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Joint Research Dissemination Program

Disseminating the Bed-and-Furrow Irrigation Method for Cotton Cultivation in Bahadurwah Minor

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EXECUTIVE SUMMARY

This research on the irrigation trials of the bed-and-furrow irrigation method for the cotton crop is part of the Joint Research Dissemination Program (JRDP) for the Fordwah Eastern Sadiqia (South) Irrigation and Drainage Project (FESS). This program is a joint effort between Mona Reclamation Experimental Project (MREP), WAPDA; On-Farm Water Management Wing (OFWM), Agricultural Department; Agricultural Extension and Adaptive Research Wing (AE&AR), Agricultural Department; and the International Irrigation Management Institute (IIMI). The irrigation trials for the dissemination of the bed-and-furrow irrigation method as designed under the JRDP encompass the command areas of the Bahadarwah Minor and Hakra 4-R Distributary. This report deals with the dissemination of the bed-and-furrow irrigation method in the command area of the Bahadarwah Minor.

The bed-and-furrow irrigation method is believed to be a water-saving technique that considers the farm as the boundary of analysis. However, if the boundary of analysis is a basin, then the water-saving aspect mentioned before is only applicable when the groundwater is brackish and is not suitable for irrigation purposes. One of the major advantages of the bed-and-furrow irrigation method is that the water advances faster to the end of the field, hence, the required water application depth is reached earlier. Less time is required to irrigate an acre, and thus, the farmer can irrigate more bunded units during the *warabandi*. The concept of light but frequent irrigation events not only allow the farmer to irrigate more bunded units, but also results into lower crop water deficits when compared with the basin irrigation method.

The research evolves around the following objectives:

1. To determine a comparative and quantitative diagnosis for irrigation frequency and water application between the basin and bed-and-furrow irrigation methods. Based on a sample of 24 farmers located in the 5 sample watercourses, the water depth applied per irrigation event was calculated based on daily discharges, irrigation duration, seepage losses and tubewell discharges.

2. To provide an overall technical assessment of the field irrigation performance for the bed-and-furrow irrigation method in terms of the water applications versus the seasonal crop water requirement. This assessment is based on the analysis of two farms, for which the water application depth has been calculated for selected basin and bed-and-furrow fields, and the irrigation requirement has been calculated by using CROPWAT.

3. To identify possible differences in cultural practices and agronomic aspects between the basin and bed-and-furrow irrigation methods. Seasonal records were kept on activities for the land preparation, sowing, hoeing, application of chemicals and fertilizers, occurrence of pests and diseases, and crop germination rate.

4. To assess the overall net income on a per-acre scale with a comparison between the basin and bed-and-furrow irrigation methods. Along with the data collection activities on cultural practices, per-acre records were kept on the expenses for the sample basin and bed-and-furrow fields. At the end of the season, the figures on the cotton yields and the prices cotton sold for on the market were obtained from the farmer. Based on this information, a cost - benefit analysis was conducted.

5. To evaluate farmers' experiences with the bed-and-furrow irrigation method. During the season, feedback on the bed-and-furrow irrigation method was obtained from the farmer. At the end of the season, a final interview was conducted with the sample farmers; however, the evaluation as presented in this report is mostly based on the formal and informal encounters with the farmers.

A total of 48 farmers spread over about 120 acres of cotton land used the bed-and-furrow shaper, which was provided by IIMI in order to convert the farmland into beds-and-furrows. Of these farmers, 40 were selected for monitoring and evaluation purposes. A sample of 25 farmers were located in the 5 watercourse command areas where the *mogha* discharge readings were taken regularly; and thus, for these farmers, it was possible to present a quantitative analysis on water use for the basin and bed-and-furrow irrigation methods.

On the comparative quantitative diagnosis pertaining to irrigation frequency and water application between the basin and bed-and-furrow irrigation methods, it was found that on average, eight irrigation turns were applied to the bed-and-furrow fields and 4 or 5 irrigation turns to basin fields (excluding the pre-sowing gift). For basins, a pre-sowing irrigation gift (*rauni*) is applied, whereas for the bed-and-furrow fields that is not the case. On an average, it took 30 minutes less time to irrigate a bed-and-furrow field (average 95 minutes) of one acre than to irrigate a basin field of one acre (average 122 minutes). This time saving factor is very crucial for the farmers and was perceived as an advantage, since more time was left to irrigate other fields.

On average, 17 percent less water depth was applied per irrigation event to the bed-and-furrow fields when compared to the basin fields. If the first four irrigation events are compared, then the water depth applied to bed-and-furrow fields showed reductions of between 12 to 41 percent in water depth applied. Per irrigation event, the bed-and-furrow method was compared to the basin method as a water saving innovation. However, if the total water use during the complete *kharif* season is compared, then all selected farmers applied more water to the bed-and-furrow fields than to the basin fields. On average, a total water depth of 528 mm was applied to the bed-and-furrow fields, while for basin fields a total water depth of 319 mm was applied during *Kharif* 1998. Farmers did not irrigate basin cotton fields frequently, but when they did, it was during the most effective period for the cotton production during the development of flowers and buds, i.e. the reproductive growth stages of cotton. In fact, the strategy adopted for the bed-and-furrow fields coincides with the concept of light but frequent irrigation applications to minimize losses, but to fulfill the crop water demand.

The agricultural and irrigation practices of two farmers were monitored in detail during the complete season. For every irrigation turn, the water volumes applied to the different fields were measured. Both farmers tried to sow cotton using the traditional basin method, but in each of the two cases, the germination failed and these fields were used for the bed-and-furrow method. The main purpose of monitoring the irrigation practices of the two farmers was to develop a water balance of the basin and bed-and-furrow fields. An estimation of the crop water requirements and the consumptive water use of cotton in these fields could be made based on the climatic data of a weather station in Bahawalnagar and the measured irrigation events. Fields of Farmers 1 and 2 do not receive enough rainfall and irrigation water for optimal crop evaporation, which varies between 1,066 to 1,251 mm, depending on the sowing date. The irrigation deficit varied between 50 and 60 percent of the total irrigation requirement. As a consequence, the yield reduction factor varied between 40 to 50 percent. The actual water use of bed-and-furrow fields was not more than in the basin fields. The pre-sowing irrigation gift in basin fields is of major importance in the water balance. So, the gap in applied water depth between basin and bed-and-furrow fields is equalized by the pre-sowing irrigation gift.

The groundwater table in the Bahadarwah Minor is, in general, shallow and varies from waterlogged areas (where the groundwater level equals the soil surface level) to 2.5 - 3 meters below the soil surface later in the season. The shallow groundwater table provides extra water to the crop through capillary rise. A rough estimation suggested that groundwater can contribute a minimum of 10 percent to the total crop evapotranspiration of cotton (135 mm) under the conditions in the Bahadarwah Minor. However, this is dependent on soil conditions and the fluctuation of the groundwater table during the season.

With respect to cultural practices and agronomic aspects, out of the 40 monitored bed-and-furrow fields, 16 fields (39 % of the total) were sown earlier using the traditional drill method. Germination failed due to salinity problems, so farmers decided to use these fields to experiment with the bed-and-furrow technique. For the 37 monitored basin fields, 4 fields (10 % of the total) were sown more than once. There was little difference in the average germination percentage of bed-and-furrow fields (62.1 %) and basin fields (65.4 %). If these figures are related to the aforementioned salinity problems of the fields, it means that germination on the bed-and-furrow fields was generally better than in basin fields. The farmers also mentioned this point as the major advantage of the bed-and-furrow method.

About 50 percent of the farmers did not maintain the beds and furrows. Salt accumulated on the beds, which may affect the germination of wheat during the *rabi* season. Farmers preferred a flat field, where salts can be removed by flushing. In some fields it was observed that a hard crust was formed after every irrigation event, which would, according to farmers, hamper root development. Farmers used the plough or ridger to open the topsoil.

During *Kharif* 1998, sample farmers spent twice as much time on activities in bed-and-furrow fields than in basin fields. Most of this extra time was spent on manual hoeing of the bed-and-furrow fields. Hoeing of the cotton fields started some 4 to 6 weeks after the fields were sown. Unfortunately, the hoeing machine for the bed-and-furrow fields arrived too late, on 23rd of July. The hoeing of a bed-and-furrow field is far more difficult and time-consuming than the hoeing of a basin field. On an average, it was found that 2,634 hours of hoeing were allocated to the bed-and-furrow fields, whereas for the basin fields this value was 992. This time-consuming aspect is the major disadvantage of the bed-and-furrow method, which has been mentioned by the sample farmers. In the absence of the hoeing machine, farmers have to either mechanically or manually remove the weeds and grasses. Smaller farmers did not have easy access to a tractor, which is a major constraint for the use of the hoeing machine for this group. If farmers would use herbicides and the special hoeing machine in the future, this labor factor could be reduced drastically.

If the two-week gap to sow the fields is excluded, then the timing of agricultural activities in basin and bed-and-furrow fields such as hoeing, fertilizer and pesticide application, and harvest, run quite similar to each other. Fertilizer application starts when the cotton starts to develop its flowers, some six weeks after sowing. The first pesticide sprays were applied some two weeks after fertilizer application. Harvest started in the first weeks of October and continued until the end of December. These activities are undertaken independent of the location of the fields in the irrigation system. Generally, farmers did not use herbicides for weed control. Differences in fertilizer applications were not experienced between basin and bed-and-furrow fields. The average farmer applies 5 sprays during the months of August and September. There was no difference in the number of pesticide applications between basin and bed-and-furrow fields.

All basin and bed-and-furrow fields were monitored for pests during the complete *kharif* season. Pests attack the cotton plants irrespective of the cultivation method. Jasid, white fly and boll worm were commonly found in 95 to 100 percent of the basin and bed-and-furrow fields. The uncontrollable presence of bollworm in *Kharif* 1998, according to farmers, had a very bad effect on the cotton yields. Major differences between the magnitude of pests in either, the basin and bed-and-furrow fields, did not exist.

The cotton yields for both, basin and bed-and-furrow fields were disappointingly low in Kharif 1998. The average cotton production was 158 kg/acre for bed-and-furrow fields and 247 kg/acre for basin fields. The variation in cotton production was high. The maximum yield was 590 kg/acre for bed-and-furrow fields and 606 kg/acre for basin fields. Some 34 farmers cultivated cotton in basin and bed-and-furrow fields. About 74 percent of these farmers had a higher cotton yield in basin fields than in the bed-and-furrow field. A direct relation between the yield and depth of water applied for basin and bed-and-furrow fields could not be found.

With respect to expenditures, the average amount of money spent on inputs for the basin and bed-and-furrow fields is almost equal (i.e. Rs. 3,320 and Rs. 3,170, respectively). For both of the irrigation methods, the major expenses are involved with the application of pesticides (Rs. 1,628 and Rs. 1,315 for the bed-and-furrow and basin fields, respectively).

The basin fields generated higher revenue than the bed-and-furrow fields for 27 cases. Based on this analysis, it was found that the bed-and-furrow irrigation method is less beneficial for the sample farmers of this area when compared to the basin irrigation method. The main cause is the average low yield for the bed-and-furrow fields. It was observed that often farmers allocated the land of poorer quality to the bed-and-furrow irrigation method experiment (i.e. the left over land), hence, the land proved to be much less productive. The average benefit-cost ratio was 1.04 and 1.86 for the bed-and-furrow and basin fields, respectively. There was no marked difference in costs and benefits of cotton fields located in the head and tail watercourses of the Bahadarwah Minor. There was no indication that marginal or small farmers were facing more economical constraints than larger farmers when adapting the bed-and-furrow method.

The major advantage of the bed-and-furrow method is better seed germination, even in saline soils. One major difference, however, was found in agricultural practices for the basin or bed-and-furrow method. This was the hoeing of the bed-and-furrow fields, which was more labor-intensive when compared to the basin fields. Timely availability of the hoeing machine can solve this problem in the future. There were no major economic constraints identified for the adaptation of the bed-and-furrow method. However, smaller farmers face the constraint in the ability to hire a tractor for the bed-and-furrow shaper and the hoeing machine. If these points are considered alone, the basin method could be replaced by the bed-and-furrow method. But, the major constraint identified for successful adaptation of the bed-and-furrow method was the dependence on a reliable and adequate water supply during the complete season, either by surface water or groundwater. Bed-and-furrow fields would require more frequent water gifts than basin fields, which was considered a disadvantage by the farmers. The water supply in Kharif 1998 was inadequate and unreliable in the Bahadarwah Minor command area. The high salinity levels of groundwater hamper an expansion in the use of tubewell water. Under these conditions, cotton cultivation using the traditional basin method is a more viable option for farmers in the Bahadarwah Minor command area.

The farmers mentioned and experienced several important advantages regarding the bed-and-furrow irrigation method. Since less time is required to irrigate a bed-and-furrow field, more time is left to irrigate other fields, and thus, the water is used more efficiently during the warabandi. This is a genuine advantage for farmers. Also, the farmers were very pleased about the protection that the crop received from flooding during heavy rainfall. This was due to the construction of furrows that allows excessive water to drain off easily, which allows better soil aeration. Despite the constraints, many farmers showed more interest in the advantages, with about 60 percent of the farmers expressing enthusiasm to continue this experiment next year.

1 INTRODUCTION

1.1 SUSTAINABLE IRRIGATED AGRICULTURE: ISSUES AND PERSPECTIVES

A continuous expansion of the world population, which will exceed 6 billion by the year 2000, demands a continuous growth of agricultural production in the world. In the coming three decades, about 80 percent of the increased crop production have to be generated through irrigated agriculture (FAO, 1994, quoted in Mauderli, 1996). However, the growth of the world population places more pressure on natural resources than land and water. Water availability per capita will decrease substantially. Fertile land drops out of production due to environmental hazards such as erosion, water logging and salinity.

An expansion of irrigated area through the development of new schemes is not feasible given the scarcity of fertile land and water. An increased irrigated crop productivity can be found in improving water use efficiencies in the existing irrigation schemes. The major advantage of an increase in water use efficiency is that a larger area can be irrigated with the same volume of water. The water use efficiency of a complete irrigation system is called the overall, or project efficiency, which expresses the amount of water given to a scheme that converts to evapotranspiration. Wolters (1992) presented a comparison of project efficiencies of irrigation schemes. These schemes were distinguished by water storage capacities in three groups: no storage, seasonal storage and carry-over storage. The project efficiencies of these groups were respectively, 40 percent, 39 percent and 41 percent. The overall, or project efficiency can be expressed as a multiplication of three sectorial ratios: main conveyance efficiency, distribution efficiency and field application efficiency. According to Mauderli (1996) the major part of the water losses occurs at the watercourse, farm and field levels. A major improvement of the total water use efficiency, and thus, the agricultural productivity of an irrigation system can be found in increased field application efficiency.

The Indus Basin in Pakistan encloses one of the largest contiguous irrigation systems in the world, covering more than 16 million hectares and crossing nine agro-climatic zones. There are 3 storage reservoirs, including possibly the world's biggest earth-filled dam (the Tarbela Dam), 19 barrages, 12 inter-river link canals, 59,500 kilometers of canals and about two million kilometers of watercourses and field channels (IIMI, 1991). The irrigation system of Pakistan faces several problems. One of the major constraints for increased crop productivity in Pakistan is soil salinity. Due to poor drainage of the vast, nearly flat Indus Plain, water logging and salinity are slowly destroying the fertility of much of the irrigated land (Johnson III, 1982). The predominant irrigation system in Pakistan is characterized by a seasonal variability of irrigation supplies. According to Bandaragoda (1991), this results in a) chronic inequity, which affects farmers in the tail of the irrigation system, and b) water shortages that occur during critical periods of the crop growth cycle. Both of these factors contribute to relatively lower yields in large areas of Pakistan's irrigation system. A research group of the Colorado State University concluded in the seventies that the mismanagement of irrigation water at the local level is a key constraint for improving agricultural production, as well as an important cause of water logging and salinity. Clyma and Corey (1975) reported that the average delivery efficiencies of watercourses were less than 60 percent, and the application efficiencies had an average of 20 percent. These figures indicated the need for a program, now commonly known as On-Farm Water Management (OFWM), which is directed at the improvement of watercourses and water management at the field level. The problem of inefficient water management at the field and farm levels remains a relevant and important issue in the development of irrigated agriculture in Pakistan.

IIMI-Pakistan conducts research on improved irrigation methods at the farm and field levels. The subject of this report, a comparison of the basin and bed-and-furrow irrigation method, is a product of research undertaken within this theme.

1.2 JOINT RESEARCH DISSEMINATION PROGRAM

In the past decade, several research institutes conducted field research on the improvement of agricultural practices of farmers in Pakistan. The Mona Reclamation and Experimental Project (MREP) conducted applied field research to develop criteria for the optimum use of land and water resources in the Fordwah Eastern Sadiqia (South) project area. As part of the research on improved agronomic and irrigation practices, MREP conducted research on the bed-and-furrow irrigation method on different sites in the FES(S) area. IIMI-Pakistan conducted research on improved irrigation methods, whereby different irrigation techniques e.g. basin, furrow, shallow corrugation and bed-and-furrow were implemented on farmers' fields to estimate the impact of changes in irrigation practices on agricultural production. The bed-and-furrow irrigation method was tested and evaluated on farmers' fields near Hasilpur in *kharif* 1997. The primary objective of the Joint Research Dissemination Program is to disseminate the above-mentioned field research results to the farming community in the FES(S) area in a collaborative project.

The Joint Research Dissemination Program was formulated in January 1998. The organizations involved in the Joint Research Dissemination Program are:

- Mona Reclamation Experimental Project (MREP);
- On-Farm Water Management Wing (OFWM), Agricultural Department;
- Agricultural Extension and Adaptive Research Wing, Agricultural Department; and
- The International Irrigation Management Institute (IIMI), Pakistan.

The following specific objectives were formulated:

- To disseminate the research results about improved agronomic and irrigation practices to the farming community, beginning with two pilot sites, and then later to the entire Fordwah Eastern Sadiqia (South) farming community;
- To strengthen the Pilot Water Users Federation (WUFs) by involving them in the introduction of improved agronomic and irrigation practices;
- To train the WUF farmers in water measurement techniques;
- To provide liaison between the WUFs and the agencies, which control agricultural inputs, and to private firms that can provide quality agricultural inputs;
- To assist in devising mechanisms for quality control of the agricultural inputs purchased by the WUFs; and
- To assess the overall impact of the research dissemination program on water use and agricultural production.

In the framework of the Joint Research Dissemination Program, IIMI is responsible for the research on irrigation trials for the bed-and-furrow irrigation technique. These irrigation trials were conducted in *kharif* 1998 in two areas:

- The pilot site of the Hakra 4-R Distributary where IIMI organized farmers at the tertiary and distributary levels as part of the Dutch-funded project "Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan"; and
- The pilot site of the Bahadarwah Minor where farmers were organized by OFWM at the tertiary and minor levels into Water Users Organizations under the World Bank-financed Fordwah Eastern Sadiqia (South) Irrigation and Drainage project.

In both areas, farmers are organized into a Water Users Federation. This document focuses on the research activities and results at the second pilot site of the Bahadarwah Minor.

1.3 BED-AND-FURROW IRRIGATION TRIALS: RESEARCH SCOPE

Methodology

The bed-and-furrow irrigation method is a cultivation technique for cotton, which is practiced worldwide. However, in Pakistan this method is not commonly used in all the cotton-producing regions in the Punjab and Sindh Provinces. The use of the bed-and-furrow method is generally restricted to larger farmers with enough financial resources to invest in this technique. The majority of farmers who are not using the bed-and-furrow technique cultivate cotton in basins. The introduction of the bed-and-furrow irrigation method, thus, is basically the introduction of a technical innovation in an existing farming system, i.e. a technology-transfer process.

In order to have a clear insight in this technology transfer process and to assess the effectiveness and usefulness of the bed-and-furrow method, the impact of this method is analyzed from different perspectives:

I. The innovation in relation to some existing features of the socio-economic environment;

II. The innovation in relation to the physical setting;

III. The innovation in relation to the technical performance;

IV. The innovation in relation to the net farmer income (from the sample fields); and

V. The innovation in relation to farmers' perceptions.

The above-mentioned five elements are combined in one approach, which results in a decision-making mechanism that evaluates a) the impact of the bed-and-furrow technology on agricultural production and water use; and b) the adaptability of the bed-and-furrow method for farmers under different environmental conditions (Kalwij, 1998).

Research objectives

The research evolves around the following objectives:

1. To determine a comparative and quantitative diagnosis for irrigation frequency and water application between the basin and bed-and-furrow irrigation methods;
2. To identify possible differences in cultural practices and agronomic aspects between the basin and bed-and-furrow irrigation methods;
3. To provide an overall technical assessment of the field irrigation performance for the bed-and-furrow irrigation method in terms of the water applications versus the seasonal crop water requirement;
4. To assess the overall net income on a per-acre scale with a comparison between the basin and bed-and-furrow irrigation methods;
5. To evaluate farmers' experiences with the bed-and-furrow irrigation method.

Farmers Reference Group

IIMI-Pakistan provided a complete set of bed-and-furrow machinery to the Water Users Organization of the Bahadarwah Minor. The set includes one bed-and-furrow shaper and one hoeing machine. Farmers paid an operation and maintenance fee of Rs 50 per acre for the use of the machinery. During *kharif* 1998, on the job training was given for the management and O&M of the bed-and-furrow set. The Water Users Organization of the Bahadarwah Minor is responsible for the management of the bed-and-furrow set at the end of the season. In cooperation with the Water Users Organization, a large group of farmers was approached through extension meetings. A reference group of 40 farmers was selected. By monitoring a large group of farmers, the impact of the technology on different social, economical and technical environments can effectively be assessed.

The group of farmers is spread over different watercourses located in the head, middle and tail reaches of the Bahadarwah Minor. All selected farmers used the bed-and-furrow irrigation method on one field and the basin irrigation method on the other. Both fields were monitored on various topics (see next paragraph) during the cotton season. Two farmers were selected in the head and the tail watercourses of the Bahadarwah Minor for detailed monitoring. These two farmers are subjects of two case studies presented in this report.

Data Collection and Management

Data collection concentrated on five main subjects, whereby different topics are distinguished. Table 1.1 presents the main subjects, topics and sources of data.

Data pertaining to the above-mentioned 5 subjects were collected from a basic reference group of 24 farmers located in 5 watercourses. However, only the advanced behavior of two detailed monitoring farmers was monitored. Data on the socio-economic environment, the net farm income and the perceptions of 14 farmers cultivating fields in other watercourses was collected.

Interviews

Farmers were interviewed through questionnaires three times during the cotton season. The first interview was taken in May and June during the sowing of cotton. This interview is basically used as an inventory of different socio-economic aspects and agricultural experiences of all farmers using the bed-and-furrow method. A second interview was taken in August and September to cover gaps of the first round of interviews and to record the experiences of farmers during the land preparation and sowing period. A final interview was conducted in December and January. Questions focused on a general evaluation of the bed-and-furrow method. Farmers' experiences and perceptions on the bed-and-furrow and basin irrigation methods were discussed and recorded by field staff.

Besides these questionnaires, observations and comments made by farmers during the weekly field visits were recorded in a separate file.

Weekly Field Visits

Every farmer was visited once a week by field staff. The farmers' agricultural practices were recorded on standard forms for both, the basin and the bed-and-furrow fields. Every agricultural activity was described by recording the date, use of labor and labor time, costs involved, machinery used, names and quantities of fertilizers and pesticides applied. Different agronomic aspects such as plant heights, the number of plants, pests and diseases in the fields were observed and recorded. Irrigation gifts for the two monitored cotton fields of every farmer were monitored using separate forms where the date, the irrigation time and the water source (canal and/or tubewell water) was recorded. All the above-mentioned information was documented in a separate file for each farmer.

Detailed Monitoring

Two farmers, one in the head and one in the tail of Bahadarwah Minor were selected to monitor their agricultural practices in detail. In order to gain more insight on the impact of the bed-and-furrow method at the farm level, the complete farming systems of these two farmers were monitored. Besides the three questionnaires, which were taken for every farmer, several open-end interviews were taken during the season. Every irrigation event was monitored. A cutthroat flume was used to measure the discharges to the fields. The irrigation advance time and the irrigation duration was recorded per *bunded* unit in the basin and bed-and-furrow fields.

Table 1.1. Data Collection Per Research Topic.

Subject	Topic	Source of Data	Data collected by
I. Socio-economic environment	Farm household composition	Interview	IIMI field staff
	Land distribution	Interview, OFWM project documentation	IIMI field staff
	Income position	Interview	IIMI field staff
	Castes	Interview	IIMI field staff
	Crop production	Interview,	IIMI field staff
	Cropping intensities	Interview, PID records	IIMI field staff
II. Physical environment	Soil characteristics	Soil sampling	Soil Survey Pakistan
	Climate	Rain gauges, Standard Evapotranspiration Pan, Secondary literature	Meteorological Department Pakistan, IIMI field staff
	Ground water	Observation wells, Ground water sampling	IIMI field staff, Soil Survey Pakistan
	Irrigation system	Daily discharge measurements of watercourses	MSc. Student, Peshawar Agricultural University
III. Hydraulic performance for bed-and-furrow vs. basin	Irrigation duration	Weekly field visits, field monitoring	IIMI and OFWM field staff
	Advanced behavior	Detailed field monitoring using flumes	IIMI field staff
	Water use efficiency	Analysis	This report
	Water application vs. crop water requirements	Analysis using CropWat	This report
IV .Net farm income Bed-and-furrow vs. basin	Land preparation	Weekly field visits	OFWM and IIMI field staff
	Seeds, fertilizers and pesticides	Weekly field visits, shop keepers interview	OFWM and IIMI field staff
	Labor	Weekly field visits	OFWM and IIMI field staff
	Cotton yield	Collection of yield data during weekly field visits, shop keepers' interviews	OFWM and IIMI field staff
V. Farmers' Perceptions	Evaluation of farmers' interests and opinion pertaining the Bed-and-furrow method	Open interviews, questionnaires, field observations	OFWM and IIMI field staff

Role of National Partners and Farmers

A field team consisting of 4 OFWM field assistants (4 days a week), 2 IIMI field assistants (6 days a week) and two field coordinators from IIMI and OFWM were mainly responsible for the implementation of the Joint Research Dissemination Program. The field team was divided into three groups, each headed by an IIMI field worker. Each group was responsible for the data collection of a group of 10 to 15 farmers in the head, middle and tail reaches of the Bahadarwah Minor command area. The IIMI field coordinator was mainly responsible for the supervision of the research activities of the field team members. The OFWM field coordinator organized meetings with the representatives of the Water Users Organization of the Bahadarwah Minor. Both field coordinators maintained contact with line departments and private agencies supplying agricultural inputs. With these private agencies, special extension campaigns on the use of fertilizers and pesticides were organized.

Once a week a progress meeting with representatives of OFWM, MREP and IIMI was held. Representatives from MREP proved to give valuable advice on the bed-and-furrow irrigation method to farmers during extension meetings, and to their OFWM and IIMI colleagues. Representatives of IIMI and OFWM coordinated the Joint Research Dissemination Program.

1.4 SURFACE IRRIGATION METHODS AND PRACTICES: SOME CONCEPTS

Among the irrigation methods used at the field level globally, a distinction can be made between: (a) surface irrigation methods like border irrigation, furrow irrigation, basin irrigation and, (b) closed conduit irrigation methods like sprinkler irrigation, drip irrigation and irrigation using the center pivot. The bed-and-furrow irrigation method falls in the first category. Surface irrigation means that water is distributed over a field by gravity. Water flow can be free as in border or basin irrigation, or can be guided over the field by small ditches as is the case for the furrow and bed-and-furrow irrigation methods.

In basin irrigation, the field is completely surrounded by a small dyke, and water covers the complete field. Large fields are divided in *bunded* units. The basins used in the research area are level and no run-off occurs. Water enters the field as rapidly as possible and is held in the basin until it is infiltrated. Basin irrigation is normally recommended for soils with a moderate to slow infiltration capacity. The basin size is determined by (a) available discharge, i.e. a small discharge requires a small basin and, (b) soil type, i.e. sandy soils with high infiltration capacities require smaller basins than for loam or clay soils with moderate to slow infiltration capacities. Different crops are suitable for basin irrigation. The method is not recommended for crops that are sensitive to wet soil conditions around the stem.

In furrow irrigation, water movement over the field is confined to small channels, i.e. the furrows. The furrows are constructed along the slope of the field. Water infiltrates from the bottom and the sides of the furrows moving downward and laterally to wet the soil. The length of the furrows is dependent on the available discharge and on the soil type. Here, the same rules apply as for basin irrigation. Crops are cultivated in a row (on a bed) in between the furrows. Three types of furrow systems can be distinguished:

- Contour furrows have a gentle slope and follow the topography of the field.
- Graded furrows are usually straight, but follow the prevailing slope of the field. Land leveling is usually required for graded furrows.
- Generally, level furrows have no slopes. A small dyke is sometimes constructed downstream of the furrow to pond the water and minimize run-off losses. High discharges are required to achieve acceptable water use efficiency.

The main difference between the furrow irrigation method and the bed-and-furrow method is the furrow spacing. When the furrow spacing is larger than the top width of the furrow, a bed is created. The main purpose of this bed is to cultivate two rows of crops. Less space is lost in the fields for the furrows, and more plants can be cultivated using the beds.

The different surface irrigation systems can be evaluated and compared by looking at the water application efficiency and the water distribution uniformity. The water application efficiency is the percentage of water effectively stored in the root zone of the crop in relation to the total quantity of water applied to the field. Water losses occur due to run-off, i.e. water reaches the end of the field and is drained, or due to deep percolation, i.e. water infiltrates below the root zone of the crop.

Water distribution uniformity expresses how even the water is distributed over a field in a percentage.

1.5 AGRONOMIC AND WATER MANAGEMENT ASPECTS FOR COTTON

Cotton Production in Pakistan

Cotton is the second important crop of Pakistan in terms of area and value added by the crop sub-sector. Raw cotton and its products contributed annually, on an average, was over 51 percent of total exports of Pakistan during the years 1992-1997. In 1995-96, the exports from this source earned 54.3 percent of the total foreign exchange, while it was only 49.2 percent in 1993-1994 (M.S. Niaz, 1997). As is presented by Figure 1.1, the average cotton yield in Pakistan has risen from an average of 240 kg per acre in the years 1980-1985 to about 590 kg per acre in 1991-1996. The area cultivated with cotton increased from 2.1 million acres in 1980-81 to 3.0 million acres in 1995-96. About 80 percent of the cotton area in Pakistan are located in the Punjab Province. The Sindh Province covers about 20 percent of the national cotton area. The North-West Frontier Province and Baluchistan have a share of less then 1 percent in the national area cultivated with cotton (Agricultural Statistics of Pakistan, 1996).

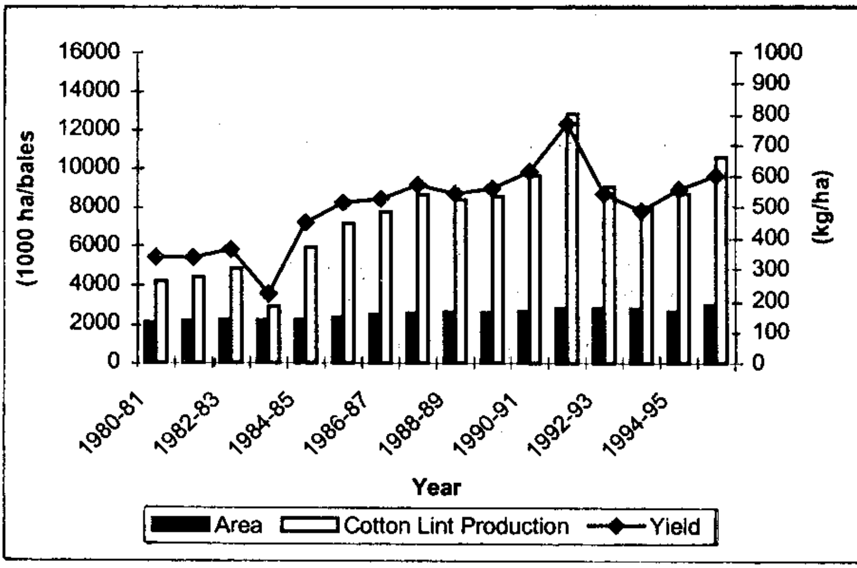

Figure 1.1. Cotton Production in Pakistan (Source: Agricultural Statistics of Pakistan, 1995-1996).

Agronomic Aspects

Cotton (Gossypium Hirsutum L., English: American Upland Cotton) is grown for seed and lint, which is the basic resource in the textile industry. Over the past decade, a wide scale of different cotton varieties has been bred in institutes such as the Central Cotton Research Institute of Multan. The varieties differ according to the length of the growing season and resistance to pests and diseases. The first picking for early maturing varieties such as CIM-240, CIM-109, Niab-78 and Krishma starts after 145-155 days, and for the late maturing varieties such as MNH-93, BH-36, SLS-1 and RH-112, after 165-175 days. Varieties such as CIM-1100 and CIM-448 are resistant to cotton leaf curl virus. Eleven cultivars, which are MNH-93, MNH-147, MNH-329, CIM-1100, CIM -109, CIM-448, Niab-78, Niab Krishma, BH-36, FH-634 and CIM-240 occupy the major cotton growing area in the Punjab Province(CCRIM, 1998).

In the development of cotton, several growth stages can be distinguished. These growth stages are presented in Table 1.2 for the early maturing variety, CIM-109.

Table 1.2. Phenology of CIM-109 (sowing date June 7).

Growing stage	Length	Days after sowing	Corresponding Dates
Emergence	7 days	0 – 7	June 7 - June 14
Emergence to squaring	20 days	7 – 27	June 14 – July 2
Squaring	21 days	27 – 48	July 2 - July 23
Early flowering	28 days	48 – 76	July 23 – August 20
Peak flowering	25 days	76 – 101	August 20 – September 14
Bolls maturation	40 days	101 – 141	September 14 – October 24
Opening of bolls	39 days	141 – 180	October 24 – December 2
Total growing season	180		

Source: CCRIM.

The average optimum temperature for the different growth stages is 30 °C. Temperature, therefore, is a major limitation to cotton production in Pakistan. Excessive day temperatures above 40 °C cause the heavy shedding of early fruiting forms (FAO 1979, CCRIM 1998). Most varieties are sown during May to June. The optimum planting time for the Bahawalnagar area is mid-May to the first week of June. Seeds under optimum moisture conditions start emerging on the third day, which is completed in a period of one week. The emergence of certified seeds is about 45-50 percent under most ideal field conditions. Vegetative growth occurs mainly during the squaring and early flowering stages. After mid-August, the effective period of boll setting for cotton starts. Irrespective of planting time and cotton varieties, about 85 percent of the total bolls are set in 45 days starting from mid-August to the end of September. The time to begin cotton picking is determined by the maturity of the crop. The amount of open cotton bolls, the quantity of dry leaves and the moisture content of the seed cotton judge the maturity (CCRIM, 1998, Meerbach 1997).

Medium and heavy textured soils with good water holding capacities, and medium to high levels of phosphorus and a pH of 5.8 to 7.5 are suitable for high cotton yields. Hard pan and sodic soils, and where green manure material has not been fully digested, have often been found to be low in oxygen. These soils retard seed emergence and seedling growth (CCRIM 1998). The rooting depth extends to a maximum of 1.8 m-depth. Cotton is tolerant to soil salinity. Though the crop is relatively tolerant for short periods of water logging, heavy rainfall has negative effects during flowering and boll opening (FAO 1979). A number of pests attack the cotton crop at different stages of plant development. The major cotton pests include cotton jasid, whitefly, thrips, spotted boll worm, pink boll worm, American boll worm, spiny boll worm, and late in the season, aphid (CCRIM 1998).

Water Management Aspects

According to the FAO (1979), cotton needs 700 to 1300 mm to meet its crop water requirements. The actual water requirement of the crop depends on the climate and the length of the total growing season. The crop water requirement per growth stage of cotton in Pakistan is presented in Table 1.3. The total consumptive use of 629 mm is rather low compared to the figures presented by the FAO (1979). Malik (1998) seems to have included the annual rainfall in the calculation of the consumptive use of cotton. The total water requirement for cotton planted in Bahawalnagar on 1 June 1998 was 1065 mm. However, after deducting the effective rainfall, the net irrigation requirement was 898 mm.

Table 1.3. Consumptive Use and Total Water Requirements of Cotton in Pakistan's Arid Climate.

Stages of growth	Seedling	Establishment	Vegetative	Flower bud formation and flowering		Yield formation			Ripening			Total
Consumptive use in m3/ha	635			635	761	963	761	761	635	635	506	6291
in mm	63.5			63.5	76.1	96.3	76.1	76.1	63.5	63.5	51	629.1
Total water requirements* (mm)	105.8			105.8	126.8	160.5	126.8	126.8	105.8	105.8	85.0	1048.5

* 60 percent application efficiency is assumed.
Source: M.N. Malik, 1998.

Table 1.3 is useful in showing the different crop development stages and the consumptive use of water. During the vegetative period, crop water requirements are low at about 10 percent of the total. During the flowering and yield formation phase, the crop water requirement is high at about 50-60 percent of the total water requirement. The crop water requirement declines in the final development stages. About 25 percent of the total water consumption is used in the ripening period. The peak water demand occurs during the peak flowering stage in the months of August and September. Water stress should be avoided during this period.

For cotton cultivation in basins, farmers apply a pre-planting irrigation gift, which is called rauni. As the root zone of cotton extends to about a 2-meter depth, CCRIM recommends moistening this complete zone by applying 2000 to 3000 m3 of water per hectare (200-300 mm). For the basin irrigation method, the date of the first irrigation is dependent on the soil, climate and the cotton variety planted. The following schedule for different cotton varieties (Table 1.4) are recommended by CCRIM:

Table 1.4. First water gift in days after planting for different cotton varieties.

Days after planting			
25-35	35-45	45-55	55-65
CIM-109 CIM-240 NIAB-78 Krishma	MNH-93 FH-682 SLS-1 RH-112	CIM-448 FH-634 MNH-329 BH-36	CIM-1100 MNH-147

Normally, the mid-season irrigation interval ranges from 15-18 days. Extreme care should be given to the timing of irrigation during the yield formation phase. There is a high possibility of injury to the crop from lack of water during this period. About 75 to 90 percent of bolls are formed during this period (August - September). Adequate moisture in the root zone could be maintained by arranging 4 to 5 irrigation events during these months. The last irrigation should be completed when 60 percent of the bolls are open. Normally, this is the time when the first cotton picking starts. This last irrigation is applied at the end of September to mid-October. During the growing season, the water supply needs to be scheduled in a manner that is favorable for reproductive rather than vegetative growth. The farmer can manage this by delaying a water gift for some time. The applied water stress will induce fruit formation.

1.6 Report Outline

A general description of the Fordwah Eastern Sadiqia (South) project area is given in Chapter 2. This chapter gives an introduction to the hydraulic characteristics of the canal system in the FES(S) area, followed by a description of project activities. The development and organizational structure of the Water Users Organization of the Bahadarwah Minor as part of the Participatory Irrigation Management project of OFWM is presented, followed by a presentation of the major characteristics of the farming system, soils and climate in the project area. Chapter 3 presents first, the selection process of the farmers and watercourses involved in the research program, and gives a detailed description of physical and hydraulic characteristics of the 5 selected watercourses. A detailed presentation of the socio-economic background and agricultural characteristics of the selected sample farmers in the Bahadarwah Minor follows. Chapter 4 describes the implementation process of the Joint Research Dissemination Program. Farmers' experiences and opinions regarding the use of the bed-and-furrow shaper and the hoeing machine are integrated in this chapter. An overview of different (in)formal meetings with farmers and the role of the farmers' organization in the dissemination program is presented. Chapter 5 presents the findings of the study of the group of sample farmers in the research area. A description and analysis of agricultural and irrigation practices of the sample farmers for basin and bed-and-furrow cultivation is presented. Here, the major differences found between basin and bed-and-furrow cultivation regarding the timing of different activities, pesticide and fertilizer applications, irrigation frequency, water depth applied to the cotton fields and the cotton yields are presented. Relations between different factors such as access to canal and/or tubewell water, the location of fields in the irrigation system, agricultural practices, irrigation frequency, the size of landholdings and cotton yields are analyzed. Finally, Chapter 5 presents farmers' reactions to the bed-and-furrow method. Chapter 6 details two case studies of sharecroppers in each, the head reach of the Bahadarwah Minor and a farmer in the tail reach of the Bahadarwah Minor. Emphasis is placed on the irrigation practices of these farmers. First, the advance time in basin and bed-and-furrow fields is analyzed. Second, a water balance for basin and bed-and-furrow fields is presented, which is based on the measured water gifts and climatic data of the area. Finally, the farmers' experiences are presented in detail. Chapter 7 presents an economic feasibility study of the basin and bed-and-furrow method. First, an overview of the investments in terms of time and money for different activities in basin and bed-and-furrow fields is presented, followed by a cost-benefit analysis of the basin and bed-and-furrow method. Here, the relations between the B/C ratio and the socioeconomic and the physical setting of the farmers are analyzed. Finally, Chapter 8 presents the major findings and the conclusion of the study.

2 SALIENT FEATURES OF THE RESEARCH AREA

The research area for the joint dissemination program is located in the southeastern part of the Punjab province, about 300km southeast of Lahore. The area falls within the boundaries of the Fordwah Eastern Sadiqia (South) Irrigation and Drainage Project, which commenced in 1992 and is to be finalized in 1999. In this chapter, first a description of the physical and hydraulic characteristics of the research area will be given, followed by a small presentation of the activities implemented by the FES(S) project. In the third section, the Farmers' Organization of the Bahadarwah Minor and Sirajwah Distributary will be introduced, followed by a brief description of the farming systems in the research area. In the last two sections, information related to the soil characteristics and the meteorological conditions in the research area will be presented.

2.1 PHYSICAL AND HYDRAULIC CHARACTERISTICS OF THE RESEARCH AREA

Eastern Sadiqia Canal

The research area covers the complete command area of the Bahadarwah Minor. The Bahaderwah Minor is part of the Eastern Sadiqia Canal System, which off-takes from the Suleimanki Headworks. Two canals off-take from the left bank of the Suleimanki Headworks: the Fordwah Canal and the Eastern Sadiqia Canal. The Eastern Sadiqia Canal is a perennial canal and was designed with a maximum discharge capacity of 4917 cusecs, but is actually running at 6000 cusecs (Mahmood, 1996). The Gross Command Area (GCA) of the Eastern Sadiqia Canal is 297,604 acres and its Cultivable Command Area (CCA) is 258.701 acres (NESPAK, 1992). The Bahadarwah Minor is located in the Malik Sub-division, which starts at the tail of the Eastern Sadiqia Canal. The Bahadarwah Minor is located in the Sirajwah section, which consists of the Sirajwah Distributary, Bahadarwah Minor, 1/R Bahadarwah Minor and Najeebwah Minor.

Sirajwah Distributary

Two, the Malik and Hakra Branch Canals, and the Sirajwah Distributary trifurcate at the tail of the Eastern Sadiqia Canal at Jalwala, about 74 kilometers from the Suleimanki Headworks. The Sirajwah Distributary has a head regulator consisting of a gated orifice. The design discharge of the Sirajwah Distributary is 197 cfs. About 36 outlets are drawing 57.5 cusecs from the Sirajwah Distributary. The GCA of the Sirajwah Distributary is 17,766 acres and CCA is 15,687 acres (Mahmood, 1996).

Bahaderwah Minor

The Bahadarwah Minor off-takes together with Najibwah Minor from the tail of the Sirajawah Distributary (see Figure 2.1). An ungated modular flowing weir serves the Najeebwah Minor, which has a design discharge of 39 cusecs. Instead of gates, wooden planks are placed in the weir notch to control the water intake. The intake of the Bahadarwah Minor is not gated and the flow condition at the intake is submerged. The design discharge of the Bahadarwah Minor is 82 cusecs, serving a GCA of 21,680 acres and a CCA of 19,753 acres. The study of Khalid Mahmood (1996) showed that during one measurement exercise, the Bahadarwah Minor was drawing approximately 32 percent more water than its design discharge of 82 cusecs. Three fall structures are located in the Bahadarwah Minor. There are 50 outlets located along the Bahadarwah Minor. Two outlets are served by the 1-R Bahadarwah Sub-minor, which has a design discharge of 3.57 cusecs. The tail structure consisted of three open flumes leading to the last three watercourses.

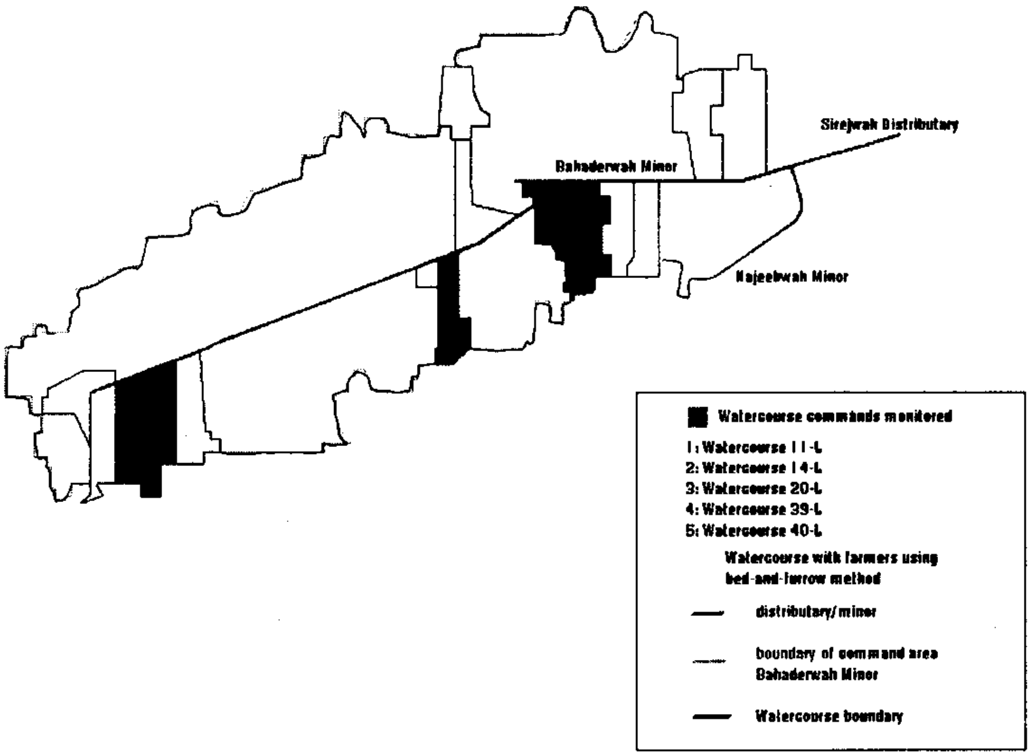

Figure 2.1. Layout of the Bahadarwah Minor Command Area.

The Bahadarwah Minor is part of a group of 18 distributaries and minors in the Eastern Sadiqia Canal command area, which are in the process of being lined. These canal sections have an original design discharge of up to 100 cusecs. These distributaries and minors are lined in order to control seepage losses. The lining consists of geo-membrane placed on compacted sub-grade and covered with a hard protective layer of concrete lining with watertight joints. The plan was that the lined section would be designed to carry the discharges about 20 percent above the original design discharges, and adequate free board would be provided for safe operation (NESPAK, 1992). Besides the lining of the canal sections, watercourse intake structures are remodeled/reconstructed and canal structures are improved. Both, the old and new designs of the Najeebwah and Bahaderwah Minors are presented in Table 2.1. The design discharge of the Bahadarwah Minor is increased with 11 cusecs, which is an increase of 13.4 percent. The Najeebwah Minor has an increase of 3 cusecs, equivalent to 7.6 percent. A reminder here is that the actual discharges for the different minors will be determined only after the lining is completed.

Table 2.1. Old and New Design Data for Lined Sections of the Bahadarwah Minor

	Old design data				New design data				
	Discharge (Cusecs)	Bed width (Feet)	Slope (Feet)	Depth (Feet)	Discharge (Cusecs)	Bed width (Feet)	Slope (Feet)	Depth (Feet)	Side slope
1/R Bahadarwah	3.57	3	1/3333	1.1	4	1	1/2500	1.32	1:1
Najeebwah	39	10.5	1/4000	2.5	42	5	1/5600	2.6	1:1.5
Bahadarwah Minor	82	19	1/7500	3	93	9	1/10000	3.65	1:1.5

Source: Lining Department

The Bahadarwah Minor was lined in *kharif* 1998. The lined canal is constructed on the same location of the old canal. Construction work was in progress in the head, middle and tail reaches of the minor. Therefore, it was found necessary to excavate a temporary canal alongside the old canal. Temporary pipe outlets of specific diameters replaced old watercourse intake structures (*moghas*). Water was guided through this temporary system. After the completion of a lined section, the water would follow its normal route. All lining work was completed during *kharif* 1998, however, some sections still need proper connections. Newly constructed Open Flumes with Roof Block (OFRB) have replaced all temporary pipe outlets.

2.2 CURRENT IMPLEMENTATION ACTIVITIES UNDER FES(S)

The Fordwah Eastern Sadiqia (South) project area is bordered on the north-west by the Malik Branch Canal, on the south by lands served by the 6-R Distributary of the Hakra Branch, and on the east by India. The gross command area (GCA) under the project is about 298,000 acres (121,000 ha) and the cultivable command area (CCA) is about 259,000 acres (105,000 ha). The FES(S) project was formulated with the objective to raise agricultural production in the project area, which is affected by: (1) waterlogging and salinity, and (2) water supply constraints.

Waterlogging and Salinity

The estimate in a World Bank appraisal report was that about 50 percent of the FES(S) project area was waterlogged, which means that half of the project area has a permanent water table within 5 feet (1.5 m) of the surface. The major causes of waterlogging are (a) the conveyance losses from the irrigation system and (b) the lack of an adequate drainage system in the project area. The estimate was that more than 45 percent of the supply from the canal head up to the farm intake percolates to the ground water. The area affected by waterlogging was increasing by 15,000 acres (6,000 ha) each year. In 1992, it was estimated that 11 percent of the area had a ground water table of less than 2.5 ft (0.76 m), 17 percent of 2.5 - 4 ft (0.76-1.22m) and 21 percent of 4-5 ft [1.22-1.52 m) (NESPAK, 1992).

The high water table, in combination with high ground water evaporation, causes a continuous capillary rise of the water and salts, thus converting effectively fertile agricultural land into salinized areas. The estimate in 1992 was that about 12 percent of the CCA was affected by soil salinity above threshold tolerance levels of most crops (NESPAK, 1992). The estimate dictates that by the year 2000, about 50 percent of the CCA would have a water table depth of less than 4 ft (1.2 m) and EC of more than 8 mmhos/cm, and that by 2010 this proportion would increase to 65 percent.

Water Supply Constraints

The design of the Eastern Sadiqia canal system was based on a water allowance of 3.6 cusecs per 1000 acres. This would permit an annual cropping intensity of 80 percent. However, the water supply increased after the commissioning of the Mangla Dam, but the canal capacity has not been increased accordingly. Instead of this, the old canal system was operated without freeboard. The annual cropping intensity increased to about 129 percent in 1992 due to the above-mentioned increased water supply, and sub-irrigation from the shallow water table. During periods of peak crop water demands, the surface water supply is short. This situation is aggravated by inequity in water distribution among watercourses and in the watercourse command areas (NESPAK,1992).

Measures

According to the PC-I (NESPAK, 1992) of the FES(S) project, two measures were required to increase agricultural production in the project area:

(a) increasing irrigation water supplies through water conservation and improved water management;
(b) reducing waterlogging and salinity through the above water conservation measures and through sub-surface drainage where essentially required.

Works in the FES(S) project phase I would consist of:

(i) Approximately 173 miles (280 km) of horizontal interceptor drains would be installed along the major branches and distributaries of above 100-cusec capacity. The intercepted water would be put back into the canal;
(ii) Approximately 18 channels with original design discharges of up to 100 cusecs would be lined (see the former paragraph);
(iii) Improvement of about 340 watercourses to standards established under the OFWM program, including precision land leveling of about 3,000 acres (1,200 ha);
(iv) WAPDA planned 16 surface drains of about 196-mile (314km) lengths in the project area. Nine additional drains of 23 miles (38 km) would be included in the FES(S) project.

Besides these construction works, activities in the FES(S) project would focus on research, monitoring and evaluation, and technical assistance and training.

2.3 Farmers' Organizations in the Bahadarwah Minor

Since 1976, On-Farm Water Management is active at the watercourse level in irrigation systems in Pakistan. On-Farm Water Management is part of the Agricultural Department. In order to reduce the water losses in the watercourse command areas, the following activities were implemented by OFWM: improvement of watercourses, Precision Land Leveling, the installation of concrete outlets (*pucca nakkas*) and the introduction of advanced water management techniques at the farm level. Besides these main activities, OFWM is currently active as participatory drainage projects in pilot projects and the organization of Community Based Tubewell Organizations, which will take over the old SCARP (Salinity Control and Reclamation Project) tubewells, or new tubewells will be constructed.

An important component in the watercourse improvement program is the organization of farmers in so-called Water Users Organizations at the watercourse level. The Government of Pakistan decided to extend farmers' participation in the operation, management and maintenance from the watercourse level to the distributary level in 1982. A pilot project, "Participatory Irrigation Management" (PIM) was launched as part of the research component of the FES(S) project at Bahawalnagar.

The objectives of PIM are:

- Strengthening farmers' institutions, i.e. WUAs, into federations and canal councils.
- Providing farmers' institutions a stronger voice in operation and maintenance of irrigation system, and developing a framework to address legal and social constraints related to them.
- Improving irrigation scheduling for a better water delivery to match crop water requirements through introducing improved operation and management.
- Introducing appropriate cropping patterns, cultural practices, and input management (OFWM, 1996).

The pilot area of the PIM project is the command area of two distributaries: Bhukan and Sirajwah. PIM started in Bahawalnagar in 1993. In a preparatory phase, a methodology for the organization of farmers was developed. In the first phase, work concentrated on the organization of farmers in the Bahadarwah Minor and Bhukan Distributary. In the second phase, the farmers in the Najeebwah and Sirajwah Minors were organized (OFWM, 1998).

Water users in the Bahadarwah Minor are organized in a three-tier system:

(a) At the watercourse level the water users are organized in a Water Users Association (WUA).
(b) The Bahadarwah Minor has 52 outlets and is divided into three sections:
    Section 1, at the head, from Watercourse 1 to Watercourse 18;
    Section 2, the middle of the minor, from Watercourse 18 to Watercourse 36; and,
    Section 3, the tail, from Watercourse 36 to the last watercourse.
    Each section has a sectional Water Users Organization (SWUO).
(c) All three Sectional Water Users Organizations are represented in the Water Users Organization (WUO) for the complete Bahadawar Minor.

Finally, the WUO of the Bahadawar Minor is part of the Water Users Federation (WUF) covering the complete command area of the Sirajwah Distributary. So, the WUF of the complete Sirajwah Distributary is composed of representatives of three WUOs:

- 3 representatives of the WUO from Bahadawar Minor;
- 3 representatives of the WUO from Sirajwah Distributary; and,
- 3 representatives of the WUO from Najeebwah Minor.

All organizational bodies, i.e. WUA, SWUO, WUO and WUF have a board of representatives with the posts of President, Vice President, General Secretary, Secretary of Information, Treasurer and Members. The water users at the watercourse level elect the office bearers of the WUA. Members of the organizations at the section, minor and distributary levels are elected among the office bearers of the lower levels.

2.4 Typology of the Farming System

The project area is located in the Punjab "Cotton-Wheat" agro-climatic zone, where conditions permit year-round cultivation. Thus, the major crops cultivated are wheat in the *rabi* season and cotton in the *kharif* season. Fodder and sugarcane are cultivated in both seasons. Rice is grown in the *kharif* season. These crops account for more then 94 percent of the cultivated area (NESPAK, 1992). Other crops grown in the area are maize and pulses. The annual cropping intensity in the FES(S) area, as estimated by the Monitoring and Evaluation Department, WAPDA, in 1988-1989, is 129 percent. In *kharif*, the cropping intensity is 55.3 percent and in *rabi* it is 74 percent. Sugarcane is accounted for in both seasons.

Crop yields are low and vary over the project area depending upon soil conditions, the degree of waterlogging, and farm practices. The estimate in 1992 was that the crop yields were about 1.6 tons/ha for rice, 1.0 tons/ha for cotton, 1.5 tons/ha for wheat and 30.2 tons/ha for sugarcane (NESPAK,1992).

About 2207 farmers cultivate a total cultivable command area of 19,267 acres in the Bahadarwah Minor command area. The average landholding size is 8.7 acres. A large group of farmers (42.5%) can be considered as small/marginal farmers, while about half of the farm population can be

Most farmers in the FES(S) project area are solely dependent on canal water for irrigation. The use of tubewells by farmers for supplemental irrigation during periods of peak crop water requirements is limited in the project area. The development of groundwater resources is limited due to poor aquifer conditions and marginal to hazardous quality ground water (generally above 1500 mmhos/cm). Water at a shallow depth in areas along canals have a much better quality (NESPAK, 1992).

2.5 Soil Physical Characteristics

The project area was reclaimed from the Cholistan Desert in the 1930s when surface irrigation water was first delivered to that part of the Punjab Province. The topography is largely flat with no natural drainage. Outcropping sand dunes occupy about 6 percent of the area. The topsoil is generally medium-textured and is underlain by several hundred meters of sand and silt (NESPAK, 1992).

Table 2.2 presents the three conventional soil groups found in the FES(S) project area. The Farida series, a group of moderately textured soils, occupies more then 90 percent of the FES(S) project area. Buchiana, a group of medium textured soils, is found in 6.5 percent of the project area. Chuharkana is a group of moderately fine textured soils, which is found in only 1.5 percent of the project area. About 0.9 percent of the project area is constantly under water.

Table 2.2. Area of Soil Aeries.

Soil series	Acreage	% With respect to CCA
Farida	237,875	91.1
Buchiana	16,840	6.5
Chuharkana	3,875	1.5
area under water	2,410	0.9
Total	261,000	100.0

Source: Planning Directorate (W) Central (1986).

2.6 Meteorological Aspects

The project area has an arid climate, except during the months of July and August, which are considered as the monsoon months (see Fig 2.2). The average annual rainfall is about 196 mm. With a potential evaporation of 2205 mm per annum, irrigation is essential for agriculture. The hottest month is June with an average maximum temperature of 46.4 °C. January is the coolest month, with an average maximum temperature of 25.3 °C and an average minimum temperature of 15.8 °C.

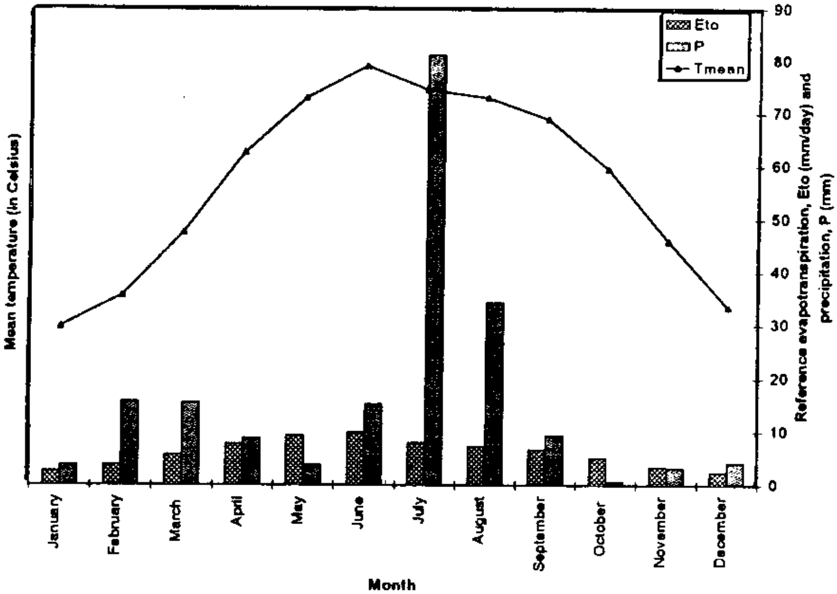

Figure 2.2. Mean Temperature, Precipitation (p) and Referencc Evapotranspiration (Eto), Based on 28 years of Meteorological Data (Source: Meteorological Institute, Bahawalnagar).

3 CHARACTERIZATION OF WATERCOURSES AND SAMPLE FARMERS

3.1 SELECTION OF WATERCOURSES AND SAMPLE FARMERS

From 20th May 1998 onwards, approximately 200 farmers were informed by group meetings or by individual contacts about the bed-and-furrow program. During the sowing period the dissemination program faced the following constraints:

- Field observations indicate that 70 percent of the available area in the head and 50 percent in the tail of the minor was already sown with cotton using the traditional basin method.
- Starting sowing with the use of the bed-and-furrow shapers was delayed till the last days of May.

IIMI and OFWM staff decided to extend the activities of the bed-and-furrow program to all interested farmers in and outside the command area of the Bahadarwah Minor. Finally, a group of 49 farmers used the bed-and-furrow shapers for an area of about 120 acres. As is presented in Table 3.1, the bed-and-furrow fields are located in different watercourses of the Bahadarwah and Najeebwah Minors.

Table 3.1. Location of Bed-and-Furrow Fields in the Research Area.

Watercourse	No. of farmers	Bed-and-furrow area (acres)	Watercourse	No. of farmers	Bed-and-furrow area (acres)
2-R	1	4.5	29-L	1	6
5-R	5	18.63	38-L	1	1
7-L	2	5.88	39-L	5	5.75
9-L	5	11.0	40-L	6	12
11-L	9	14.25	42-L	1	2
14-L	2	4	43-L	--	1.5*
18-R	1	2	45-L	--	9.5*
20-L	3	3	Najeebwah Minor	2	6
21-AL	1	2	Sirajwah Distributary	2	7
2-1R	2	5			

* These fields belong to farmers who have bed-and-furrow fields in other watercourses.

For the comparative analyses between the bed-and-furrow and basin methods, the field research concentrated on 25 farmers in 5 selected watercourses, i.e. 11-L, 14-L, 20-L, 39-L and 40-L. The discharges of the selected 5 watercourses were monitored every two days. The irrigation practices of two farmers in Watercourses 11-L and 40-L were monitored in detail for every *warabandi* turn.

Another 18 farmers in other watercourses were monitored. Data collection concentrated on the agro-economic practices of this group.

3.2 SELECTED WATERCOURSES IN THE BAHADARWAH MINOR

All outlets of the watercourses are located on the left bank of the Bahadarwah Minor. As part of the Lining Project all old fixed outlets were demolished and were replaced with temporary pipe outlets. The new outlets were constructed during the research project, and all outlets are Orifices with Roof Block (OFRB) and connected to the Bahadarwah Minor. Watercourses 11-L and 14-L are located upstream of a drop-structure where the Bahadarwah Sub-minor takes off. Watercourses 11-L and 14-L are referred to as being in the head of the Bahadarwah Minor; 20-L in the middle of the minor command area; and, Watercourses 39-L and 40-L in the tail of the Bahadarwah Minor. The main characteristics of the watercourses are presented in Table 3.2.

Table 3.2. Characteristics of Selected Watercourses.

	Watercourse 11-L	Watercourse 14-L	Watercourse 20-L	Watercourse 39-L	Watercourse 40-L
RD number	16080	18650	29550	52800	55980
Outlet	OFRB	pipe	pipe	pipe	pipe
Authorized Discharge (l/sec)	70.0	54.9	35.7	30.3	34.3
GCA (acres)	796	544	361	340	340
CCA (acres)	685	540	347	298	336

Source: Outlet Register Punjab Irrigation Department.

Watercourse 11-L

Watercourse 11-L has its outlet located at RD 16080 of the Bahadarwah Minor. Authorized discharge for Watercourse 11-L is 69.95 l/sec. The Gross Command Area of 11-L is 796 acres and the Cultivable Command Area is 685 acres. The outlet was newly constructed under the Lining Project and is an Orifice with Roof Block (OFRB). The flow condition is normally submerged. The watercourse is partly lined. All laterals are unlined. Two tubewells are located in the command area of Watercourse 11-L.

Watercourse 14-L

This watercourse off-takes from the Bahadarwah Minor at RD 18650. Watercourse 14-L has an authorized discharge of 54.9 l/sec. The Gross Command Area is 544 acres and the Cultivable Command Area is 540 acres. The outlet was temporarily constructed for the Lining project and consists of a simple pipe outlet. An OFRB will be constructed under the Lining Project. Part of the watercourse is lined. The command area of Watercourse 14-L is located on the north and south sides of the Bahadarwah Minor. About 300 meters downstream of the *mogha*, the watercourse bifurcates into a section crossing the Bahadarwah Minor through a pipe feeding the command area on the north side of the Bahadawar Minor. The other section feeds the remaining command area along the south side of the Bahadarwah Minor. Four tubewells are located in the command area of Watercourse 14-L.

Watercourse 20-L

The *mogha* of Watercourse 20-L is located at RD 29550 of the Bahardawah Minor. The Gross Command Area is 361acres and the Cultivable Command Area is 347 acres. A temporary pipe outlet of 7" diameter was constructed under the Lining Project. The pipe outlet was replaced by a permanent OFRB during the Lining Project. The authorized discharge of Watercourse 20-L is 35.68 l/sec. The watercourse is lined for quite a long distance. Tubewells are not located in Watercourse 20-L. The tail area of Watercourse 20-L is severely affected by waterlogging and salinity.

Watercourse 39-L

Watercourse 39-L is located at RD 52800 from the Bahadarwah Minor. A temporary outlet was constructed under the Lining Project. The authorized discharge of Watercourse 39-L is 30.3 l/sec. The Gross Command Area is 340 acres and the Cultivable Command Area is 298 acres. The major part of the watercourse is lined. No tubewells are located in Watercourse 20-L.

Watercourse 40-L

The outlet of Watercourse 40-L is located at RD 55980 of the Bahadarwah Minor. The authorized discharge of the watercourse is 34.26 l/sec. The Gross Command Area and Cultivable Command Area are 340 and 336 acres, respectively. A temporary pipe outlet was constructed under the Lining Project, which was replaced by a permanent OFRB.

3.3 SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLE FARMERS

The number of sample farmers is 43; 25 farmers from the 5 selected watercourses and 18 farmers from other watercourses. Of the 38 respondents, only one farmer's family has its roots in the Bahadarwah Minor area. All other farmers responded that their families migrated from India after partition. A majority of the sample farmers belong to the caste of the Joyas (57%). Other castes represented are Rajput, Khichi, Wattoo and Arian.

Family Size

As is presented by Table 3.3, the sample farmers have an average family size of 9. There is a large variation in family size among sample farmers: from a maximum of 18 persons to a minimum of 2 persons. The large variation in family size is due to the presence of families composed of a father and married sons plus grandchildren living in one compound, and on the other side young couples without children living independently or being economically independent.

Table 3.3. Family Size and Family Members Active in Agriculture.

	Family size	No. of family members active in agriculture	No. of men active in agriculture	No. of women active in agriculture
Average	9	3.1	2.2	0.9
Standard deviation	4.1	2.6	1.6	1.6
n =	43	43	43	43

The average number of family members active in agriculture is according to the sample 3.1, which can be divided into averages of 2.2 males and 0.9 females per household. The respondents of the interviews were all males. The actual contribution of women to agricultural activities of the family seems to be higher than is indicated by this average. One observation was that many women are active in hoeing cotton fields, picking cotton, harvesting and planting rice, tending livestock, etc.

Distribution of Landholdings

As is presented by Table 3.4, the group of sample farmers cultivating less than 5 acres is rather small, only 7.3 percent when compared to the percentage of farmers in the same land holding category for the complete Bahadarwah Minor area., which is 42.2 percent. A large group of sample farmers (43.9 %) has a land holding size between 5 to 12.5 acres. Thirty percent of the sample farmers have a land holding size of more than 26 acres. Compared to the distribution of land holdings in the complete Bahadarwah Minor area, small farmers are under-represented in the research sample, while large farmers are over-represented.

Landowners, Shareholders and Lessees

About 84 percent of the sample farmers cultivate their own land. Two-thirds of this group is solely dependent on its own land, while one-third of this group cultivates extra land on lease and/or share basis. Fourteen percent of the sample group is tenants, while only 2 percent of the sample group are leasing land. The rates of leasing land, on average, are Rs 3150 per acre per year (n=6), with a minimum of Rs 2500 and a maximum of Rs 4200 per acre per year. The most common share holding arrangement between landowners and tenants is a 50 percent share in fertilizer, pesticide and seed costs and a 50 percent share in the yield. Normally, these costs are first deducted from the yield at the end of the harvest and the remaining yield is divided between the landowner and the tenant. The tenant, in most cases, is responsible for land preparation including the costs for renting machinery, irrigation events, pesticide and fertilizer applications. Of 43 farmers interviewed, 9 had one or more tenants.

Table 3.4. Land Holding Size in the Research Area (source:OFWM).

Land holding size (acres)	No. of farmers Bahadarwah area	In % of total	No. of sample farmers Bahadarwah	In % of total
Less than 5	937	42.4	3	7.3
5 to 12.5	796	36.1	18	43.9
13 to 25	353	16.0	7	17.0
26 to 50	92	4.2	7	17.0
above 50	29	1.3	6	14.6
TOTAL	2207	100	41	100

Use of Permanent Labor

Among the group of sample farmers, about 14 farmers (32.6 %) use permanent labor on their farm holdings. All farmers using permanent labor are landowners and have an average landholding size of 51 acres. Out of these 14 farmers, 6 have additional income-generating activities through ownership of a large number of cattle, as a shopkeeper or schoolteacher, and as a milk producer in a factory. The average income of a laborer in the area is Rs 12000 plus 12 maunds of wheat per year

Additional Income Generating Activities

Besides income generated from agricultural production, farmers often have additional sources of income. Among the sample group, 27 farmers (approximately 60 % of the sample) stated that they did not have an additional source of income outside of agriculture. However, 16 farmers (approximately 40 % of the sample) had additional sources of income. As is presented in Table 3.5, the sources of income vary from teaching at local schools, to milk factories, to the sale of cattle, wage laboring, etc.

Table 3.5. Additional Income Generating Activities.

Source of Income	No. of Farmers
Shopkeeper	3
School teacher	3
Milk factory	2
Flour factory	1
Government service	1
Imam	1
Local medicine	1
Wage laborer	1
Income from selling cattle	3

All sample farmers having less than 5 acres of land have an additional source of income. For the group of farmers cultivating between 5 to 12.5 acres, approximately 33 percent have an extra source of income. For the other landholding size categories, about 50 percent of the farmers have an extra income besides agriculture (except for livestock).

Resource Ownership

Approximately 60 percent of the sample farmers do not own land preparation equipment. Approximately 15 percent of the sample farmers own a pair of oxen with equipment to plough and drill. The remaining farmers, approximately 35 percent, own tractors with equipment such as trolleys, ploughs, ridgers, drills and sometimes boom sprays. The farmers of the last category are mostly large landowners, as their average land ownership of 58 acres shows. According to a survey conducted by the OFWM (1997), there are 213 tractors available among the 2207 farmers in the Bahadarwah Minor; another indication that the larger landowners are over-represented in the sample group.

Most farmers own cattle like buffaloes, cows, goats, sheep, oxen or donkeys. Two farmers out of 38 respondents have a large number of goats and sheep (11 and 20, respectively), which are held for trading. About 80 percent of the farmers own 1 or more buffaloes and/or cows for milk production. About 37 percent of the sample farmers own more then 5 buffaloes and/or cows. Fodder production is important for these farmers.

3.4 PHYSICAL SETTING

Soils

All sample farmers were asked to give a description of their soil type (see Table 3.6). The descriptions are diverse; different descriptions are given for the same types of soil. According to the farmers, a large part of the area (70 %) has medium-textured loamy soils. Farmers indicate that about 25 percent have a medium- to light-textured soil (sandy, medium, sandy loam soils). Only 5 percent of the descriptions indicate soils with some clay content (*pacca* and clay loam soils). Results of a study conducted by the Soil Survey of Pakistan (1999) indicate that a vast majority of the sample fields have a sandy loam soil.

Table 3.6. Soil Descriptions.

Soil description	No. of descriptions
Sandy medium	1
Sandy	4
Medium	22
Loam medium	3
Mera (loam)	3
Sandy loam	2
Half *mera* (half loam)	2
Kacha (soft soil)	2
Pacca (hard soil)	4
Mera light (light loam)	1
Loam	3
Clay loam	1
Raila (sandy soil)	1
Kulsathe (sandy loam with salinity/sodicity problems)	1

According to the farmers, about 40 percent of the fields experience problems related to salinity and/or sodicity. Results of chemical soil analyses of the SSP in fields in 5 selected watercourses show that 50 percent of the fields are affected by salinity and/or sodicity problems (see Table 3.7). Remarkable, is the high proportion of sodicity-affected soils in Watercourse 40-L. Sodic-affected soils are distinguished from saline-affected soils by a disintegration of soil texture and a loss in permeability. Fields affected by sodicity problems require an amendment of chemicals like gypsum, while for salinity-affected fields only leaching is normally required.

Table 3.7. Salinity/Sodicity-affected Soils in 5 Watercourses of the Bahadarwah Minor.

No. of fields in	Salinity sodicity class			
	NSNS: Non saline non-sodic	NSS: Non-saline sodic	SNS: Saline-non sodic	SS: Saline sodic
Watercourse 11-L	4	2	X	2
Watercourse 14-L	3	x	X	x
Watercourse 20-L	2	x	1	1
Watercourse 39-L	2	1	X	1
Watercourse 40-L	1	4	1	1
Total	12	7	2	5

Source: Soil Survey Pakistan.

Access to Canal Water

In the Bahadarwah Minor command area, canal water is equitably distributed among farmers according to a *warabandi* schedule (see Malhotra 1982 for a description). The *warabandi* schedule should assure that every acre receives water for a fixed period of time during each week. The reality, however, is different. Farmers' access to canal water is dependent on the location of the their fields in the watercourse, and on the location of the same watercourse in the minor command area (see Munir, 1998).

As presented by Table 3.8, the number of irrigation events applied to cotton fields during *kharif* 1997 varied considerably among farmers located in watercourses in the head and tail reaches of the Bahadarwah Minor. Farmers cultivating cotton in watercourses at the head of the system applied 5 to 6 irrigation events during *kharif* 1997. Farmers in the tail watercourses applied on average 2 irrigation events for cotton in the same season. Despite the difference in the number of irrigation applications, the average cotton yield of 400 kg/acre is almost the same among farmers in the complete system. Apparently, a reduced number of irrigation events did not affect the cotton yield in the tail watercourses.

Table 3.8. Irrigation Events and Cotton Yield in *Kharif* 1997.

	Head	Middle	Tail	Total
	(n=18)	(n=9)	(n=12)	(n=39)
Irrigation events				
Average	5.47	4.67	2.04	4.23
Standard deviation	1.99	1.48	1.45	2.26
Cotton yield (kg/ha)				
Average	400.78	441.62	400.72	399.93
Standard deviation	178.58	175.05	166.92	180.41

(Based on farmers' interviews).

Access to Tubewell Water

Out of 43 sample farmers, 8 farmers (19 %) had access to tubewell water. They either own the tubewell or are able to rent water from a tubewell owner. Five farmers in Watercourses 11-L and 14-L are using tubewell water frequently. According to these farmers, two irrigation events with tubewell water are applied in *rabi* and 4 to 5 irrigation events with tubewell water are applied in *kharif*. Table 3.9 presents the Total Dissolved Solids and pH of five tubewell water samples taken. The water quality of the tubewell in Watercourse 40-L is brackish. Water samples 2 and 3 have a TDS in an acceptable range, while the water samples 1 and 4 indicate an increased salinity level and thus, are of a moderate to poor quality.

Table 3.9. TDS and pH of Tubewell Water.

Sample	Location	pH	TDS (ppm)
1	11-L	8.8	1400
2	14-L	9.0	800
3	14-L	9.2	520
4	14-L	8.9	2400
5	40-L	7.9	more then 10000
6	canal	8.7	480

3.5 FARMING SYSTEM

Cropping Intensity and Pattern

The average cropping intensity among 34 sample farmers is 162 percent. The cropping intensity in *kharif* 1998 (84 %) is slightly higher than the cropping intensity in *rabi* 1997-1998 (78 %). The cropping intensities between farmers located in the head or tail of the Bahadarwah Minor do not vary much. Only during *kharif* 1998 did farmers located in the head of the system cultivate 7.5 percent more of their land than in the tail.

The main crops grown in the Bahadarwah Minor area are wheat in *rabi* and cotton in *kharif*. Of the area cultivated by the sample group in *rabi* 1997-1998, about 67 percent were cultivated with wheat, followed by 8 percent fodder and 8 percent sugarcane. About 15 percent of the farm area were left fallow. Only 2 percent of the area were cultivated with other crops such as oilseed, barley, tobacco, berseem, mustard and grams. In *kharif* 1998 about 65 percent of the sample area were cultivated with cotton. About 10 percent of the area were cultivated with sugarcane, followed by fodder, which accounts for 8 percent. About 14 percent of the cultivable sample area are left fallow. Other crops grown are rice, watermelon and oilseed, which, together account for 3 percent of the cultivable sample area.

Every farmer interviewed cultivated wheat and cotton. Approximately 47 percent of the sample farmers preferred to cultivate a combination of wheat, sugarcane and fodder in *rabi*. Another 35 percent preferred the combination of wheat and fodder. In *kharif*, about 58 percent of the sample farmers cultivate a combination of cotton, sugarcane and fodder, while about 32 percent cultivate a combination of cotton and fodder. In both seasons, only a minority of the farmers, 11 and 13 percent, respectively, cultivate only wheat or cotton. In both seasons, about 80 percent of the farmers cultivate fodder, which is an indication of the importance of animal husbandry for the farm population.

3.6 ACCESS TO AGRICULTURAL INPUTS

Access to Credit

Out of the 39 interviewed sample farmers, 7 farmers responded that they did not take loans or credit and expressed that they did not face difficulties to obtain credit or a loan. Three of these farmers had an extra income besides their agricultural activities. Farmers had the possibility to mention different sources of credit. Half of the sample farmers had access to loans provided by the Agricultural Development Bank (ADB) during 1998, or in the previous years. These loans consist of agricultural packages for a cropping season and loans for the purchase of farm equipment such as tractors. Farmers can apply for an ADB loan to cultivate cotton or wheat before the start of the growing season. These loans have to be repaid after the harvest with an interest of about 14 percent. Loans for farm equipment can be repaid in yearly installments, with interest, over 5 years. About 80 percent of the sample farmers cultivating more then 25 acres of land are using or have used ADB loans. About 50 percent of the sample farmers cultivating land between 5 and 25 acres have access to the ADB. Small sample farmers with less then 5 acres cultivated did not use ADB loans. For other sources of credit, shopkeepers and the Commission Agent account for about 25 percent of the credit transactions. The remaining part of the credit transactions is accounted for by relatives, friends, farmers and in the case of tenants, the landowner.

Farmers informed that the problems associated with getting loans were: convincing the Credit Officer of ADB, the lengthy process of loan application and the application itself. Another difficulty mentioned was the need for co-lateral (land, tractor etc.) to obtain a loan. Six farmers responded that they were reluctant to take a seasonal loan. In the case of crop failure, farmers have to cope with repaying heavy debts to the bank.

Access to Fertilizers and Chemicals

All sample farmers were asked where they bought farm inputs as fertilizers, seeds and chemicals. Of the 39 respondents, 24 farmers bought their farm inputs from shopkeepers in Bahawalnagar, Dunga Bunga or Haroonabad. Only 9 farmers purchased their farm inputs from a Commission Agent. Six farmers bought their farm inputs from both, the shopkeeper and the Commission Agent.

About 18 percent of the farmers pay for their seeds, fertilizers and pesticides in cash. About 31 percent of the sample farmers responded that they would pay for their inputs after the harvest. About half of the sample group was paying partly in net cash and the balance after the harvest. So, about 80 percent of the sample farmers are indebted to a shopkeeper or Commission Agent until the end of the harvest.

Access to Farm Implements

Among the 39 sample farmers, 12 have their own farm implements such as trolley, drill, plough, etc. The other 27 sample farmers hire mechanical equipment when necessary. All these farmers pay for the hire of tractors and equipment in cash. The sample farmers did not mention loans or other arrangements.

A group of 21 farmers mentioned the place or person they hired the equipment from. About 24 percent of the sample farmers hire equipment from relatives and another 14 percent hire equipment from friends. A large group of farmers (43 %) responded that they rented equipment from their village. About 19 percent of the farmers are renting equipment from Dunga Bunga. This last group of farmers cultivates fields in watercourses along the head of the Bahadarwah Minor.

4 DOCUMENTATION OF THE FIELD RESEARCH PROCESS

4.1 Introduction Meetings with Farmers

At the start of the joint dissemination program it was found necessary to organize introduction meetings with farmers in the Bahadarwah Minor area. The primary target group was those farmers cultivating land in the selected watercourse command areas. Other interested farmers were also welcomed. These meetings had the following objectives:

1. to introduce IIMI staff to the farming community and the research area;
2. to provide information to the target group relating to the bed-and-furrow irrigation method: a general description of the method, advantages and disadvantages of the method and past experiences with the bed-and-furrow method;
3. to provide information to the target group on land preparation required for the implementation of the bed-and-furrow shaper: a first technical lecture;
4. to inform the target group about the Joint Dissemination Program: an explanation of the role of MONA, OFWM, IIMI and farmers in the program, the research activities of IIMI and OFWM and the supporting activities of the Joint Dissemination Program to the farming community.
5. to make an inventory of those farmers interested in participating in the Joint Dissemination Program.

In cooperation with the presidents of the Water Users Associations, introduction meetings were held with farmers on Watercourse 14-L on 23 May, Watercourses 21 A/L and 40-L on 25 May. On 29 May, an extra introduction meeting was held on Watercourse 20-L. The number of farmers attending these meetings was about 30-50 percent of the total number of shareholders in the watercourse commands. The number of farmers interested in the bed-and-furrow irrigation method was limited at the first introduction meetings.

In approximately four weeks, 200 farmers were informed by group meetings or by individual contacts about the Joint Dissemination Program.

4.2 Implementation of the Bed-and-Furrows: Use of the Bed-and-Furrow Shaper

The joint dissemination program started on 19 May, 1998 comprising IIMI, OFWM and MREP staff. Introduction meetings (see Section 4.1) were organized in the first week with farmers in the selected watercourse command areas, but it was not possible to start making bed-and-furrow fields. The required bed-and-furrow shaper was especially made for this research project and its delivery was substantially delayed.

Cotton sowing in the Bahadarwah Minor area normally starts in the first weeks of May and continues until mid-June. Due to limited time and to demonstrate the technique to farmers, it was necessary to hire an extra bed-and-furrow shaper. This bed-and-furrow shaper (now called the JB shaper) was available in Bahawalnagar through a private entrepreneur. The costs involved for renting this machine was Rs 125/acre. Farmers (Rs 50) and IIMI (Rs. 75) shared these costs.

Both bed-and-furrow shapers arrived on 29 May. The IIMI bed-and-furrow shaper was delivered in the tail watercourses of the minor, while the JB shaper started in the watercourses in the head of the Bahadarwah Minor. On 30 May a demonstration was organized at Watercourse 40-L in the presence of IIMI, OFWM and MREP staff. There are some technical differences between the two shapers, as described in Box 4.1.

During the sowing period most fields were inspected by OFWM and IIMI staff. Field staff instructed tractor drivers how to operate the bed-and-furrow shaper. When sowing was in full swing, field staff visited the fields daily to supervise and guide the tractor drivers, to interview farmers and to maintain an overview on the work in progress.

Box 4.1. A comparison of bed-and-furrow shapers

The hired JB bed-and-furrow shaper and the IIMI bed-and-furrow shaper are different in design.

The JB bed-and-furrow shaper weighs less than the IIMI shaper and makes smaller furrows. The difference in weight is mainly caused by the fact that the IIMI shaper has two toolbars and the JB shaper has only one. Besides that the furrow blades of the JB shaper are smaller in size then the IIMI shaper. The difference in weight has several effects. It was observed in the field that the JB shaper is easier to operate in soils which were not well prepared or were still wet. The JB shaper can be transported easier. However the beds and furrows of the JB shaper do often have not the required depth and shape. Due to less weight, tractor operators tend to make superficial furrows and consequently do not work up enough soil to complete a full bed.

Land Preparation

For an optimal use of the bed-and-furrow shaper, the land should be deep ploughed. The soil must be dry and soil particles should be small. Under these conditions, the shape of the bed-and-furrows can be well maintained and seeds are nicely covered with an inch of soil. Actual conditions in the field were far from optimal. Field staff observed that in many cases, *rauni* was applied to the fields. In these cases, farmers were advised to dry the soil for a couple of days and apply some extra ploughing and planking. However, a lot of farmers did not follow the advice.

The following problems were observed in fields with high soil moisture contents:

- Operation of the bed-and-furrow shaper is more difficult, the smaller tractors do not manage to lift and pull the bed-and-furrow shaper. Beds and furrows, therefore, have an irregular shape and furrows are shallow;
- Seeds are not covered by a layer of fine topsoil due to large lumps on the field. Therefore, small hooks at the end of the shaper were constructed to break these lumps and cover the seed;
- The wheel, which drives the seed distribution, gets covered with soil and fails to turn around.

After experiencing the difficulties of the bed-and-furrow preparation, farmers acknowledge the importance of good land preparation for the bed-and-furrow method (see Box 4.2).

Box 4.2. Farmers reactions on land preparation.

Ghulam Mustafa, a farmer in watercourse 39-L told: "for B/F field it is necessary to prepare the land very well. It means more ploughing and planking as compared to the basin field."

Operation of the Bed-and-Furrow Shapers

Moist soil conditions of the field made the operation of the bed-and-furrow machines difficult. Under these conditions, especially the IIMI shaper is too heavy for the Massey Fergusson 240, the standard tractor used in the project area. These tractors do not have enough power to pull the bed-and-furrow shaper, and subsequently, do not make deep furrows. In some cases, it was observed that the hydraulic system was not able to lift the IIMI bed-and-furrow shaper.

Based on regular field visits, it is estimated that about 90 percent of tractors used in the area are MF 240s. Heavier tractors, such as the Belarus MTZ 50, Fiat 480 or the Massey Fergusson 375 are scarcely found. For some days work was delayed substantially because a tractor was not available. In Watercourse 14-L and 40-L, field staff was able to make an arrangement with local tractor owners. The availability of a heavy tractor is a problem often mentioned by farmers (see Box 4.3).

The lining of the seed distribution wheel was not good and hampered the operation of the IIMI bed-and furrow shaper for several days. In wet soils, the chain of the wheel is easily covered by soil and gets stuck. The lowest chain wheel has to be placed higher in the B/F shaper or the chain has to be covered. This problem has affected germination in several fields (see Box 4.4).

When the shape of the beds and the depth of the furrows are not correct this has a negative effect on the seed germination. An observation was that irregularities in the shape and depth of the bed-and-furrows are most times related to a combination of poor land preparation and the difficult operation of the heavy bed-and-furrow shaper.

Box 4.3. Tractors and weight of the bed-and-furrow shaper

Muhammad Ismail of watercourse 40-L told: "the B/F method is suitable for those farmer which have their own big tractor". And according to Muhammad Sharif (42-L): "it is not easy to make bed-and-furrows with a small tractor. For this machine (the bed-and-furrow shaper) a big tractor is a must."

Box 4.4. Seed distribution wheel

Muhammad Ismail (40-L) and Mr Abbas (20-l) mentioned that at the time of sowing the bed-and-furrow shaper had some problem of the wheel. When the wheel was not running, the seed was not drilled, therefore there was no germination in some furrows. Both farmers sowed these gaps again manually.

Waterlogging

Three farmers who cultivate land in a waterlogged area were interested in using the bed-and-furrow method. It was possible to make one bed-and-furrow field for each of these three farmers. However, the seed failed to germinate in one field so that the farmer decided to abandon the bed-and-furrows and plant rice. In another field, the tractor failed to pull the bed-and-furrow shaper. The last of the interested farmers refused to use the bed-and-furrow method after observing the results in the fields of the other two farmers.

An area is waterlogged when the water table is permanent within 5 feet of the soil surface. Because of groundwater capillary rise, a large part or the complete soil profile is in a moist condition. This condition has several effects:

- A moist clay or loamy soil is more cohesive and heavier than a sandy soil. Therefore, it is not possible to plough the soil well with the conventional method used in the area, oxen or a light tractor.
- Only the topsoil (approximately 1-foot) can be well prepared. The topsoil may remain moist through capillary rise. The soil layer below 1 feet of soil surface may be compacted.

As a result, the land preparation in the waterlogged fields was inadequate to make bed-and-furrows.

Soil conditions in waterlogged areas restrict the operation and efficiency of the bed-and-furrow shaper. Soil tillage cannot be maintained to the required level for the operation of the bed-and-furrow shaper. The weight of the bed-and-furrow shaper and the cohesiveness of the wet soil make operation of the machine difficult. Seeds are not drilled properly under moist soil conditions. The bed-and-furrow method is applicable in waterlogged areas, but the bed-and-furrow shaper cannot prepare the fields. Bed-and-furrows can still be made manually in these areas.

Salinity

About 40 percent of the sample farmers in the research area mentioned the problem of soil salinity or *kallar* (see also Section 3.4). According to several farmers (see Box 4.5), salinity has a negative effect on the germination of the cottonseed. Of the 41 monitored bed-and-furrow fields, 16 fields (39 % of the total) were sown before using the traditional drill method. Germination failed, so farmers decided to use these fields to experiment with the bed-and-furrow technique. For the 37 monitored basin fields, 4 fields (10 % of the total) were sown more then once.

Box 4.5. Effects of soil salinity

Rehmat Ali (9-L) had a germination percentage on his bed-and-furrow fields of 25%. He tried to sow cotton two times with basin method on this field, the third time he used the bed-and-furrow shaper. According to him, the main reason for the low germination rates is the soil, which is affected by salinity and sodicity. Though the germination rate was only 25%, he was happy with the result.

According to Mr. Sukhera (29-L) germination failed three times this year with the basin method. He estimated the germination on the bed-and-furrow field at 75 %, and at his basin field at 50%. On saline patches in his fields seeds germinate with bed-and-furrow method but not with basin method.

According to several farmers, the effect of soil salinity on germination in the bed-and-furrow is less when compared to the basin method.

Salt Accumulation on Beds

Through capillary rise, salts accumulate on the beds of the cotton fields. For the wet furrows, salts are flushed out and are not visibly present. The salt accumulation is a side effect of the bed-and-furrow method, which draws the attention many farmers. They are concerned about the germination of the wheat crop in the coming *rabi* season. The salt accumulation on the beds is often mentioned as one of the major disadvantages of the bed-and-furrow technique (see Box 4.6).

Box 4.6. Salt accumulation

According to M. Sarwar s/o Shahab Din (11-L):"In bed-and-furrow field salt accumulates on top of the bed. The method is good but the only problems are the hoeing and salt accumulation."

Mr. Ubaid Ullah (40-L) acknowledged the same problem. But according to him, if he could apply sufficient water in the bed-and-furrow field than he could control the problem.

All farmers using the bed-and-furrow method were asked to give their opinions about the salt accumulation on the beds in their fields. According to 37.5 percent of the farmers, they did not have any problems of salt accumulation on the beds. The rest of the interviewed farmers observed salt accumulation on their bed-and-furrow fields. According to a majority of the last group, the salt accumulation would affect the *rabi* crop, but with good soil preparation and irrigation these negative effects could be countered. About 37.5 percent of the farmers removed the bed-and-furrows by ploughing the field. A majority of these farmers first ploughed their fields, followed by an irrigation to leach the salts.

Germination of Cotton

All sample farmers were asked to estimate the germination percentage in the monitored bed-and-furrow and the basin fields. There is little difference in the average germination percentage of bed-and-furrow fields (62.1 %) and basin fields (65.4 %). The variation in the germination percentage between the two groups of fields is almost equal. But, 39 percent of the bed-and-furrow fields had earlier problems with germination due to soil salinity. This means that germination on the bed-and-furrow fields was good. However, there is still a need to verify the extent to which the cotton growth is affected or tolerant to soil salinity. An observation in the field was that though germination was good in some fields, the plant growth in the salt affected field was retarded in a later growth stage when compared to fields without salinity problems. Therefore, though germination is possible at certain salinity levels, cotton cultivation, even on bed-and-furrows, will not be economically feasible.

If we assume that the factors affecting the cotton germination are constant, then it is possible to compare the effectiveness of the two bed-and-furrow shapers. The use of the IIMI bed-and-furrow shaper resulted in an average germination percentage of 68.8 percent, while this was 56.6 percent for the JB bed-and-furrow shaper. When compared to the germination percentage of basin fields (70%) in the same area, the JB bed-and-furrow shaper has an average lower germination percentage (56.6 %), while the IIMI shaper, when compared to the basin fields (60.5 %), has a higher germination percentage (68.4 %). So, taking the germination percentages into account, the IIMI bed-and-furrow shaper is more effective than the JB bed-and-furrow shaper.

4.3 WEEDING AND HOEING ACTIVITIES

The recommendation to farmers was to use a herbicide before or after sowing with the bed-and-furrow shaper. However, only 3 out of 43 farmers actually used a herbicide. Field observations showed that when herbicide is not applied, this may lead to uncontrollable weed growth. With a generous weekly irrigation to bed-and-furrow fields, a perfect environment for extensive weed growth is created. When farmers carefully remove weeds by hand, it takes excessive labor time (see Chapter 5). With the long hoe (*bola, kasi, kahi* or *kissi*) which is also used in basin fields, farmers cut the edge of the beds. Without good care, this has a bad effect on the shape of the bed-and-furrows. Some farmers tried to remove weeds mechanically, but this had a devastating effect on the shape of bed-and-furrows. The use of a ridger, plough with oxen or tractor normally destroys the beds and furrows, making the bed-and-furrow field flat again.

Unfortunately the hoeing machine for the bed-and-furrow fields arrived too late, on 23 July. At that time, all monitored farmers already finished the first hoeing of the bed-and-furrow fields. Only a small group of farmers were still busy hoeing their fields for the second or third time. There was hardly any demand for the special hoeing machine. Because of this, the effort to make farmers responsible for the management of the hoeing machine completely failed, as the farmers simply had no interest.

Farmers mentioned two problems regarding the use of the hoeing machine, i.e.:

- Smaller farmers do not have easy access to a tractor.
- Farmers who rent a tractor have to pay Rs 100 plus Rs 50 for the maintenance of the hoeing machine. Farmers are reluctant to pay this and preferred the use of (own) labor.

The hoeing of a bed-and-furrow field is far more difficult and time-consuming such as hoeing a basin field (see Box 4.7). In the absence of the hoeing machine, farmers have either mechanically or manually removed the weeds and grasses. According to several farmers, hoeing is the major problem in the bed-and-furrow method. However, this should be viewed from the perspective that only a small group of farmers used herbicides and were able to use the hoeing machine. With the hoeing machine, a one-

Box 4.7. Hoeing of bed-and-furrow fields

According to Munawar Malera (38-L), manually hoeing is very difficult. He said that in traditional basin method it is very easy to hoe the field by tractor with the traditional ridger.

And according to Suhail Haq (14-L): "Manual hoeing is very difficult in the furrows. When hoeing machine is available then it is OK, otherwise it is very difficult. Hoeing the basin field with tractor and/or oxen is easy."

acre bed-and-furrow field can be hoed in approximately one hour. The Water Users Federation could solve problems related to farmers' access to tractors.

About 50 percent of the farmers were reluctant to maintain the beds and furrows for two main reasons:

1. Farmers were worried about the salt accumulation on the beds, which may affect the germination of the wheat in the *rabi* season. They prefer a flat field, where salts can be removed by flushing;
2. Farmers used the plough or ridger to open the topsoil. In some fields, it was observed that a hard crust was formed after every irrigation event. According to the farmers, this will hamper root development.

4.4 (IN)FORMAL MEETINGS WITH FARMERS DURING *KHARIF* 1998

Extension Meetings

Extension meetings were organized with the Water Users Association in different villages of the Bahadarwah Minor. The main subjects of these meetings incorporated lectures in which information regarding the use of fertilizers and pesticides in cotton production was provided. Representatives from different fertilizer and pesticide companies were invited to deliver lectures on their main subject. All farmers of the area were welcomed to attend these meetings.

Together with WUO office bearers, the following meetings were organized in villages located in the coomand area of the Bahadarwah Minor:

- 30 May at Quasiwala (morning) hosted by Mr. Ubaid Ullah, WUO President of the Bahadarwah Minor, and Sunderwali (evening) hosted by Mr. Sayeed, WUO general body member. IIMI and MONA staff organized two demonstrations of the bed-and-furrow shaper. About 40 farmers attended the demonstration meeting at Watercourse 40-L, and during the evening, about 30 farmers attended the meeting at Watercourse 11-L.
- 3 July at Sunderwali, hosted by Mr. M. Azam Vice-President, SWUO 1. The meeting was organized around a lecture delivered by Mr. Nadeem, representative of Engro Chemicals. The main subject was the use of fertilizers in cotton cultivation. About 100 farmers attended this meeting. Special guests were the members of the WUO General Body members of the Hakra 4-R Distributary.
- 17 July at Quasiwala, hosted and chaired by Mr. Ubaid Ullah, WUO President of the Bahadarwah Minor. A meeting with lectures on the use of fertilizers and pesticides by representatives of three different companies Engro Chemicals, Bayer and Dow Chemicals. About 50 farmers attended this meeting.
- 26 August at Sunderwali, hosted by Mr. M. Azam, Vice-President, SWUO 1. Mr Najib Ullah, representative of the pesticide company, Noveritis, delivered a lecture on the use of pesticides in cotton cultivation. About 50 farmers attended this meeting.
- 9 October at the *dera* of Mr. Allah Ditta in Watercourse 20-L. Mr. Allah Ditta received technical support from Mr. Nadeem of Engro Chemicals for his cotton fields. This meeting was organized to demonstrate the effect of improved fertilizer application to cotton fields to farmers living in the vicinity of Watercourse 20-L. About 75 farmers attended this meeting.

Other meetings and training activities

A special meeting with the general body of the Water Users Organization of the Bahadarwah Minor was organized on 4 July at Gumti. Besides IIMI and OFWM staff, nine WUO members and 5 farmers attended the meeting. This meeting mainly served the purpose of introducing IIMI staff to the WUO. Topics during this meeting were:

- Progress and planned activities of the Joint Dissemination Program;
- WUO involvement in the Joint Dissemination Program;
- Other WUO activities.

Besides these main issues, a variety of other topics were discussed during the meeting.

On 16 September a visit was paid to a meeting organized by the Water Users Federation along the Hakra 4-R Distributary. About 15 farmers using the bed-and-furrow method in the Bahadarwah Minor area attended this meeting. A speech was delivered by Mr. Allah Ditta, in which he described his experience with the bed-and-furrow method during *kharif* 1998.

IIMI and OFWM staff delivered ischarge measurement training on 14 October, and supervised by Mr Mustaq Khan. About 35 farmers and representatives of the Water Users Federation of the Sirajwah Distributary participated in this training. Staff of the Punjab Irrigation Department was present during the day. The training concentrated on two subjects. First, the downstream gauge calibration of the Bahadarwah and Najeebwah Minors. And secondly, the calibration of watercourse outlets. A discharge measurement was conducted using the current meter in the Bahadarwah and Najeebwah Minors. The calibration of outlets was demonstrated on two outlets off-taking from the Sirajwah Distributary.

4.5 Role of the Farmers' Organization in the Research Process

Farmers in the Bahadarwah Minor command area were organized by OFWM under the Participatory Irrigation Management Project. That the existence of this organizational body would provide an excellent opportunity to start a Dissemination Program following the suggestion by Berkhout *et al*, was expressed. The bed-and-furrow shapers used in the joint dissemination program were provided by IIMI-Pakistan free of cost to the Water Users Organization of the Bahadarwah Minor.

An important objective at the start of the Joint Dissemination Program was to involve the Water Users Organization of the Bahadarwah Minor in all organizational and implementation aspects of the program. Organizational and implementation tasks would be shared among agencies and the WUO. By doing so, the WUO would receive "on the job" training during *kharif* 1998. The expectation was that the WUO could carry the full responsibility for the machinery in *kharif* 1999. The Water Users Organization would act as an intermediary body in the communication between farmers and the agencies involved in the program. This would require a preparation period in which key members of the WUO should be trained to organize extension meetings, contact interested farmers, make an operation and maintenance schedule, fee collection and other activities. However, at the start of the Joint Dissemination Program in May, it was soon felt that the above-mentioned approach could not be implemented due to a shortage of time. Besides that, the farmers' interest in the bed-and-furrow method was not as high as expected. It was found difficult to motivate the members of the different Water Users Associations at the watercourse level, and became necessary to concentrate the work of IIMI and OFWM staff first on the implementation of the bed-and-furrow fields. WUO members were consulted for advice on different matters, like the maintenance and transport of the machinery, but WUO members were unable to take the necessary quick action, which left IIMI and OFWM staff to fulfill these tasks.

Despite the fore-mentioned problems, all extension meetings were organized and hosted by WUO representatives. An arrangement was made with WUO members to provide a tractor for the operation of the bed-and-furrow shaper. Users of the tractors would pay the owner a fee of Rs. 100 for the rent of the tractor.

To secure proper operation and maintenance by the WUO of the bed-and-furrow shaper in the future, a maintenance fund was created this year. Every farmer who used the bed-and-furrow shaper paid Rs. 50 per acre as a maintenance fee. The collected maintenance fees are deposited in a WUO bank account.

On several occasions during the sowing period, field staff discussed with WUO members the collection of maintenance fees. These fees are collected for a WUO fund, so it would be a logical step forward to make WUO members responsible for the collection of these fees. However, individual WUO members did not take action in this respect. During a meeting with the general body of the WUO on 4 July, all members of the general body decided that the WUO president and the treasurer were responsible for the collection of maintenance charges. In the same meeting, it was decided that the WUO would be responsible for the operation of the hoeing machine. Despite these positive decisions and repetitive remarks by IIMI and OFWM staff, WUO members have not taken the initiative to come forward to do something. Without some pressure from IIMI and OFWM, the WUO remained inactive.

5 CULTURAL AND IRRIGATION PRACTICES OF THE BED-AND-FURROW AND BASIN METHOD

5.1 TIME-WISE CHARACTERIZATION AND DESCRIPTION OF AGRICULTURAL ACTIVITIES FOR COTTON CULTIVATION

All agricultural activities for basin and bed-and-furrow fields are presented in a time schedule in Tables 5.1 and 5.2. For the total group of basin and bed-and-furrow fields, the average start and end of each activity is presented. The standard deviation of start and end of the activity was calculated in days. This was added (maximum) and subtracted (minimum) from the average date of the start and end of the specific activity.

Table 5.1. Agricultural Activities in Time of Bed-and-Furrow Fields.

	Land preparation		Sowing	Hoeing		Fertilizer application		Pesticide application		Harvest	
	Start	End	Start	Start	End	Start	End	Start	End	Start	End
Minimum	30-4-98	27-5-98	28-5-98	15-6-98	28-7-98	29-6-98	5-8-98	1-8-98	12-9-98	1-10-98	14-11-98
Average	9-5-98	30-5-98	2-6-98	30-6-98	12-8-98	16-7-98	21-8-98	12-8-98	27-9-98	18-10-98	25-11-98
Maximum	18-5-98	3-6-98	6-6-98	16-7-98	28-8-98	3-8-98	7-9-98	22-8-98	11-10-98	4-11-98	5-12-98

Table 5.2. Agricultural Activities in Time of Basin Fields.

	Land preparation		Rouny	Sowing	Hoeing		Fertilizer application		Pesticide application		Harvest	
	Start	End	Start	Start	Start	End	Start	End	Start	End	Start	End
Minimum	25-4-98	16-5-98	10-5-98	4-5-98	14-6-98	13-7-98	21-6-98	27-7-98	26-7-98	17-9-98	26-9-98	17-11-98
Average	4-5-98	18-5-98	13-5-98	19-5-98	21-6-98	26-7-98	11-7-98	12-8-98	9-8-98	28-9-98	7-10-98	28-11-98
Maximum	13-5-98	20-5-98	15-5-98	2-6-98	28-6-98	7-8-98	30-7-98	28-8-98	24-8-98	9-10-98	18-10-98	8-12-98

Sowing of the bed-and-furrow and basin fields and the pre-irrigation gift (*rauni*) for basin fields are single activities, i.e. these activities take place only once during an agricultural season. Hoeing, fertilizer application, pesticide application and cotton picking are activities that are repeated during a period of time. For example, farmers harvest their cotton in 1 to 5 pickings. This takes place during a period starting as early as 1 October until the first week of December.

A comparison of the time schedules of agricultural activities of the basin and bed-and-furrow fields shows that land preparation and sowing of the bed-and-furrow fields started, on average, two weeks later than the basin fields. This is explained by the fact that the Joint Dissemination Program started to approach farmers in the last week of May. These farmers decided in a short period of time to use the bed-and-furrow method and prepared their land. For both, the basin and bed-and-furrow fields, sowing ends in the first week of June. Hoeing of the basin fields started on, average, one week earlier than the hoeing of the bed-and-furrow fields. However, a group of farmers delayed the hoeing activities in the bed-and-furrow fields so that the last hoeing activities in these fields were extended until the last weeks of August. Fertilizer in bed-and-furrow fields was applied one week later than in the basin fields. Pesticide application takes place in the same period of time; the average start and end of this activity is the same for the basin and bed-and-furrow fields. Harvest of the bed-and-furrow fields started, on average, on 18 October, while for the basin fields this started on 7 October. The last pickings of the cotton fields occur in the first week of December.

In the future, the time schedules of agricultural activities of basin and bed-and-furrow fields may run similar to each other, since now, the sowing of the bed-and-furrow fields commenced later than planned.

Land Preparation

Land preparation activities for bed-and-furrow fields started, on average, on 9 May and continued to 30 May. The main activities are leveling, ploughing and planking. A scraper levels about 33 percent of the fields. A scraper removes and deposits topsoil in the depressions of the field. About 28 percent of the fields were deep ploughed with a disk or chissel plough. A normal plough was used for 65 percent of the fields. The other fields were prepared with a combination of a plough and a cultivator or rotavator. A plank is used in combination with a plough. The plank crushes the larger soil particles and levels the field. About 40 percent of the monitored bed-and-furrow fields were planked.

Land preparation of the basin fields started earlier than the bed-and-furrow fields. An average farmer starts to prepare his basin fields in the first week of May. About 20 percent of the fields were leveled with a scraper. A disk or chissel plough was used on 20 percent of the fields. After the first ploughing, *rauni* irrigation is applied around mid-May. About 45 percent of the basin fields were only ploughed, the other fields were prepared with a combination of ploughing and planking.

On average, for all monitored basin and bed-and-furrow fields, 5 or 6 different land preparation activities were necessary before the fields were sown.

Sowing

Due to the late arrival of the bed-and-furrow machine, sowing of the bed-and-furrow fields started on 28 May and continued until the second week of June. The normal practice is to start sowing earlier in the month of May. The basin fields were sown from the first week of May onwards and continued until the first days of June. For basin fields, farmers use the drill, which is pulled by a tractor, or the traditional pore that drills the cottonseeds in a single row and is pulled by a pair of oxen. On average, farmers use 5 kg of seed to sow their cotton fields.

Sowing the bed-and-furrow fields failed on several occasions due to various factors such as bad land preparation, careless operation of the bed-and-furrow shaper and failure of the bed-and-furrow shaper. Approximately 60 percent of the fields were re-sown by hand. On average, 2 kg of seed was sown in 2,5 hours by hand. This adds some Rs 85 to the sowing costs for 25 bed-and-furrow fields.

Herbicides

Herbicides are used after sowing to control weed growth in the first month. During extension meetings and individual contacts, it was communicated to the farmers that it was good practice to use herbicides. However, only three farmers applied herbicide on their bed-and-furrow fields. One of these farmers also applied herbicide on the basin field.

Hoeing

The first hoeing of the cotton fields, both for basin and bed-and-furrow, starts 4 weeks after sowing. In the period from the last week of June until the first week of August, the farmers hoe their cotton fields, on average, 3 times.

For the bed-and-furrow fields, all farmers started to hoe their fields manually. Hoeing a bed-and-furrow manually is time consuming, because it is done carefully to preserve the furrows and the beds. At a later stage, farmers decided to use oxen or a ridger to clean their bed-and-furrow fields from weeds. Approximately 80 percent of the basin fields are cleaned manually the first time. The second or third hoeing is also done with oxen or by tractor. However, some 20 percent of the basin fields were only cleaned with a tractor-pulled ridger.

Fertilizers

Of the 37 bed-and furrow fields, only one field did not receive additional nutrients in the form of DAP, urea, ammonium nitrate, nitrophos or farm yard manure. Urea was applied on 35 fields, whereby 17 fields only received urea. The other 18 fields received a combination of the fore-mentioned fertilizers. Of the 35 basin fields, only 4 did not receive any fertilizers. Out of 31 basin fields, 11 fields were treated with urea. The other fields received a combination of fertilizers. The number of fertilizer applications is specified in Table 5.3. As can be observed from this table, there are no major differences in fertilizer treatment between the complete group of basin and bed-and-furrow fields.

Table 5.3. Fertilizer Applications for Basin and Bed-and-Furrow Fields.

	Fertilizers			
	DAP	Urea	Ammonium nitrate	Nitrophos
No. of bed-and-furrow fields (n=37)	7	35	8	9
B&F average application (kg/acre)	51,4	58,3	33,625	43,6
No. of basin fields (n=35)	7	27	6	10
Basin average application (kg/acre)	52,8	56,05	45,3	38,6

There are two methods of fertilizer application used by farmers. The first method is to mix the fertilizer with water at the field *nakka* during a water gift. The second method is to apply the fertilizer by hand near the stem of the cotton plant. The selected farmers did not use broadcasting. Especially the second method is time-consuming. It takes two persons approximately 1,5 hours to spread fertilizer by hand in the field.

Pesticides

A variety of pests attack cotton during different growth stages. Some pests cause harm to the plants' general health, like jasid and whitefly. A decline in plant health has an indirect negative effect on the fiber development and decreases the potential cotton yield. Some pests, like the bollworm, cause a direct yield decline by using the bolls as a kindergarten for the young larvae. The different pests are commonly found in the cotton production areas of Pakistan and are easily spread to different areas. There are different modes of pest control, however, farmers in the research area control pests only by spraying.

In *kharif* 1998, the average farmer of the reference group started spraying in the second week of August. On average, the last spray is applied in the last week of September. There was no difference in timing of pesticide applications between basin and bed-and-furrow fields. There are two application methods used in the research area. Around 85 percent of the farmers use a hand pump spray for pesticide application. It takes one person 1 to 1,5 hours to spray one acre with a hand pump spray. A small number of farmers, 15 percent, use a mechanized boom spray for pesticide application. It takes 15-20 minutes to spray one acre cotton with a boom spray.

The average farmer applies 5 sprays during the months August and September. There is no difference in the number of pesticide applications between basin and bed-and-furrow fields.

Harvest

Cotton is harvested by hand in several pickings. Cotton picking is normally an activity done by women. Women receive a share in the harvest, which varies between 1/13 and 1/16 of the harvest. Some farmers however pay the women in cash. But there is no difference between yield share and cash rates[1]. For the basin fields of the research sample the first picking started on average on 7 October. The first picking of the bed-and-furrow fields started on average some ten days later. The time difference is mainly related to the late sowing of the bed-and-furrow fields, which was described before. Depending on the production of the fields, several pickings take place in a frequency of about two weeks. The second or third picking will normally give the highest yield. In *kharif* 1998, the cotton yields for basin and bed-and-furrow fields in the research area were relatively low. The number of pickings was therefore limited to a maximum of 4 or 5 pickings for fields with a relative good yield. For an average cotton field the final pickings take place in the last week of November. The maximum date on which the cotton harvest is completed is around 6-7 December.

5.2 Farmers' Irrigation Practices for Basin and Bed-and-Furrow Methods

Data was first analyzed for its adequacy and consistency. Some fields are excluded from the sample group because of inconsistencies in the information provided by the farmers. Some farmers lost interest in the sample fields because the germination percentage was low. Farmers stopped all agricultural activities, including the water gifts.

Irrigation Frequency and the Number of Irrigation Gifts

On average, eight water gifts were applied to bed-and-furrow fields in *kharif* 1998. For basin fields, the average number of water gifts varies between 4 and 5. The pre-sowing gift (*rauni*) for basin fields is not included in this figure. The standard deviation of the number of irrigation gifts is slightly higher for bed-and-furrow fields (2.42) than for basin fields (1.86). A minimum number of three irrigation gifts and a maximum of thirteen water gifts were applied to bed-and-furrow fields. However, the vast majority of farmers applied between six to eleven irrigation gifts on bed-and-furrow fields. The minimum of water gifts for basin fields was one, and the maximum was eight. For basin fields, a majority of farmers irrigate their basin fields between four and six times during a season.

Irrigation Duration

For 37 bed-and-furrow fields the average time used per irrigation event was 95 minutes per acre. The average time used to irrigate basin fields is on average 122 minutes. These figures indicate that, on average, one irrigation event for a bed-and-furrow field takes 30 minutes less time than the irrigation of a basin field. If we take the standard deviations into account, we see that there is a large variation in time used per irrigation event, bed-and-furrow has a standard deviation of 45 minutes and basin 85 minutes. A logical explanation for this fact is the large variation in discharges in the watercourses during the season. More time is needed to irrigate one acre when the discharges are low, and less time is necessary when the discharges are high. The number of irrigation events monitored is large, approximately 300 irrigation events for bed-and-furrow fields and 140 irrigation events for basin fields.

For a total group of 31 farmers it is possible to compare the average time used per irrigation event for basin and bed-and-furrow fields. Twenty farmers (65 percent of total) required less time per irrigation event to irrigate a bed-and-furrow field of one acre compared to a basin field of one acre. Eight farmers (25 % of the total) used more time per irrigation event to irrigate their bed-and-fields compared to their basin fields. Three farmers (10 % of the total) irrigated their basin and bed-and-furrow fields in the same time per irrigation event.

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[1] For example, a farmer pays Rs 70 per maund cotton harvested. With an average price of Rs 1000 per maund, the cash rate is equal to a share of 1/14th of the total harvest.

Conclusion

Farmers in the Bahadarwah Minor spend more time to irrigate a basin field of one acre than to irrigate a bed-and-furrow field of one acre. On average, it takes 30 minutes less time to irrigate a bed-and-furrow field of one acre than to irrigate a basin field of one acre.

Depth of Water Applied per Irrigation Event

For the calculation of the depth of water applied to the cotton fields, use was made of the following information:

- daily discharges of the 5 watercourses;
- distance of the cotton field to the watercourse intake, whereby a distinction was made between lined and unlined sections;
- seepage losses in the watercourse, whereby no seepage loss was assumed for the lined section and a seepage loss of 200 mm/day[2] for the unlined sections;
- measured tubewell discharges, which were assumed to be constant.

As is presented by Table 5.4, the average irrigation gift for 17 bed-and-furrow fields was 67 mm, while for 14 basin fields this was 81 mm. The standard deviation of depth of water applied per irrigation event is almost the same for basin and bed-and-furrow fields. The difference in water depth applied per irrigation event is on average 14 mm. So basin fields received some 14 mm more water per irrigation event then bed-and-furrow fields. Which means that on average a reduction of 17 percent of the water application depth per irrigation event was accomplished for the bed-and-furrow fields. However the irrigation frequency of bed-and-furrow fields is two times higher then the irrigation frequency of basin fields.

Table 5.4. Depth of Water Applied Per Irrigation Event for Basin and Bed-and-Furrow Fields.

	bed-and-furrow	Basin
Total number of irrigation gifts	134	55
Average (mm)	67	81
Standard deviation	41	45
Average number of irrigation gifts per acre	8	4

As is presented by table 5.5, the average depth of water applied during the first four irrigation gifts of bed-and-furrow fields is smaller then for the basin fields. The first irrigation gives a difference of 11mm, which increases to a difference of 38 and 35 mm for irrigation 3 and 4. During the first and second irrigation 12 and 25 percent less water is applied to the bed-and-furrow fields compared to the basin fields. The quantity of water applied to bed-and-furrow fields on the third and fourth irrigation is 37 to 41 percent smaller then for basin fields. If the bed-and-furrow fields and basin fields would have the same irrigation frequency during a season this would indicate a reduction of water application for cotton fields in favor of the bed-and-furrow method. However, the irrigation frequency for basin fields is twice as high as for bed-and-furrow fields

Table 5.5. Average Depth of Water Applied (mm) First Four Irrigation Gifts.

	First four irrigations			
	1	2	3	4
A:Basin (mm)	92	75	92	95
B: Bed-and-furrow (mm)	81	56	54	60
A-B (mm)	11	19	38	35
(A-B)/a*100 (percent)	12	25	41	37

[2] According to FAO Paper 44: Design and optimization of irrigation distribution networks, the infiltration rate for a sandy loam unlined canal is approximately 200 mm/day.

Conclusion:

Compared to the basin fields on average 17 percent less water depth was applied per irrigation event to the bed-and-furrow fields. The reduction in water depth applied to bed-and-furrow fields varied between 12 to 41 percent during the first four irrigation events of the season. Per irrigation event the bed-and-furrow method is compared to the basin method a water saving innovation.

Depth of water applied during the complete kharif season

The total water depth applied to basin and bed-and-furrow located in 5 watercourses in Bahaderwah Minor is presented in table 5.6. During the complete kharif season, all farmers applied more water to their bed-and-furrow fields then to their basin fields. The average water depth applied to the bed-and-furrow fields was 528 mm, while for the basin fields the average was 319 mm. This figure does not include the pre-sowing gift for basin fields. The ratio between average water depth applied for bed-and-furrow and basin fields is 5 : 3. The variation in water depth applied of basin and bed-and-furrow fields is very large. For bed-and-furrow fields the minimum water depth applied is 132 mm and the maximum is 934 mm. For the basin fields the minimum water depth applied is 18 mm (only one irrigation applied) and the maximum water depth applied was 543 mm. Despite the smaller irrigation gifts (see former paragraph) for bed-and-furrow fields per irrigation event, the total water depth applied is higher then for basin fields.

Table 5.6. Total Water Depth Applied Bed-and-Furrow and Basin Fields During Kharif 1998.

		Bed-and-furrow		Basin	
Farmer	Access to tubewell water	Irrigation frequency	Total water depth applied (mm)	Irrigation Frequency	Total water depth applied (mm)
1	No	11	414	--	no basin
2	Yes	10	743	5	459
3	No	8	511	5	384
4	Yes	10	915	4	283
5	Yes	9	818	3	242
6	Yes	8	700	4	383
7	Yes	10	934	6	391
8	No	10	841	8	543
9	No	10	904	4	474
10	No	5	137	1	18
11	No	8	262	5	349
12	No	6	211	--	no basin
13	No	4	132	--	no basin
14	No	3	235	2	180
15	Yes	8	746	5	491
16	No	8	250	1	97
17	Yes	6	221	2	175
Average		8	528	4	319
Standard deviation		2,34	308	1,98	158

Conclusion:

All selected farmers applied more water to the bed-and-furrow fields as compared to the basin fields. On average a total water depth of 528 mm was applied to the bed-and-furrow fields, while for basin fields a total water depth of 319 mm was applied during kharif 1998. The bed-and-furrow method as used by the selected farmers in Bahaderwah Minor can not be considered as a water saving practice in terms of total water use compared to the traditional basin method.

5.3 Irrigation And Cultural Practices In Relation To Crop Development Stages

The crop development stages of cotton were described in chapter 1. The major difference between cotton cultivation in basin and bed-and-furrows is the irrigation frequency (see above) and the timing of the different irrigation events. For the bed-and-furrow method a pre-sowing gift is not recommended, while for good basin cultivation this is a prerequisite. The basin fields receive one irrigation during the land preparation and before sowing. Water is stored in the soil and the first irrigation of the basin fields is postponed for several weeks. The germination and emergence of the cotton plants is completely dependent on this pre-sowing gift. As is presented by table 5.7, it takes on average two months after sowing before the first basin irrigation is applied. If we take this average then the first basin irrigation coincides with the first flowering of the cotton plants. Some farmers prefer to irrigate the basin fields somewhat earlier. Which means that the first irrigation is applied when the cotton plant is squaring and the plant is supported in the vegetative growth. On average 3 or 4 irrigations are applied in a frequency of two weeks after the initial flowering stage. The last irrigation is applied when the cotton bolls are maturing, some 130 days after sowing. In the final growth stage, when the bolls are opening in general no irrigation is applied.

Table 5.7. First Basin Irrigation After Sowing Cotton in Kharif 1998.

First basin irrigation	
n=	34
Average number of days after sowing	63
Standard deviation	23

In general the pre-sowing irrigation gift is used for the vegetative growth of the cotton plant. Farmers start to irrigate the basin fields during the first flowering, and apply water in the reproductive growth stages of the cotton plant. Water shortage during these critical stages reduces the number of bolls per plant. Farmers do not irrigate basin cotton frequently, but when they irrigate it is done during a period when it is most effective for the cotton production.

Instead of a single pre-sowing water gift, the bed-and-furrow fields were irrigated frequently in the initial crop development stage. After sowing 27 farmers irrigated their bed-and-furrow fields three times consequently with an interval of less then 14 days. After the first three irrigations farmers allow a larger irrigation interval between different irrigation events. However a large majority of the farmers irrigate 60-70 days after sowing: i.e. the early flowering stage. After this period more frequent irrigations are applied for peak flowering and boll maturation. The average depth of water applied in the initial stage of bed-and-furrow cotton is 191 mm for the first 3 irrigations and 251 mm for the first 4 irrigations. This covers the gap between the total depth of water applied between basin and bed-and-furrow fields for one season.

The main cultural practices for cotton cultivation after sowing are hoeing, fertilizer application and pesticide application. If the agricultural activities are considered in relation to the different growth stages, farmers did not make much difference between basin and bed-and-furrow fields. Four or five weeks after sowing cotton develops side branches from the main stem, i.e. the squaring of the cotton plant. In the same period weeds have developed and increase the competition for scarce water and nutrients. In general farmers started to hoe their cotton fields manually during this growth stage. Hoeing the fields manually has several advantages over a ridger during this growth stage. The cotton plant is rather small, and it is possible to hoe accurately and efficiently between the different cotton plants in a row. With a ridger it is only possible to hoe between the cotton rowsFarmers tend to hoe the cotton fields with a ridger in the late growing stages one or two times.

It was expected that farmers applied fertilizer shortly after sowing. However this was not the case, farmers waited till 5 weeks after sowing before they started to apply fertilizer. This period coincides with the start of the flowering stage of cotton. Fertilizers are therefore in general applied for the reproductive growth stage and not for the vegetative growth stage of the cotton plants.

Pest control

All basin and bed-and-furrow fields were monitored for pests during the complete kharif season. Monitoring started in the last week of July. Table 5.8 presents data of a group of 24 bed-and-furrow fields and a group of 22 basin fields. All monitored fields were on average visited 5 times (minimum of 3 and a maximum of 7 visits) and checked for pests. Continuously is defined as the pest is observed in a period of more then 4 weeks or during three visits. A short period is defined as the pest is observed in one occasion or in a period of less then one month.

Table 5.8. Occurrence of Pests in Basin and Bed-and-Furrow Fields.

	Jasid	Thrips	White fly	Boll worm	Mites
Bed-and-furrow (n=24)	24	10	22	24	2
Continuously	14	1	17	18	
Short period	10	9	5	6	2
Basin (n=22)	22	7	22	21	1
Continuously	11	5	18	16	
Short period	11	2	4	5	1

There was little difference between basin and bed-and-furrow fields. Pests attack the cotton plants irrespective of the cultivation method. Jasid, white fly and boll worm were commonly found in the basin and bed-and-furrow fields. These pests were found in 95 to 100 percent of the fields. Thrips and mites were found in respectively 37 percent and 6 percent of all the fields. White fly and boll worm are difficult to control, they remain present once they have attacked a field in 75 - 80 percent of the fields. Jasid seems to be controlled easier, in 45 percent of the fields presence of jasid was temporarily.

Thrips seems also to be a temporary pest or can be controlled easier then for example jasid or whitefly. Thrips was continuously present in 40 percent of the fields.

The spread of pests in time gives the following picture. Jasid was observed since the end of July or the first week of August. Thrips was observed in August, whereby in 60 percent of the cases presence was restricted to the month of August. White fly and bollworm were first observed in the final week of August and first week of September. Mites were only found in October. It should be noted however that especially the presence of bollworm in the early growth stages is difficult to observe. In some fields bollworm was present from the last week of July onwards. Most farmers started to spray their fields in the first and second week of August. Attacks of white fly and bollworm were difficult to control, their presence was continuously observed in most fields.

If the growth stages of cotton are considered we see that once the cotton was in full flowering farmers start to apply pesticides. Pesticide application is in general repeated five times till the boll formation of cotton was finished. If the timing of pesticide sprays, the growth stage of cotton and the presence of pests (see above) are considered together, then the pesticide sprays are meant as curative measures against pests. If pesticide sprays would be applied in an earlier stage it has the function of preventive control.

Bollworm attacks the cotton boll directly. The other pests are a hazard to the plants general health condition and influence indirectly the cotton production. The uncontrollable presence of bollworm in kharif 1998 had according to farmers a very bad effect on the cotton yields.

Conclusion:

Agricultural activities in cotton fields as hoeing, fertilizer and pesticide application are concentrated around the reproductive growth stages of cotton i.e. most activities start when cotton is flowering. The timing of these activities were the same for basin and bed-and-furrow fields.

5.4 IRRIGATION AND CULTURAL PRACTICES IN RELATION TO THE PHYSICAL FEATURES

Irrigation Practices In Relation To Physical Features

The irrigation practices in relation to the physical features are discussed here by looking at:

- water use in relation to the location of the fields in the irrigation system; and,
- water use in relation to access to tubewell water.

Table 5.6 presented the total depth of water applied to basin and bed-and-furrow fields in the different watercourse command areas of Bahaderwah Minor. There is a big difference between the fields located in the watercourses 11-L, 14-L and 20-L and the fields located in the tail watercourses 39-L and 40-L. As is presented in table 5.9, the average water depth applied is 719 mm for the seven bed-and-furrow fields located in 11-L and 14-L. While this is 274 mm for the eight bed-and-furrow fields located in 39-L and 40-L. For the basin fields the difference in water application depth is not as large as for the bed-and-furrow fields. On average 357 mm water was applied to six basin fields in watercourses 11-L and 14-L, and 218 mm was applied to six basin fields in watercourses 39-L and 40-L.

Table 5.9. Average Water Depth Applied in Cotton Fields in Head and Tail Watercourses of Bahaderwah Minor.

	Bed-and-furrow fields	Basin fields
Average water depth applied fields in 11-L &14-L (mm)	719	357
Standard deviation	196	79
Average water depth applied fields in 39-L and 40-L (mm)	274	218
Standard deviation	197	173

Table 5.10 presents the irrigation frequency of basin and bed-and-furrow fields located in the head and tail watercourses of Bahaderwah Minor. For both basin and bed-and-furrow fields the irrigation frequency is lower in the tail watercourses then in the head water courses.

Table 5.10. Average Irrigation Frequencies Cotton Fields in Head and Tail of Bahaderwah Minor.

	Average irrigation frequency	
	Basin	bed-and-furrow
Cotton fields in head of Bahaderwah Minor	5,28	9,00
Cotton fields in tail of Bahaderwah Minor	2,80	6,75

The watercourses in Bahaderwah Minor receive an authorized discharge (see Chapter 3.2). Water is in principle equally distributed among all watercourses of Bahaderwah Minor[3]. Figure 5.2 presents the ratio between the measured discharge and authorized discharge received by the different

[3] The ratio between authorized discharge and Cultivable Command Area is 0.1 for the five watercourses.

watercourses of Bahaderwah Minor which were monitored during kharif 1998. If the ratio is smaller then 1, then the measured discharge is lower then the authorized discharge. If the ratio is larger then 1, then the measured discharge is higher then the authorized discharge.

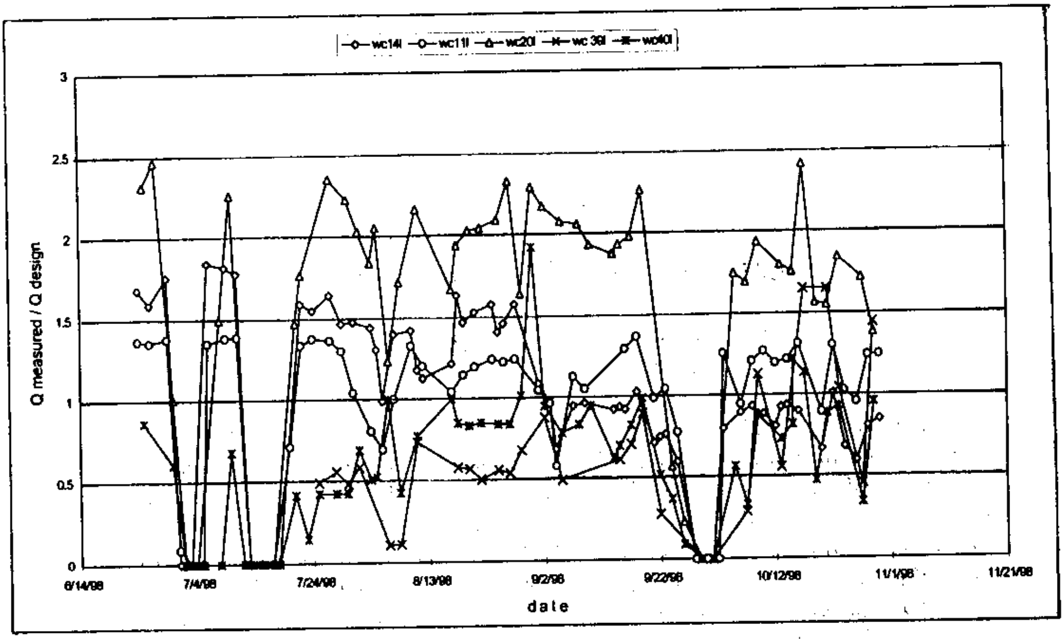

Figure 5.1. Actual Q / Design Q of 5 water courses in Bahaderwah Minor.

Watercourse 11-L received a discharge which was in general higher then the authorized discharge, the ratio QM/QA varies around 1.4 during the complete kharif season. Watercourse 14-L received till September 1998 a discharge, which was approximately 50-70 percent higher then the authorized discharge. After September 1998 the actual discharge declined, till about 80-100 percent of the authorized discharge. Till September 1998, farmers in watercourse 14-L received an adequate water supply. After September the canal water supply was more or less equal to the authorized discharge. Watercourse 20-L received during kharif 1998 a discharge, which was in general twice as high as the authorized discharge. When the Minor is not closed, farmers in watercourse 20-L have easily and more than adequately access to canal water. The watercourses 39-L and 40-L received till October 1998 a discharge, which was lower then the authorized discharge. Only after October 1998, the actual discharge was higher then the authorized discharge. Farmers in these watercourses did not have adequate access to canal water especially not during the months July, August and September 1998.

Conclusion:

Cotton fields located in the tail watercourses of Bahaderwah Minor received less canal water (than the authorized discharge) and show the tendency of being irrigated less frequently than cotton fields located in watercourses in the head of Bahaderwah Minor command area. This is caused by an inequal water distribution among watercourses in Bahaderwah Minor command area. Watercourses located in the head of the Minor get a discharge, which is in general higher then their authorized discharge. Watercourses in the tail of the minor received a discharge that was in general lower then the authorized discharge.

A group of farmers used tubewell water in addition to canal water for the irrigation of their cotton fields. These farmers owned a tubewell or they paid in cash for tubewell water per hour. Table 5.11 presents the depth of water applied to basin and bed-and-furrow fields for farmers who have access and for those farmers who do not have access to tubewell water. Farmers who had access to tubewell water applied more water to their cotton fields then farmers who did not have access, irrespective of the distinction basin and bed-and-furrow fields.

Table 5.11. Water Application Depth on Basin and Bed-and-Furrow Fields and Access to Ground Water.

	Farmers without access to tubewell water		Farmers with access to tubewell water	
	bed-and-furrow (n=10)	Basin (n=7)	bed-and-furrow (n=7)	Basin (n=7)
Average water depth applied (mm)	390	292	725	346
Standard deviation	280	197	239	116

Conclusion:

Farmers who have access to tubewell water applied more water to their basin and bed-and-furrow fields. When a farmer has easy access to tubewell water or canal water he applies a depth of water to bed-and-furrow fields which is about two to two and a half times (200-260 %) more then in a situation in which access to water is problematic. For the basin fields a farmer applies only about 125-150 % more water in the optimum situation. In case of problems to water supply the impact on the bed-and-furrow fields is more severe then on the basin fields.

Cultural Practices in Relation to the Physical Environment.

For land preparation, sowing, hoeing, fertilizer and pesticide application, one or two indicators are selected. With these indicators, which are presented in table 5.12., a comparison between cotton fields in the head and tail of Bahaderwah Minor can be made. The average number of land preparation activities (leveling, ploughing etc.) for cotton fields in the head and tail watercourses is almost equal. There is only a general difference in the number of land preparation activities between basin and bed-and-furrow fields. There is a difference in the average weight of seed used for sowing. However this difference is in favour of cotton fields in the tail, where on average more seed was used. Despite an unfavourable water supply, farmers in the tail used on average more seed for sowing. The number of hoeings in the tail watercourse is lower compared to the head watercourses for both basin and bed-and-furrow fields. The cotton fields in the watercourses in the head of the system got on average one extra hoeing compared to the fields in the tail. A comparison in use of fertilizer between head and tail is difficult to make when the different fertilizers and different quantities are considered. As mentioned before there is a lot of variation in use of fertilizer among farmers. However, the total costs per acre of fertilizer use can be compared. There is on average a difference of Rs 95 for bed-and-furrow fields and a difference of Rs 198 for basin fields in the head and tail watercourses. This difference indicates that more fertilizer is applied to cotton fields in the head watercourses. If the number of pesticide sprays is compared, then the cotton fields in the head watercourses receive on average one extra pesticide spray. However, this difference is not represented in the average expenditure for pesticides between head and tail watercourses. Costs of pesticide sprays in the tail are even higher then the costs made for spraying cotton fields in the head watercourses. This would indicate that farmers in the tail apply a larger quantity of pesticide or use a more expensive pesticide then farmers in the watercourses at the head if the prices of pesticides are equal for these farmers.

Table 5.12. Agricultural Practices of Cotton Fields in Head and Tail watercourses of Bahaderwah Minor.

		Total number of land preperation activities	Seed (kg/acre)	Number of hoeings	Fertilizer (Rs/acre)	Number of pesticide sprays	Pesticide (Rs/acre)
Bed-and-furrow							
Head	Average	5,56	4,83	3,94	697	5,50	1378
n =18	Stdev	1,85	0,79	1,20	342	1,29	768
Tail	Average	5,45	6,25	2,91	602	4,82	1699
n=11	Stdev	2,94	1,61	1,22	426	1,60	759
Basin							
Head	Average	4,89	4,82	3,50	688	5,61	1794
n=18	Stdev	1,45	0,99	1,10	304	1,29	646
Tail	Average	4,73	5,05	2,73	490	4,73	1752
n=11	Stdev	3,04	1,27	1,56	533	1,49	797

Conclusion:

A difference in canal water supply between watercourses in the head and tail of Bahaderwah Minor has a limited influence on the agricultural practices of the farmers. The number of hoeings is less for cotton fields in the tail. A comparison of fertilizer costs indicates that farmers in the head use more fertilizer then farmers in the tail watercourses. There was no difference in land preparation activities, sowing or pesticide application between cotton fields in the head and tail watercourses.

5.5 Relating Irrigation Practices To Crop Yield

The average yield was 158 kg/acre for 36 bed-and-furrow fields and 247 kg/acre for 34 basin fields in Bahaderwah Minor. The variation in cotton production was high. The standard deviation for cotton yields in bed-and-furrow fields was 117 kg/acre and 144 kg/acre for basin fields. The maximum yield was 590 kg/acre for bed-and-furrow fields and 606 kg/acre for basin fields. This means that cotton yields for both basin and bed-and-furrow fields were disappointing low in kharif 1998. Some 34 farmers cultivated cotton in basin and bed-and-furrow fields. About 74 percent of these farmers had a cotton yield of the bed-and-furrow field which was lower then the cotton yield of the basin field.

Table 5.13 gives an overview of the cotton yields of selected basin and bed-and-furrow fields and the depth of water applied during kharif 1998. If water depth applied would be presented in a graph against gross yield, it shows a wide spread of points both for basin and bed-and-furrow fields. This means that no direct relation can be found between yield and depth of water applied for these fields.

As was concluded in the last paragraph, there was not much difference between agricultural practices between basin and bed-and-furrow fields. Taking this fact and the wide spread in cotton yields, it must be concluded that a relation between agricultural practices and cotton yields is hard to find. The pest attacks had such a devastating effect on the cotton yields for both basin and bed-and-furrow fields in kharif 1998, that a comparison of relations between yields and irrigation and agricultural practices is unrealistic.

5.6 Farmers' Reactions On Basin And Bed-And-Furrow Cultivation

At the end of the season farmers were asked to give their opinion about the bed-and-furrow method. Out of 34 farmers, 20 farmers responded that they would use the bed-and-furrow method in the next seasons. Four of these farmers located in the tail watercourses commented that they would do this only when water availability was reliable. A group of 14 farmers responded that they would not use the bed-and-furrow method anymore.

Table 5.13. Irrigation and Crop Yields of Bed-and-Furrow and Basin Fields.

No.	Watercourse	Bed-and-furrow		Basin	
		Irrigation water depth (mm)	Gross Yield (kg/acre)	Irrigation water depth (mm)	Gross Yield (kg/acre)
1	11-L	414	258		
2	11-L	743	184	459	184
3	14-L	934	150	391	579
4	11-L	915	64	283	240
5	11-L	818	135	242	343
6	14-L	700	355	383	307
7	11-L	511	148	384	278
8	20-L	841	260	543	300
9	20-L	904	229	474	173
10	40-L	235	160	180	440
11	40-L	746	123	491	141
12	40-L	250	145	97	175
13	40-L	221	6	175	40
14	39-L	137	100	18	360
15	39-L	262	77	349	308
16	39-L	211	140		
17	39-L	132	82		

The cotton yields in basin and bed-and-furrow fields was unexpectedly low in kharif 1998. Farmers were asked to give an indication of their expected cotton yield two months before the harvest and during the harvest. More then 90 percent of the farmers indicated that the expected yield two months before harvest was much more then the cotton yield during harvest. The remaining 10 percent of the farmers indicated that the expected yield was the same as the actual yield. According to 75 % of the farmers the main cause of the yield decrease is a pest i.e. a majority indicated a heavy attack of American and spotted boll worm. Some 18 % of the farmers indicated that the decrease is due to water shortage. This group of respondents was cultivating land in the tail water courses. The remaining causes mentioned are damage due to heavy rainfall (3%) and late sowing of the cotton (3%).

Farmers formulated advantages and disadvantages of the bed-and-furrow method, which is represented in table 5.14. The main constraints farmers faced in using the bed-and-furrow method is a) hoeing, which is labor intensive; b) the high irrigation frequency; and, c) salt accumulation on the beds. The main advantages mentioned by farmers are a good germination of cotton and a decrease in water use per irrigation event. Some farmers mentioned that the bed-and-furrow method, compared to the basin method, saves water during the complete season. In the early growth stage of cotton the plant is vulnerable for excessive rainfall in basin fields. This is not the case in bed-and-furrow fields.

5.7 CONCLUDING REMARKS

Due to the late arrival of the bed-and-furrow shaper activities as land preparation, sowing and hoeing started on average two weeks later in the bed-and-furrow fields as compared to the basin fields. It is reasonable to expect that this gap will not occur in the coming kharif seasons.

A large majority of the farmers does not use herbicides. There were no major differences in fertilizer and pesticide application between basin and bed-and-furrow fields.

Major differences were found in irrigation practices for basin and bed-and-furrow fields.

Table 5.14. Advantages and Disadvantages of the Bed-and-Furrow Method.

Advantages of bed-and-furrow irrigation method		disadvantages of the bed-and-furrow irrigation method	
good germination	17	Bed-and-furrow need water every week	16
crop development is good	4	hoeing is labour intensive	18
good fruit formation	3	increase salinity on beds	13
water saving per irrigation event	25	other fields get less water	3
water saving in whole season	11	need water early	2
no negative effect from rainfall	19	poor crop development	1
good yield	3	fertilizer application is labour intensive	2
easy application or less fertilizer	7	soil crust	2
good tillering	3	less yield	3
good result on saline soil	3	dry beds not good for wheat	1
		not suitable for waterlogged and saline soils	1
		no own tractor	1
		vulnerable for water shortage	1

About eight irrigations were applied to bed-and-furrow fields and 4 or 5 irrigations were applied to basin fields. It takes less time (approximately 30 minutes) to irrigate a bed-and-furrow field of one acre then a one acre basin field. Per irrigation event a smaller volume of water is applied to bed-and-furrow fields then to basin fields. The total water depth applied during the complete kharif season was on average 528 mm for bed-and-furrow fields and 319 mm for basin fields. The bed-and-furrow method can not be considered as a water saving practice in the Bahaderwah Minor area.

The initial crop development in basin fields is dependent on a pre-sowing irrigation. First irrigation of basin fields is applied when the cotton starts to develop flowers. Bed-and-furrow fields were irrigated 3 to 4 times in the first 4 to 6 weeks after sowing whereby a water depth of 200 to 250 mm is applied. Water gifts were continued when the cotton started to develop flowers. Fertilizers were applied during the flowering stage. For both the basin and bed-and-furrow fields, pesticide application started during the flowering of the cotton and was in general repeated five times till the boll formation of cotton was finished. According to field observations and farmers comments a continued pest attack of boll worm has reduced the cotton yield substantially in the Bahaderwah Minor area.

Basin and bed-and-furrow fields located in the tail watercourses of Bahaderwah Minor were irrigated less frequently and received a smaller volume of water then cotton fields located in watercourses in the head of Bahaderwah Minor command area. Canal water is not equally distributed among watercourses in Bahaderwah Minor command area. Watercourses located in the tail of the Minor receive infrequent small discharges compared to watercourses in the head of the minor. Farmers who had access to tubewell water applied more water to their basin (125-150 %) and bed-and-furrow (200-260 %) fields then farmers without access to tubewell water.

The location of the cotton fields in the irrigation system did not influence agricultural practices as land preparation, sowing, hoeing, fertilizer and pesticide application.

Variation in cotton yields was high in Bahaderwah Minor area. The average yield was 158 kg/acre for 36 bed-and-furrow fields and 247 kg/acre for 34 basin fields. No direct relationship between crop yield and water depth applied could be found. A large majority of the farmers had a better yield in the basin fields compared to the bed-and-furrow field.

The main constraints farmers faced in using the bed-and-furrow method were

a) hoeing, which is labor intensive;
b) the high irrigation frequency; and,
c) salt accumulation on the beds.

The main advantages mentioned by farmers are:

a) a good germination of cotton;
b) a decrease in water use per irrigation event;
c) the method saves water during the complete season;
d) cotton in initial growth stage is not affected by rainfall.

About 40 percent of the interviewed farmers would not use the bed-an-furrow method in the future, whereas about 60 percent of the farmers would like to use this method in the future.

6 FARM LEVEL ANALYSIS: TWO CASE STUDIES

6.1 Features Of The Sample Farmers

Agricultural practices of two farmers were monitored from May till December 1998. Focus point of this part of the study was to record in detail the experience of these farmers in using the bed-and-furrow method on their farm in relation to the basin method. The farmers were selected based on the following criteria:

- The farmers' land holding size should be representative for the farmers community in Bahaderwah Minor. The landholding size should be in the range of 5 till 50 acres.
- One farmer should be a landowner, the other one should be a sharecropper.
- One landholding should be located in the head of the minor, the other in a tail watercourse of the Bahaderwah Minor.
- The farmers should have their warabandi turn during the day. This was an important criterion, because the discharges had to be monitored continuously during the weekly water turns.
- The farmer should in principle be willing to cooperate with the research program.

Based on these criteria two farmers were selected. One farmer is a sharecropper cultivating 5 acres in watercourse 11-L. The second farmer is a landowner in 40-L, cultivating 31 acres in different watercourses. The main socio-economic features of the two sample farmers are presented in the following two paragraphs.

6.1.1. Sample Farmer 1

Household:

Farmer 1 is approximately 25 years old and has no formal education. He belongs to the Joya caste. The farmer is married and has one son. He lives with his wife and son together with his mother-in-law and three brothers-in-law (18,15 and 11 years old) in one house. His mother owns 6 acres land, which she leases out for sharecropping. The farmer has seven brothers.

Income:

Farmer 1 has only income from his agricultural activities as sharecropper. He owns one young buffalo.

He estimated that his yearly income in 1997 was about Rs 20,000 with 10 maunds wheat for home consumption. The mother in law has 4 acres land, which she leases out for 50 % of the harvest. Last year she earned 10 maunds wheat. The income of the mother-in-law and the farmer are kept separate. They live together in one household and they share the daily expenses. The brothers-in-law do not provide income.

Agriculture:

The farmer is sharecropper since 10 years. In 1997 he cultivated the 6 acres of his mother on a sharecropping agreement. He cultivated 5 acres from one landowner in kharif 1998. The farmer does not own any farm machinery as a donkey car or a plough. Farm implements are rented by the landowner, but the sharecropper has to pay 50% of these costs after the harvest.

The farmer cultivated 4 acres cotton in kharif 1997. The yield was 12 maunds per acre. Two acres were left fallow. In rabi 1997-1998 he cultivated 4 acres wheat, with a yield of 26 maunds per acre.

One acre was left fallow and one acre was used for the cultivation of fodder. The total cropping intensity for 1997-1998 for 6 acres was 150 percent (kharif 83 % and rabi 67 %).

Farmer 1 cultivates 5 acres of one land owner on a sharecropping basis. The landowner provides seeds, fertilizers, pesticides and machinery for land preparation. After the harvest these costs will first be deducted from the yield, the remaining part of the yield will be divided equally between the landowner and farmer 1.

The fields are located in the middle section of watercourse 11-L. As is shown in Figure 6.1, all fields are connected by one lateral to the main watercourse. Cotton is cultivated in all fields. Farmer 1 used the traditional basin method in the fields with the killa numbers 14,15, 23 and 24. The bed-and-furrow field, killa number 25, is located at the tail of the lateral. According to Farmer 1, the fields with killa number 14 and 15 have a slightly higher elevation then the other three fields. The fields at the head of the lateral are owned and cultivated by the landowner.

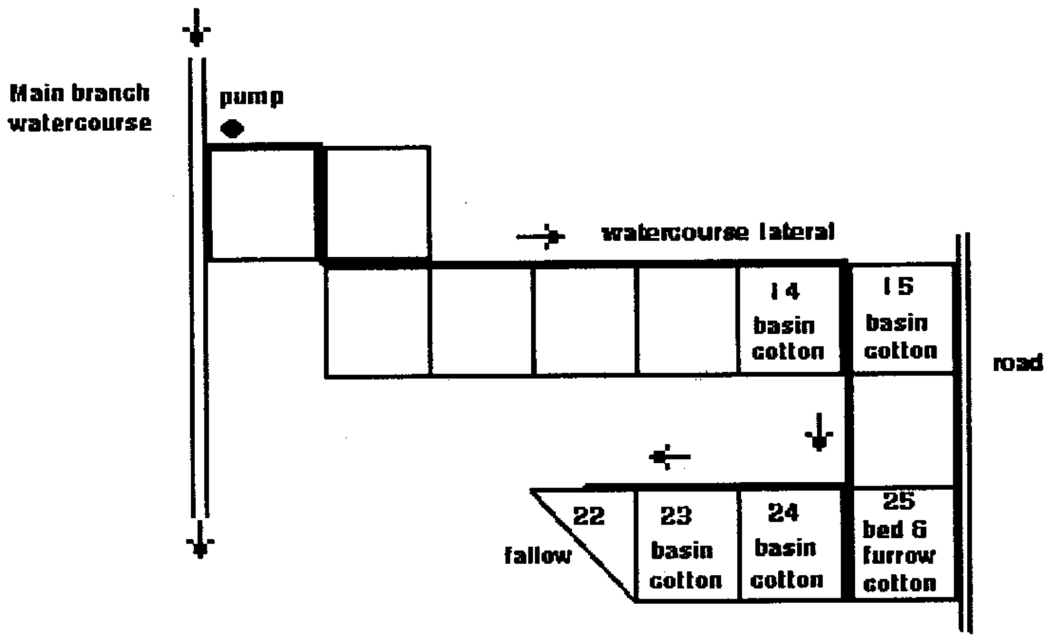

Figure 6.1. Fields of Farmer 1 Watercourse 11-L.

Irrigation:

According to both Farmer 1 and the landowner the weekly water turn is every Thursday from 13:50 till 20:57. The landowner and his sharecroppers use this water turn. It is necessary to make a distinction between the formal water allocation and the informal water allocation. First the formal water allocation is described by looking at the warabandi list followed by a description of the informal water allocation.

Farmer 1 has as a sharecropper no formal water turn. He uses part of the water turn of his landowner. Two farmers are registered in the warabandi list, who have their water turn during the time which Farmer 1 irrigates his land. The first warabandi is registered in the name of Shah Nawaz, who owns 27 acres. His warabandi is every Thursday from 12:09 - 18:36. The second warabandi is registered in the name of Saboo s/o Bakher, who owns 28.25 acres. His warabandi is every Thursday from 18:36 till 1:36. According to the landowner, his actual formal water turn is covered by these two water turns. Saboo was the father of the landowner. The family of the landowner leased 19.75 acres from Shah Nawaz. The rest of Shah Nawaz' land (7.25 acres) was purchased by two other farmers.

According to the landowner, the total land covered by the water turn is 21-22 acres, the warabandi time is 14 minutes per acre. According to his information, the following table presents the area cultivated by the different sharecroppers.

Table 6.1. Land Distribution Landowner 11-L.

Cultivator	Nr. of acres
Landowner	7.75
Farmer 1	5
Sharecropper A	2
Sharecropper B	6
Sharecropper C	1
Total	21.75

Based on this list and the warabandi time of 6 hours and 53 minutes, the warabandi time would be 18-19 minutes per acre. This does not mean that the sharecroppers get a proportional share of the warabandi. There is no structural arrangement between the landowner and his sharecroppers related to area cultivated and the duration of the weekly irrigation. According to field observations and farmers reactions, the landowner decides every week which fields are irrigated. The landowner was present during most irrigations and supervised the work of the sharecoppers.

A tubewell is located at the head of the lateral and is owned and operated by the landowner. The tubewell was installed in December 1996. According to Farmer 1 the operating costs are Rs 70 per hour. When the tubewell is operated to irrigate the fields of Farmer 1, the landowner and Farmer 1 share the costs. According to farmer 1 the landowner will collect this money from him after the cotton harvest. According to Farmer 1, tubewell water is normally used when there is less water in the canal. He added that the season is also hot so the crop needs extra water. The landowner also uses his canal water, so at that time he uses canal water mixed with tubewell water. According to the landowner the quality of the tubewell water is bad. A water sample taken from the tubewell had a TDS of 1400 ppm, which is according to WAPDA standards water of marginal quality. Ground water sample taken by SSP at the location of Farmer 1 had a very high salinity (EC 6.16 dS/m)

Soil Characteristics:

Farmer 1 described his soil as a medium soil. The bed-and-furrow field has salinity problems this was also experienced by the landowner in the past rabi season. Wheat germination percentage was in some parts of this field very low. According to Soil Survey Pakistan (1999), fields of farmer 1 have a sandy loam soil with a sandy loam/fine sandy loam surface. All fields, except for acre no. 14, were imperfectly drained which means that at the time of soil sampling the water table was at a depth of 100 - 150 cm depth. All fields were classified as saline-non-sodic soils.

6.1.2. Sample Farmer 2

Household:

Farmer 2 is 53 years old, and has three years of basic education. He belongs to the Warah caste. He has 6 sons and no daughters. The total number of dependent is eight. Two of the eldest sons (25 and 22 years old) are working full-time on the family land and in keeping buffalos. The two youngest sons are still going to school. Farmer 2 has recently started a milk factory. One son is mainly responsible for this. He collects milk from other farmers and processes the milk. The product is sold to bakeries and a cheese factory. The other son is helping his brothers. The father of farmer 2 owned 19.75 acres, which was divided amongst 4 sons. Farmer 2 sold two acres of his share and cultivates three acres in watercourse 40-L. Besides that he has leased 28 acres in Najeebwah for the last six years (Rs 3000 acre/year).

Income:

Sources of income of farmer 2 are crop cultivation and buffalo keeping. Most important source of income is milk production from buffalos. Farmer 2 started some 8 to 10 years with buffalo keeping and now he owns some 20 to 25 buffalos. According to Farmer 2, one buffalo produces on average 8 kg milk per day. The market rate of 1 kg milk is around Rs 7.5. The average price of a buffalo is Rs 10,000. According to farmer 2, crop cultivation is very expensive the last years. According to him the yields do not cover the costs of inputs so sometimes he has no income from crop cultivation. Therefore he started keeping buffalos, which is a good source of income. It was difficult for him to give an estimate of his income per year. However he gave a rough estimate of Rs 50,000 from crop cultivation and buffalo keeping for six months. Farmer 2 uses one permanent labourer, mainly for buffalo keeping. The salary of this labourer is Rs 800 per month and 20 maund wheat per year.

Agriculture:

Farmer 2 cultivates 3 acres in watercourse 40-L. The cropping pattern for these fields are presented in table 6.2. The cropping intensity per year is 175 percent.

Table 6.2. Cropping Pattern Fields in Watercourse 40-L Farmer 2.

Rabi 97/98	Kharif 98
7 kanal* wheat 1 kanal tobacco 2 acres fodder	7 kanal cotton (basin) 3 kanal fodder 1 acre cotton (bed-and-furrow) 6 kanal fallow
Cropping intensity = 100 percent	Cropping intensity = 75 percent

*8 kanal is 1 acre

The location of the fields of farmer 2 in watercourse 40-L is presented in Figure 6.2. Farmer 2 cultivates the fields numbered 1,10 and 11. Farmer 2 has two brothers who cultivate both 5 acres in the same block. The three brothers do not have a separate warabandi turn, but decide every week which fields will be irrigated. This is the only activity were the brothers have to work together, the brothers' incomes are kept separate. To understand this situation, the fields of the two brothers are included in this description. Brother A cultivates the fields 2,8,9,12 and 15. Brother B cultivates the fields 3, 4, 5, 6 and 7. During rabi 97-98 the three brothers cultivated 3 acres fodder, 8 acres wheat and 2 acres were left fallow. In kharif 98 they cultivated together 10 acres cotton, 1.7 acres fodder and 1.3 acres was left fallow. The cropping intensity was 175 percent for rabi 97-98 and kharif 98.

Cropping pattern for the fields in Najeebwah for rabi 97/98 and kharif 98 is described in the following table 6.3. The cropping intensity for one year is 162 percent.

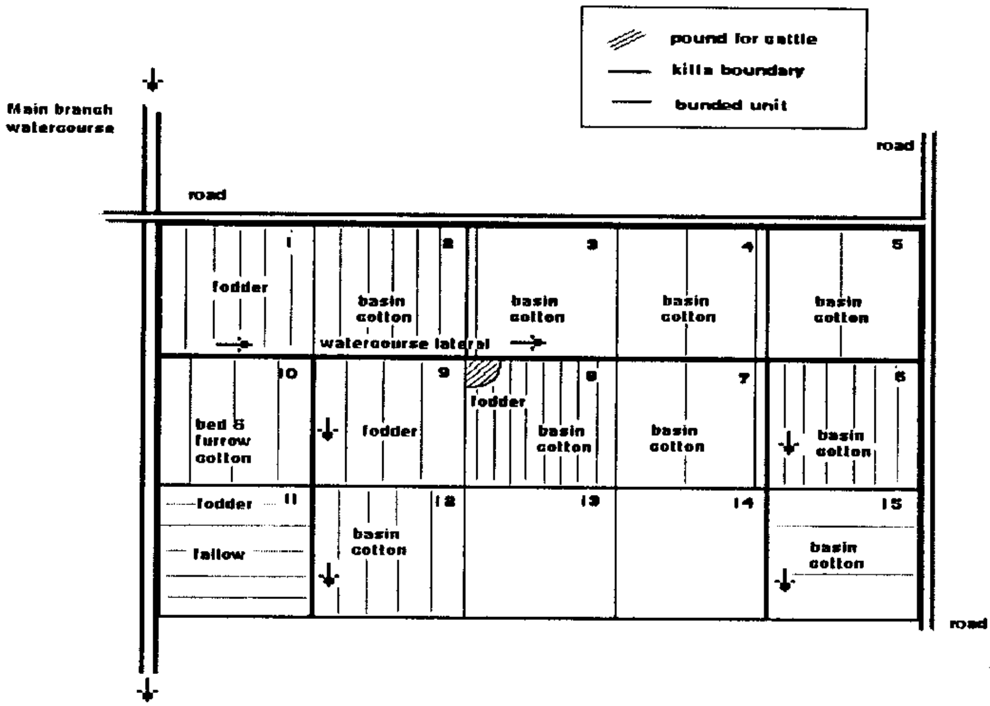

Figure 6.2. Field of Farmer 2 Watercorse 40-L.

Table 6.3. Cropping pattern Fields in Najeebwah Farmer 2.

Rabi 97/98	Kharif 98
22 acres wheat 1.5 acres sugarcane 1 acre fodder 1 acre fallow 2.5 acres continuos barren land	16 acres cotton 1.5 acres sugarcane 2.25 acres fodder 5.75 acres fallow 2.5 acres continuos barren land
Cropping intensity = 91 percent	Cropping intensity = 71 percent

Farmer 2 has agricultural equipment for a pair of oxen like a plough and plank and a jundra.

Irrigation:

Farmer 2 shares with his two brothers the warabandi on Thuesday from 9:30 till 17:15. The warabandi is still registered in their fathers' name, so there is no formal division of warabandi among the three brothers. They have divided this water turn among the three brothers by relating the time to the number of acres cultivated per brother. According to farmer 2, every week they decide together who will irrigate which field. Usually one of the brothers will use one week the complete warabandi, while the next week another brother will use the complete warabandi. This is normally repeated during the complete season. This schedule is flexible however. According to the son of farmer 2, who is mainly responsible for the fields in watercourse 40-L, the three brothers do not have a fixed schedule. Every week they start to irrigate in the morning and then the schedule can change. This is dependent on the availability of canal water and the water demand of the crops. Depending on the field conditions, the water gifts are adjusted to the crop water demand of the different fields

Soil Characteristics:

According to Soil Survey Pakistan, the fields of farmer 2 have a sandy loam soil with a sandy loam/ fine sandy loam surface. The bed-and-furrow field (acre no. 10) has no salinity or sodicity problems, as well as acre no. 8. The basin field (acre no. 2) was classified as a non-saline-sodic soil. The acres no. 12 and 15 were classified as saline-non-sodic soils.

6.2 AGRICULTURAL PRACTICES

Both farmers have tried to sow cotton with the basin method before they used the bed-and-furrow shaper. The germination of the cotton failed in the field of farmer 1 due to the salinity of the field. It is not clear why the field of farmer 2 failed to germinate. After sowing, farmer 1 estimated to have a germination percentage of 25 to 30 percent in his bed-and-furrow field and germination percentage of 75 % in his basin field. According to the farmer, this was due to a salinity problem in his field and the low rate of seed he used. Farmer 1 was positive about this germination rate, according to him this was the best germination he observed in this field compared to previous years. Farmer 2 estimated a germination percentage of 90 % in the bed-and-furrow field and a germination percentage of 70 % in his basin field.

The agricultural activities of farmer 1 and 2 for the basin and bed-and-furrow fields are presented in table 6.4 and 6.5. Farmer 1 has applied almost the same activities in his basin and bed-and-furrow field. The seed rate used for sowing the basin field is higher then for the bed-and-furrow field. Quantities of fertilizer used are the same. Due to a low crop density, less pesticides were used in the bed-and-furrow field. Plant density in the bed-and-furrow field was estimated at 12,000 plants per acre. In the basin field a number of 33,000 plants per acre was estimated. The major difference between the basin and bed-and-furrow field of farmer 2 is the application of fertilizers. In the basin field no fertilizers were applied while in the bed-and-furrow field a combination of farm yard manure, urea and DAP was used during the season. Plant density in the bed-and-furrow field was 26,500 plants per acre and for the basin field 24,500 plants per acre.

During the complete season from June till November, different pest attacks as mites, white fly, thrips, Jasid and boll worm were found in the cotton fields of farmer 1. It seems that spraying did not have any effect in the fields of farmer 1. In both cotton fields of farmer 2 jasid and thrips was observed in August. In September spotted boll worm was observed in bed-and-furrow field. However sprays controlled this, in october no boll worm was observed. The basin field was not attacked by boll worm. Whitefly was observed in both fields in September and October.

6.3 COTTON YIELD AND B/C RATIO

Tables 6.6 and 6.7 present cotton yields per picking for the basin and bed-and-furrow fields of farmer 1 and 2. The major difference between the cotton fields of farmer 1 and 2 is the period between sowing and the first harvest. Farmer 1 started the first harvest in both fields after 128 days, while farmer 2 waited 169 and 177 days for basin and bed-and-furrow respectively before the first harvest was started. For both farmers the production in the basin field was much higher then in the bed-and-furrow field. Farmer had a gross cotton yield of 73 kg in the bed-and-furrow field and 212 kg in the basin field. Farmer 2 had a gross yield of 260 kg cotton in the bed-and-furrow field and 565 kg (excluding closed bolls) in the basin field.

Table 6.4. Agricultural Activities Farmer 1.

Bed-and-Frrow Field

	Land preparation				Sowing	Hoeing		
Date	28-4-98	11-5-98	17-5-98	31-5-98	1-6-98	8-7-98	20-7-98	12-8-98
Costs (Rs/acre)	100	200	200	200	285	xx	xx	150
Time (minutes/acre)	30	60	60	60	45	540	180	45
Description	1 time ploughing	Two times ploughing	Two times ploughing	Two times ploughing	1.5 kg CIM 109 and 1.5 kg BH 36	3 days by hand	1 day by hand	With hoeing machine

	Hoeing		Fertilizer application			Pesticide application			
Date	16-9-98	8-10-98	30-7-98	12-8-98	12-9-98	16-8-98	30-8-98	12-9-98	24-9-98
Costs (Rs/acre)	60	40	370	450	9	210	210	144	288
Time (minutes/acre)	xx	Xx	68	45	xx	45	60	60	60
Description	0.63 acre with oxen	0.37 acre with oxen	50 kg ammonium nitrate	50 kg urea	1 kg urea mixed with pesticide spray	handspray 175 ml cyphermethrin and 350 ml metamidophos	handspray 160 ml cyphermethrin and 350 ml metamidophos	handspray 160 ml cyphermethrin and 160 ml metamidophos	handspray 160 ml cyphermethrin, 160 ml metamidophos and 320 ml monochrotophos

Basin Field

	Land preparation					Sowing	Hoeing		
Date	28-4-98	8-5-98	11-5-98	28-5-98	31-5-98	1-6-98	28-6-98	18-7-98	
Costs (Rs/acre)	100	150	200	xx	200	280	xx	xx	
Time (minutes/acre)	30	60	60	120	60	45	960	120	
Description	1 time ploughing	Scraper	Two times ploughing	Rouny irrigation	Two times ploughing	2 kg CIM 109 and 2 kg BH 36	4 days by hand	0.5 acre with oxen	

	Hoeing		Fertilizer application			Pesticide application			
Date	18-7-98	4-8-98	18-7-98	30-7-98	12-9-98	16-8-98	29-8-98	12-9-98	24-9-98
Costs (Rs/acre)	50	100	370	450	14	279	279	230	432
Time (minutes/acre)	20	240	30	45	xx	60	90	90	90
Description	0.5 acre ridger with tractor	with oxen	50 kg ammonium nitrate	50 kg urea	1.5 kg urea mixed with pesticide spray	handspray 230 ml cyphermethrin and 470 ml metamidophos	handspray 240 ml cyphermethrin and 470 ml metamidophos	handspray 240 ml cyphermethrin and 240 ml metamidophos	handspray 240 ml cyphermethrin, 240 ml metamidophos and 480 ml monochrotophos

Table 6.5. Agricultural Activities Farmer 2.

Bed-and-furrow field

	Land preparation			Sowing		Hoeing		
Date	6-5-98	20-5-98	3-6-98	4-6-98	12-6-98	21-6-98	14-8-98	17-8-98
Costs (Rs/acre)	100	200	60	650	xx	xx	150	xx
Time (minutes/acre)	25	45	60	60	120	3240	40	??
Description	1 ploughing	2 ploughings and planking	2 ploughings and planking	5 kg CIM 446	domestic seed	3 days by hand	hoeing machine	BU4 remove furrows

	Fertilizer application					Pesticide application			
Date	20-5-98	13-8-98	14-8-98	14-8-98	3-9-98	18-8-98	1-9-98	13-9-98	2-10-98
Costs (Rs/acre)	xx	252	175	375	180	425	480	420	on credit
Time (minutes/acre)	xx	45	45	xx	60	60	60	60	60
Description	Farm Yard Manure with ploughing	36 kg urea	25 kg urea	25 kg DAP with hoeing machine	25 kg urea	handspray 500 ml polytrin C	handspray 200 ml telstar 200 ml ethion	handspray 200 ml telstar 200 ml ethion	handspray Thiodon 660 ml, Advancher 480 ml, Furee 120 ml

Basin field

	Land preparation		Sowing	Hoeing		
Date	28-4-98	1-5-98	1-5-98	15-6-98	18-6-98	5-7-98
Costs (Rs/acre)	xx	200	300	100	xx	200
Time (minutes/acre)	xx	120	45	30	720	60
Description	rouny	2 times ploughing and planking	4 kg CIM 1100	with ridger	4 days by hand	two times with ridger

	Pesticide application					
Date	14-8-98	24-8-98	3-9-98	12-9-98	20-9-98	22-9-98
Costs (Rs/acre)	140	320	335	603	375	on credit
Time (minutes/acre)	90	90	90	90	90	90
Description	handspray 250 ml Methamidophos and 160 ml cyphermethrin	Handspray 200 ml telstar	handspray 200 ml telstar and 250 ml methamidophos	handspray 500 ml endosulfan and 250 ml Bulldog	handspray 500 ml polytrin C	handspray Thiodon 660 ml, Advancher 480 ml, Furee 120 ml

Table 6.6. Cotton Yields Basin and Bed-and-Furrow Field Farmer 1.

	Bed-and-Furrow Field			Basin Field		
Date	7-10-98	3-11-98	18-11-98	7-10-98	2-11-98	18-11-98
Yield (kg/acre)	7 kg	56 kg	10	11,5 kg	173 kg	27,5
Costs (acre)	2.5 kg	1/16 share	2,5 kg	3,5 kg	1/16 share	7.5 kg
Nr of pickers	15	5	10	15	27	10
Time (minutes)	60	300	60	90	210	180

Table 6.7. Cotton Yields Basin and Bed-and-Furrow Field Farmer 2.

	Bed-and-Furrow Field		Basin Field			
Date	28-11-98	15-1-99	17-10-98	7-11-98	1-12-98	1-12-98
Yield (kg/acre)	200	60	115	320	130	50 kg bolls
Costs (acre)	Rs 60 per maund	Rs 60 per maund	1/16 share	Rs 60 per maund	Rs 60 per maund	xx
Nr of pickers	6	4	10	9	10	xx
Time (minutes)	360	720	180	420	200	xx

The total costs and benefits[4] of the monitored basin and bed-and-furrow fields of both farmers are presented in table 6.8. Farmer 1 has lost a substantial sum of money in the bed-and-furrow field. His basin field generated some revenue. Farmer 2 achieved a very good result in his basin field with a B/C ratio of 3.66. The result of the bed-and-furrow field is positive but less compared to the revenue generated of the basin field.

Table 6.8. Costs & Benefits of Cotton Fields Farmer 1 and 2.

	Farmer 1		Farmer 2	
	Basin	bed-and-furrow	basin	bed-and-furrow
Total costs (Rs/acre)	3134	2916	3825	4480
Net yield (kg/acre)	190,2	64,5	557,8	260
Net value of harvest (Rs/acre)	4852	1645	13983	6467
B/C ratio	1,55	0,56	3,66	1,44

Conclusion:

For both farmers the economic results of the bed-and-furrow fields were not good compared to the basin fields. The investments made in the bed-and-furrow fields did not result in an acceptable B/C ratio, which was much lower then the B/C ratio in the basin fields.

6.4 IRRIGATION PRACTICES

Tables 6.9 to 6.12 present the depth of water applied per water gift for the basin and bed-and-furrow fields of farmer 1 and farmer 2. The total water depth applied for the bed-and-furrow fields was respectively 288 mm for farmer 1 and 327 mm for farmer 2. The water depth applied to the basin fields was respectively 170 mm for farmer 1 and 127 mm for farmer 2. These figures do not include the pre-sowing irrigation gifts for the basin fields. Though farmer 1 has access to tubewell water, he did not apply more water to his bed-and-furrow field as compared with farmer 2.

The farmers applied 7 and 8 water gifts to the bed-and-furrow fields. The basin fields received 4 and 2 irrigation gifts. In the first month, the bed-and-furrow fields were irrigated every week. The watergifts are used for the germination and emergence of the small cotton plants. Water gifts are

[4] Total costs include payments in cash for the harvest. The net yield is the gross yield minus the share paid in kind for the harvest. For farmer 2 a cotton price of Rs 995 is assumed, which is the average cotton price of the sample farmers in Bahaderwah minor. Cost of the last spray of farmer 2 is assumed to be approximately Rs 600.

stopped for several weeks and some 60 to 70 days after sowing irrigation of the bed-and-furrow fields is continued again. This period of time coincides with the start of the flowering of the cotton plants.

A comparison of the applied water depths of the basin and bed-and-furrow fields shows that the per irrigation more water is applied to the basin fields then to the bed-and-furrow fields. The average water depth applied is 36 mm for the bed-and-furrow field of farmer 1 and 41 mm for farmer 2. The basin fields received per irrigation event on average 51 mm for farmer 1 (excluding fourth irrigation) and 64 mm for farmer 2.

Conclusion:

The main differences between irrigation practices for basin and bed-and-furrow fields are:

a) basin fields receive a pre-sowing irrigation, while bed-and-furrow fields receive several light irrigations after sowing;

b) bed-and-furrow fields were irrigated more frequently (7-8 times) then basin fields (2-4 times); and,

c) basin fields received per irrigation event more water then the bed-and-furrow fields.

Table 6.9. Basin Water Gifts Farmer 1.

Acre no. 549/9/24				
Date	Number of days after sowing	Volume of water applied (m3)	Depth of water applied (mm)	Remarks
30-07-98	59	222	57	1 acre
13-08-98	73	214	55	1 acre
10-09-98	101	164	42	1 acre
9-10-98	139	60	15	0,75 acre
Total		660	170	

Table 6.10. Water Gifts in Bed-and-Furrow Field Farmer 1.

Date	Nr of days after sowing	Volume of water applied (m3)					Depth of water applied (mm)
		BU1	BU2	BU3	BU4	Total	Total
4-06-98	3	31	33	29	23	116	29
11-06-98	10	27	41	36	25	129	32
25-06-98	24	44	22	8	0	75	19
30-07-98	59	---	---	---	---	141	35
13-08-98	73	---	---	---	---	140	35
27-08-98	87	---	---	---	---	220	55
10-09-98	101	---	---	---	---	119	30
8-10-98	129	---	---	---	---	208	52
Total						1148	288

Table 6.11. Water Depth and Volumes Applied to Basin Field Farmer 2.

		Volumes of Water Applied (m3)						
Date	Nr of days after swoing	BU 1	BU2	BU3	BU4	BU5	BU6	total
20-8-98	111	35	51	47	42	56	67	297
17-9-98	139	48	40	41	46	46	38	259
		Depth of Water Applied (mm)						
Date		BU 1	BU2	BU3	BU4	BU5	BU6	total
20-8-98	111	52	76	69	62	83	99	73
17-9-98	139	72	59	61	68	68	56	64

Table 6.12. Water Depth and Volumes Applied to Bed-and-Furrow Field Farmer 2.

Date	Nr of days after sowing	BU 1		BU2		BU3		BU4		Total	
		Volume (m3)	Water depth (mm)	Volume (m3)	Water depth (mm)	Volume (m3)	Water depth (mm)	Volume (m3)	Water depth (mm)	Volume (m3)	Water depth (mm)
4-6-98	0	32	32	31	31	26	25	16	15	105	26
11-6-98	7	48	47	36	36	41	40	51	51	176	43
18-6-98	14	57	56	41	40	41	41	41	41	180	44
25-6-98	21	41	40	22	22	25	25	23	22	110	27
13-8-98	70	0	0	0	0	48	48	51	50	99	24
20-8-98	77	56	55	40	40	0	0	0	0	96	24
27-8-98	84	0	0	0	0	61	60	70	69	131	32
3-9-98	91	72	71	65	64	0	0	0	0	137	34
10-9-98	98	0	0	0	0	47	46	53	52	99	25
17-9-98	105	48	48	44	43	0	0	0	0	92	23
29-10-98	147	0	0	0	0	41	40	58	58	99	24
Total		353	349	279	275	330	326	363	359	1325	327

6.5 Advance Time for Basin and Bed-and-Furrow Fields

The advance time is defined as the time between the moment water enters the furrow or bunded unit and the moment when water has reached the end of the furrow or bunded unit. The advance time gives an indication of the uniformity of water distribution in a field. There is always a difference in depth of water applied between the head and tail of a field when the discharge is constant. More time is available in the head of the field for water infiltration. If the advance time is reduced it will mean that the difference in applied water depth between head and tail is smaller.

Tables 6.13 and 6.14 present the advance times in basin and bed-and-furrow fields of farmer 2. For the discharges between 20 - 30 l/s the advance time of bed-and-furrow fields is less then for the basin fields. Given a discharge in the range of 20 - 30 l/s, it takes on average 9 minutes before water has reached the end of the furrows in the bed-and-furrow fields. For the same discharge it takes on average more then 30 minutes before water has reached the end of the basin fields.

It was not possible to compare the advance times in the fields of farmer 1, because the discharges were not constant during the irrigation events.

Conclusion:

The advance time in bed-and-furrow fields is less then the advance time in the basin fields. This indicates a higher uniformity of water distribution in the bed-and-furrow fields.

Table 6.13. Advance Time in Bed-and-Furrow Fields Farmer 2.

	Bed-and-furrow field					
Q (l/s)	11,07	25,06	28.67	20,74	17,36	34,79
Bu No.	Advance time					
1	13	8	9	10	Xx	19
2	20	6	9	7	Xx	19
3	17	6	10	11	21	xx
4	18	6	11	13	20	xx

Table 6.14. Advance Time in Basin Fields Farmer 2.

	Basin field		basin field	
Q (l/s)	20,25	26,97		25,83
Bu No.	Advance time (minutes)		Bu No.	advance time (minutes)
1	33	34	1	22
2	45	30	2	17
3	35	34	3	20
4	36	36	4	22
5	46	37	5	19
6	53	30		

6.6 DEVELOPING A WATER BALANCE FOR BASIN AND BED-AND-FURROW FIELDS

Based on the climatic data of a weather station in Bahawalnagar and the measured irrigation events of the two detailed monitoring farmers an estimation of the crop water requirements and the consumptive water use of cotton in these fields can be made. Cropwat 5.7, which was developed by FAO was used for this simulation. The standard crop coefficients (Kc) for cotton as presented in FAO (1979) were used.

Given the weather characteristics of kharif 1998, the potential water use for cotton planted on 1st of May is 1251 mm. Cotton planted on 1st of June has a potential water use of 1066 mm. It was observed that rainfall in the area varies locally. It is assumed that rainfall follows the pattern as observed and measured by the weather station in Bahawalnagar. The total rainfall from 1st of June 1998 was 221 mm. It is assumed that the total rainfall is effectively available for the crops. Regarding the soil moisture content at the planting date, the following assumptions were made. Basin fields received a pre-sowing water gift. It is assumed that the total root zone is filled so that total available moisture is 100 percent. The bed-and-furrow fields were sown before using the basin method. They actually received a pre-sowing gift some two weeks before the fields were sown with the bed-and-furrow shaper. Here we assume that 50 percent of the root zone is filled with water. However an extra simulation is made for a bed-and-furrow field without a pre-sowing gift, which has consequently a completely dry root zone. A field application efficiency of 70 percent is assumed for both basin and bed-and-furrow fields[5]. Results of the simulation are presented in table 6.15.

In the Cropwat simulation, fields of farmers 1 and 2 do not receive enough rainfall and irrigation water for optimal crop evaporation. The irrigation deficit varies between 50 and 60 percent of the total irrigation requirement. As a consequence the yield reduction factor varies between 40 to 50 percent. It should be reminded that the optimal crop evaporation calculated by Cropwat is based on a fully covered field. In case of farmer 2 who had a low germination and consequently a low crop cover, this would mean that the actual crop evaporation is lower then simulated.

Under the assumptions, which were explained above, rainfall is an important factor in the water balance. The factor effective rainfall equals the water gift of canal water in bed-and-furrow fields and is in basin fields two times more then the canal water gift. Though the bed-and-furrow fields were irrigated more frequently and received more canal water, the actual water use of bed-and-furrow fields was not more then in the basin fields. This is caused by the pre-sowing irrigation gifts in basin fields, where the water supply from the initial soil moisture content is of major importance in the water balance. So the gap in applied water depth between basin and bed-and-furrow fields is

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[5] This is a disputable assumption. Based on the advance times it was concluded that the water distribution uniformity is higher for bed-and-furrow fields then for basin fields. Which should mean that the field application efficiency of bed-and-furrow fields is higher then for basin fields. However no verified data is available which gives a good indication of this gap in field application efficiencies.

covered by the pre-sowing irrigation gift. The effective water use in bed-and-furrow fields is not higher compared to the basin fields in this simulation.

The basin field of Farmer 2 was sown on 5 May, while the other fields were sown around 1 June. Due to the dry and hot weather of May, this basin requires 200 mm more water then the other fields. This means that an earlier sowing of cotton leads to a higher crop water requirement for the complete kharif season. If the soil of a bed-and-furrow field is completely dry (which is recommended for land preparation) then the irrigation deficiency is higher then for the basin fields under current practices. If it is assumed that some water is stored in the bed-and-furrow field then the irrigation deficiency equals or is less compared to the basin fields.

Table 6.15. Water Balance Simulation of Cotton Fields Farmer 1 and 2.

	Water balance cotton fields farmer 1			Water balance cotton fields farmer 2				
	Bed-and-furrow		Basin	Bed-and-furrow BU 1 and 2		Bed-and-furrow BU 3 and 4		Basin
Initial soil moisture content (%)	0,0	50,0	100,0	0,0	50,0	0,0	50,0	100,0
Total gross irrigation (mm)	287,0	287,0	169,0	301,9	301,9	352,9	352,9	137,7
Total net irrigation (mm)	200,9	200,9	118,3	211,3	211,3	247,0	247,0	96,4
Effective rain (mm)	208,0	208,0	208,0	200,1	200,1	200,1	200,1	221,1
Supply from soil moisture (mm)	-1,0	97,0	195,3	-0,5	97,5	-3,2	102,0	193,9
Actual water use (mm)	407,9	505,9	521,6	410,9	508,9	443,9	541,9	511,3
Potential water use (mm)	1065,7	1065,7	1065,7	1037,7	1037,7	1037,7	1037,7	1250,7
Actual Irr. Requirement (mm)	857,7	857,7	857,7	837,6	837,7	837,6	837,6	1029,6
Irrigation deficiency (%)	61,7	52,5	51,1	60,4	51,0	57,2	47,8	59,1
Yield reduction (%)	52,5	44,7	43,4	51,3	43,3	48,6	40,6	50,3

The simulation indicates that the irrigation practices of these farmers are far from optimal. The crop is largely dependent on rainfall and water is applied extensively. Though the farmers are located in tail and head watercourses there is hardly a difference in applied water depth. However if a larger group of farmers is compared, as was done in chapter V, there is a strong relation between location of fields in the irrigation system and the applied water depth.

The Cropwat simulation does not incorporate capillary rise of water by a ground water table close to the soil surface. Plants with a deep root zone can make use of this water for evapotranspiration. It means that soil moisture content is not depleted during a season but that there is a continuous refilling. During kharif 1998 the groundwater table was monitored in 5 different watercourses in Bahaderwah Minor. The average water depth in 5 watercourses was 1.97 m below soil surface. The average minimum water depth was 1.53 m below soil surface in June and depleted to an average maximum water depth of 2.28 m below soil surface. It should be noted that these figures are averages. Some areas are waterlogged, like the tail of 11-L and 20-L, where the groundwater depth varied from a ground water level near soil surface to 1 meter below soil surface. To get a rough idea about the supplementary irrigation from groundwater in the area, the computer model CAPSEV is used. The main problem was that hardly any information is available of soil hydraulic properties in the FESS area. It is assumed that the soil hydraulic properties of a Dutch zavel soil (Wösten et al. 1994) are representative for a sandy loam soil, which is commonly found in Bahaderwah Minor. The soil hydraulic properties were used to calculate the maximum possible fluxes from various ground water levels to different depths below soil surface. The root zone of cotton can extend to a depth of more then 1 m below soil surface. The minimum value of capillary rise to 1 m. below soil surface is 0.075 cm/day for a ground water depth at 250 cm below soil surface and a soil, which is not completely dry and has a pF of 3. Similar minimum values can be found for other combinations of ground water levels and capillary fluxes to various soil depths. It means that for a growing season of 180 days a minimum of 135 mm rises to the root zone and can be effectively used by the plant.

This capillary flux will reduce the irrigation deficiency with approximately 10 percent. These figures are presented to give an idea about the importance of capillary rise in a crop water balance. If a loamy soil is taken with a lower saturated conductivity capillary rise will be reduced drastically. But if the ground water of the above mentioned example is 50 cm higher then the maximum flux can increase to 1.7 mm/day. A negative effect of capillary rise is an increase in soil salinity.

Conclusion:

The total water depth applied during kharif 1998 to basin and bed-and-furrow fields of the detailed monitoring farmers did not fulfill the irrigation requirement of the cotton fields. Irrigation deficiency of bed-and-furrow fields, which are completely dry before sowing reaches 60 percent of the irrigation requirement. By applying a pre-sowing irrigation gift in basin fields, water is stored in the soil, which contributed a substantial part to the water consumption of the plant. Though rainfall is limited in the area, it is of major importance in the water balances of both the basin and bed-and-furrow fields. The shallow ground water table makes through capillary rise water available for the crop. A rough estimation is that groundwater can contribute a minimum of 10 percent of the total crop evapotranspiration of cotton under the conditions in Bahaderwah Minor. Capillary rise of groundwater has the disadvantage of increased soil salinization. More research is required to understand the relationship between groundwater, soil hydraulic properties and the water requirements of different crops in this area.

The two detailed monitoring farmers have applied less water to the bed-and-furrow fields (gross water depth 287 mm and 353 mm) compared to the average figure of the other farmers in Bahaderwah Minor area (average 528 mm). This is the same for the basin fields as well. It does mean that the two detailed monitoring farmers represent a group of farmers who apply less water to their cotton fields. This case study is not representative for the group of farmers who apply 500 to 900 mm water per acre.

6.7 Farmers' Perception On the Basin and Bed-and-Furrow Methods

Sample Farmer 1

The experience of farmer 1 with the bed-and-furrow method is overall negative. Before he used the bed-and-furrow method he tried to sow cotton with the traditional drill method. The farmer told that because of salinity of the field seed did not germinate. After sowing with the bed-and-furrow shaper, the farmer was positive about the germination in the bed-and-furrow field (25 - 30 percent) though it was compared to the basin fields very low. It should be mentioned that the farmer used only 3 kg of seed. During the rest of the season the cropping density remained low, it was estimated that 12,000 plants were standing in the bed-and-furrow field and some 33,000 plants in the basin field.

Regarding the germination in bed-and-furrow fields on saline effected soils, the farmer mentioned that in general when the season would be cool the germination percentage would be good. But when the season would be hot, the germination percentage would be low and the emerging plants would be dying in the field.

According to farmer 1 the bed-and-furrow method is not a water saving method compared with the basin method. According to farmer 1: " The water is faster in bed-and-furrow field reaching the end of the field. But with filling time, the B/F field uses the same time as the basin fields". The land owner agreed with this statement. According to farmer 1 the only advantage of the bed-and-furrow method is that at sowing time water is saved because no rouny irrigation is applied. Sample farmer 1 mentioned that in basin fields water would be applied after every 2 - 3 weeks of irrigation. In bed-and-furrow fields more water is used. The farmer told that during more water turns water would be applied to the bed-and-furrow field. The bed-and-furrow field must be irrigated after every 15 days after sowing.

According to the farmer the time required to irrigate a field is not dependent of the cultivation method, but is dependent of the level of the field in relation to the watercourse. The basin fields with acre number 14 and 15 were higher then the fields 23 to 25. Therefore the fields 23 to 25 were irrigated most of the time with nakkal water and it takes more time to irrigate fields 14 and 15 as compared to the bed-and-furrow field. According to the farmer the soil type does not make a difference in irrigation time.

The number of bunded units in the basin fields varied from 4 to 6 per acre. Sample farmer 1 told that due to an unlevel field he makes different number of bunded units. After the first rouny irrigation he observes the level of the basin fields and makes the bunded units.

Crop condition in the field was not good according to farmer 1, because sowing of the cotton was too late. Germination was influenced by rainfall, a hard soil crust was formed. Farmer 1 told that he would not use the bed-and-furrow method next year. Only if OFWM or IIMI bear the expenses than he would use the bed-and-furrow method. The main reason he mentioned was that the hoeing was difficult. Hoeing in basin fields was easier. Hoeing in basin fields would be possible with a pair of oxen and a plough, manually, or with a tractor. According to the farmer, the tractors in the area are small and the bed-and-furrow shaper and hoeing machine were too heavy for the tractors. Even if the machinery would be available with a heavy tractor organized by the WUO, farmer 1 would not use the method again. The other reason he mentioned was that he had no money.

Farmer 1 mentioned that there was a salinity problem on the beds. According to a fellow tenant if water was used in the basin fields then the salts would leach down. But in the bed-and-furrow field the salts do not leach down. According to the farmer, in basin fields there was no salinity problem. Because of the increased salinity on the beds the farmer ploughed a part of the field and irrigated it.

Sample Farmer 2

Before using the bed-and-furrow method sample farmer 2 tried to sow cotton with the traditional drill method on the same field. However seeds failed to germinate, therefore he used the bed-and-furrow method. Farmer 2 stated that the germination in the bed-and-furrow field was good as compared to the basin field. He estimated that the germination in the bed-and-furrow field was 90 %, and in the basin field this was 70 %. According to farmer 2, the basin field required 5 hours for one irrigation and the bed-and-furrow field 2 hours. This is a lot of time for one irrigation. The farmer mentioned that this is a consequence of the construction of a new outlet which discharge was smaller then before. According to the farmer, with the old outlet one acre basin field could be irrigated in 3 hours and the bed-and-furrow field in 1,5 hours.

The farmer mentioned that his farm land has the lowest elevation in the command area of watercourse 40-L. His fields required less time for an irrigation compared to the fields of other farmers in watercourse 40-L. According to the farmer, the bed-and-furrow field has compared to the other fields of his farm the lowest elevation. Therefore the water runs faster to the tail of the field as compared to the basin fields. Farmer 2 stated that the bed-and-furrow field required 40 to 50 percent of the water which is normally required to irrigate a basin field. The bed-and-furrow method saves water per irrigation event. The farmer could not give an estimation of the total water use of bed-and-furrow in relation to basin fields in one season.

An advantage of the bed-and-furrow method mentioned by farmer 2 was that with less discharge it was possible to irrigate the bed-and-furrow field. While under the same conditions it was not possible to irrigate a basin field. Farmer 2 mentioned the following disadvantages. The bed-and-furrow field needed more ploughing as compared to basin fields, because the bed-and-furrow method required a soft soil. Hoeing the bed-and-furrow fields was a problem. According to the farmer, a farmer needed two persons permanently if he did not have a big tractor. It would be possible to use a small tractor, but the owners were hesitant to give their tractor because the hoeing machine was too heavy. According to farmer 2, it would not be possible to use a ridger for hoeing. The farmer mentioned that with frequent irrigations the soil became hard, which had a negative effect on the plant growth. The hardening of the soil was not related to salinity or use of tubewell water, it was according to farmer related to the nature of the soil.

According to farmer 2, the irrigation requirements of the bed-and-furrow method influenced the cultivation of other crops on his farm. He stated that he would not use the bed-and-furrow method next season because of the frequent irrigations. In his opion there would be no irrigation left for fodder. With basin only 1 or 2 irrigations were applied. The remaining time could be used to irrigate other fields. According to the farmer this was also a matter of water availability in the area. He stated that the shortage of canal water in the command area is a major constraint in using the bed-and-furrow method in the future.

The farmer had six to eight bunded units per acre in the basin fields. He explained that he did this for two reasons. First, with more bunded units per acre the area to be irrigated is decreased. With smaller discharges a small area could be covered more quickly. Secondly, the number of bunded units was dependent on the level of the field. The most important factor was according to him the limited discharge.

Conclusion:

Both farmers mentioned the following advantages of the bed-and-furrow method.

- Seed germination in the bed-and-furrow fields was good. The bed-and-furrow method is a good method to use in salt affected soils.
- Less time is required to irrigate one acre bed-and-furrow field compared to a one acre basin field.

A major constraint mentioned by both farmers is the limited availability of canal water in the area. The bed-and-furrow method requires a reliable and adequate water supply. Though the bed-and-furrow method is water saving during one irrigation event, the irrigation frequency is much higher then for basin fields. Under the conditions of unreliable and inadequate water availability the farmers perceive this as a problem. Farmer 2 mentioned specifically that the irrigation requirements of the bed-and-furrow method would influence the water availability for fodder fields. The farmer has cattle for milk production and his first priority is to have a good fodder crop. Other constraints mentioned are:

- hoeing of the bed-and-furrow fields requires more time and labour;
- salts accumulate on the beds (farmer 1);
- the heavy bed-and-furrow shaper and hoeing machine require access to a good heavy tractor, which is perceived as a problem by both farmers.

Both farmers are of the opinion that the elevation of the fields is the most important factor in determining the time which is required to irrigate an acre. The cultivation method either basin or bed-and-furrow is of minor importance.

6.8 CONCLUDING REMARKS

Yield results of the bed-and-furrow method of the two detailed monitoring farmers were disappointingly low for kharif 1998. Several factors have contributed to a low yield of both basin and bed-and-furrow fields. Late sowing of the cotton, pest attacks at the end of the season and an unreliable water supply during the season. Sample farmer 1 had severe problems with the germination in his field due to salinity problems. It can be questioned whether under these circumstances cultivation of other crops is feasible as well. Perhaps only salt tolerant crops as jantar tolerate the soil conditions of his field.

From an economic perspective the results of bed-and-furrow are not attractive for the farmers to continue with the bed-and-furrow method in the next seasons. The investments made in the bed-and-furrow fields did not pay off in the form of a good harvest. The B/C ratio of the bed-and-furrow fields was much lower then the B/C ratio of the basin fields.

Several differences in irrigation practices between bed-and-furrow and basin cultivation were observed and measured. The major difference is the pre-sowing gift for basin fields, followed by a long period of no water gifts, while bed-and-furrow fields start with a dry soil and should receive several light irrigation after sowing. The bed-and-furrow fields were irrigated more frequently (7-8 times) then basin fields (2-4 times), but the basin fields received per irrigation event more water then the bed-and-furrow fields. The advance time in bed-and-furrow fields was less then the advance time in the basin fields. This indicates a higher uniformity of water distribution in the bed-and-furrow fields.

A water balance study with the aid of CROPWAT 5.7 indicates that the total water depth applied during kharif 1998 to basin and bed-and-furrow fields of the detailed monitoring farmers did not fulfill the irrigation requirement of the cotton fields. Under the irrigation practices of the sample farmers the irrigation deficiency of bed-and-furrow fields reaches 60 percent of the irrigation requirement. The irrigation deficiency in basin fields is some 50 percent of the total irrigation requirement. Water stored in the top 1.5 m soil contributed a substantial part to the water consumption of the plant. Rainfall is limited in the area, but is an important component in the water balances of all cotton fields. The shallow ground water table, which varies from 1 to 2.5 m from the surface, can theoretically contribute a minimum of 10 percent of the total water use of cotton. However, capillary rise of groundwater has the disadvantage of increased soil salinization.

Advantages of the bed-and-furrow method mentioned by the two farmers were:

- Seed germination in the bed-and-furrow fields was good. Considering the germination alone, the bed-and-furrow method is a good method to use in salt affected soils;
- Less time is required to irrigate a bed-and-furrow field compared to a basin field if both fields have the same dimensions.

Disadvantages of the bed-and-furrow method were:

- Hoeing of the bed-and-furrow fields requires more time and labour;
- Salts accumulate on the beds, which will hamper the germination of the next wheat crop in rabi.

Constraints mentioned were:

- Unreliable and inadequate availability of canal water in the area. Though the bed-and-furrow method is water saving during an irrigation event, the irrigation frequency is much higher then for basin fields. Under the conditions in the area farmers argue that it will be difficult to fulfill the requirements of the bed-and-furrow method;

- In line with the first constraint, farmer 2 mentioned specifically that the irrigation requirements of the bed-and-furrow method would influence negatively the water availability for his fodder fields. The farmers' first priority would be to irrigate the fodder fields, because he has cattle for milk production;
- The heavy bed-and-furrow shaper and hoeing machine require access to a good heavy tractor. This tractor is not easily available for the farmers in the area.

7 ECONOMIC FEASIBILITY ANALYSIS

For the economic analysis of the feasibility of the bed-and-furrow method, first an analysis of the costs involved in using the bed-and-furrow method will be presented, which will be compared with the basin method. Besides the cost factor also the time expenditure of both methods will be analyzed and compared. Secondly an analysis of the benefits of the bed-and-furrow method will be presented in comparison with the basin method.

7.1 COST AND TIME EXPENDITURE PER ACTIVITY

Land Preparation

Table 7.1 presents the time and costs of land preparation activities of basin and bed-and-furrow fields. Land preparation of the bed-and-furrow fields is more costly then the land preparation of the basin fields. For land preparation, an average farmer spends Rs 469 per acre on bed-and-furrow fields and Rs 357 per acre on basin fields. The difference in costs expresses the higher degree of mechanization necessary to prepare a good bed-and-furrow field. There is no differences on the time spent for land preparation activities between basin and bed-and-furrow fields. On average, three hours were used for land preparation of the cotton fields.

Table 7.1. Land Preparation Costs and Time for Basin and Bed-and-Furrow Fields.

	Basin fields	Bed-and-furrow fields
Average Cost (Rs/acre)	357	469
Standard deviation	195	298
Average Time (minutes/acre)	170	180
Standard deviation	125	128

Sowing

The average time used to sow one acre of cotton is 50 minutes for both, basin and bed-and-furrow fields. As is presented in Table 7.2, the costs for sowing are higher for the bed-and-furrow fields, because sowing is completely mechanized. Some basin fields were sown by the traditional method, which is cheaper than using a tractor with a drill. The expenses of the seed used in the bed-and-furrow fields indicate that farmers have used a higher quality of seed.

Table 7.2. Costs of Sowing Basin and Bed-and-Furrow Fields.

	Basin fields	Bed-and-furrow fields
Average cost of drilling (Rs/acre)	60.4	135.8
Standard deviation	45.4	30.7
Average weight of seed (kg/acre)	4.96	5.21
Standard deviation	1.07	1.42
Average cost of seed (Rs/acre)	208.4	265.5
Standard deviation	170.2	120.3

Herbicides

The costs of applying herbicide ranges between Rs 400 to Rs 450 per acre. These high costs combined with the risk of germination failure explain why a large majority of the farmers does not use herbicide. Farmers mentioned that there is a chance to lose a large sum of money if germination fails. Farmers prefer to wait and see the germination percentage of their fields. Based on this observation, they decide in a later stage to invest more. However, the use of herbicides was not effective at that time.

Hoeing

The time spent on hoeing activities is dependent on the extent of the weed problem in different fields, which varies considerably. However, as is presented in Table 7.3, the major difference between bed-and-furrow and basin fields is the total time spent for hoeing. On average, it will take one person 2 days (working 8 hrs/day) to clean a basin field, while it will take the same person more then 5 days to clean the bed-and-furrow field. The standard deviation indicates that there are bed-and-furrow fields where the time spent on hoeing is extremely high; about 10 days for one person.

Table 7.3. Hoeing Activities for Selected Basin and Bed-and-Furrow Fields.

	Basin			Bed-and-furrow		
	No. of hoeings (acre)	Time (min/acre)	Costs (Rs/acre)	No. of hoeings (acre)	Time (min/acre)	Costs (Rs/acre)
Average	3,1	1048	111	3,3	2634	131
Standard deviation	1,2	880	111	1,3	2798	172

The average costs for hoeing seems to indicate that there is not much difference between basin and bed-and-furrow fields. However, for 37 percent of the bed-and-furrow fields, no expenses were made on hoeing, while no costs were made for 22 percent of the basin fields. This explains the large variation in costs made, but also shows that when costs are made for hoeing bed-and-furrow fields, these are, on average, higher (Rs 207) than for basin fields (Rs 143).

Fertilizers

The market prices for Ammonium nitrate ranges between Rs 350 to Rs 375 per 50 kg bag, for nitrophos Rs 550 to Rs 560 per 50 kg bag, for Urea Rs 360 to 460 per 50 kg bag and for DAP between Rs 600 to 620 per 50 kg bag. Table 7.4 presents the average expenses made by farmers who actually applied fertilizers. This figure does not include farmers who did not apply fertilizers. The average expenses made for fertilizer application are almost equal for basin and bed-and-furrow fields.

Table 7.4. Expenses made for Fertilizer Application Basin and Bed-and-Furrow Fields.

	Basin	Bed-and-Furrow
Average fertilizer expenses (Rs/acre)	642	653
Standard deviation	391	432

Pesticides

As is presented by Table 7.5, the average costs of pesticide application per acre are higher (Rs 350) for the bed-and-furrow fields when compared to the basin fields. This indicates that farmers have applied pesticides on bed-and-furrow fields that are more expensive than the pesticides used for the basin fields. The time required to spray one acre by hand, on average, is 45 minutes.

Table 7.5. Costs and Number of Pesticide Applications for Basin and Bed-and-Furrow Fields.

	Basin (n=35)	Bed-and-furrow (n=36)
Average number of sprays per acre	5,19	5,12
Standard deviation	1,31	1,30
Average costs (Rs/acre)	1379	1752
Standard deviation	853	684

Harvest

Normally, groups of women pick the cotton for a fixed share in kind of the harvest. This share varies from 1/13th to 1/16th of the total harvest. Occasionally, a fixed price is paid to the women, which averages Rs 60 per maund. The total time spent varies according to the yield. If the expected yield of picking is low, for example, for the first and last pickings, farmers prefer to use family labor.

7.2 TOTAL COSTS AND TIME EXPENDITURE FOR BASIN AND BED-AND-FURROW FIELDS

The average cost and time spent on basin and bed-and-furrow fields for the group of sample farmers are presented in Figure 7.1. The average investment in one acre of cotton for basin and bed-and-furrow is almost equal, i.e. for bed-and-furrow Rs 3,170 per acre and for basin Rs 3,032 per acre. The standard deviation for bed-and-furrow is Rs 1,301 and for basin Rs 1,217. The time spent on a per-acre basis is for the bed-and-furrow method about twice as much as for the basin method, i.e. 3411 minutes per acre for bed-and-furrow fields and 1667 minutes per acre for basin fields. However, the variation in time spent per acre for bed-and-furrow fields is very high. The standard deviation is 2976 min/acre, while for basin fields this is 1057 min./acre.

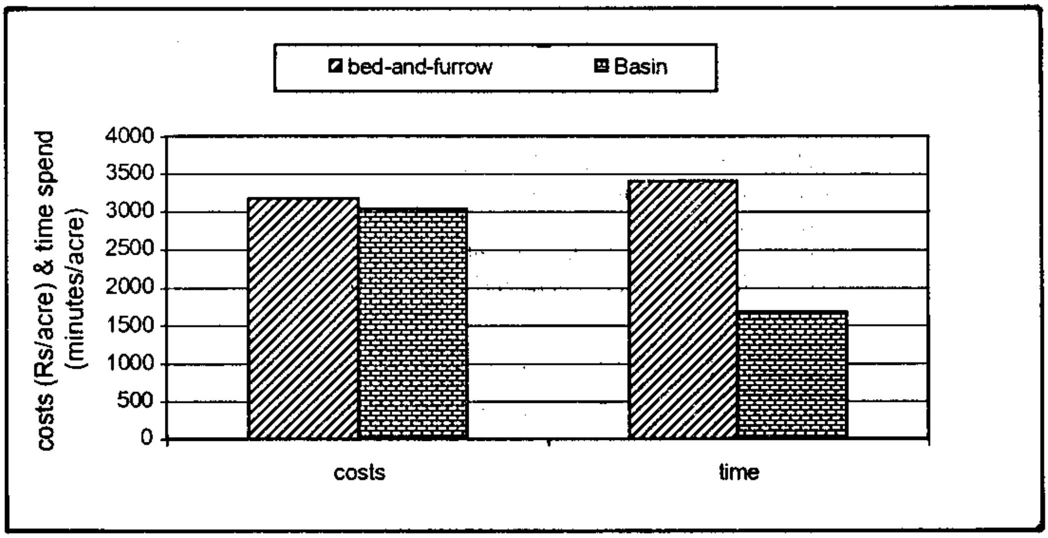

Figure 7.1. Average Cost and Time Expenditure per Acre of Cotton.

Conclusion:

The average amounts of money spent on inputs for basin and bed-and-furrow fields are almost equal. The average expenses made for cotton cultivation is Rs 3,000 per acre.

7.3 COSTS COMPOSITION FOR BASIN AND BED-AND-FURROW FIELDS

Figure 7.2 presents the average costs per agricultural activity for the sample basin fields and bed-and-furrow fields. Though the total average costs for both methods are almost equal, there are some major differences in the way expenses are made. First of all, the land preparation for the bed-and-furrow method is more expensive than for basin fields. The bed-and-furrow method requires a good land preparation, which directly expressed in the costs involved. On average, Rs 468 are spent for land preparation for bed-and-furrow when compared to Rs 357. The difference is marginal compared to the total costs involved in cultivating cotton; only 3 percent. Average sowing costs are higher for the bed-and-furrow method when compared to the basin method. This has two reasons. First, a group of farmers sow their basin fields with the traditional pore and bullocks. No machinery has to be hired. Secondly, there is a tendency to use more expensive seed per acre for the bed-and-furrow method. On an average, 5.2 kg seed with an average cost of Rs 51 was used for the bed-and-furrow fields. For the basin fields an average of 4.95 kg seed with a cost of Rs 42 was used for sowing. Regarding sowing practices, two extra costs are involved for the bed-and-furrow method. First of all, the loss of seed that did not germinate in the basin field and some costs for re-sowing in cases were the bed-and-furrow machinery did not work well. The average extra cost is Rs 165. The average costs for hoeing, fertilizer application and costs for additional water gifts (purchased from tubewell owners) are for the basin and bed-and-furrow fields almost equal. The major difference in expenses is found in the pesticide costs. For bed-and-furrow fields, on average, Rs 1315 is spent on pesticides; while for the basin fields this is on average Rs 1628. The number of sprays applied for basin and bed-and-furrow fields are almost the same, i.e. on average 5.19 for bed-and-furrow fields and 5.11 for basin fields. So, the difference in pesticide costs is related to the quantity and/or quality of spray applied.

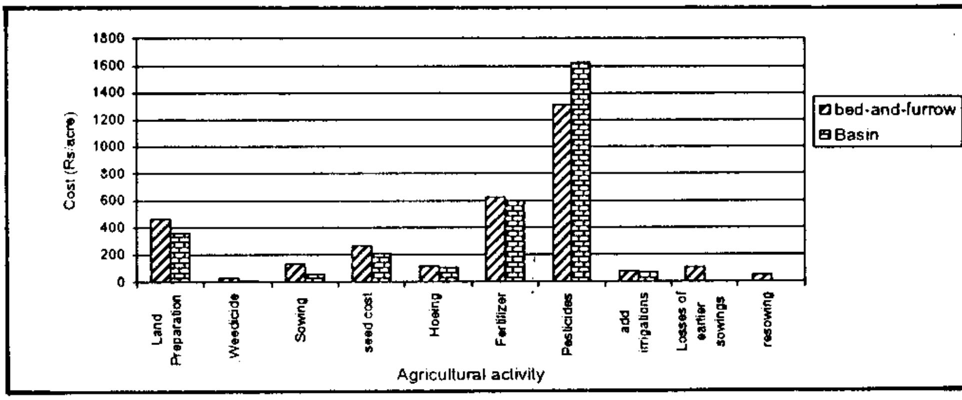

Figure 7.2. Average Cost per Agriculture Activity.

Conclusion:

Major differences in expenses made for basin and bed-and-furrow cultivation are found in land preparation, sowing and pesticide application. The extra costs involved for the land preparation of bed-and-furrow fields was Rs 100, which compared to the total costs involved, is only 3 percent. Due to problems with the bed-and-furrow shaper during sowing, farmers made some extra costs for re-sowing. Farmers spent about Rs 300 more on pesticide sprays for basin fields when compared to the bed-and-furrow fields.

7.3.1. Time Spent on Agricultural Activities

Figure 7.3 represents the time spent on different agricultural activities for basin and bed-and-furrow fields. For most of the agricultural activities, the time consumption is almost equal. The major gap is found in time spent on hoeing. The average time needed for hoeing a basin field is 992 minutes per acre, while this is 2634 minutes per acre for a bed-and-furrow field. So, the difference in work time between basin and bed-and-furrow fields is largely due to the time-consuming hoeing activities in bed-and-furrow fields. Noted, should be that a majority of the farmers did not use herbicides or the special hoeing machine for bed-and-furrow fields. If farmers use these techniques in the future, the time spent on bed-and-furrow fields can be reduced drastically. However, applying these techniques makes the bed-and-furrow method more cost intensive. According to farmers who used herbicide in the research area, these costs are about Rs 400 per acre. For both, basin and bed-and-furrow fields, sample farmers in the research area hoe these fields on average 3 times. If farmers use the special hoeing machine for the bed-and-furrow field two times during the season, this will cost on average additionally Rs 300 per acre. The total extra expenses of applying this package is Rs 700, which is based on an average expenditure of Rs 3,000 an increase of 23 percent in costs per acre.

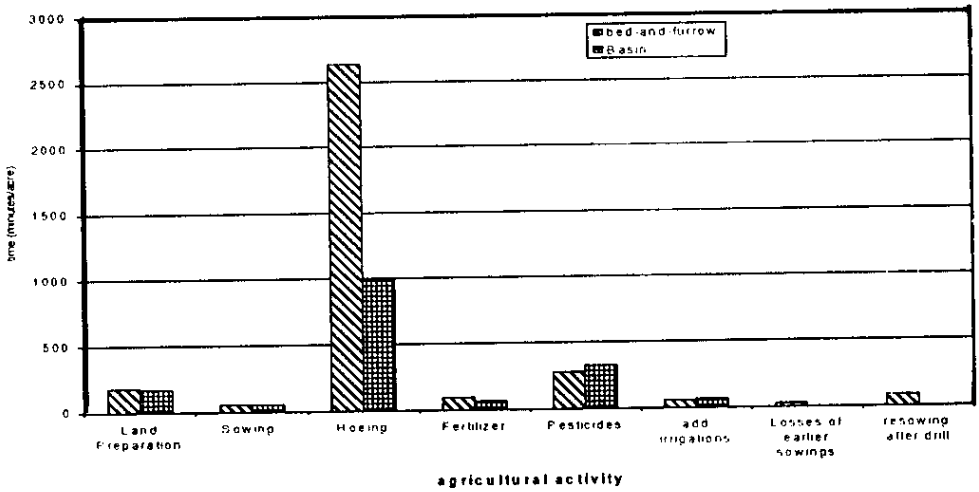

Figure 7.3. Average Time Spent per Agriculture Activity.

Conclusion:

During *kharif* 1998, the sample farmers spent twice as much time on activities in bed-and-furrow fields when compared to basin fields. However, if farmers use herbicides and the special hoeing machine in the future, this time can be reduced drastically. Applying this package means an increase of 23 percent in total costs per acre.

7.4 Costs and Benefits for Basin and Bed-and-Furrow Fields

Table 7.6 presents the costs and benefits for basin and bed-and-furrow fields in *kharif* 1998. The average price for cotton was Rs 995 per maund. The total yield is calculated as the gross production per acre minus the costs of picking, which is either in cash or in a share of the cotton yield. The average revenue generated by the bed-and-furrow method was Rs 129 per acre. For the basin method, the average revenue generated was Rs 2406 per acre (see Table 7.2). The average B/C ratio was 1.06 for the bed-and-furrow method and 1.77 for the basin method. The variation in production expenses, yields and consequently the B/C ratio is quite high among the farmers. Therefore, the revenue generated in basin and bed-and-furrow fields is presented per farmer. A comparison between 35 couples of basin and bed-and-furrow fields cultivated by the same farmer shows that in 27 cases the basin field generates higher revenue than the bed-and-furrow field. In 8 cases the bed-and-furrow field generates higher revenue than the basin field.

Table 7.6. Costs and Benefits for Cotton Cultivation in Basin and Bed-and-Furrow Fields in the Bahadarwah Minor.

		Bed-and-Furrow				Basin				Revenue b/f
No.	Water-course	Total costs (Rs/acre)	Total yield (Rs/acre)	Real revenu (Rs/acre)	Benefit/ cost ratio	Total costs (Rs/acre)	Total yield (Rs/acre)	Real revenu (Rs/acre)	Benefit/ Cost ratio	minus revenue basin (Rs/acre)
1a	11-L	1261	889	-373	0,70	3800	9523	5723	2,51	-6095
1b	9-L	2095	3007	912	1,44	3079	3226	148	1,05	764
2a	11-L	1380	0	-1380	0,00	2334	2498	164	1,07	-1544
2b	7-L	4656	4222	-434	0,91	4778	3424	-1353	0,72	919
3	11-L	4469	5417	948	1,21	3409	4411	1002	1,29	-54
5	11-L	3283	4176	893	1,27	3054	4176	1123	1,37	-230
6	14-L	2646	3400	754	1,29	2636	13280	10643	5,04	-9889
7	11-L	3733	1416	-2316	0,38	3713	5182	1469	1,40	-3785
8	9-L	4622	3101	-1521	0,67	4252	4094	-158	0,96	-1363
9	11-L	2406	3120	714	1,30	2587	7800	5213	3,02	-4499
10	14-L	3808	7887	4079	2,07	3505	6812	3307	1,94	772
11	7-L	4720	5512	792	1,17	5708	9895	4188	1,73	-3396
12	7-L	2225	121	-2104	0,05	2232	1458	-774	0,65	-1330
13	11-L	3033	3401	369	1,12	3484	6374	2891	1,83	-2522
14	9-L	3043	8693	5650	2,86	2268	10505	8237	4,63	-2587
15	5-R	3658	2150	-1508	0,59	3656	4211	555	1,15	-2063
16	5-R	3018	1506	-1512	0,50	3202	2152	-1050	0,67	-462
17	9-L	5184	1452	-3731	0,28	3358	5291	1933	1,58	-5664
18	20-L	3705	6063	2358	1,64	1967	7031	5064	3,57	-2706
19	20-L	3802	5546	1744	1,46	2997	4186	1189	1,40	556
20	18-R	3151	2858	-293	0,91	2799	2174	-625	0,78	332
21	2-1 R	3483	3215	-268	0,92	285	0	-285	0,00	17
22	2-1 R	4594	5715	1121	1,24	4074	7229	3155	1,77	-2034
23	29-L	5343	2350	-2993	0,44	2938	5640	2702	1,92	-5695
24	40-L	4353	3803	-550	0,87	4073	10539	6466	2,59	-7015
25	40-L	4088	2873	-1215	0,70	4187	3285	-902	0,78	-314
26	40-L	2718	3361	643	1,24	2621	4052	1431	1,55	-787
27	40-L	3638	140	-3498	0,04	2485	933	-1552	0,38	-1946
28	39-L	1250	117	-1133	0,09	900	1399	499	1,55	-1632
29a	42-L	4844	13911	9067	2,87	4814	14165	9351	2,94	-284
29b	43-L	4297	7013	2716	1,63	4172	6779	2607	1,62	109
30	39-L	3242	2288	-955	0,71	2665	8355	5690	3,14	-6645
31	39-L	1353	1799	446	1,33	1544	7540	5996	4,88	-5550
32	39-L	2920	3258	338	1,12	2560	2560	0	1,00	338
33	39-L	2801	1891	-911	0,67					
34	38-L	3668	3731	63	1,02	2866	3032	166	1,06	-102

7.5 COST AND BENEFITS IN RELATION TO PHYSICAL SETTING

A comparison of costs and benefits between cotton fields in the head and tail watercourses is presented in Table 7.7. The B/C ratio is slightly higher for cotton fields located in the tail watercourses. If the bed-and-furrow fields are considered, the difference is found in a higher production per acre, while for the basin fields the difference is found in less expenses made for basin fields in the tail watercourses.

Table 7.7. Average Costs and Benefits for Basin and Bed-and-Furrow Fields in Head and Tail Watercourses.

		Bed-and-furrow				Basin			
		Total costs (Rs/acre)	Total yield (Rs/acre)	Real revenu (Rs/acre)	Benefit/ cost ratio	Total costs (Rs/acre)	Total yield (Rs/acre)	Real revenue (Rs/acre)	Benefit/ cost ratio
Total group of farmers	Average	3402	3594	192	1,05	3114	5520	2406	1,82
	St dev	1109	2770	2454		1085	3446	3172	
Head: farmers 1 – 17	Average	3291	3304	13	1,05	3392	5795	2403	1,81
	St dev	1163	2421	2246		894	3254	3308	
Tail: farmers 24 – 34	Average	3264	3682	418	1,02	2990	5694	2705	1,95
	St dev	1131	3701	3094		1204	4164	3598	

Conclusion:

The average production and Benefit/Cost ratio for basin and bed-and-furrow fields was low compared to the maximum production generated in the command area of the Bahadarwah Minor. In the first *kharif* season, cotton cultivation using the bed-and-furrow method was less beneficial for farmers than the traditional basin cultivation. There is no marked difference in costs and benefits of cotton fields located in the head and tail watercourses of the Bahadarwah Minor.

7.5.1. Cost-Benefit Analysis and the Farmers' Socio-economic Setting

Distinguishing different landholding categories can represent farmers' socio-economic setting. Table 7.8 represents the costs and benefits made by farmers of 5 different landholding categories. The results are varied over the different land holding categories. The marginal farmers (< 5 acres) have achieved good results in both basin and bed-and-furrow fields. However, only 3 farmers are part of this category, so it is not possible to generalize this finding. Farmers of the middle categories have achieved bad results in the bed-and-furrow fields, but were able to achieve an average B/C ratio of 1.64 and 2.63. Larger farmers (26 to 50 acres) were unable to generate much income out of cotton cultivation. Their B/C ratios are a bit higher than the break-even point where B/C is 1. Farmers in this category had an average B/C ratio of basin fields, which was even lower than the average B/C ratio of their bed-and-furrow fields. Large farmers (> 50 acres) achieved relatively good results when compared to the other categories. They make more costs on basin and bed-and-furrow fields than smaller farmers. The total time spent on agricultural activities on basin and bed-and-furrow varies a lot among the different land holding categories. For the basin fields, the total time spent per acre decreases when the land holding size increases. This is not the same for the bed-and-furrow fields. The differences in time spent between basin and bed-and-furrow fields in the larger landholding categories are striking.

Table 7.8. Costs and Revenues of Cotton Cultivation for Different Landholding Categories.

	Bed-and-Furrow					Basin				
Land holding category	N =	Average revenue (Rs/acre)	Average time (min/acre)	Average costs (Rs/acre)	Average B/C ratio	N =	Average revenue (Rs/acre)	Average time (min/acre)	Average costs (Rs/acre)	Average B/C ratio
< 5 acres	3	5947	4382	3726	1,70	3	5982	2373	2847	2,33
5 to 12.5 acres	15	2912	3262	3019	0,93	15	4889	2191	3013	1,64
13 to 25 acres	7	2005	3969	3148	0,73	6	6564	1472	2883	2,63
26 to 50 acres	4	4460	4540	3926	1,15	5	3639	1317	3520	1,06
> 50 acres	6	6001	4998	4486	1,33	5	8870	828	4014	2,17
Average	35	3697	3943	3460	1,05	34	5683	1751	3197	1,87

The sample farmers have other income-generating activities as well. A comparison of farmers with and those without extra income shows that there is no difference in costs made per acre (see Table 7.9). Farmers with extra income generating activities had a better B/C ratio for basin and bed-and-furrow fields.

Table 7.9. Farmers' Other Income Generating Activities.

	Bed-and-Furrow					Basin				
	N =	Average revenue (Rs/acre)	Average time (min/acre)	Average costs (Rs/acre)	Average B/C ratio	N =	Average revenue (Rs/acre)	Average time (min/acre)	Average costs (Rs/acre)	Average B/C ratio
Farmers with extra income	15	4600	3791	3224	1,36	14	6239	1730	3187	2,08
Farmers without extra income	20	3020	4057	3637	0,82	20	5293	1766	3205	1,72

There is no indication that small/marginal farmers, or those without extra income generating activities face a constraint in investing extra money and time in bed-and-furrow fields.

7.6 FARMERS' REACTIONS

A large majority of the sample farmers (73 %) responded that the bed-and-furrow method requires more labor input than the basin method. Only 6 percent of the farmers responded that the basin method requires more labor input. The other farmers (21 %) responded that the basin and bed-and-furrow methods require the same labor input. About 59 percent of the sample farmers responded that the basin method generated higher revenues than the bed-and-furrow method. Only 19 percent of the sample farmers were of the opinion that the bed-and-furrow generated higher revenues than the basin method. The other farmers (22 %) indicated that there was no difference in revenue generated by the basin and bed-and-furrow method. Both these reactions endorse the actual findings as presented in this chapter.

About 75 percent of the farmers were of the opinion that the bed-and-furrow irrigation method can increase the reliability of crop production. However, a majority of these farmers were of the opinion that this can only be achieved under certain conditions. Most of these farmers reacted that the reliability of canal water supply should be improved. About 25 percent of the farmers reacted that the bed-and-furrow would not increase the reliability of cotton production. With some improvements, the bed-and-furrow method is still an attractive method of cotton cultivation for a majority of the farmers.

7.7 CONCLUDING REMARKS

The bed-and-furrow method was less beneficial for farmers than the traditional basin method. The average investments made for inputs on basin and bed-and-furrow fields are almost equal. The average expenses made for cotton cultivation is Rs 3,000 per acre. About 50 percent of these costs are covered by pesticide applications.

Extra costs involved for land preparation of bed-and-furrow fields was Rs 100, which, when compared to the total costs involved, is only 3 percent. During *kharif* 1998, sample farmers spent twice as much time on activities in bed-and-furrow fields when compared to basin fields. Most of this extra time was spent on manually hoeing of the bed-and-furrow fields. This is a major constraint in the adaptation of the bed-and-furrow method. However, if farmers will use herbicides and the special hoeing machine in the future, this labor factor can be reduced drastically. However, this would increase the total costs made per acre with 23 percent.

There was no marked difference in costs and benefits of cotton fields located in the head and tail watercourses of the Bahadarwah Minor. There is no indication that marginal/small farmers face more economical constraints than larger farmers in adapting the bed-and-furrow method.

8 MAJOR FINDINGS AND CONCLUSIONS

8.1 INTRODUCTION

As was presented in Chapter 1, the following perspectives are important when considering an assessment of the impact of the bed-and-furrow method:

1. The innovation in relation to the existing socio-economic environment;
2. The innovation in relation to the existing physical environment;
3. The innovation in relation to the technical performance;
4. The innovation in relation to the net farmer income; and,
5. The innovation in relation to farmers' perceptions.

In this final chapter, the impact of the bed-and-furrow method in relation to the above-mentioned perspectives will be presented first, followed by a discussion of constraints identified in the adaptation of the bed-and-furrow method. Finally, the conclusions of the research program will be presented.

8.2 THE BED-AND-FURROW METHOD AND THE SOCIO-ECONOMIC ENVIRONMENT

The cultivation of cotton with the bed-and-furrow method did not require extra land preparation activities when compared to the basin method. However, an extra cost of Rs 100 was made for hiring the bed-and-furrow shaper with a tractor, which, compared to the total costs involved, is only 3 percent.

A large group of farmers commented that the bed-and-furrow shaper and hoeing machine were too heavy. The weight of the machinery is a problem for the small tractors, which are most commonly found in the area. Heavy tractors are not easily available in the area. Especially true for smaller farmers, is that the availability of acquiring a heavy tractor can become a problem in the future. Noted, should be that a good, well-prepared dry soil is that the operation of the bed-and-furrow shaper is easier even for a small tractor. A reduction in the weight of the bed-and-furrow shaper will be disadvantageous in that the furrows will become shallow and that the beds will not have the right shape.

Though field staff recommended it, a large majority of the farmers did not use herbicides. No major differences in fertilizer and pesticide application were found between basin and bed-and-furrow fields. Generally, fertilizers were applied when the cotton started to flower, about 2 months after sowing. At that time, farmers started to apply pesticide sprays in both, the basin and bed-and-furrow fields. Pesticide sprays were generally repeated five times until the boll formation of cotton was finished.

Activities undertaken in the bed-and-furrow fields were mostly similar to the agricultural activities undertaken in basin fields. For the bed-and-furrow fields, the same quantities were used for seed, fertilizer and pesticides, as for basin fields. If farmers with different landholding sizes face difficulties to access inputs, this problem is similar for bed-and-furrow cultivation as well for basin cultivation. From this point of view, there is no constraint in the adaptation of the bed-and-furrow method for farmers with a different socio-economic background. The only constraint that remains is that smaller farmers have difficulties in hiring a tractor for the bed-and-furrow shaper.

8.3 THE BED-AND-FURROW METHOD AND THE PHYSICAL ENVIRONMENT

Daily measurements of 5 watercourse outlets showed that canal water was not equally distributed among watercourses in the Bahadarwah Minor command area. Watercourses located in the tail of the minor received infrequent small discharges when compared to watercourses in the head of the minor, which received more frequent water and in larger volumes. As a consequence, basin and bed-and-furrow fields located in the tail watercourses of the Bahadarwah Minor were irrigated less frequently and received a smaller volume of water than cotton fields located in watercourses in the head of the Bahadarwah Minor command area.

A major constraint for the tubewell exploitation of the shallow ground water is the water quality. Water samples of 5 tubewells were taken. If the salinity levels of these samples are considered, then two water samples had moderate to poor water quality. One water sample taken in the tail of the minor was brackish and the other two samples had a good water quality. Farmers who had access to tubewell water applied more water to their basin (125-150 %) and bed-and-furrow (200-260 %) fields than farmers without access to tubewell water.

The location of the cotton fields in the irrigation system did not influence agricultural practices as did land preparation, sowing, hoeing, fertilizer and pesticide application.

8.4 TECHNICAL PERFORMANCE OF THE BED-AND-FURROW METHOD

Sowing and Germination

On average, basin fields were sown around 15 May. Sowing the bed-and-furrow fields was delayed by two weeks due to the late arrival of the IIMI bed-and-furrow shaper. Bed-and-furrow fields were sown around 1 June. If proper arrangements are made and the bed-and-furrow shaper is available on time, it is reasonable to expect that this gap will not occur in the next *kharif* season. A good germination of the cottonseed, even in fields affected by salinity problems, was the major advantage of the bed-and-furrow method when compared to the basin method. Many farmers tried to sow basin fields, but seed failed to germinate; when they used the bed-and-furrow method on the same field after a couple of weeks, germination results were good.

Irrigation

Important, is to make a distinction between individual irrigation events and the complete water gift during a season. For the individual irrigation events, the following facts were determined: To irrigate a bed-and-furrow field of one acre takes less time (approximately 30 minutes) than to irrigate a basin field of the same size. Per irrigation event, a smaller volume of water is applied to bed-and-furrow fields when compared to basin fields. The advance time in bed-and-furrow fields was less when compared to the advance time in basin fields. This indicates a higher uniformity of water distribution in the bed-and-furrow fields. So, if the individual irrigation events are compared, the bed-and-furrow method is advantageous in that less water is used. At the same time, when compared to basin fields, it is distributed better over a field.

The initial growth stage of cotton in basin fields was dependent on a pre-sowing irrigation. First, irrigation of basin fields was applied when the cotton started to develop flowers. Instead of providing one irrigation event with a large volume of water, bed-and-furrow fields were irrigated 3 to 4 times in the first 4 to 6 weeks after sowing. After this period, the bed-and-furrow fields did not receive a water gift for several weeks. When the cotton started to develop flowers, water gifts were continued. During the complete *kharif* season, eight irrigation events were applied to bed-and-furrow fields and 4 or 5 irrigation events were applied to basin fields. On average, the total water depth applied was 528 mm for bed-and-furrow fields and 319 mm for basin fields. These figures do not include the pre-sowing gift for basin fields.

The basin and bed-and-furrow fields of two farmers in the Bahadarwah Minor were monitored in detail during *kharif* 1998. Farmer 1, located in the head of the minor, applied 170 mm water in 4 irrigation turns to his basin field and 288 mm water in 8 irrigation turns to his bed-and-furrow field.

Farmer 2, located in the tail of the Bahadarwah Minor, applied 137 mm water in 2 irrigation turns to his basin field. The bed-and-furrow field of Farmer 2 received 327 mm water spread over 8 water gifts. Though Farmer 1 had access to tubewell water and made frequent use of it, he applied less water to his fields than did Farmer 2.

The above-mentioned figures were used together with climatic data of Bahawalnagar to simulate a water balance of the cotton fields monitored by using CROPWAT 5.7. The total water depth applied during *kharif* 1998 to basin and bed-and-furrow fields of the detailed monitoring farmers did not fulfill the irrigation requirement of the cotton fields. If a complete dry soil profile is assumed at the time of sowing, the irrigation deficiency of bed-and-furrow fields reached 60 percent of the total irrigation requirement, which varies between 850 mm and 900 mm. Because of the pre-sowing irrigation gift, a complete wet soil profile is assumed to exist during sowing for basin fields. The irrigation deficiency in basin fields was 50 percent of the total irrigation requirement. Here, the water stored in the top 1.5 m soil depth contributed a substantial part to the water consumption of the plant. Rainfall is scarce, about 200 mm, but an important water source if effectively used. The command area of the Bahadarwah Minor has a shallow ground water table, which varies from 1 to 2.5 m beneath the soil surface. Theoretically, this ground water table would make available a minimum of 100 mm of water through capillary rise in sandy loam soils. An estimation of the maximum or average contribution of capillary rise to the water consumption of the crop was not possible. This subject requires more study. Capillary rise of groundwater has the disadvantage of increased soil salinization.

Cotton Yields

According to observations of field staff and comments of farmers, a continued pest attack of American boll worm has reduced the cotton yield substantially in the Bahadarwah Minor area. The variation of cotton yields in basin and bed-and-furrow fields was high in the Bahadarwah Minor area. The average yield was 158 kg/acre for 36 bed-and-furrow fields and 247 kg/acre for 34 basin fields. Several factors have contributed to low cotton yields for both, basin and bed-and-furrow fields:

- late sowing of the cotton;
- pest attacks at the end of the season; and,
- an unreliable water supply during the season.
- No direct relationship between crop yield and water depth applied could be found. A large majority of the farmers had a better yield in the basin fields when compared to the bed-and-furrow fields.

8.5 The Bed-and-Furrow Method and Net Farmer Income

From an economic perspective, the investments made in the bed-and-furrow fields did not pay off in the form of a good harvest. The average investments made for inputs are almost equal for basin and bed-and-furrow fields. The average expenses for cotton cultivation is Rs 3,000 per acre. About 50 percent of these costs are covered by pesticide applications. The Benefit/Cost ratio of the bed-and-furrow fields (average B/C = 1.06) was much lower than the B/C ratio of the basin fields (average B/C ratio = 1.77).

There were no marked difference in costs and benefits of cotton fields located in the head and tail watercourses of the Bahadarwah Minor. There is no indication that marginal/small farmers face more economical constraints than larger farmers when adopting the bed-and-furrow method.

Farmers spent twice as much time on activities in bed-and-furrow fields when compared to basin fields in *kharif* 1998. Most of this extra time was spent manually hoeing the bed-and-furrow fields.

This is a major constraint in the adaptation of the bed-and-furrow method in the future. However, if farmers would use herbicides and the special hoeing machine, labor time spent on manual hoeing can be drastically reduced. The disadvantage is that this package would increase the total costs made per acre by 23 percent.

8.6 Farmers' Perceptions of the Bed-and-Furrow Method

Farmers mentioned the following disadvantages of the bed-and-furrow method:

a) Hoeing is labor intensive: farmers spend much more time hoeing the bed-and-furrow field when compared to the basin field;

b) The high irrigation frequency of the bed-and-furrow fields, which should be considered in relation to the unreliable canal water supply; and,

c) Salt accumulation on the beds, which would have a negative effect on the wheat crop in the *rabi* season. Many farmers removed the bed-and-furrows with a plough for this reason.

Farmers mentioned the following advantages of the bed-and-furrow method:

a) Good germination of cotton in bed-and-furrow fields when compared to basin fields, and germination was especially good on salt-affected soils;

b) A decrease in water use per irrigation event: less time was required to irrigate a one-acre bed-and-furrow field;

c) The bed-and-furrow method saves water during the complete season; and,

d) The cotton plant is not affected by rainfall in the initial growth stage.

About 60 percent of the sample farmers were interested in using the bed-an-furrow method in the future.

The two farmers of the case study mentioned the same (dis)advantages as mentioned above. However, the second farmer commented that because of the irrigation requirements of the bed-and-furrow fields, less water would be available for his fodder fields. The farmers' first priority would be to irrigate the fodder fields, because he has cattle for milk production.

8.7 Discussion

Under the present water scarcity conditions in the area, farmers have adapted a manner of extensive semi-rain-dependent cotton cultivation in basins. Farmers secure a part of the cotton water demand by using the storage capacity of the soil in the form of pre-sowing irrigation gifts. Water use requirements of cotton are by far not met. The bed-and-furrow method requires more irrigation events in a short interval and is more dependent on canal/tubewell water. Especially in the tail of the Bahadarwah Minor, canal water availability was unreliable and inadequate. Due to high salinity levels, the ground water resource is hardly developed. Unless this situation is improved, the bed-and-furrow method cannot compete with the basin method in this environment.

If farmers would irrigate cotton in basins more frequently (intensive), and thus, meet the water requirements of the crop more optimally, the bed-and-furrow method would clearly be a water saving practice. Under the conditions in the Bahadarwah Minor, one can hardly discuss this issue because the average farmer is under-irrigating his basin fields. Still, the water distribution efficiency in the bed-and-furrow field is higher and the time to irrigate an acre is reduced.

An increase in available volumes of water cannot be expected in the Bahadarwah Minor. However, there are two factors that can improve the reliability of water supply, especially for farmers in the tail of the command area:

- The expectation could be that the lining of the minor and the installation of new outlets will be completed in 1999. If the minor runs under the design conditions and outlets are not tampered with, it can be expected that water will be distributed more equally over the watercourses in the command area of the Bahadarwah Minor.
- The Water Users Federation of the Sirajwah Distributary can guard an equal water distribution in the command area of the Bahadarwah Minor.

In view of the costs involved when using the bed-and-furrow method, the method seems easily adoptable because the average investments made in basin and bed-and-furrow fields were almost equal. The adoptation of the bed-and-furrow method will not bring an extra burden to small farmers. However, access to a tractor (especially a heavy tractor) for the bed-and-furrow shaper and hoeing machine would be a problem for this group of farmers.

There are hardly any differences in agricultural practices for basin and bed-and-furrow fields. The only important difference is the time required to hoe a bed-and-furrow field that is twice more than for basin fields. But, as mentioned before, improving the availability of the hoeing machine on time can solve part of the problem.

A problem encountered by many farmers was the salt accumulation on the beds of the bed-and-furrow fields. This is perceived by farmers as a threat to the germination of the *rabi* crop, which, in most cases, is wheat. However, before the wheat is sown, farmers apply (as in basin fields) a pre-sowing irrigation gift. This could flush the salts out of the topsoil. This problem requires more field study over two seasons (*kharif* and *rabi*) to monitor the effects on the wheat crop as well.

8.8 CONCLUSIONS

When compared to the basin method, the major advantage of the bed-and-furrow method is a better seed germination, even in salinity-affected soils. From an agronomic point of view, major differences were not found in the use of either the basin or bed-and-furrow methods. The only problem encountered during *kharif* 1998 was the hoeing of the bed-and-furrow fields, which, compared to the basin fields, were more labor intensive. The special hoeing machine, which should be available on time for every farmer, can solve this in the future. There are no major economic constraints for the adoptation of the bed-and-furrow method by farmers in the Bahadarwah Minor command area. In consideration of the socio-economic background of the farm population, smaller farmers face a constraint in having access to a tractor, which, in most cases, is hired.

If the above mentioned points are considered alone, the bed-and-furrow method can easily replace the basin method. However, bed-and-furrow fields require more irrigation events than basin fields. Therefore, the bed-and-furrow method requires a reliable and continuous water supply during the complete season. The water supply in kharif 1998 was inadequate and unreliable in the Bahadarwah Minor command area. Under these conditions, cotton cultivation using the traditional basin method is a more viable option for farmers.

About 60 percent of the farmers who used the bed-and-furrow method in *kharif* 1998 were interested to continue experimentation in the coming seasons. This is a successful achievement for a program that was developed and implemented in nine months.

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