results in the rice-wheat areas of the country. In other South Asian countries, it is on the research agenda for testing. In zero tillage, the seed is drilled into the ground without tillage. A special inverted-T opener type drill is used in Pakistan for this purpose. The IRRI agricultural engineering group has been trying to adapt this drill to animal drawn and power driven implements. It would be very beneficial for the Agricultural Mechanization Center (AMC) group in Paro to collaborate with IRRI and CARD to develop suitable drills for farmers in Bhutan.

The major advantage of zero tillage is the reduced cost, since land preparation, a major cost of wheat production, is eliminated. In addition to lower costs, zero tillage allows earlier planting, can save one irrigation (during land preparation much residual soil moisture is lost), and results in uniform plant stands because the seed is placed uniformly at the correct depth where soil is moist.
Usually, weeds are not a problem after rice and those summer weeds that do exist do not compete well with wheat because of the cooler temperatures. Due to the reduced soil disturbance in zero tillage, winter weed germination is low.

Zero tillage should also be tried in rainfed wheat to help cut costs. However, in rainfed wheat, weeds may be more of a problem and minimal tillage may give better control. In minimal tillage, some plowing is done to kill weeds before planting. The same drill can be used for minimal tillage systems.

Mechanization
Harvesting and threshing are other major costs for wheat production—estimated at 30% of gross returns in South Asia. Wheat is more difficult to thresh than rice. In most other South Asian countries, particularly India and Pakistan, mechanized threshing on a contract basis has replaced traditional methods. Fees are paid in cash or in-kind, which requires some excess production. This and the weight of even a small power thresher as well as repair and maintenance needs restrict thresher use in Bhutan to the more accessible areas.

The paddle thresher, presently being introduced to farmers for rice, is not suitable for wheat although one engineer at AMC was told that some farmers in Paro had success with wheat by reversing the rotation of the pedal thresher. This needs to be investigated along with possible design changes to the paddle thresher to improve efficiency. This could be a solution for the remote areas.

Fertilizer and Sustainability
Both rice and wheat are exhaustive crops that remove large quantities of nutrients from the soil. If these nutrients are not available in sufficient quantities for the next crop, yields will be below potential. The new varieties of rice and wheat are bred to respond to fertilizer. Their shorter height and stiff straw allow the plant to produce more grain without lodging.

Farmers are presently using organic fertilizers to provide nutrients for wheat. However, as shown in Table 9, this is a very expensive way of fertilizing wheat. There is also evidence from CARD research reports (6) that addition of farm yard manure (FYM) does not significantly increase yields of wheat. This may be due to the quality of the FYM or the lag time needed to make nutrients available to the plant. If wheat yields are to be increased more, inorganic fertilizer needs to be used.

The FAO fertilizer research group attached to the Ministry of Agriculture (MOA) is developing N-P-K recommendations using response experiments in different areas of Bhutan. This work should continue with close coordination with CARD. In addition to this development of N-P-K recommendations, the following fertility work is needed:

Efficiency of fertilizer use
All inorganic fertilizers are imported into Bhutan from India. Using these materials efficiently is a must to prevent waste of foreign exchange. This requires research on fertilization for cropping systems rather than single crops. What is the economic fertilizer rate and how best should it be applied and to which crop? Are there residual carryovers of nutrients between crops? Is it better to apply phosphorus to wheat or rice? Some of the general answers to these questions are available in the literature, but they still need verification in Bhutan.
**Organic fertilizer**
Are organic fertilizers essential for wheat production? Do they justify the large expense and are sufficient quantities available for intensification programs? Are there alternative sources of nutrients? Green manuring with Dhaincha (*Sesbania aculeata*) has given good results at CARD. This may be a cheaper and better way to fertilize wheat than organic manures. Green manuring is only possible in the Wangdi Punakha Valley and the southern areas (environments 3 and 5) where sufficient time exists between wheat harvest and rice transplanting to grow Dhaincha. In the higher elevation areas of Paro and Thimphu (environment 2), there is insufficient time for this third crop. Rotation of wheat with other leguminous crops or fodders may be more feasible in these higher areas.

**Sustainability and Yield Declines**
An issue that must be addressed in any crop intensification program is the ability of the system to sustain productivity over time. There is evidence in major rice-growing areas of India, Bangladesh, and Pakistan that yields of both rice and wheat are declining despite the use of inputs. This issue of sustainability has not received much attention and the reasons for the declines are not fully known.

In Bhutan where use of inorganic fertilizers is low and fertility requirements are mainly provided by FYM, it is essential to consider sustainability issues before embarking on crop intensification programs. If sufficient inputs cannot be provided to the system, future productivity may decline to levels worse than existing monocropping systems. This effect of wheat on lower yields in the next rice crop has been offered as one reason why farmers do not grow wheat on all their land in the winter. Simple, well designed, long-term trials may be needed to measure this effect in Bhutan. CARD is considering initiating such research. However, it should be stressed that this type of trial is expensive and takes time to produce results. Continuity over time and proper management to allow comparison of results over the years is essential. Care must be taken to keep treatments to a minimum and to keep plot size as large as possible, so that plots can be split at a later date to research the reasons and remedies for declines in yield.

Sustainability can also be researched by monitoring farmers' fields over time and keeping good records of inputs and outputs for certain selected fields.

**Micro-nutrients**
One possible explanation for declining yields despite the use of N-P-K fertilizers is the deficiency of micro-elements. Boron deficiency partly explains sterility problems in wheat in northwestern Bangladesh, northern Bihar, West Bengal, and eastern Terai areas of Nepal. A similar problem could exist in Bhutan. Unfortunately, micro-nutrient deficiencies are not easily distinguished in wheat and symptoms appear in patches in fields rather than throughout the crop. Some research on possible problems should be done, especially if responses to N-P-K seem to be lower than expected. The use of FYM and green manures may help delay micro-nutrient deficiencies by recycling these nutrients in the soil.

**Weeds**
There have been some reports that weeds are a problem in wheat cultivation in rainfed areas and lower elevation paddies (environments 4 and 5). Handweeding is practiced by some farmers as a control measure. Weeds may become more severe with intensification, especially where more fertilizer and water are used. Weed populations need to be monitored to assess possible future problems.
Phalaris minor is a major grassy weed in rice- wheat rotations in South Asia and is not easily controlled by handweeding. Losses to this weed can average 20 to 25% and, in some cases, farmers are forced to cut the field for fodder because weed levels are so high. It can be controlled by herbicides, but this technology requires specialist training that presently does not exist among Bhutanese farmers. Crop rotation and the use of pre-irrigation are other methods to be considered.

Weeds will definitely become more severe as intensification increases, especially if more fertilizer and water are used.

Irrigation and Water Management
It is far easier to intensify wheat production and increase yields on irrigated land than on rainfed land. Where irrigation is available, it should be used as efficiently as possible. CARD is verifying the information on the most critical stages of irrigation for wheat. These results should be evaluated per unit of water rather than maximum yield. It is more productive for the country to irrigate larger areas with less water than few areas with irrigation levels for maximum yields.

In the rice-wheat system, wheat irrigation is complicated by the formation of a plow pan during puddling for rice. Waterlogging occurs after irrigation because of the slow vertical movement of water. Wheat is particularly sensitive to waterlogging at the early seedling stages and it may be beneficial to delay the first irrigation or not allow the water to sit too long in the field. More frequent small irrigations may be better than a few long irrigations. Of course, the plow pan also restricts rooting and drought stress can occur easily in the rice paddies, too.

In rainfed areas efforts are needed to conserve moisture for wheat growth. Possible avenues are short turn-around times (discussed in the section on variety development), minimum tillage (discussed earlier), and mulching. No research has been done on this so far.

Variety Development
Other cereals besides wheat are discussed here because food self-sufficiency—which is the ultimate objective behind this report—may be achieved more easily in some environments or crop rotations if certain other cereals are considered as well.

Wheat
The selection scheme for new spring wheat varieties presented in Table 7 is sufficient for Bhutan. The limitations in manpower and the relatively small area under wheat in each of the major environments do not justify a crossing program even with wheat intensification. Considering the strong breeding programs in neighboring India, Nepal, Pakistan, and Bangladesh, which have large areas similar to one or more of Bhutan's major environments, strong links including occasional visits and yearly introductions from these countries as well as CIMMYT should suffice. An intermediate step could be to introduce F2 populations from well chosen crosses made for Bhutanese environments that are then selected in the target environments of Bhutan. This would save the labor intensive process of making crosses, but would require experienced wheat breeders.
These methods of introduction, selection, and subsequent testing up to variety release should be done within each of the major wheat growing environments in Bhutan described earlier.

**High elevations (Environment 1).** For variety improvement at high elevations, a station should be selected preferably above 2800 m. For true winter wheats under rainfed conditions, drought and cold tolerance are the main characters required. According to the findings of the BNPP in the late 1970s and early 1980s, genetic material from eastern Europe (received through CIMMYT) was promising; a new effort should be made to include Turkish winter wheats as well. Winter wheat grown under rainfed conditions at high elevations provides probably the least scope for varietal improvement due to the environmental harshness of this area. It may be speculated, however, that if wheat can give substantially better yields, it may replace some of the winter barley presently grown on the better land (8). Wheat grown in spring on high elevation holds more promise for improved varieties because water is not limited. European spring wheats showed good results in BNPP trials, but were all inferior to rye, oats, and triticale yields. Material from the High Elevation Screening Nursery of CIMMYT may offer more competitive wheats carrying the required resistance to stripe rust and *Septoria* spp. (leaf blotch).

**Higher mid-elevation valleys (Environment 2).** A testing station must be found for the higher mid-elevations, where wheat is partly harvested as grain and partly grazed or cut green for fodder. Simthoka appears to be a more suitable location than Paro because it is at the upper limits of this environment, thus offering strong test conditions. Varieties for grain harvest can be received from CARD and no separate introductions would be necessary. The main selection criteria for this station would be earliness to mature before rice transplanting, possibly with a proportionately long vegetative and short generative phase to overcome the cold winter months.

For fodder, Sonalika is an unsuitable variety and testing should be done of wheats with a higher biomass (high tillering ability and strong vegetative growth). Research on fodder should include other species like fodder barleys, triticales, oats, or even noncereals such as alfalfa or clover. Sources for respective germplasm can be sought through CIMMYT. Cooperation with animal husbandry experts and leading farmers would also be important.

**Lower mid-elevation valleys (Environment 3).** Only for the lower mid-elevations, such as the Wangdi Punakha Valley, has there been good progress in selection from introduced test lines. Varieties should be released soon to reduce the risk of rust epidemics. Characters required for selection in these areas are increased yield potential over Sonalika under favorable and unfavorable conditions, earliness, and multiple gene resistance to *P. striiformis* and *P. recondita*. The release of an improved variety for this environment should be possible soon.

**Rainfed areas (Environment 4).** Little is known about characters needed for rainfed spring wheat. As a first step, introductions selected for irrigated areas should be tried on the same elevation under rainfed conditions, which means the best entries at environment 2 (Simthoka or Paro) should go to environment 4a (Table 5) and those from environment 3 (CARD) should go to environment 4b (Table 5). The CIMMYT High Elevation Screening Nursery can also be used in environment 4a for selections.
Low elevations (Environment 5). For low elevations, selection work can be carried out at Bhur Farm if its facilities are upgraded. This station should introduce selected lines directly from the Nepali Terai region, northwestern Bangladesh, the hotter Terai areas of India, as well as selected CIMMYT nurseries (Warmer Area Wheat Screening Nursery, Acid Soil Screening Nursery). These should carry genetic material with the necessary characters for this environment such as high yield potential, tolerance to heat at early stages and during grain filling, acid soil tolerance for certain soils, and resistance to leaf rust and *Drechslera sorokiniana* syn. *Helminthosporium sativum*.

**Conclusion.** The order of environments for potential rapid progress from variety selection is lower mid-elevation, low elevation, upper mid-elevation, rainfed areas, and high elevation. CARD is well underway with this work and should maintain the present size of activities in breeding. Bhur Farm has to take over more responsibilities for the southern areas. Simthoka or a nearby station will have to be equipped and staffed for wheat work and a highland station location would have to be selected, equipped, and staffed.

**Other cereals**

*Barley.* Barley area is about 35% that of wheat and, as such, warrants some breeding attention. At least two naked barley varieties exist, one spring-sown and one autumn-sown. Both are grown rainfed in high elevations. Selection for better varieties can be done relatively easily along with the other cereals at the high elevation research station. Sources of germplasm are Pakistan and Nepal, where naked barley grows under similar conditions, and ICARDA in Syria, which has the world mandate for barley research among the international agricultural research centers.

*Triticale.* *Triticale (X Triticosecale)* is a man-made crop resulting from crossing wheat and rye. Compared with wheat, it has advantages on acid soils with poor fertility and in biomass production. Its grain can be used the same way as wheat. European winter triticales and CIMMYT spring triticales should be tried at high elevations along with the respective wheats. Spring triticales also hold promise for the upper mid-elevations (environment 2) as a fodder crop.

*Rye.* Local and introduced rye varieties have been tried by BNPP at high elevations with excellent results (8). Selection of rye genotypes is technically more difficult because it is a cross-pollinated crop. Improvement of local varieties should be the easiest way to increase yields. European ryes can also be tried.

*Oats.* Because there seems to be no feed use of small grain cereals in high elevations, oats may not be acceptable there in spite of the good preliminary results of BNPP. However, it is worthwhile to compare oats with fodder wheat at upper mid-elevation sites (environment 2).

**Seed Supply**

Bhutan is in a much better position with regard to seed supply than many other developing countries due to NASEPP. The seed processing facilities of NASEPP are currently being upgraded and decentralized through funds from Japan and Denmark. An in-depth review of seed production in Bhutan was recently commissioned by Deutsche Gesellschaft fuer Technische Zusammenarbeit GmbH (GTZ) in Germany (10). Hence no general description is needed here. However, some special comments for wheat should be made.
Decentralization of operations is very important due to Bhutan’s topography and infrastructure. This contributes to the economics of production and the quality of wheat seed. Large-scale storage in tropical lowlands, however, presents a substantial problem for wheat. In addition, it is difficult to produce good quality seed in tropical lowlands. Therefore, middle and high elevations may have some natural advantage in wheat seed production and efforts should be concentrated there in the beginning.

It has been observed during the last 3 years that contract seed growers in the Punakha Valley had insufficient guidance in how to grow a good wheat crop. This emphasizes the importance of proper training of NASEPP’s field staff and their role in extending this information to farmers. Only in this way can good quality seed production become a feasible enterprise for the farmer.

The 33% adoption rate of wheat seed assumed in the GTZ project proposal is highly unlikely. In many developing countries a maximum of 10% is achieved. The only factor that could possibly increase this rate may be the farmers in the low elevation areas who have seed storage problems during the monsoon and who therefore might rely on NASEPP for their seed supply.

The maintenance breeder suggested in the GTZ project proposal (10) should not be established as a separate entity but work within CARD. Among the listed responsibilities of CARD in the GTZ report (pages 11-18), maintenance, selection, and collection of germplasm logically are CARD’s mandate together with the training of extension staff. Other responsibilities of the maintenance breeder listed by GTZ would not be required if the work is done within CARD.

To satisfy the farmers’ demand for seed, the production areas of Bhutan are too small to warrant all the multiplication steps of larger wheat producing countries. However, the assumed multiplication rate of about 10 in the GTZ project proposal is very low. If seed is planted at a rate of 20 kg/acre (50 kg/ha) and a yield of 1012 kg/acre (2500 kg/ha) is obtained, which is reasonable with good fertility and irrigation, then the multiplication ratio would be 50.

The last two considerations indicate that substantially less seed is probably needed, which can be produced in fewer steps than suggested to get from breeders’ seed to certified seed.

**Recommendations for Wheat Intensification in Bhutan**

**Background and Assumptions for Recommendations**

Attempts have been made to fit the recommendations in this report to the activities proposed in the draft of the current Sixth 5-Year Plan (1987-92). Before listing the recommendations, the following assumptions are considered as accepted policy for the country. These issues are discussed in detail in the Sixth 5-Year Plan and need no further comment.

- Wheat continues to be treated as a priority crop for intensification even though production will not be economically competitive with imports from India.

- Procurement of surplus production at local centers is provided to farmers. Surplus wheat would be utilized by the Food Corporation of Bhutan (FCB) to substitute for the imports presently distributed in western Bhutan and the
development projects in the East (Nganlam Cement Project). They can also be used by local assistance programs such as the World Food Program (WFP) within the country.

- A suitable price for wheat is set in advance of sowing that allows farmers a reasonable return on investment.

- Labor policies are set to prevent undue rise in labor rates and competition with other important development and maintenance activities. The present restriction on foreign labor has created labor shortages and increased labor costs.

- Import of sufficient inorganic fertilizer and distribution of this input at the local level is provided.

- Credit is made available for purchase of inputs and services. Credit should also be simplified.

- Sufficient manpower can be identified and trained to meet the demands of wheat research and extension without unduly competing with the manpower of other crop production programs.

Data Constraints
One of the crucial parts of the Sixth Plan strategy is to overcome the deficiencies in availability of reliable data for planning and research purposes. This applies to all spheres of agriculture. Although the needs are listed below for wheat, most of this information will have to be collected for all crops over the coming years:

- Meteorological and hydrological data.

- Basic data on soils.

- Reliable information on imports and distribution of wheat, both official and from the private sector in order to plan market development.

- Basic data on area and yield of wheat, crop sequences and patterns, consumption and utilization, and the frequency and distribution of land and other physical assets (water, labor, credit, inputs).

- Agricultural research data, including basic micro-level socio-economic information of farmers' practices, input-output data, labor profiles and bottlenecks, extension efforts and major yield constraints.

- Information/feedback from the regular monitoring and evaluation of ongoing projects and programs.

Initially, these data should be collected from the Sixth Plan's selected integrated area-based agricultural development programs in order of assigned priority for these programs, because obviously not all areas can be handled simultaneously. This information should be stored in a computer database and be available for research purposes of any kind.
Wheat Research

Organization of wheat research personnel

The present Bhutanese wheat research program started at CARD in 1982-83 with the testing and evaluation of genetic material imported from India and CIMMYT. At CARD, one research officer assisted by three assistant research officers and a Volunteer Service Overseas (VSO) volunteer is in charge of wheat research. This same group is also responsible for research on rice and other crops and has substantial extension duties as well. An assistant research officer is under the control of CARD at Bhur Farm, Gaylegphug. All other research trials dispatched from CARD are handled by researchers assigned to other programs and projects.

The small size of Bhutan, its relatively small acreage of wheat, and manpower constraints prevent the formation of a distinct wheat program. It is recommended that a wheat coordinator, based at CARD, be appointed to coordinate all the activities of wheat research, extension, input supply, and training in the country. Similarly, a rice and a maize coordinator could be assigned for duties concerning these crops. Figure 1 shows how the wheat coordinator would function. He would report directly to the Chief Research Officer (CRO) at CARD, who would in turn report to the Director of the Research and Extension Division of the DoA. The CRO would also ensure proper coordination among the rice, wheat, and maize coordinators so that research addresses the issues for each crop as well as the interactions that occur when these crops are grown in Bhutan’s cropping patterns.

The following are the wheat coordinator’s responsibilities:

- Prepare the annual wheat research plans together with his staff, other coordinators, and possibly CIMMYT visitors for the various wheat growing environments of the country. This includes on-station and on-farm research.

- Supervise and ensure reliable implementation of the research plans with other researchers at different institutions in the country.

- Analyze, evaluate, and write the annual research report for wheat.

- Organize and participate in suitable training courses for research and extension staff as needed.

- Liaise with NASEPP, AMC, FCB, the FAO fertilizer project, extension, irrigation projects, and other national programs involved in wheat production to ensure integration of these agencies to a common wheat production strategy.

- Advise the DoA through the CRO on important findings and policy issues for wheat production.

- Be a key contact for international agencies that conduct wheat research such as CIMMYT, ICARDA, and South Asian national wheat programs.

- Be responsible for ordering, receiving, distribution, storage, and compilation of data from requested international germplasm.
• Be the link between research and extension to ensure any new findings are quickly extended to farmers and that any feedback from farmers is incorporated in the research planning.

• Plan monitoring tours with other researchers and extension personnel in key wheat producing areas during the wheat season to evaluate the crop condition, major farmer constraints, and problems and identify researchable issues.

The coordinator himself and other staff doing wheat research would also be assigned to other crop research programs as presently set up. This would ensure that the research includes a systems component rather than just a single commodity approach. Junior staff would thus report to the coordinator during the wheat growing season and the respective other coordinators during the summer.

**General guidelines for research**

Breeding activities should consist mainly of selection of materials adapted to each environment (see section of variety development). Materials from neighboring countries with similar environments but stronger research programs should be obtained for screening. Selection criteria should include high yield, good fit of duration to existing cropping patterns, wheat environments, and stable disease resistance.

Crop management research should receive more attention and it is suggested that an agronomist be selected as the wheat coordinator. Crop management research should start with a survey of the wheat producing areas around each station to obtain data on area, production, yield, farmer management practices, crop condition, and major constraints. The assignment of an agricultural economist would be useful to help organize these surveys. The survey would help focus crop management research on the most important issues. Crop stand and early establishment seem to be major issues at the moment.

Crop management research should be balanced between on-station research under controlled conditions and verification trials and demonstrations of technology in farmers’ fields. Emphasis should be on applied practical research rather than basic research. The latter can be obtained from neighboring countries through exchange of visits or review of literature.

Crop management research should be linked with extension. The agronomist should visit and place experiments in farmers’ fields and extension agents should visit stations and farmers’ field trials. Extensionists can work with the research specialist on surveys, verification trials, and demonstrations. In this way, feedback of information from farmers to researchers is ensured.

Suitable manpower will be needed at the five stations proposed for wheat research in Figure 1. Two B.Sc. level junior scientists should be available at each station to organize research activities. Incentives for good work should be provided through promotions, awards, training, and visits to places inside and outside Bhutan.

One key manpower component is the availability of mid-level technical staff and labor. Working and living conditions should be sufficient to encourage this staff to remain on the station and conduct duties reliably. Once this staff is trained,
transfers should be minimal. This will allow continuity of the program and increase the work quality and efficiency.

Wheat research by major environment
Wheat is grown in Bhutan throughout the country from low elevations in the south to high altitudes in the north, irrigated and rainfed, and on many different soil types. Five different major environments for wheat production were described earlier. Not all these environments are equally important for the present wheat intensification program, but each has unique problems that warrant separate research agendas, although there are also common problems among environments.

Figure 1 proposes that five stations be developed to handle wheat in these environments. Not all of them need to be developed at once, and a phased development based on priority wheat producing programs, available staff, and development of these stations through other projects can be pursued. The Sixth Plan intends to develop or strengthen all these stations during the next 5 years. Research priorities for each of them are summarized in Table 10 in order of priority within each category and described below.

The CARD station would be the central research station in the country and house the wheat and rice coordinators. It would also represent the mid-altitude rice growing valleys at lower elevations (environment 3). Wheat breeding there would concentrate on finding better varieties for the Wangdi Punakha Valley with a higher yield potential than Sonalika, but tolerant to varied management levels and with better stripe rust resistance. Crop management research would focus on crop establishment, earlier planting, fertilizer and water efficiency, weed control, and harvest procedures. Based on the rice-wheat system, the possibility of green manuring to improve fertility is a major researchable issue as well.

The Bhur Farm near Gaylegphug would represent the southern lowlands (environment 5). Emphasis would be placed on evaluation of nurseries for this zone, particularly materials from the Indian and Nepalese Terai, which carry resistance to the potential diseases problems of leaf rust and Drechslera spp. Rice-wheat would be the researched cropping system. Green manuring and seed storage would be important researchable issues in addition to on-farm and on-station crop management research.

Simthoka or Paro stations should be used to develop wheat varieties for the higher elevation areas of the mid-altitude rice environments (environment 2) where frost and problems of turn-around time with rice occur. Stripe rust resistance would also be needed. As green manuring is not possible, rotations with leguminous crops should be tried. On-farm and on-station crop management research is needed to solve rotational problems and test new crops.

Khangma in Tashigang, the largest wheat producing district, would concentrate on rainfed wheat and barley following maize (environment 4), but could also evaluate materials from CARD or Bhur Farm in riceland. Even more emphasis would be needed on crop management issues such as moisture conservation, minimal tillage, fertilizer efficiency, and weed control.

Bumthang would represent the high elevation areas where winter wheats and barley are grown (environment 1). This area probably holds the least potential for increasing wheat production, but research could complement the activities of
Figure 1. Suggested organization of wheat research in Bhutan.
Table 10. Summary of recommended research in different research stations representing major environments of Bhutan.

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<th>CARD Environment 3</th>
<th>Simthoka Environment 2</th>
<th>Bhur Farm Environment 5</th>
<th>Khangma Environment 4</th>
<th>Bumthang Environment 1</th>
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<td>Rotation</td>
<td>Rice - wheat irrigated</td>
<td>Rice-wheat irrigated</td>
<td>Rice-wheat irrigated</td>
<td>Maize - wheat rainfed</td>
<td>Wheat rainfed</td>
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<tr>
<td>Variety selection criteria for wheat</td>
<td>Stripe rust resistance</td>
<td>Stripe rust resistance</td>
<td>Leaf rust resistance</td>
<td>Drought tolerance</td>
<td>Cold tolerance</td>
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<td></td>
<td>Earliness</td>
<td>Cold tolerance</td>
<td>Earliness</td>
<td>Early and late</td>
<td>Stripe rust resistance</td>
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<td></td>
<td>High yield</td>
<td>Long vegetative growth phase</td>
<td>Acid soil</td>
<td>Drought tolerance</td>
<td>Cold tolerance</td>
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<td></td>
<td>Tolerance to poor management</td>
<td>High biomass</td>
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<tr>
<td>Additional species to be tested</td>
<td>Fodder barley Triticale Oats Alfalfa Clover</td>
<td></td>
<td>Barley Triticale Oats</td>
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<td>Rye</td>
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<tr>
<td>Management research issues</td>
<td>Establishment Early sowing Fertilizer Green Manuring Water efficiency Zero tillage</td>
<td>Establishment Early sowing Rotations with leguminous species Zero tillage Fertilizer</td>
<td>Early Sowing Green manuring Fertilizer Seed storage Zero tillage</td>
<td>Moisture conservation Minimum tillage Fertilizer</td>
<td>Sowing date Moisture conservation Potato based</td>
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BNPP. A survey of the production practices for the local winter wheat, its yield, area, and agronomy would help guide the identification of feasible research issues. Suitable genetic material for this region can be obtained through CIMMYT.

**Training**
Very little expertise exists within Bhutan on wheat research. The only participant in a CIMMYT wheat training course is not presently conducting research. All other scientists in charge of wheat research at CARD and Bhur Farm hold at most B.Sc. degrees from India, but not specifically in wheat research. If wheat research is to be promoted, more manpower and proper training are required.

The wheat coordinator should have a M.Sc. degree in agronomy or breeding and the junior research officers should have B.Sc. degrees. Some staff members should be sent to CIMMYT (wheat) or ICARDA (barley) to receive practical training in crop improvement and management through the respective 7-month training courses. When staff members return from these short courses, they should import the knowledge they gained through in-country training of other station staff.

It is essential that researchers spend time on training the field assistants and laborers, who ultimately do the field work. Research is only as good as the quality of the activities in the field.

**Equipment and transport**
Certain equipment is required for wheat research--mainly to ensure timely work and to increase the efficiency and precision of the program.

Each station should have the following set of equipment--some of which can be shared with other crops.

- Suitable drills for planting trials on station and in farmers’ fields. Single-row and three-row drills of simple design are available for this purpose.

- Suitable threshers for single plants, bundles, and larger yield and seed samples. These are designed to prevent mixing of entries and are available from various foreign sources. A portable thresher would be useful for off-station trials.

- Sprayers and suitable accessories for applying plant protection chemicals.

- Seed cleaners to grade and provide good seed for trials.

- Seed storage facilities including suitable containers to maintain research materials in good condition. Some chemicals should also be available to control storage pests. Ideally, each station should have an environmentally controlled room for valuable seed storage.

- A programmable calculator or computer for planning trials and analyzing results. Available portable computers may be better than larger PC desk models because they can be battery operated when power is down and can be moved easily between offices.
• Balances for weighing inputs and outputs.
• Measuring tapes for laying out plots.

In addition a small amount of funds should be available for procuring small consumable items such as buckets, tags, bags, string, paper, pencils, etc.

Transportation is a key element, and usually the most problematic. Without transportation, scientists cannot pay visits to or conduct research in farmers' fields. They cannot guarantee when they will arrive to meet farmers, extensionists, and input supply staff. Each station should have a pick-up truck and at least one motorcycle to meet these vital transportation needs.

Short-term consultants, visits, and publications
Continued awareness of wheat research results in the rest of the world is necessary to keep researchers up to date on new technology. This can be done by inviting short-term consultants to visit Bhutan at regular intervals to participate in research planning or monitoring tours. CIMMYT regional and headquarters staff can allocate certain amounts of time if requested.

In part, as rewards for good work, some resources for participation of wheat staff in regional or international workshops or conferences should be available.

Some funds should be allocated to purchase books and journals relevant to wheat research. The various international agricultural research centers should be requested to include the library of the DoA on their mailing lists. A small library at each station should be maintained for national materials and common reference books.

Extension
Links between Research, Extension, and the National Agricultural Training Institute (NATI)
Research is of little use if it is not transferred to and adopted by farmers. Time for short training courses on important wheat production issues should be set aside by all researchers to train extension agents and, if possible, progressive farmers. If these courses are arranged properly, feedback from farmers and extension agents will occur and improve the scientists' understanding of farmers' problems. These courses should be held throughout the country to allow contact with maximum numbers of extension agents and farmers.

The National Agricultural Training Institute (NATI) is newly established to provide diploma courses in agriculture. This institute should be in close contact with the wheat coordinator and his scientists to ensure that correct and up-to-date information is included in the curriculum. Visits of students to research centers, on-farm trials, and farmers' fields should be encouraged. NATI should invite national research staff, volunteers, and visitors to present recent research findings to their students and make suggestions on how to improve the course material.

Extension issues
Currently, only basic knowledge can be extended outside of the Wangdi Punakha Valley because no research results are available from other production areas. The present good relationship between extension and research must be
continued to enable researchers and extension agents to work together to build up knowledge of all the wheat production environments of the country. There is a good chance of success through the ongoing agricultural development projects at Wangdi, Chirang, Tashigang, and Gaylegphug.

References Cited

1. Agriculture Handbook Bhutan. No year or author.


Punaka Wangdi Valley Development Project.  
Chirang Hill Irrigation Project.  
Tashigang - Mongar Area Development Project.  
Taklai Project and Gaylegphug Area Development Project

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Appendix 1: Important Resource Persons Contacted in Bhutan during Information Gathering for this Report

Dasho Khandu Wangchuk, Director General, DoA  
Pem L. Dorji, Chief Planning Officer, DoA  
Sherub Gyeltshen, Project Manager, Punaka Wangdi Valley Development Project, Loseba  
D.B. Rai, Head, Research and Extension Division, DoA  
Birendra Dhakal, Planning Division, DoA  
Pushpa Raj Gurung, Research Officer, BNPP, Yusipang  
Ganesh Chhetri, Officer-in-charge, CARD, Wangdiphodrang  
Mahesh Ghimerey, Assistant Research Officer, Bhur Farm  
Duptoph Wangchuk, DAO, Tongsa  
T.B. Ghallay, Assistant Research Officer, CHIP, Dhamphu  
D.P. Karki, NASEPP, Bhur Farm  
Chitrim Wangchen, AMC, Paro  
Rinchen Tshering, FCB, Phuntsoling  
Mr. Wangdi, EO, Taklai Irrigation Project, Gaylegphug  
Pema Tamang, Plant Quarantine Officer, DoA  
Tshering Wangdi, NASEPP, Paro  
Mandhoj Mukhia, Extension Inspector, CHIP, Dhamphu  
Kezang Wangdi, Extension Supervisor, Drakten Block, Tongsa  
Tiku Dukpa, Extension inspector, Lamidara  
Sangay Dorji, Extension Supervisor, CHIP, Dhamphu  
Jigme Wangdi, Research and Extension Division, DoA  
J.R. Green, Extension Specialist, Manpower Development & Training Project, DoA  
Samm Bbuyemusike, UNV Planning Division, DoA  
Dong Arida, IRRI Entomologist, Bhur Farm  
Joynal Abedin, UNV Agriculturist, Bhur Farm
Appendix 2. List of Abbreviations/Acronyms

AMC--Agricultural Mechanization Center, Paro
BNPP--Bhutan National Potato Project, Thimphu
CARD--Centre for Agricultural Research and Development, Wangdiphodrang
CHIP--Chirang Hill Irrigation Project, Dhamphu
CIMMYT--Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center), Mexico
CRO--Chief Research Officer
DAO--District Agricultural Officer
DoA--Department of Agriculture, Thimphu
EEC--European Economic Community
EO--Extension Officer
FAO--Food and Agriculture Organization of the United Nations
FCB--Food Corporation of Bhutan, Phuntsoling
FYM--Farm yard manure
GTZ--Deutsche Gesellschaft fuer Technische Zusammenarbeit GmbH., Germany
ICARDA--International Center for Agricultural Research in Dry Areas, Syria
IFAD--International Fund for Agricultural Development
IRRI--International Rice Research Institute, The Philippines
MOA--Ministry of Agriculture, Bhutan
NASEPP--National Seed and Plant Program, Paro, Bhutan
NATI--National Agricultural Training Institute, Paro, Bhutan
**Nu.**—Ngultrum (Bhutanese Currency Unit)

**OIC.**—Officer in Charge

**UNV.**—United Nations Volunteer

**VSO.**—Volunteer Service Overseas

**WFP.**—World Food Program