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Managing Irrigation for Environmentally Sustainable Agriculture In Pakistan

Joint Research Dissemination Program

DISSEMINATING THE BED-AND-FURROW IRRIGATION METHOD FOR COTTON CULTIVATION IN THE HAKRA-4-R DISTRIBUTARY IN COLLABORATION WITH THE WATER USERS FEDERATION

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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 Hakra 4-R Distributary and Bahadurwah Minor. This report deals with the dissemination of the bed-and-furrow irrigation method in the command area of the Hakra 4-R Distibutary.

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 achieved 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 allows the farmer to irrigate more bunded units, but also results in 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 32 farmers located in the 7 sample watercourses, scattered over the five physically determined sub-systems of the Hakra 4-R Distributary, the water depth applied per irrigation event was calculated based on daily discharges, irrigation duration, tubewell discharge (estimated), and calculated seepage losses.

2. 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 the crop germination rate.

3. 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 that cotton sold for on the market were obtained from the farmer. Based on this information, a cost - benefit analysis was conducted.

4. 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, on which the evaluation as presented in this report is based.

In different watercourse command areas (W/C) of the Hakra 4-R Distributary and beyond this distributary, 50 farmers converted land into beds-and-furrows for the cotton crop, ranging from 0.25 acres to 31 acres. Four out of the 50 farmers are from neighboring distributaries that also off-take from the Hakra Branch Canal (Hakra 6-R, Hakra 3-R/1-L, and Hakra 1-L, respectively). The total area covered with the bed-and-furrow irrigation method is 186 acres, of which 27.25 acres have been laser leveled.

The analysis regarding the irrigation interval and frequency reveals that for the bed-and-furrow irrigation method the interval decreased and the number of irrigation applications increased, on an average, by two (ranging from 4 to 10 applications). On an average, irrigation applications for the bed-and-furrow and basin methods were 7 and 5, respectively. Although, the total irrigation duration is more for the bed-and-furrow irrigation method, a significant time reduction per irrigation event has still been observed; hence, the farmers have the ability to irrigate more fields during their *warabandi*. The total time allocation to irrigation practices is 30.6 percent more for the bed-and-furrow irrigation method. Further, more time was spent on tubewell operation for the bed-and-furrow fields.

The evaluation on the irrigation requirement and the water application depth reveals that season-wise, for both the irrigation methods, the irrigation applications have been deficit and the irrigation requirements are not fulfilled. An irrigation requirement of 743 mm is calculated for the period of May 19 (average sowing date) to November 5 (average last applied irrigation). The average irrigation application depth is 563 mm and 436 mm for the bed-and-furrow and basin irrigation methods, respectively, which results into a season-wise deficit of 24 percent for the bed-and-furrow irrigation method and 41 percent for the basin irrigation method. A significant difference in deficits between the two methods exists. Hence, the hypothesis is that the lighter but more frequent irrigation applications for the bed-and-furrow method allow farmers to irrigate more bunded fields during a *warabandi*, and also results in lower crop water deficits when compared to the basin irrigation method, which results in higher farm productivity over the season.

The major time differences pertaining to cultural practices also occurred for the hoeing and thinning activities for the basin irrigation method. Due to the unavailability of the hoeing device (on time), farmers spent a lot of time on manual hoeing. However, data reveals that a considerable amount of time was spent on the hoeing activity. It is expected, however, that when the hoeing device is used and farmers use weedicide, time spent on hoeing can be significantly reduced. Overall, however, the analysis shows that 32.4 percent more time is spent on the bed-and-furrow irrigation method pertaining to irrigation and cultural practices.

With respect to relating irrigation practices to the landholding size, a clear relationship could not be identified. It seems that regardless of the landholding size, farmers adopt more or less the same irrigation strategies. With respect to relating irrigation practices to soil physical and chemical features, it was observed that more water is applied to soils affected with sodicity. Another observation was that the tubewell water was used more frequently in the watercourse command area for which the actual water allowance was below the designed water allowance. In this watercourse, farmers responded to the water shortage by complementing the irrigation practices with the use of tubewell water.

A total of twelve farmers (out of the 50 farmers) used the bed-and-furrow irrigation method in conjunction with the precision laser leveling, covering an area of 28.75 acres. The irrigation practices (duration and water use) were analyzed for seven sample farmers. Based on this small sample size, a significant difference in irrigation performance when the precision laser leveling is used prior to the implementation of the beds-and-furrows could be concluded. The total irrigation duration, total water depth applied and average water depth applied per irrigation event is reduced by 45.4 percent, 54.4 percent and 32.4 percent, respectively.

With respect to the cotton production data and water use efficiency (WUE), the overall cotton production was 15 percent higher for the bed-and-furrow fields than the basin fields (i.e. 9.48 and 8.1 maunds per acre, respectively). The average farm production level (i.e. 8.24 maunds per acre) of the sample farmers was slightly below the Bahawalnagar District level (i.e. 10.4 maunds per acre), based on three years' production data (1992-1994). A slightly higher plant density was observed for the sample bed-and-furrow fields when compared to the basin fields, which may have an impact on the cotton production of the respective fields. The WUE, defined as the ratio of the yield and the total volume of water applied (kg/m^3), turned out to be about the same for the bed-and-furrow and basin sample fields (0.251, and 0.254, respectively).

The occurrence of crop diseases was considerable during *Kharif* 1998, whereby most crops were affected by the American Bollworm and White Fly. Pest Management plays an important role if the yield has to be protected from these kinds of diseases, which is still insufficiently developed in this research area. Farmers are unaware of preventive measures and are often too late to respond when the disease has occurred.

The financial analysis revealed that major differences in expenses occurred for the seed costs, hoeing and pesticides, which turned out to be higher for the bed-and-furrow irrigation method. On an average, however, there is not a significant differences in expenditures, reflected in a ratio of 0.97 (the ratio between the expenditures for the bed-and-furrow and basin irrigation method, respectively). The total revenue shows a similar tendency, reflected in a B/C ration (benefits-costs) of 0.98 and 0.97 for the bed-and-furrow and basin irrigation method, respectively. The implementation of the bed-and-furrow irrigation method has no negative impact on the expenditures, assuming that the required farm implements are available on a rental basis.

With respect to agronomic aspects, based on farmers' feedback it was found that the germination rate is better for the bed-and-furrow fields, of which the maximum encountered germination rate was 80% to 95% for the bed-and-furrow fields and 70% to 80% for the basin fields (mentioned by the farmers). Further, farmers perceived a better resistance of the crop towards rain and flood of the crop sown in the bed-and-furrow field, since the soil covering the crop was not subjected to permanent crusting, but would soften again. Also, 26 farmers indicated that the crop growth was faster for the crops of the bed-and-furrow field and more fruit formation was observed. With respect to seed usage an increase in seed usage per acre was observed for the bed-and-furrow field. This includes seed usage for gap filling, an activity that only took place for the bed-and-furrow fields.

With respect to the water management and irrigation practices farmers felt that the *peecha bara* (irrigation efficiency) increased (mentioned by 15 farmers); and water saving takes place, hence more acres of land are irrigated *during the warabandi*, mentioned by 15 farmers. Although farmers indicated also water saving season-wise, this was found to be in contradiction with the analysis. Event-wise, there is a water and time saving, but not season-wise.

Overall, the constraints were mostly felt with the farm implements (the bed-and-furrow shaper and hoeing device) and the implementation phase of the beds-and-furrows. The bed-and-furrow shaper was perceived too heavy to be pulled by an average tractor (e.g. MF 240). Using a tractor from the OFWM (on rent) solved this problem, plus the problem of access to a tractor of heavier horsepower. The soil wetness caused the metering wheel to malfunction (halted). Difficulties occurred in preparing straight furrows, which, at a later stage, made the use of the hoeing machine difficult since the crop would be damaged. Also, seed was not covered by the soil due to the sowing tine or wet soil, and some problems in the sowing device occurred. Farmers' main suggestions were that the bed-and-furrow shaper should be lighter in weight, but the material should be stronger, and improvements in the metering wheel and sowing device should be made.

To delegate responsibilities to the Water Users Federation in the bed-and-furrow dissemination process proved to be very efficient for Hakra 4-R Distributary. When the plan of the bed-and-furrow irrigation method was explained to the farmers, they were very receptive towards the idea. The Federation placed a lot of effort in awareness building activities for the farmers in the command areas. Despite several drawbacks pertaining to the late delivery of the implements, the weather, and organizing the proper rotation of the bed-and-furrow shaper, it has been very encouraging to observe that farmers have the ability to organize activities collectively, and foremost, their keen interest in experimenting with improved irrigation practices. However, it was experienced that the WUF needs to learn how to operate and act independently. During the dissemination process of the bed-and-furrow irrigation method, IIMI still remained the driving force in many instances.

In the future, the role of the WUF has to be clearly defined, and also the role of the farmers. Based on the final interviews, it became clear that most of the farmers (26) are not willing to join hands with the WUF with respect to sharing costs for the implements and considered the WUF as responsible for this. This, however, implied that farmers consider the WUF as independent from the farmers with their own financial sources, instead of farmers' representatives who are dependent on farmers' contributions. If the WUF has to bear the costs, then still the money has to come technically speaking from the users, which are the farmers. The management of the bed-and-furrow shaper was perceived as the task of the WUF (finance secretary) and a few farmers mentioned that both IIMI and the WUF should manage the bed-and-furrow use. This indicates that IIMI is still considered as a potential actor in the process, which actually should not be the case. Being organized should give the farmers the strength and willingness to undertake any activity themselves.

Overall, the attitude of the farmers towards the bed-and-furrow irrigation method has been very receptive, expressed in an enthusiasm and interest in using the irrigation method in the next *kharif*. The three main reasons for continuing with the bed-and-furrow irrigation method are: better crop germination; water saving; and safety from rainfall. Only two farmers were very negative towards the bed-and-furrow irrigation method due to crop failure.

Comparing analytical results and farmers' reactions, there are no major reasons to identify what would make the bed-and-furrow irrigation method not appropriate for the farming community. The irrigation method can be adopted, but a certain experience in operating the implements and organizing the use of the implements should be improved, which has been recognized by the WUF. Further, it needs to be a requisite for farmers to have access to a proper tractor. Otherwise, many farmers will be exempted from the bed-and-furrow use and then, in the end, it will become only an instrument for a selected group of farmers (mainly the rural elite), a tendency which occurred with the laser-leveling technology several years back, that was totally confiscated by the large farmers.

The bed-and-furrow irrigation method is a means to facilitate on-farm water management. However, it is still an option for which a farmer is free to choose and it is by no means imposed on them. But with introducing this irrigation method to the farmers, an achievement has been to make farmers realize that they have a choice when it comes to managing their irrigation water at the field and farm level.

The bed-and-furrow irrigation method, however, could only become truly successful if other aspects of irrigation management and farming management are considered. A requisite for using this method is that the farmer can rely on the water supply from the main system.

During the data collection activities and analysis, it become apparent that the current farming system is far from productive and which, to a large extent, can be ascribed to the occurrence of the fatal diseases. Preventive measures are requisites and as long as there is no serious and effective pest management program, farming cannot become a productive enterprise in this area.

1. INTRODUCTION

1.1. ISSUES IN IRRIGATED AGRICULTURE

To have a sustainable development in the irrigated agriculture stresses on one hand the need of using natural water resources in an efficient manner in order to avoid over-exploitation, and to deal with water scarcity. On the other hand, however, sustainability is embedded in a more complex structure, and includes physical, economic and social factors. The technology to sustain irrigated agriculture exists, but its use is limited by a number of factors, such as lack of economic incentives for irrigators; lack of education on best management practices; the high cost of improving structures, pressurised irrigation systems, and drainage systems; institutional constraints, such as water rights and water transfers; and the effects of irrigation return flows on the environment (ASCE 1990).

Many irrigated areas in the world are suffering from waterlogging and salinity problems (of the world's cultivated lands, about 23% are saline and 37% sodic). Waterlogging has resulted in severe salinity problems and declining yields. The main cause of waterlogging is excessive water input into a system that has finite storage and limited natural drainage capacity (Hoffman et. al. 1992). It is important to recognize that inefficient irrigation is the major cause of salinity and shallow water tables in most irrigation projects of the world and that the need for artificial drainage can be substantially reduced through improvements in irrigation management (ASAE 1990).

Farmers are the managers of the irrigation water at the field and farm level. However, farmers' potential role in options for improving the irrigation system performance in terms of increasing the productivity of water is often not properly addressed and investigated. Presently, there is a need to address farmer' role in the debate on sustainable irrigated agriculture. Hence, to investigate the debate from the angle of possible potential solutions on improved on-farm water resource management, adaptable by farmers, and to relate farmers' constraints to the on-farm irrigation performance. Further, there is a need to investigate the importance and role of institutional arrangements to facilitate on-farm water resource development, and thus, to investigate the potential of collective actions at the field and farm level, undertaken by farmers and supported by national institutions.

The research, - presented in this report -, encompasses the assessment of the potential for having improved irrigation practices, through the bed-and-furrow irrigation method, integrated in the current farming system, with the participation of the water users in the implementation process in order to achieve better irrigation water management practices.

1.2. JOINT RESEARCH DISSEMINATION PROGRAM

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 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). Although the initial thinking of a collaborative mode of research dissemination was discussed in November 1997 during a meeting between MREP and IIMI, a formal meeting took place among the concerned national and international partners on January 4, 1998 (held at MREP, in Bahawal), which resulted into the formulation of the main scope of the Program. The scope of the Dissemination Program evolves around the following objectives:

1 To disseminate the research results about improved agronomic and irrigation practices to the farming community, beginning with two pilot sites, and later to the entire FESS farming community;

2 To strengthen the Pilot Water Users Federation (WUFs) by involving them in the introduction of improved agronomic and irrigation practices;

3 To train the WUF farmers in water measurement techniques;

4 To provide liaison between the WUFs with the agencies which control agricultural inputs purchased by the WUFs; and

5 To assess the overall impact of the research dissemination program on water use and agricultural production.

Each agency, including the WUFs, has their specific role in this Program and for follow up on this Program. In many instances, responsibilities are shared and activities jointly undertaken in order to facilitate the Program and to have a clear trend of transferring information and research results to others. As defined in the planning document (MREP et. al. 1998), the roles are listed below.

MREP is responsible for the technical guidance and formulating agronomic recommendations relating to crop production such as preparatory tillage, crop variety, seed rate, sowing method, fertiliser levels, when to irrigate and how to irrigate, as well as suggestions for appropriate plant protection measures against the pests and diseases. MREP provides technical assistance to the individual and groups of farmers. Extension notes will be prepared for dissemination based on their research work.

AD&AR solely has a supportive role towards the other involved agencies during 1998, however, they will take the leading role next year, with a main focus on the presentation of a "*technology package*" to the farmers, translated into farmers' language. AD&AR plays a key role in forming the bridge between farmers and scientists in the FESS Project.

OFWM has its role in the introduction of improved agronomic techniques and irrigation methods to the farming community. IIMI and OFWM both are responsible for providing discharge measurement training to the farmers of Bahadarwah Minor. During this exercise, MREP and AE staff provide the technical support along with the implementing staff to the farmers.

IIMI's role is focused on the irrigation trials, which includes the co-ordination of the research component pertaining to the pilot testing of the bed-and-furrow irrigation method in selected watercourse command (W/C) areas of Hakra-4R Distributary and Bahadarwah Minor. In the Bahaderwah Minor the irrigation trials are being monitored jointly with OFWM, with MREP having a supporting role.

All the participating agencies of the Program or related activities will go through the WUF (Hakra-4R) and WUO (Bahadarwah Minor). With respect to the involvement of the farmer organizations in the irrigation trials, the intention is to have them involved in the site selection for the irrigation trials, and to have the actual preparation of the beds-and-furrows organized systematically. The beds-and-furrows are prepared by using the bed-and-furrow shaper. An implement being fabricated by a farmer himself (Mr. Haji Arshad, Bilal Farm, near Khanpur). Two bed-and-furrow shaper units are provided by IIMI to the WUF of Hakra-4R, including two hoeing machines and one unit to the WUO of Bahaderwah Minor[1].

Over the past few years, farmers expressed their concern pertaining to poor access to proper seeds and limited knowledge on the application of fertilisers and chemicals. For this reason, the Dissemination Program included a component which mainly emphasised on creating a link between farmers and agricultural input suppliers (Governmental as well as private companies). Different companies were invited to provide lectures to the farmers and to establish a mode of collaboration between the farmers (through the WUO and WUF) and the companies. Involved companies are chemical companies, Punjab Seed Corporation, Punjab Agricultural Development and Supplies Corporation, and fertiliser companies.

1.3. BED-AND-FURROW IRRIGATION TRIALS

1.3.1. Research Objectives and Methodology

The research and the results, presented in this report, evolve around the monitoring and evaluation of the dissemination process pertaining to the implementation of the bed-and-furrow-irrigation method in the command area of Hakra-4R Distributary. The following objectives have been formulated for the research:

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 assess the overall net income on a per-acre scale with a comparison between the basin and bed-and-furrow irrigation methods;
4. To evaluate farmers' experiences with the bed-and-furrow irrigation method.

The analysis requires an interpretation of the performance of the bed-and-furrow irrigation method from different perspectives. The bed-and-furrow irrigation method is considered in the context of this research as a new technology or innovation, since it is considered as a new technology, to be introduced to the existing farming system. The analysis is embedded in the following perspectives: (i) The innovation in relation to the existing socio-economic environment; (ii) The innovation in relation to the existing physical setting; (iii) The innovation in relation to the technical performance; (iv) The innovation in relation to the farmer's obtained net income; and (v) The innovation in relation to farmers' perceptions and experiences.

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

In different watercourse command areas (W/C) of the Hakra-4R Distributary and beyond this Distributary, 50 farmers converted land into beds-and-furrows for the cotton crop, ranging from 0.25 acre to 31 acres. Four farmer out of the 50 farmers are from neighbouring distributaries, also taking off from the Hakra Branch Canal (Hakra-6R, Hakra 3R/1L, and Hakra-1L, respectively).

[1] At the time of the commencement of this program, a WUF had not been formed yet. This formation took place during Kharif 1998, whereby the WUF covers Sarejwah Distributary along with its two minors, Bahaderwah and Najeebwah Minors.

The following approaches of data collection are applied, then segregated into quantitative and qualitative information:

1. Obtaining general information (household composition, socio-economic environment, farming-related aspects): applied to all 50 farmers;
2. Obtaining on a weekly basis information related to irrigation, cultural and crop development: applied to 32 farmers;
3. Obtaining farmers' feedback (comments and observations) during the irrigation season: applied to 32 farmers; and
4. Final detailed interview pertaining to irrigation, cultural, agronomic practices, yield, etc: applied to 50 farmers.

The selected 32 farmers under point 2 encompasses seven watercourse command areas, scattered over the five physically determined sub-systems of the Hakra-4R Distributary. Particulars on the sample watercourses and sample farmers are presented in Chapter 2. Over the course of the season, some sample farmers dropped out due to failures in crop development, whereby the farmers opted for changing the crop. In addition, some of the data obtained from sample farmers has not been used for analysis due to inconsistency or incompleteness of the data.

1.3.2. Data collection and management

During the *kharif* season, data has been collected pertaining to: i) irrigation practices; ii) cultural practices; iii) farming related expenditures; iv) yield (output); v) agronomic aspects; vi) soil physical and chemical properties; vii) water quality (groundwater); viii) meteorological aspects; ix) vertical movements in the groundwater level; x) socio-economic aspects; and xi) farmers' perceptions (observations and comments). Table 1.1 presents the particulars on the data collection activities.

The data is processed in MS Office '98 Software, like Word and Excel. Graphs are made in Excel, whereas the drawings are made in MS Power point. CROPWAT version 6.0 for Windows (FAO) has been used for calculating the reference evapotranspiration and the irrigation requirements for selected sample fields.

1.4. CONCEPT OF THE BED-AND-FURROW IRRIGATION METHOD

1.4.1. Surface Irrigation Methods

The main characteristics of surface irrigation systems are that the water is distributed over the field in an open conduit by gravity, and therefore is mathematically treated as an unsteady gradually and spatially varied flow. For these systems, soil infiltration and crop flow resistance has a major influence on the distribution of water.

Surface irrigation systems are categorised into basins, borders and furrows and which function hydraulically in a different manner. Basin irrigation refers to having a small area irrigated, of which the area had relatively flat, level surfaces and is enclosed by dykes to prevent runoff. In many circumstances, border irrigation can be viewed as an expansion of basin irrigation to include long rectangular, or contoured field shapes, longitudinal but no lateral slope, and free draining conditions at the lower end (Walker and Skogerboe 1987). Further, borders can have a closed-end downstream boundary as well. With furrow irrigation, the entire field is not flooded, but the water moves through small channels across the field. There is speak of furrows when the water does not over top the furrow, and there is speak of corrugations when the water over tops the furrows and as yet the water floods the entire field.

Table 1.1. Data collection activities and source of information.

Data	Data collection activity		Source
Irrigation practices	Irrigation duration sample fields Discharge at the distributary outlet	quantitative quantitative	Farmers IIMI
Cultural practices	Land preparation, hoeing, weeding, application of chemicals and fertilizers	qualitative	Farmers, IIMI
Input related expenditures	Pertaining to irrigation and cultural practices	quantitative	Farmers, IIMI
Yield	Total weight of cotton bolls per acre or bunded unit and the price obtained at the market	quantitative	Farmers, IIMI
Agronomic aspects	Crop stages and condition	qualitative	Farmers, IIMI
Soil physical properties	Soil type, mechanical aspects	quantitative	SSoP (1)
Soil chemical properties	ECe, SAR, ESP	quantitative	SSoP
Water quality	ECe, ESP, SAR, RSC	quantitative	SSoP
Meteorological aspects	Precipitation, temperature, humidity, wind speed, daily sunshine hours	quantitative	MIB (2)
Observation well readings	Vertical movement of the groundwater table	quantitative	IIMI
Socio-economic	Household composition, farm composition, farming features, etc	quantitative	Farmers, IIMI
Farmers' perceptions	Different issues pertaining to the use of the bed-and-furrow method in comparison with the basin irrigation method	qualitative	Farmers, IIMI

(1) SSoP = Soil Survey of Pakistan
(2) MIB = Meteorological Institute Bahawalnagar; IIMI has taken pan evaporation reading on a daily basis) and also collection rainfall data.

Furrows provide better on-farm water management capabilities under most surface irrigation conditions. Flow rates per unit width can be substantially reduced and topographical conditions can be more severe and variable (Walker and Skogerboe 1987). Furrows can be used in conjunction with basins or borders, whereby one quite common combination is the basin-furrows.

The basin irrigation method is the most commonly used irrigation method in Pakistan. Foremost, because it is the traditionally method of irrigation for the farmers. Further, it is used because of its low cost and input requirements and it is for the farmers an easy method to manage. Mostly, the basins are characterised by poor levelling. Therefore, many undulations and irregularities occur across the soil surface. The method is used for most of the major crops, such as cotton, wheat, maize, sugarcane, rice and fodder crops. For irrigating vegetables, to a large extent, the furrow irrigation method is used, whereby the vegetable is sown on ridges or beds. Further, a commonly used method for growing potatoes is the furrow irrigation method. Next to the use of the basin irrigation method for the major crops, an increasing tendency occurs for (mainly) cultivating cotton by the bed-and-furrow irrigation method, however, this method remains to a certain extend confined to larger farms. This, because of its input requirements, such as the proper farm implements like the bed-and-furrow shaper, which is not widely accessible in Pakistan as a regular farm implement.

1.5. Bed-and-Furrow Irrigation Method

The main characteristics of the bed-and-furrow irrigation method is that furrows are made in a basin at a 2.5 feet space interval (i.e. a 2.5. feet furrow spacing), whereby a bed arises between the furrows. With these dimensions, the tractor wheels match the furrows. The dimension, however, may be different for different systems. The seeds are sown in two rows near the edge of the bed

(Figure 1.2). Mostly, the furrow length will not cover the entire length of the basin, but a space is left at the head and tail reach of the field, either left like a basin or furrows are created perpendicular to the direction of the flow. Since the field (or bunded unit) is entirely dyked and the field slope is negligible, the method can be interpreted as basin - bed-and-furrow irrigation. The bed-and-furrow irrigation method is suitable for crops like cotton, vegetables, maize and sugarcane.

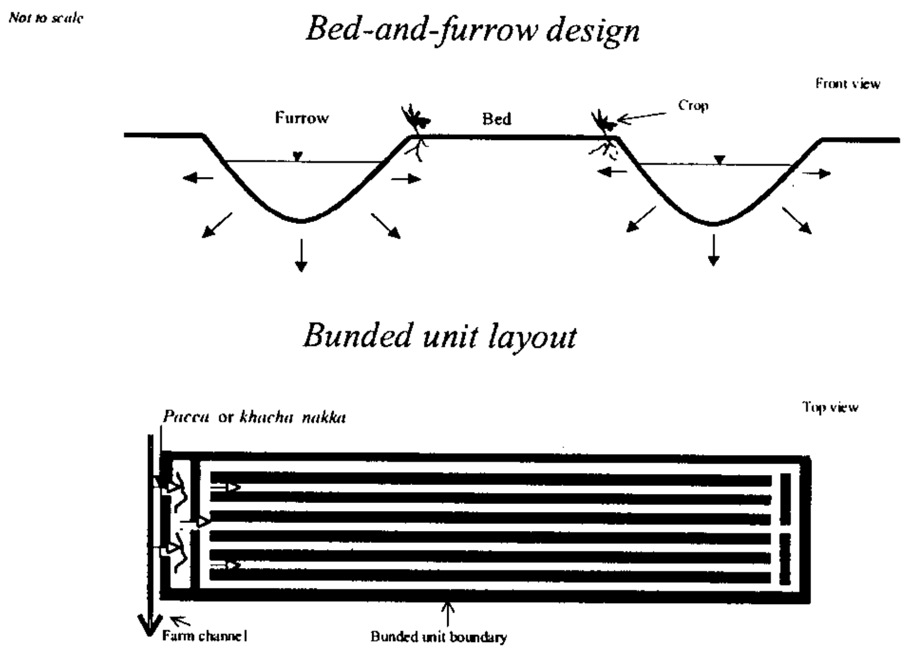

Figure 1.2. Cross-section and top view of beds-and-furrows.

Quite some advantages of the bed-and-furrow irrigation method are recognized by the farmers who are using the bed-and-furrow irrigation method, such as: (i) better crop protection for climatic circumstances; (ii) better crop development; (iii) water saving; and (iv) yield enhancement (Berkhout et. al. 1997). Additional advantages are mentioned by the Directorate General Agriculture (Water Management Program (1997): (i) minimum tillage / seed bed preparation reduces over all energy requirement at the farm; (ii) minimum chances of plant submergence and damage due to excessive rain or flood; (iii) compacting the furrows with tractor wheel results in minimized deep percolation and increased lateral movement of irrigation water; (iv) better seed germination and root growth as traffic and root zones are permanently separated; (v) due to early maturity of cotton for 30 days, the no. of pesticide sprays are decreased and it is convenient to sow wheat well in time which results in better yields; and suitability for saline and sodic soils as crusting does not occur around plants as a result of irrigation.

1.6. Precision Laser Leveling

In addition to implementing the bed-and-furrow irrigation method, under the same program, precision laser leveling was introduced to the farmers of the research area during Kharif 1998. The use of laser technology in the precision land leveling is the recent development in Pakistan, which not only minimizes the cost of precision land leveling but also ensures the desired degree of precision. Since last few years, a few laser units have been provided in most of the districts in the Punjab province for the precision land leveling of the farmer's fields. But unfortunately, these units are accessible to big landlords or influential farmers. Therefore, during the planning meeting for the Joint Research Dissemination program, it was decided to provide one laser land-leveling unit (by

OFWM) to the Water User Federation of Hakra 4-R Distributary. The planning was also to have this unit transferred to Bahaderwah Minor, however, this activity was not really established in this area.

For efficient utilization of scarce water resources, precision land leveling of the farmer's field is an important component of the advanced irrigation practices at the farm level. Precision land leveling facilitates improved layout of the fields into borders, furrows, beds-and-furrows and corrugations. It not only improves the water application efficiency, uniformity in seed germination, crop growth, but also helps in reducing salinity and waterlogging. Prevision laser leveling is considered as an intervention for improved irrigation practices.

Traditional way of precision land leveling includes surveying of the field, staking and designing of the fields; calculation of cut and fill areas and then use of a scraper and land planer for leveling the field. Despite all of these labor-intensive efforts, accuracy cannot be achieved to a desired standard.

Laser-controlled land leveling was introduced to the Delta area of central Utah in 1980 by the USDA-ARS, US Water Conservation Laboratory and the Utah Agricultural Extension Service. Tests revealed that yields of wheat and barley were increased by more than 50%, presumably due to more uniform water distribution during irrigation events.

The laser system consists of a transmitter, control panel and the receiving unit. With the laser system the reference plane is generated above-ground by the rotating laser beam, and receivers on the leveling machines pick up this reference to provide the operator at all times with alignment information to position both the blade and machine for rapid and accurate leveling work.

In contrast to the traditional way, precise field surveys are accomplished through use of a laser transmitter unit and a telescope grade rod. The resultant data is then used to determine the final field grade for laser plane leveling.

Basically, laser-controlled land leveling makes better uniform flow possible. The advance flow is not hindered as much because of less irregularity in the field micro-topography. In other words, the laser-controlled land leveling facilitates the advance phase and consequently the uniformity. About laser-controlled leveling, local irrigators in the United States stated that the single most important water management practice they can employ is "lasering" (personal communication with Dr. W.R. Walker, 1997).

1.7. AGRONOMIC AND WATER MANAGEMENT ASPECTS FOR COTTON

1.7.1. Main Features of Cotton

Cotton (*Gossypium Spp*), - cultivated for its fiber as well as seeds (produce oils) -, is grown virtually around the world in tropical latitudes, and as far as north as 43°N latitude in the Federal Republic of Russia, and 45°N in the People's Republic of China.

Cotton is sensitive towards frost. Cotton's main requirements are according to Federal Water Management Cell (1997) 150-180 frost-free days with average temperatures between 25-32 °C (Pakistan). Kohel and Lewis (eds., 1984) mention that cotton (in the USA) is grown in the south of the isotherm giving 200 frost-free days. There is a direct relationship between potential yield and the number of growing days (Kohel and Lewis, eds. , 1984). The number of growing days relates to the region and variety; i.e. as few as 120 growing days may be acceptable in some regions while more than 200 may be required elsewhere. All cottons, however, require approximately the same number of growing days to reach first bloom regardless of where the cotton is grown (Kohel and Lewis, eds., 1984). Another factor limiting cotton yield is the total amount and distribution of rainfall during the growing season. A minimum of approximately 50 centimeters of moisture is needed to mature the crop even at the low acceptable yields of 0.75 bales/ha (Kohel and Lewis, 1984). Further, sunshine is vital to cotton, according to Doyle (1941), (quoted from Kohel and Lewis, eds., 1984), and areas with more than 50% cloudiness are not suited for cotton, regardless of temperature and moisture. Further, rapid and consistency of spring warming determines where cotton can be grown successfully (Kohel and Lewis, eds. 1984). Outside the USA cotton is grown under the same climatic constraints as described for the USA. Strong and / or cold winds seriously affect the delicate young seedlings and at maturity will blow away fiber from opened bolls and cause soiling of the fiber with dust (Doorenbos and Kassam, 1992). Continuous rain during flowering and boll opening will impair pollination and reduce fiber quality (Doorenbos and Kassam, 1992).

Any soil used effectively to grow any row crop can be used for the cotton crop (within the defined climatic region). The basic needs of cotton from the soil are water, oxygen, available nutrients, and anchorage for roots (Kohel and Lewis, eds. 1984). Soils vary greatly in water holding capacity and in water movement potentials. The most desirable soils, in terms of moisture relationships with the growing plant are silt loam (Kohel and Lewis, eds. 1984). A pre-plant irrigation for cotton on a sandy soil, for example, will require a second irrigation by the second week after first flower buds (squares) are visible (USA). In contrast, a silt loam soil should hold until after first bloom, or 2 to 3 weeks later (Kohel and Lewis, eds. 1984).

Different stages are distinguished for the cotton crop: Seed germination (establishment); Vegetative development; Bud formation (squaring); Early flowering (starts when the first flowers develops); Peak flowering; Boll formation (yield formation) and boll opening; and ripening.

The germination is optimal at temperatures of 18 to 30°C, with a minimum of 14°C and a maximum of 40°C. Delayed germination exposes seeds to fungus infections in the soil. For early vegetative growth, temperature must exceed 20°C with 30°C as desirable. For early vegetative growth, temperature must exceed 20°C with 30°C as desirable. For proper bud formation and flowering, daytime temperature should be higher that 20°C and night temperature higher that 12°C, but should not exceed 40°C and 27°C, respectively. Temperatures between 27 and 32°C are optimum for boll development and maturation but above 38°C yields are reduced (Doorenbos and Kassam 1992).

Each stage requires a specific water requirement, depending upon the climate and soil physical characteristics. In fact, cotton requires at least 50 cm of water to grow a crop of minimum acceptable yield. Yield level, other things being equal, becomes a function of available water supply at successive stages of growth (Kohel and Lewis, eds. 1984; p. 246). According to FAO (1997) cotton needs 700 to 1300 mm of water to meet its crop water requirements.

The duration of each stage, depends on the climate, but is also crop variety related and the management of the crop in terms of cultural and irrigation practices. For example, the germination occurs less rapidly and successfully when irrigation water is not applied on time or according to the crop requirement. Excessive water use may hamper the crop development. On of the main factors affecting the crop development is the measure of soil aeration. Cotton is a sensitive crop towards flooding, especially if the water remains ponded for several days on the soil surface. From Kohel and Lewis (eds. 1984; p. 248), an oxygen stress occurs when the soil oxygen falls below 10%, and is prolonged for more than a few hours in the fruiting stage or growth, will induce shedding of small flower buds and small bolls. Poor fruit set, according to Patrick et. al. (1973), is commonly found in cotton grown on soils with poor internal drainage (quoted from Kohel and Lewis, eds. 1984).

Maintaining a high soil-moisture level may encourage excessive vegetative growth at the expense of boll set. It is said to result in development of a larger number of vegetative limbs and shedding of a larger percentage of squares and young bolls from the fruiting branches. For these reasons, it may be good practice to allow the soil moisture to reach a lower level between irrigations during the fruiting period than during the earlier growth period. However, it should not drop to a level where wilting occurs. If irrigation is stopped too early, yield may be reduced and late-developing bolls may not mature fully (UCAES 1967).

Irrigation applications too late in the season may result in delayed opening of matured bolls, increased boll rot and lodging, reduced defoliability, delayed harvest date, and increased field losses during harvest. Too-late irrigation applications also will reduce quality by preventing the fibres of late-setting bolls from reaching full development. The data of the last irrigation should be so timed that moisture will be available to complete the full development of those bolls that normally can be expected to mature.

1.7.2. Cotton Cultivation in Pakistan

The main cotton growing regions of Pakistan are covering the Punjab and Sindh Provinces (South part of the Northern Irrigated Plains of the Punjab and the Southern Irrigated Plain of Sindh). Cotton growing, however, has also expanded into the Southern Irrigated Plain on the Right Bank in Balochistan and North Sindh. Also, cotton is well suited to the recently developed irrigation portion of the Sulaiman Piedmont at DI Khan and DG Khan under the command of the Chashma Right Bank Canal (Federal Water Management Cell 1997).

There are many different varieties in production, whereby different varieties recommended for different districts of Sindh and Punjab. For example, Bahawalnagar District has as main varieties MNH 93, NIAB 78, BH 36, CIM 109 and Rohi (Desi), with the sowing period starting from mid-May and lasts till Mid-June.

Many farmers are cultivating local varieties (called desi), and have as main characteristics that it has a short lint, is adapted to the local circumstances and has a longer growing season, a lower water and fertiliser demand, lower yield but a higher yield security and also resistance against viruses is higher (Meerbach 1997). Farmers have sometimes the tendency to mix variety seed with desi seed.

Pest and diseases are a main problem occurring each year for the cotton crop, of which the most common are the cotton leaf curl virus and whitefly. This year, also the American Bollworm occurred severely. Cotton Leaf Curl Virus, is a virus that causes thickening and mottling of the leaves at adult stage. Varieties that are partially resistant to this virus are CIM 109, CIM 240, and NIAB 78 (Federal Water Management Cell 1997). White fly (Bemisia) is a disease whereby the insect nymphs and adults suck the sap from the leaves, and leave honey dew, resulting in soothing mould and shedding of leaves from July to September. The American Bollworm attacks the cotton resulting in shedding of bolls, buds and flowers from June to September (Federal Water Management Cell 1997).

Over the last fifty years, the total area under cotton has increased from 1.2 million to 2.8 million hectares, production from 1.1 million to 12.8 million bales and the yield from 159 to 768 kg of lint per hectare in 1991 (CCRI 1998). Further from 1992 to 1997 the area remained about the same but the production decreased of which the main causes were the cotton leaf curl virus and white fly. Figure 1.2 presents the cotton area and production in Pakistan for the period 1947 – 1997 (after Central Cotton Research Institute, 1998).

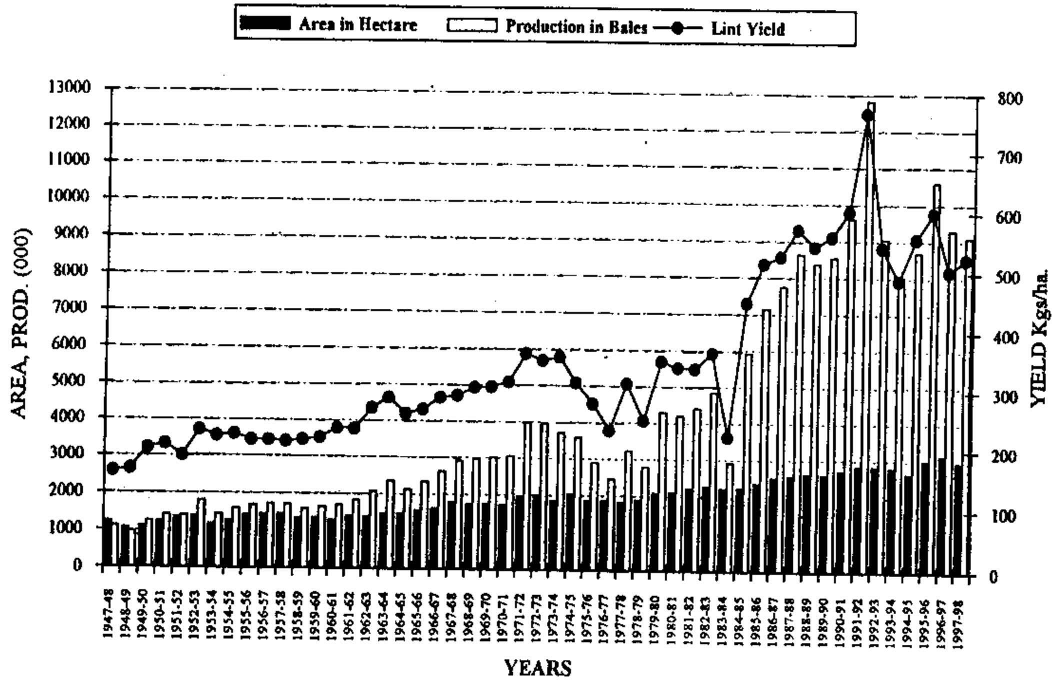

Figure 1.2. Total area under cultivation and cotton production in Pakistan, for the period 1947-1997 (after CCRI 1998)

2. SALIENT FEATURES OF THE RESEARCH AREA

2.1. HYDRAULIC FEATURES OF THE HAKRA 4-R DISTRIBUTARY

The Hakra 4-R Distributary falls under the Fordwah-Eastern Sadiqia Irrigation System, which encompasses an area of 150.000 ha. The irrigation system is divided into the Eastern Sadiqia Division (perennial system) and the Fordwah Division (non-perennial system). The Fordwah and Eastern Sadiqia Canals off-take as one canal; the Fordwah-Eastern Sadiqia Canal at the left bank of the Suleimanki Headworks on the Sutlej River and bifurcates into two separate canals after approximately 50 meters. The Eastern Sadiqia Canal is designed for 4917 cusecs, but is running at 6000 cusecs. The Eastern Sadiqia Canal is trifurcated at RD 245+000 (at Headworks Jalwala) into the Hakra Branch Canal, Malik Branch Canal and Sirajwah Distributary (Mahmood 1996).

The Hakra 4-R Distributary off-takes at reduced distance (RD) 89750-R from the Hakra Branch Canal at Gulab Ali Headworks. In fact, at this headworks, three distributaries off-take from the Branch Canal, i.e. Hakra 1-L, Hakra 3-R, and Hakra 4-R. The designed discharge for the Hakra 4-R Distributary is 193 cusecs, with a total gross command area (GCA) of 48250 acres. The defined water duty for the Hakra 4-R Distributary and the watercourses is 3.6 cusecs per 1000 acres. The canal network of the Hakra 4-R Distributary consists of 123 irrigation outlets that serve the total canal command area. The total length of the main distributary is about 37 km. The cultivable command area of the main distributary is 27609 acres (Mirza and ul Hassan, 1996), which is being irrigated by 75 outlets that supply water to about 2765 shareholders along the main distributary. The distributary has five drop-structures at RD 24, 46, 72, 82, and 107 (Mirza and ul Hassan 1996). Two minors, 1-RA Labsingh and 1-R Badruwala, off-take from the main system at RD 23200-R and RD 72100-R, respectively (Mirza and ul Hassan, 1996).

The 1-RA Labsingh Minor consists of 15 irrigation outlets having a total design discharge of 22 cusecs, covering a canal command area of 6077 acres. The total length of the minor is 22000 ft (about 7 km), and is unlined. The direct beneficiaries getting canal water from this minor are about 565 shareholders (Mirza and ul Hassan, 1996).

The 1-R Badruwala Minor off-takes from the main distributary canal at RD 72100-R, and has a length of 50623 ft. (17 km). The minor is unlined and comprises 33 irrigation outlets with a designed discharge of 43 cusecs, covering a canal command area of 10621 acres. Direct beneficiaries are about 1393 shareholders.

The Hakra 4-R Distributary, which falls under the Hakra Canal Division, Bahawalnagar, receives the water supply based on its position in the rotational schedule, which is a priority-based system that runs subject to the availability of supply. Appendix A presents the rotational program for the *kharif* season. According to this program, the Hakra 4-R Distributary falls under Group B and Sub-group B1. Every alternating week, the Hakra 4-R has the first priority; all the other weeks it has a second priority. The probability of receiving water depends on the availability of water in the main system. In addition to the first priority, the priorities are sub-divided according to the sub-groups. The priorities change on a weekly basis. Each sub-group is divided into first and second priority as well, whereby each priority has three rankings.

The disributary had no water for a considerable number of days during the *kharif* season. During the period of mid-May 1998 until mid-December 1998, 64 days of no water in the distribuary were reported (i.e. it could have been more days in reality), equivalent to 9.1 weeks, for the period mid-May until October 20 1998, this figure was 44 days, equivalent to 6.3 weeks. Figure 2.1 shows the number of days that there was no water in the distributary, starting from a particular date (This includes rotational schedule). The water scarcity during November and December caused a delay in the *rauni* application of wheat for many farmers, and consequently, delayed the sowing of wheat.

The Hakra 4-R Distributary command area is divided into five hydrological-based sub-systems. The division is based on the existence of two minors and the possibility of dividing the main distributary into three reaches, i.e. head, middle and tail, preferably on the basis of hydraulic structures along the main distributary (Mirza and ul Hassan 1996). Researchers initiated this segregation to facilitate the process of organizing farmers at the watercourse and distributary levels. The boundaries of each sub-system presented in Table 2.1 have been decided upon in consultation with the end users. Table 2.2 elaborates salient features pertaining to each sub-system.

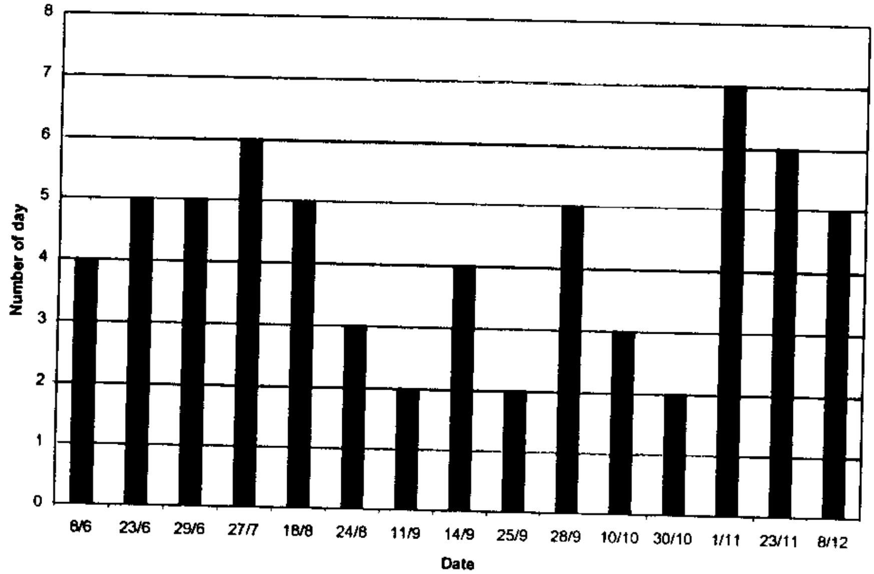

Figure 2.1. Periods of Drought in the Hakra 4-R Distributary (mid-June to mid-December 1998).

Table 2.1. Specifications on the Five Sub-systems of the Hakra 4-R Distributary.

Sub-system number	Zone	Physical boundary
Sub-system 1	Ghulab Ali	RD 00 to RD 46+000
Sub-system 2	Haroonabad	RD 46+001 to RD 72+000
Sub-system 3	Tail	RD 72+001 to RD 112+050
Sub-system 4	Khatan	Minor 1RA/4R
Sub-system 5	Minor 1R	Minor 1R/4R

Table 2.2. Salient Features of each Sub-system of the Hakra 4-R Distributary.

Sub-system	No. of irrigation outlets	Lined watercourses	Gross Command Area (acres)	Cultivable Command Area (acres)	Authorized withdrawals (cusecs)	Number of tubewellls	Number of shareholders
1 Head	25	6	10,350	9,435	34.97	43	735
2 Middle	23	17	8,190	7,030	29.13	45	1,010
3 Tail	27	16	12,220	10,635	41.95	82	1,030
4Minor 1RA	15	6	6,930	6,100	21.85	16	565
5 Minor 1R	33	21	11,650	10,200	40.24	51	1,350

The Hakra 4-R Distributary is subjected to rehabilitation under the Fordwah Eastern Sadiqia (South) Phase-I Irrigation and Drainage Project (FESS)[2]. The rehabilitation includes the partial lining of the main distributary and the two minors, and watercourse improvements. Table 2.3 presents details on the lining activities pertaining to the Hakra 4-R Distributary under FESS.

Table 2.3. Lining Activities for the Hakra 4-R Distributary and its Minors (after NESPAK 1992)

Channel name	**Total length**	**Discharge**	**Reach**		**Lining length**
	(Feet)	**Capacity (cfs)**	**From RD**	**To RD**	**(Feet)**
4-R Hakra / Haroonabad	112,050	115	58,500	89,179	30,679
4-R Hakra / Haroonabad	112,050	34	89,179	112,050	22,871
1-RA Labhsingh	22,000	28	0	22,000	22,000
1-R Badruwala	50,623	50	0	12,515	12,515
				Total:	88,065

In addition, under this project, horizontal interceptor drains will be installed along the distributary at the right and left sides, respectively, parallel to the distributary reach RD 0 to RD 58,500 (information obtained from NESPAK 1992).

2.2. Institutional Features

The farmers of the Hakra 4-R Distributary are organized into farmers organizations (FOs); a process that covers the period 1995-97[3], and is based on the concept of a three-tier structure. Adopting a step-wise, true and transparent democratic process involving 158 community-based Social Organization Volunteers at the grassroots level, and who contributed, together with IIMI researchers and social organizers to the formation of:

- 120 Water Users Associations (WUA);
- 5 Sub-system level Water Users Organizations (WUO)); and
- 1 Water Users Federation at the distributary level (WUF).

At the WUA level (Tier 1), out of a general body of all water users, two to five representatives are selected to form the *mogha* committee. One representative from each watercourse is selected for the general body of the informal sub-system WUOs (Tier 2) and out of the general body, five members are selected for the executive body. The latter forms the general body of the WUF (Tier 3), comprising 25 members. Out of this general body, the executive body of the WUF is selected, comprising five members (i.e. president, vice-president, general secretary, secretary information, and treasurer). For more details regarding the formation of the WUF, refer to Bandaragoda et. al., (1997).

[2] FESS is a six years project (FY 1993-FY 1998), which received extension till June 1999, sponsored by the Pakistan Water and Power Development Authority (WAPDA), and executed by WAPDA, Punjab Irrigation Department (PID) and Punjab Agricultural Department (PAD). The main components of the project are the installation of interceptor drains and canal lining, all to be taken place in the Sadiqia Division of the Fordwah Eastern Sadiqia Irrigation System. The defined objectives of FESS are: (i) raise agricultural production, employment and income; (ii) reduce the recharge to the ground water table, thereby reducing the need for expensive subsurface drainage and environmentally harmful effects related with such drainage; (iii) increase equity of water distribution among users; and (iv) strengthen the capacity of WAPDA and GOPunjab to plan, implement, operate and maintain similar projects (information obtained from NESPACT 1992, PC1 Proforma).

[3] Under the FESS Project, similar activities pertaining to organizing farmers were undertaken at the Sirajwah Distributary by the On-Farm Water Management (OFWM) Wing of the Agriculture Department. A similar concept (3 tier approach) forms the basis of the process.

2.3. Farming and Physical Features

The Hakra 4-R Distributary system is supplying irrigation water to about 41 villages, including small hamlets. The total population, benefiting directly or indirectly from the distributary system is estimated to be around 0.1 million. There are about 4,690 water users residing in 41 villages, including hamlets along the Hakra 4-R Distributary.

A socio-economic baseline survey (Cheema et al. 1997) of the Hakra 4-R Distributary shows that the majority of the farmers (56%) owned up to 5 acres of land. Overall, about 83 percent of the respondents had landholdings below 12.5 acres in size, which is very close to the provincial figure of 87 percent, owning less than 12.5 acres of land. About 12 percent of farmers had land holdings between 12.6 acres to 25 acres, while 6 percent of the total sample farmers had 25.1 acres of land and above. This indicates that, at the Hakra 4-R Distributary, the majority of the farmers have small landholdings, and which is assumed to be constraining to fulfil the family's food and fiber needs.

On the basis of tenancy status, the farming system can be divided into three broad categories: 1) owner cultivation; 2) tenancy; and 3) owner-cum-tenancy cultivation. The baseline survey (Cheema et al. 1997) shows that in the command area of Hakra-4R Distributary, about 51 percent own land, around 33 percent are owner-cum-tenants, while the remaining 16 percent are tenants. This indicates that a vast majority (84%) of farmers at the Hakra 4-R Distributary are either owners or owner-cum-cultivators, though they have small land holdings. Thus, this could be one of the major factors for the low adoption of advanced irrigation and agronomic techniques available for increased crop and water productivity.

The main crops grown in the Hakra 4-R Distributary command area are wheat (57%), cotton (42%), sugarcane (8%), and rice (8%), as well as fodder during the *rabi* (8%) and *kharif* (12%) seasons. In general, the spatial variation in the cropping pattern is non-existent. However, the intensity of land use is more at the head reach (167%) when compared to tail reach (111%) of the Hakra 4-R Distributary. For the *kharif* season, cotton, sugarcane and rice are the most popular cash crops. Sorghum, *bajra*, maize and *jantar* are sown as fodder. Occasionally, vegetables are also sown. For the *rabi* season, wheat (although less profitable) is the most popular crop. Berseem is the main fodder crop, which is generally sown for feeding domestic livestock. Some of the farmers also cultivate vegetables and oilseeds. Orchards are present on a few farms, especially orchard of the citrus family. As illustrated for the *kharif* cropping pattern, crop information has been collected from 9 watercourse command areas of the Hakra-4R Distributary during *Kharif* 1998. Figure 2.2 shows the results. The cropping intensity is 74.5 percent, of which the major crop cultivated is cotton (44.8%), followed by fodder (14.1%) and sugarcane (7.3%) and rice (7%).

Though underground water is generally unfit for irrigating crops, the scarcities, inequity and unreliability in canal water supplies have compelled the farmers to install about 247 shallow water tubewells along the distributary to meet the crop water requirements. Table 2.4 presents a detailed analysis of water samples collected and analyzed by the SSoP in July 1998. The ground water analysis shows that most of the water is unsuitable for agriculture, ranging from medium saline to very high saline and sodic nature.

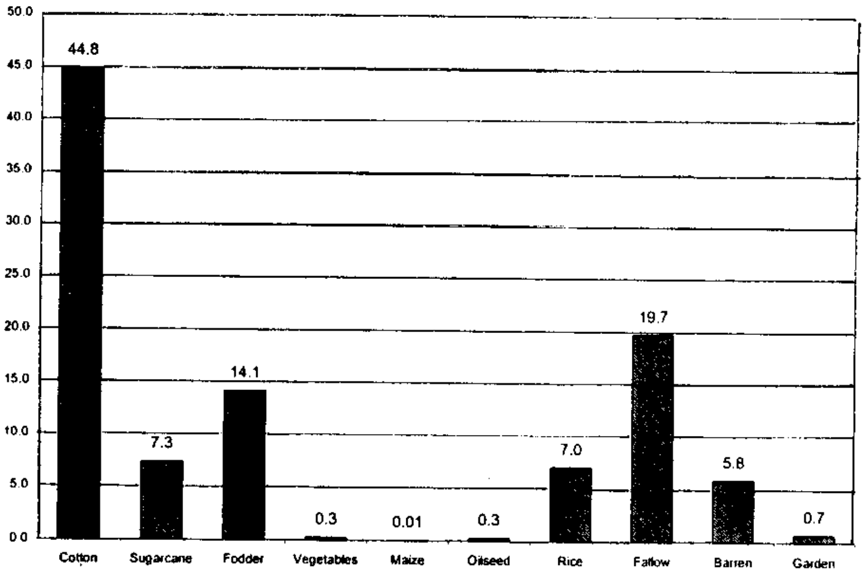

Figure 2.2. Cropping Pattern of *Kharif* 1998 (Based on 9 Watercourse Command Areas).

Table 2.4. Water Quality Analysis for Selected Areas of the Hakra-4R Distributary.

Farm No.	pH	EC dS/m	SAR	RSC me/l	Quality class	Nature of hazard
SS1-01	7.7	4.24(E3)	0.26(S1)	Negative(R1)	E3 S1 R1	Very high salinity
SS2-10	8.16	1.71(E3)	3.13(S1)	Negative(R1)	E3 S1 R1	Medium salinity
SS3-24	7.19	6.61(E3)	14.3(S3)	Negative(R1)	E3 S3 R1	Very high salinity sodicity
SS4-33	8.4	1.16(E2)	5.97(S1)	Negative(R1)	E2 S1 R1	Medium salinity
SS5-43	7.88	4.60(E3)	7.27(S2)	Negative(R1)	E3 S2 R1	Very high salinity
A: Absent	RSC: Residual sodium carbonate			EC: Electric Conductivity SAR: Sodium Adsorption Ratio		Time of sampling: July 1998 Source: SSoP

Generally, the water table depth in the research area is considered shallow. In reality, however, the groundwater level varies spatially over the research area. Average values for a selected watercourse command area in each sub-system, range from 2.18 feet (in SS2) to 7.46 feet (in SS5). Table 2.5 summarizes the average of the monitored ground water table depth for the period spanning from the end of June to mid-December 1998.

Table 2.5. Average Ground Water Level for the Different Sub-systems.

Groundwater level	SS1 (46237-R)		SS2 (52050-R)		SS3 (112050-TL1)		SS4 (22000-TL1)		SS5 (33730-L)	
	Head	Tail	Head	Tail	Head	Tail	Head	Tail	Head	Tail
Average depth (ft)'	3.06	4.51	2.18	3.02	5.68	6.16	4.08	3.99	7.22	7.46
Sample size	n = 23	n = 23	n = 16	n = 16	n =23	n =23	n = 25	n = 27	n = 21	n = 20
Standard deviation	0.70	0.6	0.99	0.56	1.18	0.99	0.73	0.69	0.56	0.67
Minimum value	2.2978	2.646	0.7	1.933	1.713	4.345	3.114	2.194	5.896	5.842
Maximum value	4.561	5.73	3.98	3.91	7.322	7.262	5.541	4.818	7.864	8.105

During the irrigation season, the water table depth fluctuates, with a declining vertical movement in time until mid-September. After mid-September the tendency is reversed (i.e. a water level reaches closer to the surface). The vertical ground water movement is graphically presented in Figure 2.3, and is based on ground water data collected from the observation well installed at the head reach of Watercourse 46237-R (SS1).

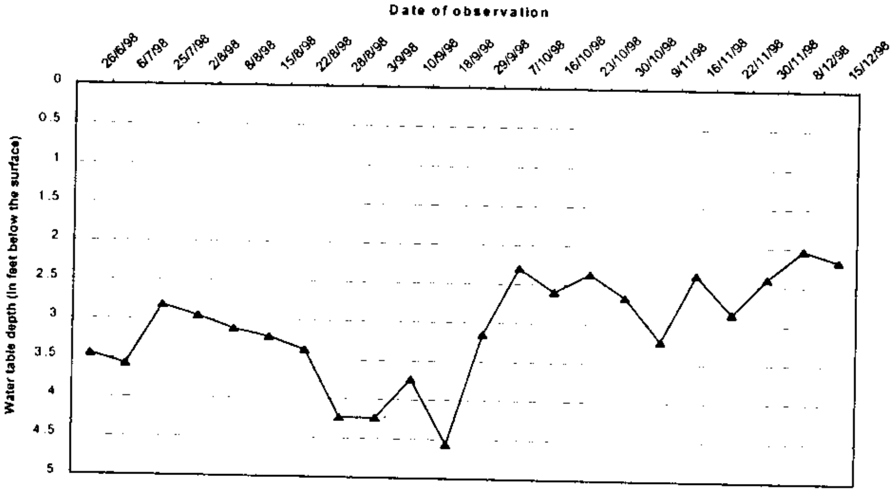

Figure 2.3. Vertical Ground Water Movement over Time (End of June to mid-December 1998; Sub-system 1, Watercourse 46237-R).

The water table depth has an influence on the crop production, which influences the total irrigation requirements. A study, undertaken by MREP (Ali and Sabir 1975) reveals that a fairly good cotton yield could be obtained without any subsequent irrigation event after the pre-sowing irrigation (of 100 mm) when the water table depth is up to between 0.5 to 2 meters below the surface. According to Ali and Sabir (1975), the most favorable yield can be obtained under a condition whereby the ground water table is more than four meters below the surface, under the condition that at least four to five irrigation events are applied during the growing season. Table 2.6 summarizes the results of the study by Ali and Sabir (1975).

Table 2.6. The Effect of Irrigation Strategies on Cotton Yields under Different Water Table Depths (Ali and Sabir 1975).

No. of	Irrigation +	Water table Depth (m)				
Irrigation	Rainfall (cm)	<1	2-Jan	3-Feb	4-Mar	>4
No	28.4	1090	973	617	647	674
One	35.9	1138	1332	743	865	1069
Two	43.4	1146	1237	950	985	1225
Three	50.9	1245	1474	1046	1217	1429
Four	58.4	1279	1364	1139	1359	1651
Five	65.9	1415	1560	1210	1431	1747
Rainfall received during crop season = 28.4 cm						(Yield in kg/ha)

2.4. Climate

The climate in the area is hot and arid. Based on 28 years' precipitation data from the Meteorological Institute in Bahawalnagar, the average annual rainfall per year is 196 mm. The highest average maximum temperature is reached in June, equivalent to 46.4 °C, whereas January is the coolest month with an average maximum temperature equivalent to 25.3 °C and an average minimum temperature equivalent to 15.8 °C. The relative humidity is high during the *kharif* (summer) and *rabi* (winter) monsoon rains, and may reach up to 80 percent in summer (August) and 86 percent in winter (January). The reference evapotranspiration, calculated by CROPWAT[4], is about 2205 mm per year, and thus, supplementary water supply to the crops is essential for agriculture to exist. Figure 2.4 presents the mean temperature, precipitation (P) and reference evapotranspiration (Eto), based on 28 years' meteorological data obtained from the Meteorological Institute in Bahawalnagar.

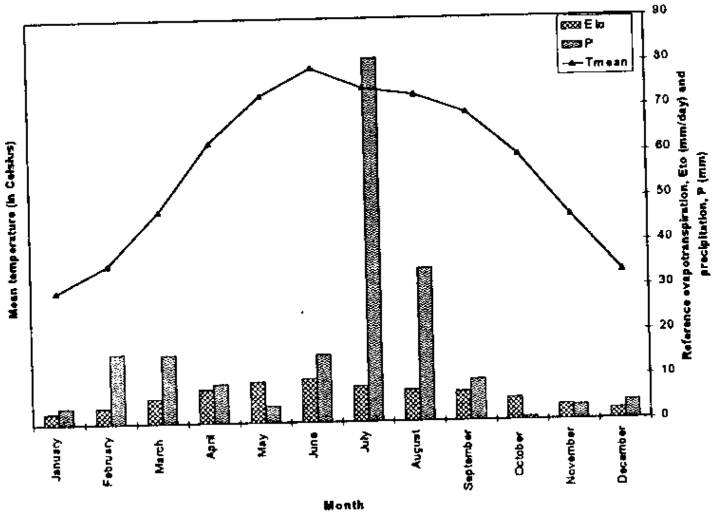

Figure 2.4. Climatic Information (Based on 28 years's data; Meteorological Institute, Bahawalnagar).

2.5. Characterisation of the Sample Farmers and Watercourses

2.5.1. Area Converted into Beds-and-Furrows

During *Kharif* 1998, a total of 186 acres had been implemented with the bed-and-furrow irrigation method in the command area of the Hakra 4-R Distributary and neighboring distributaries. Of all farmers (50), the bed-and-furrow irrigation method was implemented on almost 30 percent of the land destined for cotton cultivation,. Relating this to the total cotton cultivation for eight watercourse command areas, 36 percent of cotton has been cultivated by using the bed-and-furrow irrigation method. Table 2.7 presents the area of cotton cultivation and the bed-and-furrow use during *Kharif* 1998.

Table 2.7. Area of Cotton Cultivation and the Bed-and-Furrow use during *Kharif* 1998.

	Total cotton area (acres)	Number of farmers	Sown with the b/f method		Total area under cotton in SS's	B/F
			acres	Percentage		%
SS1 (3 w/c)	71.5	9	23.5	32.9	206	11.4
SS2 (1 w/c)	34.5	3	10	29.0	103	9.7
SS3 (2 w/c)	134.3	15	37.5	27.9	284.8	13.2
SS4 (1 w/c)	24.53	8	17.4	70.9	209.4	8.3
SS5 (1 w/c)	90.9	11	29.6	32.6	186.1	15.9
Outside CA	265.5	4	68	25.6		
Total	*621*	*50*	*186*	*29.9*	989.3	36.0

[4] CROPWAT is a computer program to calculate crop water requirements and irrigation requirements for climatic and crop data. The program is developed under the Land and Water Development Division of the Food and Agricultural Organisation (FAO) of the United Nations (UN).

Farmers from outside the Hakra 4-R Distributary command area (Hakra 6-R, 3-R and 1-L) are large farmers owning land ranging from 31 to 150 acres, and possess various farm implements, have permanent labor and are considered productive farmers. Although these farmers are excluded from analysis, data has been collected regarding farming features, and yield data has been retrieved from these farmers at the end of the *kharif* season. Specific information about these farmers can be found in Appendix A. Of the 46 farmers from the Hakra 4-R Distributary area, 32 were selected for data collection activities pertaining to the irrigation and cultural practices. The main selection criteria for these farmers pertained to the location (i.e. from a practical perspective it was decided to confine the data collection activities to seven watercourse command areas). Of the remaining 16 farmers, who are located outside the selected watercourse command areas, basic information has been collected as background information. Further, at the end of the season, yield data was collected from these farmers. With these, farmers' interviews were conducted at the end of the season to gauge their experience with the bed-and-furrow irrigation method. Basic features of the non-sample farmers are presented in Appendix A, along with yield information pertaining to *Kharif* 1998.

A total of 12 farmers (of 50) used the bed-and-furrow irrigation method in conjunction with precision laser leveling. A total of 28.75 acres has been laser leveled, of which 1.5 acres concern the laser leveling of basin fields.

2.5.2. Location of the Sample Farmers

Of the 32 sample farmers, the following number of farmers has been selected from each Sub-system:

- 9 farmers from Sub-system 1 (SS1); RD 24582-R, RD 46240-L and RD 46237-R;
- 2 farmers from Sub-system 2; (SS2); RD 52050-R
- 4 farmers from Sub-system 3 (SS3); RD 112050-TL and RD 107055-R
- 8 farmers from Sub-system 4 (SS4); RD 22000-TL1; and
- 9 farmers from Sub-system 5 (SS5); RD 33730-L.

Two farmers from Sub-system 1, RD-46240L, are only included in the irrigation frequency and cultural practices analysis, since daily outlet discharge information was not collected for their respective watercourses. Salient features of the sample watercourse command areas are presented in Table 2.8.

Table 2.8. Salient Features of the Watercourse Command Areas.

W/C	Sub-system	GCA (acres)	CCA (acres)	Authorized discharge (cfs)	Outlet structure	Lining status
24582-R	SS1	182	182	0.66	APM	unlined
46237-R	SS1	115	115	0.41	Pipe	partially lined
52050-R	SS2	310	310	1.2	OF	unlined
107055-R	SS3	349	349	1.46	OFRB	unlined
112050 TL	SS3	358	358	1.29	OF	partially lined
22000-TL1	SS4	525	481	1.73	OF	partially lined
33730-L	SS5	378	302	1.22	OF	partially lined
APM = adjustable proportional module				OF = open flume		
Based on Mirza and Ul Hassan (1996).				OFRB = open flume with roof block		

Figure 2.5 presents the Hakra 4-R Distributary and the location of the sample watercourse command areas.

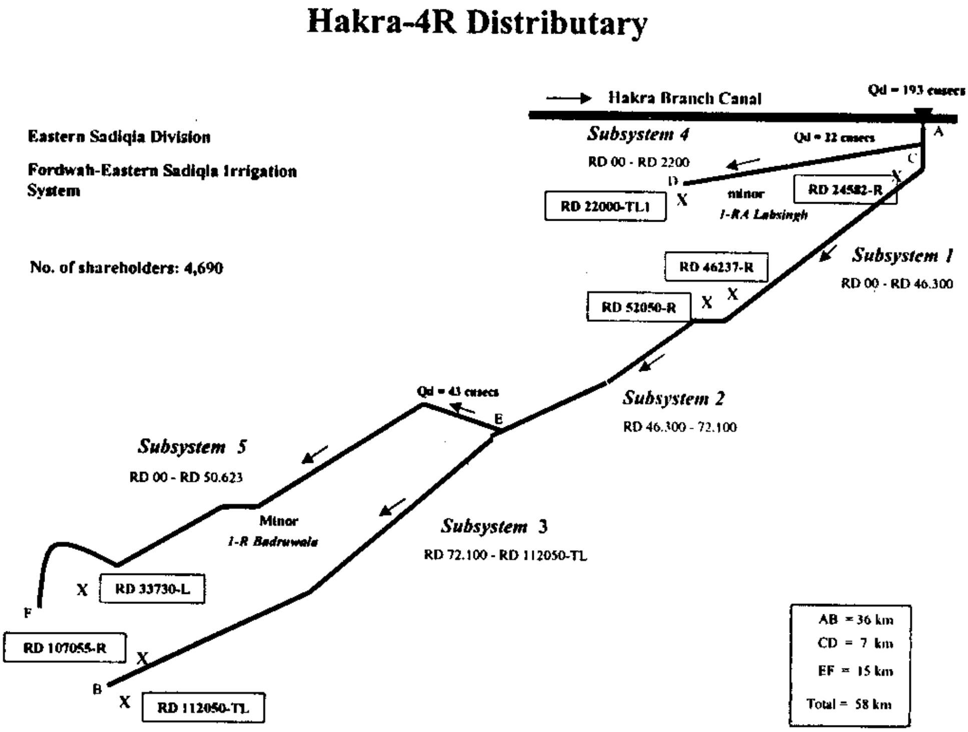

Figure 2.5. Layout of the Hakra 4-R Distributary and the Locations of the Sample Watercourse Command Areas.

During the *kharif* season, the *mogha* readings were noted and converted into discharge values. In order to evaluate the adequacy of the water supply, the average duty on a monthly basis and season wise has been calculated for several outlets. Table 2.9 presents the results.

The actual water duty does not match the designed water duty. The head reach watercourses (RD 46237-R and RD 52050-R) draw more water than actually designed, with an average water duty for the total season of 5.95 and 7.39, respectively. The water course located at the tail of the 1-RA Labsingh Minor (i.e. RD 33730-L) received consistently less water than authorized; a trend which has also been analyzed for the tail watercourse (RD 33730-R) of the 1-R Badruwala Minor. On an average, the tail reach watercourse of the distributary (RD 112050-TL) has a lower actual water duty. Only in May and October was the actual water duty more than designed. For RD 107055-R, the data was only available for a few months due to construction work at the outlet. Overall, this watercourse received less water than authorized.

2.5.3. Socio-economic Features

Most sample farmers own land, of which five have leased additional land in. Only one farmer has leased land (in Sub-system 4), and the sample farmers of Sub-system 2 are both tenants, with 2 and 8 acres, respectively. Farmers owning land are counted according to different ranges in landholding size, as presented in Table 2.10. Only five farmers are small farmers, while most own land between 5 and 25 acres. Only two farmers are considered large farmers, each owning 25 acres of land. Appendix A provides the details on the land ownership for each sample farmer. One farmer (1.1) of Sub-system 1 also takes care of his brother's land (16.75 acres) located in the same watercourse command area, and shares the expenditures and profit with his brother.

Table 2.9. Actual Water Duty for Selected Outlets (*Kharif* 1998).

	RD 46237-R cfs/1000 acres	RD 52050-R cfs/1000 acres	RD 107055-R cfs/1000 acres	RD 112050-TL cfs/1000 acres	RD 22000-TL1 cfs/1000 acres	RD 33730-R cfs/1000 acres
Design water duty	3.6	3.6	3.6	3.6	3.6	3.6
Actual water duty						
(On monthly basis)						
May	9.61	data not available	data not available	5.12	data not available	data not available
June	6.22	6.31	data not available	3.11	3.62	3.06
July	5.48	6.68	3.28	2.87	2.32	2.85
August	6.99	10.44	3.82	3.48	4.27	2.87
September	5.63	8.49	3.01	2.68	2.62	2.52
October	7.17	8.5	4.64	4.96	2.41	3.52
November	4.1	3.58	1.53	1.64	2.5	2.46
December	4.82	7.06	data not available	3.06	2.36	2.71
Overall actual water duty:	5.95	7.39	3.29	3.18	2.87	2.87

Table 2.10. Classification of Farmers who Own Land.

Acres	Number of Farmers	Average Area (acres)	Standard Deviation	Minimum Value	Maximum Value	Leased Land (additional)	Average Area (acres)
< 5	5	3.6	0.92	2.5	4.875	3	-
5 - 12.5	10	8.6	2.37	6	12.4	2	3.5
12.5 - 25	10	15.6	3.5	12.5	24.25	0	3.5
25 – 50	2	25	0	25	25	0	-
>= 50	0	-	-	-	-	-	-

The reported family size varies from 3 to 28, with an average of 9.8. The families members of all the sample farmers are active in agriculture, including women. In addition, some farmers have permanent labor, as reported by 8 out of the 32 sample farmers, which concerns 1, 2 or 3 permanent laborers.

Sixteen sample farmers reported other income generating activities, and often concerns another family member. The natures of income generating activities are diverse, i.e. school teachers, wage laborers, farm input business, goldsmith, shopkeeper, poultry farm, working abroad (England, Saudi Arabia, cloth selling business, Pakistani army and involvement in business (tractor, transport).

Farmers own various resources ranging from, e.g. a tractor, trolley, thresher, ragger, ridger, rotavator, scraper, drill, etc. However, 21 farmers do not own any farm implements and are dependent on renting or borrowing. Ten out of the 32 sample farmers own tractors, and seven farmers reportedly have ploughs.

All the farmers reported to have cattle such as cows, buffaloes, donkeys, goats, hens and chickens. All sample farmers, except one from Sub-system 1 and one from Sub-system 3, have buffaloes used for traction or milk production. The number of buffaloes ranged from 1 to 12, with an average of 4 to 5 buffaloes. In addition, most of the farmers have goats, while only one farmer mentioned having sheep. Donkeys and cows are also common cattle. Only six farmers own tubewells. Quite a few farmers (11) mentioned using tubewell water on a rental basis, though not frequently.

2.5.4. Access to Resources

Only two farmers mentioned real access to credit. Eighteen farmers claimed they had no access to credit from a bank; 3 farmers had not tried; and 8 mentioned that it is too difficult, it is a burden or they never felt the need. Four farmers mentioned receiving loans from a bank before, and one of these farmers used it to purchase a tractor.

Seeds, fertilizers and chemicals are mostly bought on credit from the commission agent or shopkeeper; rarely would somebody pay cash. One farmer mentioned that he paid partly in cash and partly credit when purchasing inputs; 3 farmers pay in cash for inputs like seeds, fertilizers and chemicals. With respect to farm implements, those required are purchased on rent, which occurs in cash payment.

2.5.5. Cropping Pattern

The major crops cultivated among the sample farmers during *Kharif* 1998 are cotton, fodder, sugarcane, and rice. Of the total land of the sample farmers (i.e. 357.8 acres), 63.6 percent is cultivated with cotton, 10.2 percent fodder, 9 percent sugarcane, 2.3 percent rice, and 13 percent is left fallow. Some farmers cultivated vegetables (0.5% of the total area) and *dara* (kind of fodder). During *Rabi* 1997/98, the major crops cultivated were wheat, sugarcane, fodder and maize, covering 58 percent, 10.3 percent, 9.5 percent, and 4.6 percent, respectively of the total area cultivated (437.13 acres). A few farmers cultivated oilseeds and vegetables. Of the total cultivable land, 14 percent remained fallow during *Rabi* 1997/98.

For both seasons (i.e. *rabi* and *kharif*), the sample farmers maintained a high cropping intensity; 88.54 percent and 88.1 percent for *Rabi* 1997/98 and *Kharif* 1998, respectively. During *Rabi* 1997/98, the lowest and highest cropping intensity value was 48 percent and 100 percent, respectively. For *Kharif* 1998 these values are 64 percent and 100 percent, respectively.

The Irrigation Department has fixed cropping intensities for the area commanded by the Fordwah Eastern Sadiqia during the implementation of the Sutlej Valley Project in the 1930s, established separately for *kharif* and *rabi*, and indicates the percentage of CCA entitled to receive water during a particular season. In Fordwah Eastern Sadiqia, a general cropping intensity of 80 percent for perennial canals (40% for *kharif* and 40% for *rabi*) and 60 percent for non-perennial canals have been fixed (Kuper and Strosser 1992). Relating farmers' practiced cropping intensities to the authorized cropping intensities, it can be concluded that the actual cropping intensity is far above the authorized one. Consequenctly, the demand for water is higher than the existing capacity of the canals, resulting in a scarcity of water for the cultivated crops.

2.5.6. Physical Setting

Most of the soils of the sample farmers are classified as Hasilpur soils. Some soils are of the Haroonabad series.

Hasilpur soils are characterized as soils consisting of deep / very deep, somewhat excessively drained, brown to dark-yellowish brown, calcareous, non-saline, non-sodic and weakly-structured sandy loams / fine sandy loams having a solum 50 to 75 cm thick. The substratum is usually massive and / or laminated, ranging from sandy loams / fine sandy loams to loamy sandy and even at places, very fine sandy loam / silt loams (SSoP 1999).

The Haroonabad series occupies the level parts of the plains and is developed mainly in the Hakra alluvium with some admixture of material from the Sutlej River. The soil comprises deep, mostly yellowish-brown, well-drained with moderate sub-soil permeability, calcareous, weakly structured, loams having a solum 50-100 cm thick. The substratum is generally brown to dark-yellowish brown, massive to laminated loams, clay loams or sandy loams with or without a few fine to very fine lime modules. At places, it may consist of a buried soil (SSoP 1999).

Table 2.11 presents the sample fields classified according to the soil series and variants. Most of the sample fields are either sandy loam or loam. In order to categorize the sample fields according to the soil quality, the analyzed Exchangeable Sodium Percentage (ESP in %) and Electric Conductivity (EC_e in dS/m) are plotted in Figure 2.5. For every soil, two soil samples were taken and analyzed accordingly.

Table 2.11. Soil Typology according to Soil Series and Variants (Source: SSoP).

Soil typology	Farmer Number			
Hasilpur loam, saline sodic variant	1.1	3.15	5.41	
Hasilpur sandy loam, saline sodic variant	4.3			
Hasilpur sandy loam, saline sodic surface	3.15	1.2		
Hasilpur, sandy loam, saline surface	1.9	3.13	4.29	4.31
Hasilpur, very fine sandy loam	1.7	4.32		
Hasilpur sandy loam surface underlain by silty clay	3.14	3.16		
Hasilpur sandy loam saline sodic variant	5.37	5.38	5.42	
Hasilpur sandy loam	4.34	5.36	5.39	
Hasilpur loam	5.4			
Harunabad loam	1.4 (b/f)	1.8	2.11	
Harunabad loam, saline surface	1.4 (b)	1.5	1.6	2.1
Harunabad very fine sandy loam	5.43	5.44		

(b/f) = bed-and-furrow sample field; (b) = basin sample field.

The ESP refers to the measure of sodification. Sodification refers to an increase of sodium with respect to calcium and magnesium (van Dam and Aslam 1997). EC_e is a measure for the salinity status, whereby salinity refers to the total dissolved concentration of major inorganic ions. The used soil quality criteria, as presented in Figure 2.6 are according to the USDA (1954), whereby:

- *Non-saline non-sodic:* $EC_e \leq 4$ dS/m, and ESP $\leq$ 15%
- *Saline non-sodic:* $EC_e \geq 4$ dS/m, and ESP $\leq$ 15%
- *Non-saline sodic:* $EC_e \leq 4$ dS/m, and ESP $\geq$ 15%
- *Saline sodic:* $EC_e \geq$ dS/m, and ESP $\geq$ 15%

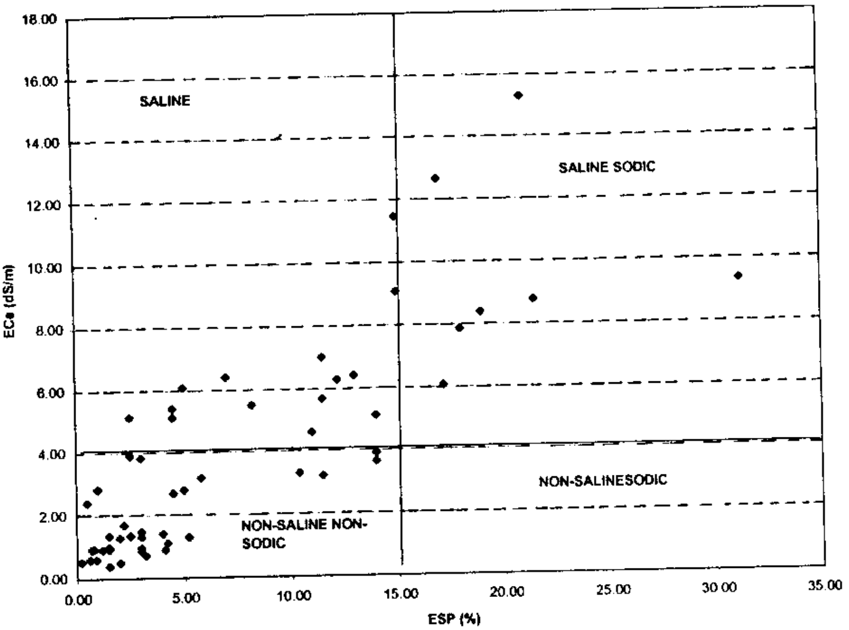

Figure 2.6. Soil Samples Categorized according to Quality.

Most of the soils from the sample farmers were found to be non-saline and non-sodic. Non-saline sodic soils were not found. A few sample fields were found to be either non-saline sodic or sodic.

3. DOCUMENTATION OF THE FIELD RESEARCH PROCESS

The farmers of the Hakra 4-R Distributary started experimenting with the bed-and-furrow irrigation method in *Kharif* 1998. This improved agronomic and irrigation technique was implemented by the WUF, with the technical assistance from the Mona Reclamation and Experimental Project (MREP), On-Farm Water Management Directorate (OFWMD), Punjab Agriculture and Extension Directorate (PAED) and the International Irrigation Management Institute (IIMI). This chapter presents the steps undertaken towards the implementation of the bed-and-furrow irrigation method, interactions between farmers and researchers and institutions during the season, and initial comments obtained from the farmers during the season.

3.1. AWARENESS BUILDING ACTIVITIES

The Water Users Federation (WUF) of the Hakra 4-R Distributary became motivated to experiment with the bed-and-furrow irrigation method after a study tour to Haji Arshad's farm near Khanpur on August 11, 1997. About 40(s) elected WUF members participated in the study tour. One of the objectives was to become familiar with the bed-and-furrow irrigation method, and thus, to learn from other farmers' experience.

Although IIMI staff were involved in the organization of the bed-and-furrow irrigation trials, yet it was the task and responsibility of the WUF to realize the implementation of the bed-and-furrow irrigation method. An underlying objective was for IIMI to strengthen the WUF and to make them aware that they have the ability to undertake activities under joint efforts.

The federation undertook several actions in order to introduce the bed-and-furrow irrigation method in the area, with the facilitation of IIMI staff. The federation organized village lectures and study tours. The activities are listed below:

- ✓ An inter-sub-system study tour, the purpose being to interact with a farmer using the bed-and-furrow irrigation method. Nine farmers of Sub-system 1 made a study tour to Sub-system 5 under the leadership of the WUF president. The study tour was made on April 13, 1998. In Sub-system 5, a farmer cultivated his wheat crop using the bed-and-furrow irrigation method.
- ✓ The federation organized five training sessions to launch the bed-and-furrow experiment for the cotton crop. The training sessions were held for the water users of the five selected watercourses of the Hakra 4-R Distributary. Training was arranged in the command area sample watercourses between March 25-29, 1998. There were a total of 123 water users in these five watercourses. However, the total participants were 142. The reason for the higher number of participants than actual water users are that there was an open invitation to the water users in the respective villages of the sample watercourses. The Mona Reclamation and Experimental Project (MREP) provided the input for the five training sessions, which focused on making farmers aware of the bed-and-furrow irrigation method. The farmers, however, did not feel completely satisfied after the training; questions and confusions remained. The following issues were raised and discussed during the training meetings,
    - Preparation of land;
    - Launching hoeing and fertilizer application activities;
    - The possibility of salt occurrence on the bed;
    - The timing of the arrival of the implements; and

- The allocation of area for implementing the bed-and-furrow irrigation method.

✓ The WUA members, especially in Sub-system 4, visited the farmers and informed them about the new technology. One WUA member was experienced with cultivating cotton on beds, but with a traditional ridger. He informed the farmers about his experience, which he considered to be successful.

✓ A one-day training program was held at the village Bhukhrana in the command of the Hakra 1-L Distributary. The farmer, Malik Imtiaz, gave the training on the use of the bed shaper. He first delivered a lecture and then practically operated the shaper. A total of 15 farmers from the Hakra 4-R Distributary benefited from the training.

Also, at the commencement of the season, a brochure prepared by IIMI was distributed in the research area. The brochure deals with practical tips and quantitative information pertaining to water use and yield for the bed-and-furrow irrigation method, based on data collected from selected command areas of the Fordwah Distributary and Tareen Farm, near Lodhran, during previous years.

3.2. Managing the Bed-and-Furrow Shaper and Laser Leveling Device

In the federation meeting held on April 29, 1998, the WUF General Body of the Hakra 4-R Distributary made a decision about the use of implements. A total of 17 members attended the meeting. The decisions were:

✓ First, a committee was constituted for this purpose. The committee comprised ten persons, two persons from each sub-system. The committee's members offered their services voluntarily.

✓ The rent was fixed at Rs. 150/hour and Rs. 50/acre for the laser leveler device and the bed-and-furrow shaper, respectively. It was also decided that for the laser leveler device, Rs.10/hour would be charged as an extra for the driver's logistic support.

✓ Both implements will remain in each sub-system for five days at a time.

✓ The committee was made responsible for the booking and rent collection of the implements.

The Water Users Federation general body held a meeting in April 1998, in which they constituted a 10-member committee to look after the activities pertaining to use of the bed-and-furrow shaper. However, their progress concerning rent collection was not satisfactory. There were certain justified reasons precluding their effectiveness. Among many important are the late arrival of machines, unexpected rains, unavailability of heavy tractor to pull the machine, inexperienced operators, larger command area and lack of experience and managerial skills of the committee members. The WUF general body, in a subsequent meeting, stressed that members collect dues up to the end of the season. The majority of the farmers has already paid the rent. IIMI field staff also had to pool their efforts for rent collection. In the future, for efficient use of the machinery, the WUF is strategizing the procedure, rules and regulations.

3.3. Site Selection

3.3.1. Initial Proposition

The social organizers (i.e. IIMI field staff), with the assistance of federation members, met with a number of WUA presidents to discuss the selection of their particular watercourse to implement the bed-and-furrow irrigation method and to use of the laser leveling device. The majority of the WUA presidents were reluctant to implement the bed-and-furrow irrigation method at a large scale in the watercourse command area; however, it was agreed to allocate five to ten acres for the bed-and-furrow irrigation method. The major reason of the reluctance was the availability of unsuitable land for this technology. Since a large portion of the area is waterlogged, farmers prefer to cultivate rice in the area. However, after long discussions with WUA, WUO and WUF members five watercourses were selected, one from each Sub-system, after consultation with their respective presidents and members. Table 3.1 presents the selected watercourse command areas.

Table 3.1 Selected Watercourse Command . Areas for Implementing the Bed-and-Furrow Irrigation Method.

S#	Sub-system	Watercourse No.	Watercourse RD
1	SS1	28A	46237/R
2	SS2	31	52050/R
3	SS3	66	112050/TL
4	SS4	10	22000/TL1
5	SS5	17A	33730/L

The selection of the respective watercourse command areas is based on the following criteria:

- Waterlogged condition of the area should not be severe;
- The water users should be co-operative;
- The water users should be willing to adopt the bed-and-furrow irrigation method;
- The number of water users should be manageable from a practical point of view;
- The watercourse should be easily accessible; and
- The water users should be willing to accept the certain amount of risk involved (there may be unforeseen situations).

3.3.2. Additional Watercourses

Initially, the farmers in the sample watercourses turned out to be reluctant to adopt the bed-and-furrow method; they first intended to see its impact. In addition, some negative-minded farmers incited them about the technology. They usually propagated the chance that the salinity might appear on the soil surface. Consequently, they would not be able to acquire a good wheat crop in those fields in the next season. They also propagated that the manual hoeing is difficult for the bed-and-furrow method, as the hoeing is possible only with a special device. The farmers who planned to use the bed-and-furrow irrigation method were informed by the WUF that the hoeing machine would be provided to them.

Other reasons for reluctance and delay in the use of the bed-and-furrow irrigation method were:

- ✓ Late delivery of the first bed-and furrow shaper, the farmers waited for the bed-and-furrow shaper to some extent and later, several farmers starting sowing the fields by the traditional method (flat sowing). So, less farmers intended to use the bed-and-furrow irrigation method as initially scheduled;
- ✓ Unavailability of the big horse power tractor. As the small horse power tractor (e.g. Massey Ferguson 240) cannot operate the bed-and-furrow shaper properly, especially when the soil is moisture and not well prepared; the heavier tractors were seldom available; Later on a tractor of OFWM was used (on rental basis at the rate of Rs. 50 per acre), and which solved the problem;
- ✓ It was difficult to manage the area with only one bed-and-furrow shaper; a second shaper was scheduled to arrive, however, it did not arrive until mid-June; and
- ✓ The wheat harvesting was delayed due to rain, so these fields, planned for using the bed-and-furrow irrigation method, could not be used yet. Suddenly, after harvesting the wheat, the demand for the shaper increased, while the demand could not be met immediately due to the availability of one shaper only.

Field staff and researchers realized that the probability of having a low number of farmers using the bed-and-furrow irrigation method would only become higher, if an adjustment in the number of sample watercourse was made. Therefore, it was decided that any farmer from any watercourse command area could use the bed-and-furrow irrigation method. This resulted in an increase in the number of farmers using the bed-and-furrow irrigation method. The demand suddenly rose also later in June, due to the observing of the first positive effects of the bed-and-furrow irrigation method: the germination looked good. By the end of the sowing period, 46 farmers from Hakra 4-R Distributary used the bed-and-furrow irrigation method and 4 farmers from outside the Hakra 4-R Distributary command area.

3.3.3. Allocation of the Implements

3.3.3.1 Bed-and-Furrow Shaper

There was only one bed shaper available at the start of the cotton season, as the second one reached very late (around mid-June); almost 95 percent area had been cultivated at that time. In the federation meeting, farmers decided that each sub-system would have the implements at their (bed-and-furrow shaper and laser leveling device) disposal for five days. Each sub-system was responsible for bringing the implements to their respective sub-system.

Initially, the implements were allotted on a priority basis, as in the federation meeting. Farmers of Sub-system 3 indicated their demand, and thus, the implements were first allotted to the farmers of this sub-system for the period from May 1 to May 5. Unfortunately, rainfall occurred during these days (allocated time) and farmers of this sub-system could not use the implements properly and the implementation of the bed-and-furrow irrigation method was delayed.

Similarly, the farmers of Sub-system 4 could not use the bed-and-furrow shaper due to rainfall; hence they had to give the implements to Sub-system 5, according to the rotational schedule, without any successful implementation on their fields. Delay was already in the rotation schedule due to earlier delays of the arrival of the implement in Sub-system 4, hence upon arrival in Sub-system 5, this area only had three days to implement the bed-and-furrow irrigation method. Farmers from Sub-system 2 came to collect the implements after 3 days. Since it was already later in the season, nobody was eager for more delays. The farmers of Sub-system 2 completed the implementation in two days and the implement was returned to Sub-system 4.The bed-and-furrow shaper remained in Sub-system 4 for one night, when it was transferred to the farmers of Sub-system 1. The farmers in Sub-system 1 used the implement in three different watercourse command areas. Next, the bed-and-furrow shaper returned to Sub-system 5, where the implement was used in three watercourse command areas. Later, Sub-system 3 had the bed-and-furrow shaper at their disposal and completed the implementation of the bed-and-furrow irrigation method for 17 farmers.

After the demand in the sub-systems was covered, the WUF allowed the bed-and-furrow shaper to be used by farmers outside Hakra 4-R Distributary command area.

A main reason why frequent delays occurred when taking the bed-and-furrow shaper from one sub-system to another was the unavailability of a tractor, including difficulties to find a tractor and driver willing to spend time on this implementation activity. Farmers of Sub-system 1 had to pay Rs. 150 per acre in order to obtain a tractor and driver, while a normal price would be Rs. 100 per acre. Additionally, the availability of one bed-and-furrow shaper during the peak demand was difficult to manage. Rainfall disturbed the original rotation schedule and increased the demand towards the end of the sowing period, which also placed more pressure on the implement. Luckily, by that time the second bed-and-furrow shaper arrived, though some faults occurred and had to be corrected in the implement.

3.3.3.2 Laser Leveling Device

'he WUF of the Hakra 4-R Distributary took the initiative to introduce the laser land leveling echnology in the area, especially for the small farmers. The Director General (DG), Water Management, Punjab, handed over a complete laser unit set to the WUF for use in their jurisdiction n a rental basis. The federation members benefiting from the laser land leveler are paying the rent nd the same is being deposited in the government account.

nitially, the farmers were not much aware about its purpose, and considered it as expensive (rate oes by the hour). Later on, after seeing its preliminary effect on water saving, equal seed ermination and good crop stand, farmers started becoming inclined towards the technology. Now, everal farmers claimed to prefer laser land leveling above the bed-and-furrow shaper. The laser eveler has been used in three sub-systems, as it arrived late and there was very little time left for owing. Some farmers wanting to use both, the laser leveler and bed-and-furrow shaper, but failed lue to the unavailability of the laser-leveling device. Remarks received from farmers about the laser eveler during the season are presented below.

- ✓ Less chances of waterlogging and salinity due to equal distribution of water throughout the field;
- ✓ Bed-and-furrow practices are inappropriate without using the laser leveling device first; and
- ✓ The area leveled with the laser-leveling device will remain properly leveled for the next three years.

Some farmers, however, were of the opinion that it is just a waste of money; one can easily get a field properly leveled through the traditional method.

3.4. WEEDING AND HOEING ACTIVITIES

Almost all the sample farmers, from the very first day, demanded the hoeing machine. Some farmers even adopted the technology with the condition that the hoeing machine will be provided to them. Unluckily, the hoeing machines (i.e. two sets) arrived too late and were found defective several times during its operation. Therefore, farmers had to send it to the workshop many times. Only four farmers used the hoeing device. Mostly, the people were thinking it would be harmful to use at this time of the season (July), as the crop attained good height. In addition, many fields turned out to be inappropriate to use the hoeing device due to the fact that during the implementation of the beds-and-furrows, the furrow lines were not straight. In this condition, using the hoeing device would harm the crops.

Since the hoeing machine could be used at the same time for the application of fertilizers (a built-in device), farmers delayed the fertilizer application due to its late arrival. Several farmers, however, found their own solutions. They used *tarpali* (ploughed three times) to hoe and for fertilizer application, and they found it perfectly all right.

Constraints in the operation of the hoeing machine, as commented by farmers:

- The parts of the hoeing machine were not properly adjusted, thus hindered its proper functioning;
- The poor quality material used in the manufacturing of the machine resulted in the breakage of this during testing;
- The discs of the machine were not sharp, so did not work properly;
- Low horse power tractor is not suitable for the operation of the machine; and
- Lack of technical knowledge to operate the machine.

Additional comments regarding the hoeing machine received by farmers:

- Implements reached the area too late;
- Without proper hoeing machines, there is no scope for the bed-and-furrow technique in the future;
- The bed-and-furrow experiment was not up to the desired standards this year due to late delivery of hoeing machines;
- The hoeing machine is indispensable for controlling the weeds; its timely availability is the key to success;
- The fruiting of the crop has been affected because of late hoeing; and
- In several instances, the fertilizer were not applied on time, and consequently, the yield has been affected.

3.5. INFORMAL MEETINGS WITH FARMERS DURING THE SEASON

A number of informal meetings with the farmers during the study period, which mostly concerned discussions about the bed-and-furrow irrigation method in the initial stage of the season were held in evening times, and later coincided with the data collection activities as presented in section 1.3.

During the informal meetings, farmers spoke about their bed-and-furrow experience. Comments received during the season are presented below.

3.5.1. Germination Stage

The farmers of Sub-systems 1, 2, 4, and 5 were satisfied with the seed germination rate. The germination rate varied from 75 to 100 percent. The farmers even reported 100 percent germination in the poor and unfertile soils, and they had to perform thinning due to good germination. However, some farmers, like in Sub-system 3, had reported a very poor germination rate, i.e., less than 25 percent. Due to poor crop stand, the majority of the farmers of Sub-system 3 destroyed the cotton crop in the bed-and-furrow fields for other crop cultivation purposes. The farmers reported that the poor germination was not because of the bed-and-furrow method as such, but that several factors, of which some were related to the implementation of the bed-and-furrow irrigation method, had contributed in poor seed germination. For example:

- ✓ The bed-and-furrow shaper arrived very late and farmers had already cultivated the cotton on flat sowing, in their fertile soil; often, the poor quality soil remained for the bed-and-furrow experiment. Also, farmers were reluctant to spare good soil for this experiment;
- ✓ The quality of the seed available in the market was very poor;
- ✓ The land was not properly prepared prior to the use of the bed-and-furrow shaper due to the lack of knowledge. Some people cultivated in the *wtter* (wet) field;
- ✓ The late sowing is also the cause of the poor germination, as mostly the sowing was done in the month of June, a time when the soil is already too warm to have a good germination; and
- ✓ Shortage of the canal water was another cause of poor germination. During *Kharif* 1998, the distributary was being lined and breaches often occurred, which caused poor water supply when it was needed.

3.5.1.1 Some Negative Comments

- Frequency of irrigation increases, therefore, it is difficult to mange the frequent irrigation events at the initial stage of the crop development because of an unreliable water supply in a rotational irrigation system;

- The beds become hard, so that, most probably, at the end of the season, it will be difficult to plough the beds; and
- The furrows were damaged in some fields due to heavy rain, the plants fell down, and the crop suffered.

3.5.1.2 Some Positive Comments

- Crop is comparatively better when compared to flat sowing in basins;
- It is easy to drain out the rainwater;
- Crop remains safer, despite the over-irrigation;
- More productive if early sowing, as it is a waterlogged and saline area (SS3);
- The technology is good and some farmers mentioned that they would manage their own bed-and-furrow shaper for the next year; and
- Good results, despite the less fertile soil.

3.5.1.3 Remarks from outside the Hakra 4-R Distributary Command Area

- Farmers from the Hakra 6-R Distributary commented that despite the late sowing, the crop is comparatively better than flat sowing;
- Farmers from Bhukrana commented that it is a very nice technique and is hoping for a good product due to this. Had the bed-and-furrow shaper been made available at a proper time, he would have applied the technique in his other fields as well; and
- Farmers at the Hakra 3-R Distributary are satisfied with the technology and intend to continue this technique in the future as well.

3.6. FARMER DAYS

3.6.1.1 First Farmer Day

The WUF and the Social Organisation Field Team (IIMI) at Haroonabad arranged a farmer-day at Chak 57/4-R on a 5-acres plot sown by WUF's General Secretary, on September 16, 1998. The arrangements were partially sponsored by Engro Chemicals (Pvt.) Limited Pakistan and Dewoo (Pvt.) Limited, Pakistan. The social organisers arranged most of the logistics. Around 150 farmers from various Sub Systems and other distributaries were invited. However, the actual participation was over 180. This included farmers from the bed-and-furrow experimental sites at Hasilpur, Bahadarwah Minor, Hakra 4-R Distributary, and Hakra 6-R Distributary. The Water Management Specialist and Project Director (OFWM) also participated.

Various farm implements, including the bed-and-furrow shaper, hoeing device and laser-levelling device, was placed next to the seating arrangement. This provided an opportunity for the participants to see the various implements.

The farmer-day comprised presentations from various persons about the organisation and the experiment. Different farmers shared their experiences about cultivation of cotton (and wheat) on beds-and-furrows. Most of the speakers regarded this technology suitable for waterlogged and saline soils. The sponsor's presentations were focussed on the requirement of fertilisers and pesticides for the cotton and other crops. Several farmers inquired different things about the pest control. At the end, the farmers visited the field and learned how to identify the pests, especially the American Bollworm.

3.6.1.2 Second Farmer Day

The WUO of Subsystem 3 arranged another farmer-day on September 30, 1998 at Chak 66/4-R on a 2 acre plot sown by one of the WUO members. Engro Chemicals (Pvt.) sponsored the arrangements. There were 95 participants at the farmer day. The program lasted for about 2.5 hours.

The farmer-day comprised presentations from various persons about the IIMI, farmer's organisation, and the experiment. Different farmers shared their experiences about cultivation of cotton with the bed-and-furrow irrigation method. The sponsor presentations were focussed on the requirement of fertilisers and soil analysis. There was also presentation from DOW Company, which focussed on pesticides for the cotton and other crops. Several farmers inquired about different matters pertaining to the pest control. At the end, the farmers visited the field and learned how to identify the pests, especially the American Bollworm and white fly.

3.6.1.3 Future Planing Of The WUF Discussed During The Season

The WUF is planing to introduce the bed-and-furrow irrigation method on a larger scale. This year some constraints occurred like the late delivery of the implements, resultantly, mostly the farmers could not avail this opportunity. WUF is also planing to raise the rent of the implements. Some farmers have given the suggestion that the rate should be at least Rs.100/acre instead of Rs. 50/acre. The WUF have showed dissatisfaction over the role of bed-and-furrow committee. Perhaps this was the reason that they changed the body of the committee. Now the committee is comprised of five members instead of ten members. The WUF has also complained over the operation of laser leveling device, as mostly, it remained under the control of OFWM's staff. Now, it has totally come under the control of one of the executive members, the Information Secretary in the WUF. All these decisions were made in the federation general body meeting. The federation had also decided that in future the implements will be sent to each Sub System, for a period proportionate to the command area of that particular zone. The WUF also decided in the meeting that the implements would not be sent beyond the command area of 4-R Distributary.

4. QUANTITATIVE INTERPRETATION OF IRRIGATION AND CULTURAL PRACTICES

4.1. Time Wise Presentation Of The Irrigation And Cultural Practices

During the *kharif* season, all the activities pertaining to irrigation and cultural practices were retrieved from the farmers and noted. Figure 4.1 presents a summary of the various irrigation and cultural practice, whereby the range (i.e. horizontal line) of each activity implies the earliest and latest performance of the particular activity.

The land preparation activities are concentrated from half May till the end of the month and around mid May for the bed-and-furrow and basin fields, respectively. The sowing of cotton is concentrated within the last ten days of May and the last week of May, lasting till the first days of June for the bed-and-furrow and basin fields, respectively. On an average farmers starting sowing for the bed-and-furrow field four days earlier that for the sample basin fields. Overall, hoeing activities, the application of fertilizers (mainly Urea and DAP), and the application of pesticide sprays commenced earlier for the bed-and-furrow fields. Inter-culturing, - only reported by 5 and 6 farmers for the basin and bed-and-furrow fields, respectively-, started later for the bed-and-furrow fields. The picking activities cover basically the same period for the basin as well as bed-and-furrow fields.

With respect to the irrigation practices, it can be derived from Figure 4.1 that for the bed-and-furrow fields the number of irrigation applications is higher as compared to the basin irrigation method. The quantification of the impact of the various differences in irrigation and cultural practices for the bed-and-furrow and basin irrigation methods are presented in the following paragraphs of this chapter.

4.2. Irrigation Intervals And Applications

With respect to the number of irrigation applications, the *rouni* (= soaking irrigation), applied for basins only, is included in the analysis, whereas the *rouni* for wheat (*rabi* crop) has been excluded from analysis. The latter is considered as an irrigation application not beneficial or required for the cotton crop, but solely contributes to the preparation phase for wheat or other *rabi* crop. It is a general practice by farmers to apply this particular *rouni*, while the cotton crop is still not harvested due to time shortage between the crop seasons. Farmers prefer to commence wheat cultivation as early as possible, having a favorable temperature, since this benefits the crop production. Further, farmers face problems when staring wheat cultivation in January, since there will be water shortage due to the annual canal closure for maintenance purposes.

With respect to the irrigation interval, this analysis is based on determining the number of days between the different successive irrigation events. Table 4.1 presents the results of the analysis on irrigation interval and the number of irrigation applications.

It can be derived from the table that the number of irrigation applications for the bed-and-furrow irrigation method ranges between 4 and 10, with an average of 7, whereas the number of irrigation applications for the basin irrigation method, ranges between 2and 7, with an average of 5 irrigation applications. This increasing tendency of irrigation applications has been of great concern to the farmers, who faced difficulties in coping with the frequent water demand of the cotton crop sown in the beds-and-furrows fields, due to the warabandi system, and the often unavailability of water in the distributary. Further, farmers give also a priority to the fodder crop when it comes to irrigation application.

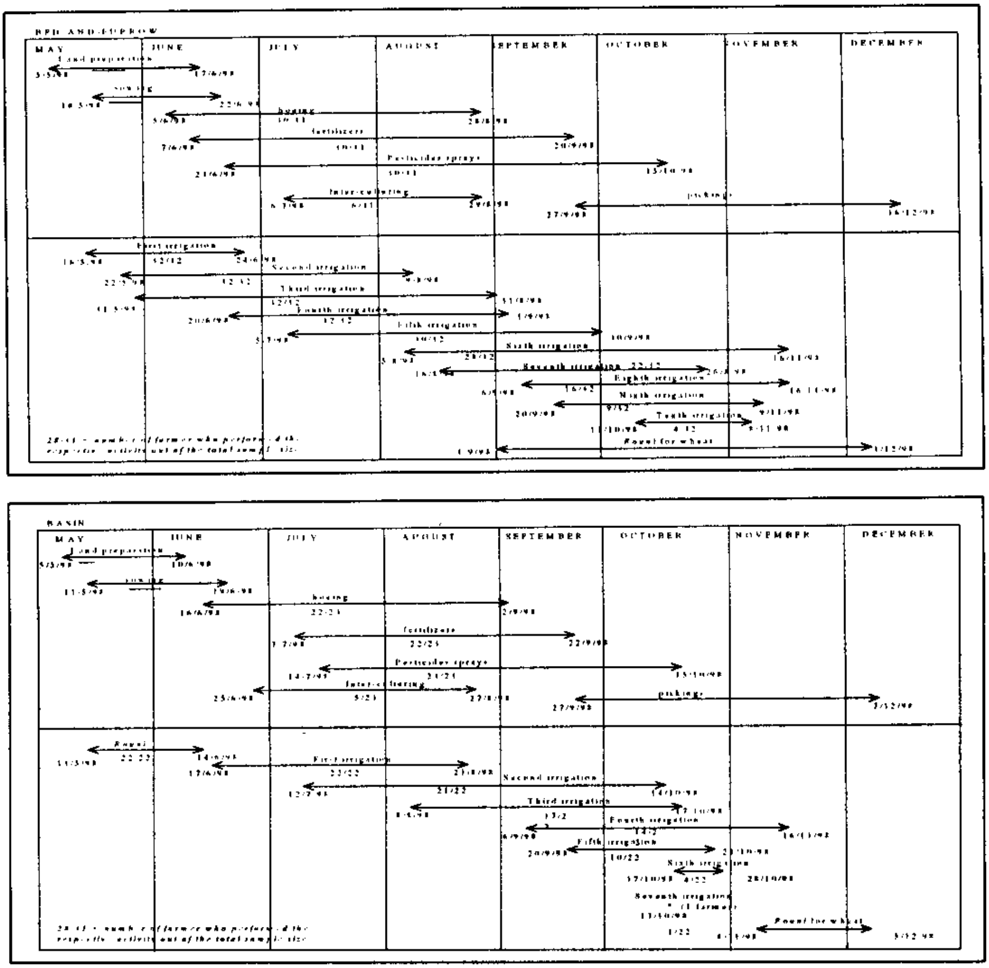

Figure 4.1. Time-wise presentation of the irrigation and cultural practices for the bed-and-furrow and basin irrigation method (Kharif 1998).

Table 4.1. Irrigation intervals and the number of irrigation applications for the bed-and-furrow and basin fields (Kharif 1998).

	Bed-and-furrow									Number of Applications
Interval	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	
Average:	10	21	27	23	26	18	22	29	18	7
Sample size:	n = 32	n = 32	n = 32	n = 30	n = 28	n = 21	n = 15	n = 9	n = 4	n = 32
Standard deviation:	7.5	11.6	14.1	10.9	13.1	8.8	12.3	10.4	4.0	2
Minimum value:	1	7	7	7	7	7	7	14	14	4
Maximum value:	46	64	62	56	55	40	42	42	21	10
	Basin									Number of Applications
Interval	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	
Average:	57	34	24	33	29	23	-	-	-	5
Sample size:	n = 23	n = 21	n = 17	n = 12	n = 6	n = 3	-	-	-	n = 21
Standard deviation:	24.2	12.6	13.0	13.2	10.4	8.1	-	-	-	2
Minimum value:	25	7	3	14	14	14	-	-	-	2
Maximum value:	105	56	49	61	43	28	-	-	-	7

Overall, the strategy of smaller irrigation intervals is applied to the bed-and-furrow irrigation method. The first irrigation event is applied right after sowing, followed, - in the case of mostly all the farmers -, by a second irrigation application after either one or two weeks. For the basin irrigation method, the first irrigation after sowing occurs mostly after 2 to 8 weeks after the rouni. For the following irrigation events an interval of about 3 to 5 weeks is maintained. The frequency for the later irrigation events for the bed-and-furrow irrigation method shows a similar tendency, however, those farmers who applied up to 8 to 10 irrigation events, maintained a smaller interval for these irrigation events.

4.3. AN ANALYSIS OF THE IRRIGATION DURATION AND AMOUNT OF WATER APPLIED

Based on the irrigation duration for each irrigation event, and the daily mogha discharge calculations, the water application depth per irrigation event and for the entire season has been calculated. In order to determine the conveyance losses, the total distance from mogha to field inlet was measured. The conveyance losses were calculated after Barral (1994), who in his report elaborates conveyance losses for a particular watercourse configuration, soil type and discharge.

Table 4.2 presents the analysis regarding the irrigation duration and irrigation application depths per irrigation event and accumulated for the entire irrigation season. It can be derived form the table that for an irrigation event the average irrigation duration is considerably less per acre for the bed-and-furrow irrigation method in comparison with the basin irrigation method. On a contrary, however, the average total irrigation duration per acre for the entire season is 36.6 percent more for the bed-and-furrow irrigation method, and which is undoubtedly related to the larger number of irrigation applications. The time saving per irrigation event, however, is beneficial to the farmers, since it allows more fields to be irrigated per warabandi turn.

A similar tendency is reflected in the irrigation application depth. Less water is applied during an irrigation event for the bed-and-furrow irrigation method, which can be assumed to enhance the irrigation application efficiency. However, detailed analysis is required to confirm this. Earlier analysis[5] revealed that light but frequent irrigation events may lead to under-irrigation per irrigation event. On an average the total water application depth for the entire season is 15.5 percent more. Figure 4.2 presents the average total application depth for selected farmers for the bed-and-furrow and basin field. As illustration, Table 4.2 includes for the analysis on irrigation duration and application depth for the basin irrigation a segregation between having the rouni included in and excluded from the analysis, respectively. The significant difference in irrigation duration and irrigation application depth reflect the major share of the rouni irrigation in the total duration and water application depth.

The evaluation on the irrigation requirement (by using CROPWAT) and the water application depth reveals that for both the irrigation methods, season-wise the irrigation applications have been deficit and the irrigation requirements are not fulfilled. An irrigation requirement of 743.04 mm is calculated for the period May 19 (average sowing date) to November 5 (average last applied irrigation). The average irrigation application depth is 563 mm and 436 mm for the bed-and-furrow method and basin irrigation method, respectively, which results in a season-wise deficit of 24 percent for the bed-and-furrow irrigation method and 41 percent for the basin irrigation method. There is a significant difference in deficit between both the methods, hence it can be hypothesized that when the irrigation requirement is attempted to be fulfilled, less significant difference in total water use will appear and, hence, perhaps more favorable (i.e. less total water use) for the bed-and-furrow irrigation method.

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[5] These observations are described in a field report, based on the monitoring of bed-and-furrow sample fields during Kharif 1997, for selected sample farmers, situated in the command area of the Fordwah Distribuary. The results are presented in Kalwij et. al. 1998).

4.4. TIME ALLOCATION TO IRRIGATION PRACTICES

Section 4.3 discussed the irrigation duration for the bed-and-furrow and basin irrigation methods, and which reflect the time spent by the farmer for labor on irrigation. Related to irrigation practices is the usage of tubewell water, used to supplement the canal water supply. During Kharif 1998, 9 sample farmers used tubewell water for the bed-and-furrow field, of which 5 farmers own a tubewell. Out of the 9 farmers, only 2 farmers also applied tubewell water to the basin sample fields. A total of 1540 hours of tubewell operation were applied to the bed-and-furrow fields whereas 460 hours of tubewell operation were spent on the basin field, with average values of 48.13 and 20 hours, respectively. The average time spent on the irrigation applications (i.e. 913.6 and 699.3 minutes for the bed-and-furrow and basin irrigation methods, respectively), an increase of 30.6 percent of time spent on irrigation practices results from using the bed-and-furrow irrigation method.

Table 4.2. Average irrigation duration and irrigation application depth for selected basin and bed-and-furrow fields (Kharif 1998).

Bed-and-Furrow (Irrigation duration in minutes per acre)												Total Duration
Event:	1	2	3	4	5	6	7	8	9	10		
Average:	113.3	99.5	120.6	112.6	113.6	104.9	107.7	118.7	144.1	167.5		933.3
Sample size:	n = 18	n = 18	n = 18	n = 18	n = 18	n = 18	n = 15	n = 13	n = 7	n = 4		n = 18
Standard Deviation:	50.3	48.9	51.5	47.9	57.6	53.8	56.8	61.6	34.9	15.0		494.7
Minimum value:	40	30	45	40	30	24.5	25.5	40	93	150		310
Maximum value:	180	180	170	160	180	180	180	170	180	180		1750
Basin (Irrigation duration in minutes per acre)											Tot. Duration With Rouni	Tot. Duration Rouni excl.
Event:	Rouni	1	2	3	4	5	6					
Average:	158.8	130.3	132.7	141.3	140.3	186.7	150.0				683.0	524.1
Sample size:	n = 13	n = 13	n = 13	n = 10	n = 8	n = 3	n = 2				n = 13	n = 13
Standard Deviation:	65.5	67.2	65.1	58.4	72.9	50.3	42.4				403.4	348.6
Minimum value:	75	15	70	60	32	140	120				310	208
Maximum value:	270	240	240	240	250	240	180				1480	1210
Bed-and-Furrow (Irrigation application depth in mm)												Total Depth
Event:	1	2	3	4	5	6	7	8	9	10		
Average:	67.5	62.8	78.2	64.8	74.2	62.5	72.2	72.9	67.5	125.1		544.2
Sample size:	n = 16	n = 16	n = 16	n = 15	n = 16	n = 15	n = 13	n = 11	n = 5	n = 3		n = 12
Standard Deviation:	32.9	29.0	35.4	20.0	42.1	41.8	42.4	42.5	26.5	15.2		265.3
Minimum value:	41.7	31.3	37.2	31.3	14.0	23.8	20.6	29.1	46.1	107.6		316.9
Maximum value:	149.9	130.5	160.3	98.7	156.5	150.5	154.8	147.9	114.3	134.9		1324.8
Basin (Irrigation application depth in mm)											Total Depth With Rouni	Total Depth Rouni excl.
Event:	Rouni	1	2	3	4	5	6					
Average:	103.8	89.0	110.1	120.2	195.4	423.3	582.7				475.1	378.9
Sample size:	n = 12	n = 12	n = 11	n = 9	n = 6	n = 3	n = 2				n = 11	n = 11
Standard Deviation:	75.2	71.4	69.2	67.1	74.4	76.1	64.1				252.6	226.7
Minimum value:	49.2	13.4	45.0	31.5	22.2	78.1	84.0				264.5	204.5
Maximum value:	158.0	159.6	228.5	171.3	127.0	144.6	117.4				979.4	821.4

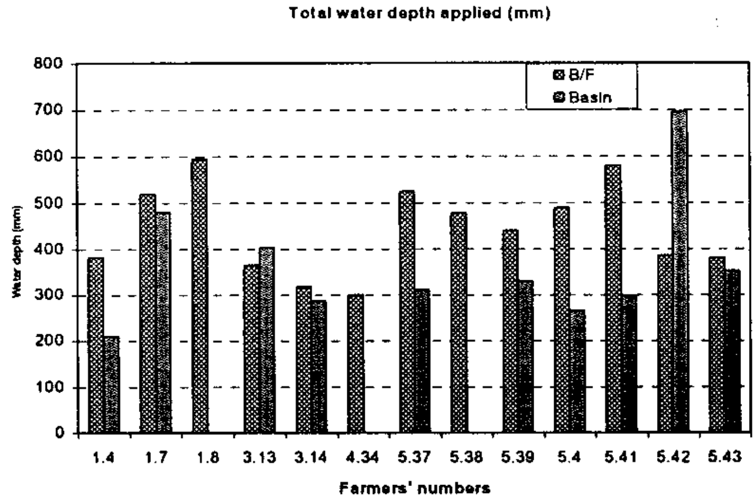


Figure 4.2. Total irrigation application depth for the bed-and-furrow and basin irrigation methods (Kharif 1998).

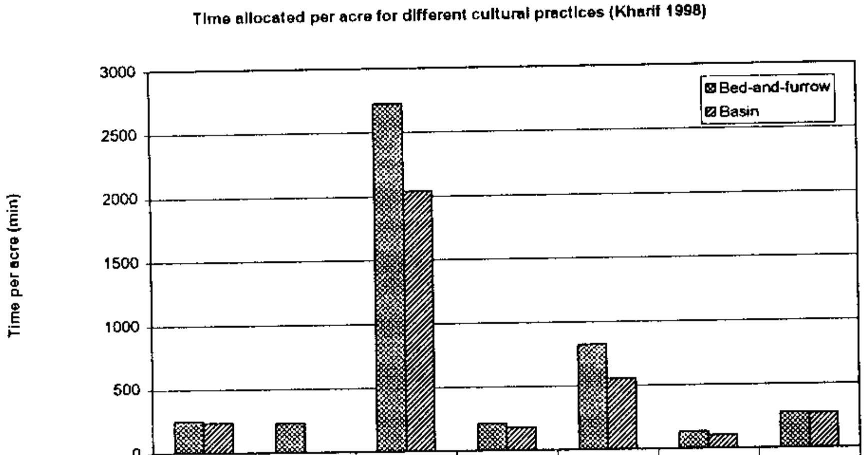
4.5. TIME ALLOCATION TO CULTURAL PRACTICES

Table 4.3 summarizes the average value of the total time allocated for specific cultural practices-related activities. It should be noted that for each activity the analysis pertains to the farmers who performed that specific activity. In other words, if a farmer has not included a specific activity in his cultural practices, the farmer is excluded from analysis (i.e. sample size). The results are graphically presented in Figure 4.3. Information regarding the spent time on pickings and harvesting is excluded from analysis due to incompleteness of the concerned data.

Table 4.3. Average time allocation for different activities pertaining to cultural practices (Kharif 1998).

Bed-and-furrow Time input per acre	Land Preparation	Laser leveling	Hoeing	Inter-culture	Thinning	Fertilizer	Pesticides
Average:	250.9	233.2	2724.8	213.2	824.0	132.3	275.6
Sample size:	n = 29	n = 7	n = 27	n = 17	n = 10	n = 28	n = 29
Standard deviation:	123.3	254.1	1726.4	189.0	706.8	90.0	197.5
Min. value:	50	60	100	60	180	30	60
Max. value:	450	660	6080	720	1200	410	705
Basin Time input per acre	Land Preparation		Hoeing	Inter-culture	Thinning	Fertilizer	Pesticides
Average:	236.1		2037.5	176.3	554.3	102.0	271.6
Sample size:	n = 19		n = 18	n = 12	n = 7	n = 18	n = 19
Standard deviation:	115.1		1519.1	133.4	312.1	46.1	112.0
Min. value:	115		50	60	180	28	75
Max. value:	450		4800	480	960	180	450

Although, for activities such as land preparation, inter-culturing, and the application of fertilizers and chemicals not much time difference can be concluded, yet for activities, like hoeing and thinning, respectively, a clear time difference can be concluded, which concerns an increasing tendency in time allocation to hoeing and thinning in the case of the bed-and-furrow irrigation method, in comparison to the basin irrigation method. A main reason for this increasing tendency in time allocated to hoeing for the bed-and-furrow irrigation method is that the regular practice of hoeing, - use of a tractor and plough-, could not be applied due to the furrow configuration in the field. Although, a hoeing machine was available (though late), yet this was used by a few farmers only, due to the reasons explained in Section 3.7. Consequently, the hoeing was done manually, which was very time and labor intensive. More thinning occurred, most probably, due to a denser sowing by the sowing device of the bed-and-furrow shaper. In general, farmers are not inclined towards the use of weedicide, which preferably has to be applied after the first irrigation event. Weedicide reduces the number of dense and tough weed growth. Seven farmers mentioned during the final interview at the end of the season that they used weedicide, however, quantitative information was not available. It assumed that when farmers use weedicide, the time spent on hoeing for the bed-and-furrow irrigation method will reduce, though it will involve additional costs as well. In addition, it can be assumed that, when farmers are using the hoeing device in the future, hoeing activities will become less time consuming. Several farmers also performed gap filling activities (sowing seeds manually on open spots) for the bed-and-furrow irrigation method. Quantitative information, however, was not available.



	preparation land	leveling laser	hoeing	culture inter-	thinning	fertilizer	pesticides
Bed-and-furrow	251	233	2725	213	824	132	276
Basin	236		2038	176	554	102	272

Cultural practices

Figure 4.3. Average time allocation for different activities pertaining to cultural practices (Kharif 1998).

The total average time spend of the sample farmers on cultural practices is for the bed-and-furrow and basin irrigation method (i.e. the sample fields), 3787 and 2850.1 minutes per acre, respectively. Adding the time spend on irrigation practices, 913.6 and 699.3 minutes per acre for the bed-and-furrow and basin fields, respectively, results to a total average time spend on the bed-and-furrow and basin irrigation method of 4700.6 and 3549.3 minutes per acre, respectively, resulting into an increase in time of 32.44% for the bed-and-furrow irrigation method (based on the accumulation of the average values for irrigation and cultural practices. Figure 4.4 presents the average spent time on irrigation and cultural practices for the bed-and-furrow and basin irrigation method, respectively.

4.6. Relating Irrigation Practices To Landholding Size And Physical Factors

The actual irrigation practices, irrigation frequency and the average application depth are related in this section to the landholding size, soil physical and chemical characteristics, water table depth and actual water duty, which has a main objective to determine whether clear relationships between irrigation practices and the defined factors exist.

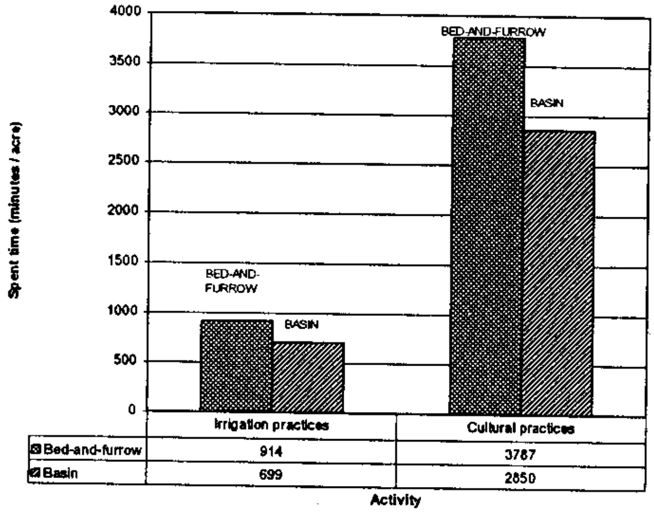


Figure 4.4. Total time spend on irrigation and cultural practices for the bed-and-furrow and basin irrigation method.

4.7. IRRIGATION PRACTICES AND LANDHOLDING SIZE

Figure 4.5 presents graphically the difference ranges in landholding size for which the number of irrigation applications, for the bed-and-furrow and basin irrigation methods, are plotted. It can be derived from the figure that no clear relationship can be established between the number of irrigation applications and the land holding size. In other words, most of the farmers, regardless the size of the owned land, are adopting more or less the same irrigation strategies with respect to irrigation frequency. The farmers with the largest landholding size, however, show the tendency of less difference in the irrigation frequency between the bed-and-furrow and basin irrigation methods.

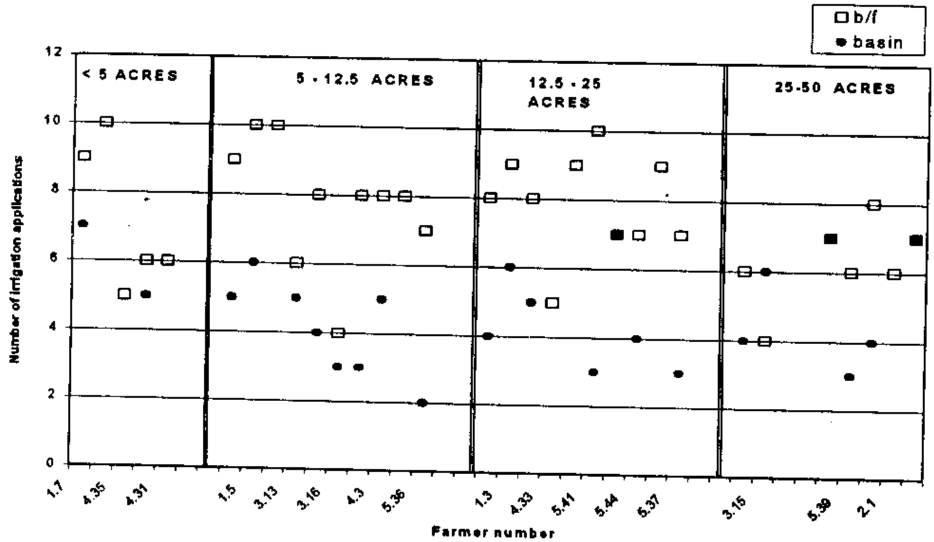


Figure 4.5. Irrigation practices in relation to the landholding size (owned land only).

4.7.1. Irrigation Practices and Soil Characteristics

The Figures 4.6 and 4.7 present soil physical and chemical characteristics of the sample fields (bed-and-furrow and basin, respectively) in relation to the number of irrigation applications and total water application depth. With respect to soil type, not a clear relationship could be defined, based on the existing data set. With respect to soil quality, for the saline sodic fields, it can be observed that the average application depth per irrigation event is relatively higher for the bed-and-furrow irrigation method, a tendency which is also reflected in the total volume of water applied (Table 4.4). For the basin irrigation method, however, for both the non-saline sodic and saline sodic soils, the average water application depth is higher as compared to the non-saline non-sodic and saline non-sodic. It appears that more water is applied to fields subjected to sodicity problems.

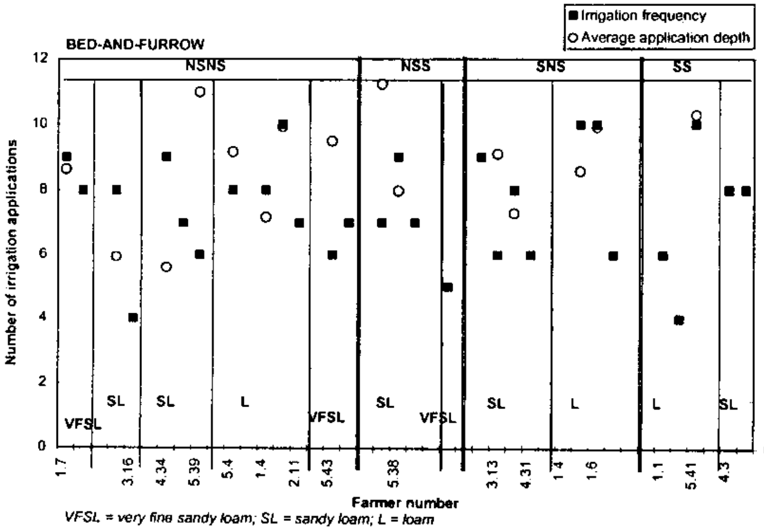


Figure 4.6. Irrigation practices in relation to soil type and quality for the bed-and-furrow irrigation method.

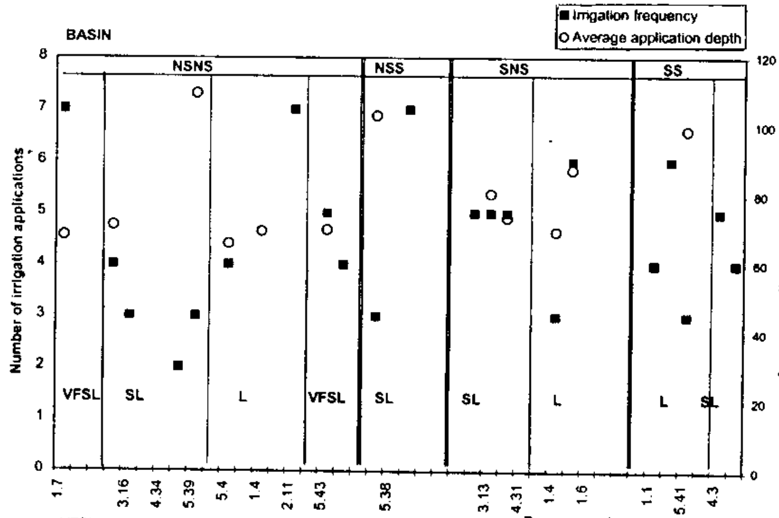


Figure 4.7. Irrigation practices in relation to soil type and quality for the basin irrigation method.

Table 4.4. Irrigation practices in relation to soil quality.

	NSNS	NSS	SNS	SS
Bed-and-furrow				
Avg. frequency	7.5	7	7.9	7.2
Standard deviation	1.6	1.6	1.9	2.3
Sample size	n = 13	n = 4	n = 7	n = 5
Avg. application depth (mm)	55.8	61.1	58.2	68.7
Standard deviation	12.9	12	7.3	-
Sample size	n = 8	n = 2	n = 4	n = 1
Avg. total volume of water (m^3)	1764.8	1873.4	1512.4	2781.2
Standard deviation	483.3	286.3	53.2	-
Sample size	n = 8	n = 2	n = 2	n = 0
Basin				
Avg. frequency	4.3	5	4.8	4.4
Standard deviation	1.7	2.8	1.1	1.1
Sample size	n = 9	n = 2	n = 5	n = 5
Avg. application depth (mm)	75.9	101.3	77.9	99.1
Standard deviation	16.6	2.8	7.9	-
Sample size	n = 6	n = 1	n = 4	n = 1
Avg. total volume of water (m^3)	1383.6	2033.6	1239.1	-
Standard deviation	339.9	1102.2	556.5	-
Sample size	n = 5	n = 1	n = 2	n = 0

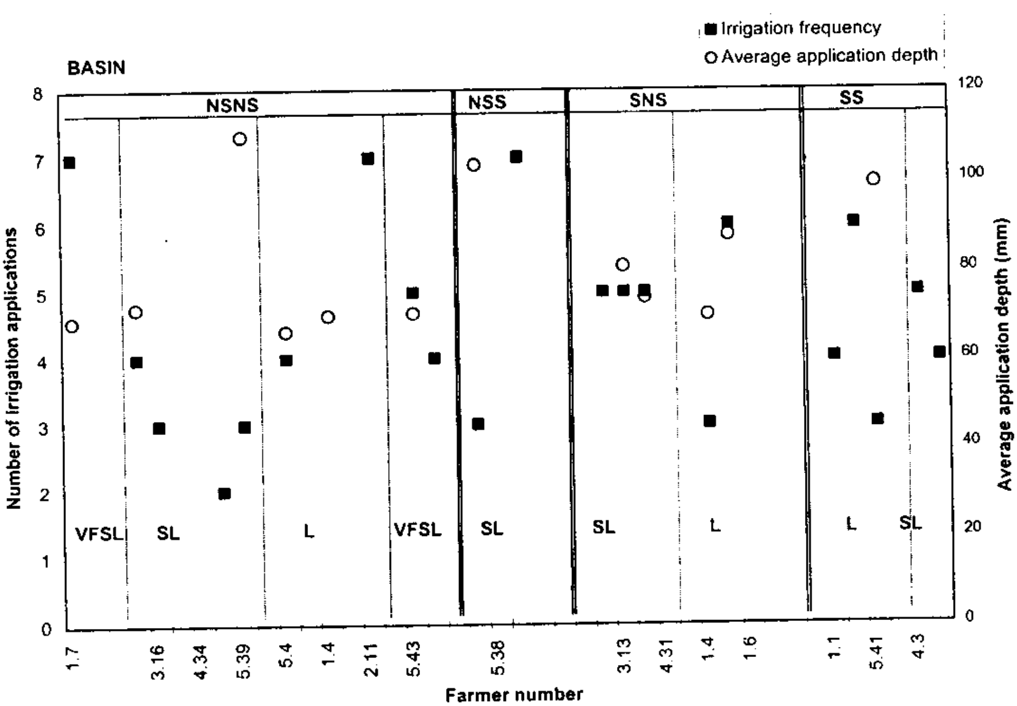


Figure 4.8. Irrigation practices in relation to soil type and quality for the basin irrigation method.

4.8. IRRIGATION PRACTICES AND TUBEWELL WATER USE

Several farmers applied tubewell water to the sample fields, of which 8 farmers applied tubewell water to the bed-and-furrow fields (with an average of 2.75 times) and 7 farmers to the basin fields (an average of 2,14 times), resulting into 1540 hours and 460 hours of tubewell operation for the bed-and-furrow and basin fields, respectively. In most of the instances, canal water has been used in conjunction with the canal water. The bed-and-furrow irrigation method influenced the irrigation practices by having farmers using more tubewell water as compared to the basin irrigation method. This relates to the more frequent irrigation applications for the bed-and-furrow irrigation method.

Another observation to be added, with reference to section 2.5 (Table 2.9) is the occurrence of a relationship between tubewell water use and actual water duty. Analysis shows that RD-337730 (SS5) had a very low actual water duty (average over the season as well as monthly). Farmers in this watercourse, however, were the most frequent users of tubewell water. It appears that these farmers complemented the low canal water availability with tubewell water use.

4.8.1. The Effect of the Laser-Leveling Technique on Irrigation Duration and Water Use

Several farmers have laser leveled the bed-and-furrow sample fields. Table 4.4 presents the farmers who used the laser-leveling device in relation to average values for farmers who did not use the laser-leveling device for the bed-and-furrow fields.

It can be noted that there is a significant difference in irrigation practices performance. These farmers who have laser-leveled the field show the tendency of less irrigation water applications per irrigation event. The total water application depth by 54.4% and the average water application depth per irrigation event reduces by 32.4%. It can be stated that on an average that less water is used when the laser-leveling is undertaken. The leveled and smooth field conditions have an impact on the total water use, resulting in a tangible reduction.

Table 4.5. Results pertaining to irrigation practices segregated for bed-and-furrow fields laser-leveled and not laser-leveled.

Farmer number	Irrigation frequency	Total Irrigation duration (min / acre)	Total water application depth (mm)	Average water application depth per event (mm)
3.14	8	518.4	316.9	39.6
3.15	4			
5.37	7	976.2	524.4	74.9
5.38	9	723.9	478.8	53.2
5.42	7	663.6	385.6	55.1
5.43	6	570	379.6	63.3
5.44	7			
Average (ll)	6.86	690.42	417.06	57.22
Sample size	n = 7	n = 5	n = 5	n = 5
Standard deviation	1.57	178.61	83.30	13.04
Average non-users of laser-leveling (nll)	7.56	1264.98	915.36	84.65
Ratio (ll/nll)	0.91	0.55	0.46	0.68
Reduction (%)	9.3	45.4	54.4	32.4

5. PRODUCTION DATA AND WATER USE EFFICIENCY

5.1. PRODUCTION DATA

The collection of the yield data occurred during the pickings activities, whereby most of the farmers conduct three to four pickings. Due to rainfall during this period, several farmers picked the open cotton bolls and kept them near the house for drying in the sun. Later on, the cotton was taken from the boll. Table 5.1 presents the yield data, converted into maund per acre for the sample bed-and-furrow and basin field along with the farm production average. The share in yield that went to the pickers is excluded from analysis. Sub-system wise there is a difference in crop production; it appears that overall the farmers from SS5 had a better yield. In comparing the crop production of the bed-and-furrow fields with the basin fields it can be concluded that the bed-and-furrow fields were on an average better, resulting into a 15% yield increase when using the bed-and-furrow irrigation method, and is higher than the average farm production. Cotton production data specified for each sample farmer is presented in Appendix B.

Overall, however, the yield was very low, partly due to an earlier start of the summer. May 1998 was exceptionally warm, which resulted in an earlier heating up of the soil, which has a negative effect on the seed germination. In addition, on one hand a low rainfall and on the other hand an unexpected rainfall and several crop diseases affected the crop production. Uncertainties with respect to crop production are discussed in section 5.4.

Table 5.1. Cotton production data for the sample farmers (Kharif 1998).

Cotton yield	Bed-and-furrow maunds / acre	Basin maunds / acre	Farm production maunds / acre
Sub System 1	9.6	6	9.5
Sample size	n = 9	n = 7	n = 9
Sub System 2	7	9.5	4
Sample size	n = 2	n = 1	n = 2
Sub System 3	8.0	9.7	7.3
Sample size	n = 7	n = 4	n = 7
Sub System 4	8.3	3.9	6.3
Sample size	n = 6	n = 3	n = 6
Sub System 5	11.7	11.6	10.9
Sample size	n = 10	n = 8	n = 10
Avg. sample farmers	9.48	8.1	8.24
Sample size	n = 34	n = 24	n = 33
Standard deviation	5.46	5.43	3.88
Minimum value	1.3	1	2.4
Maximum value	28	20	17.3

Figure 5.1 presents the production data graphically, segregated in production for the bed-and-furrow and basin field (production in maund per acre). The lower positioned horizontal line presents the average farm level cotton production (8.4 maunds/acre), whereas the upper positioned horizontal line indicates the average production for Bahawalnagar District, converted into maund / acre, based on three cotton seasons, i.e. from 1992 to 1994 (see also the next paragraph).

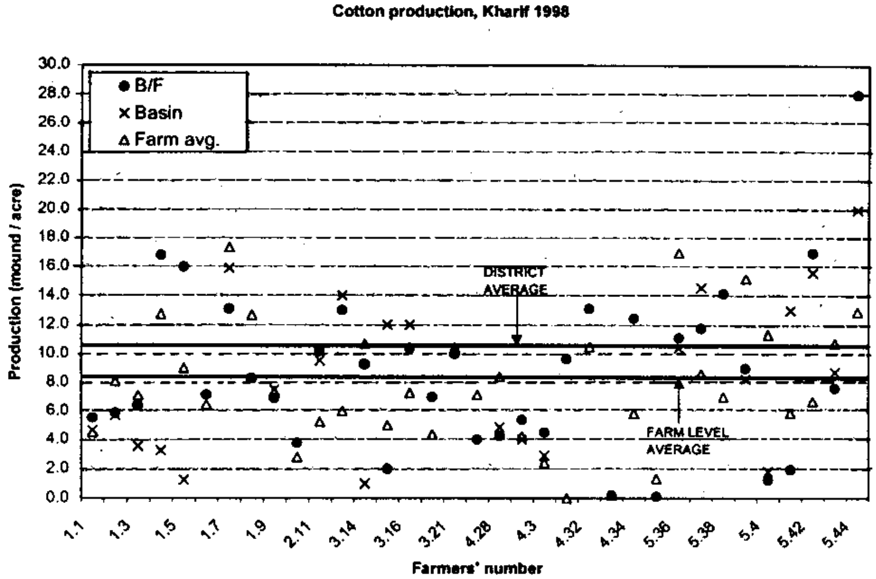


Figure 5.1. Cotton production for the bed-and-furrow and basin sample fields (Kharif 1998).

Based on crop area production data on cotton yield in Bales[6] per total area cultivated with cotton (hectares), average yield for three years has been derived (maund / acre) in order to provide an indication of the production level for the sample farmers. The sample farmers fall under the Bahawalnagar District. Table 5.4 presents the cotton production for the Bahawalnagar and Vehari Districts (Vehari District is solely mentioned as illustration) for three successive cotton seasons.

The average cotton production figures as calculated for the sample farmers lies below the presented figures in Table 5.2, though the difference is not significant.

Table 5.2. District-wise cotton production data.

Bahawalnagar District			
	1992-93	1993-94	1994-95
Bales/ ha (a)	3.5	2.9	3.2
Bales/ acre	0.87	0.72	0.81
maund/ acre	11.35	9.34	10.50
Vehari Distrct			
Bales/ ha (a)	3.4	3.2	3.4
Bales/ acre	0.84	0.81	0.86
maund/ acre	10.91	10.53	11.14

(a): Source: Ministry of Food, Agriculture and Livestock (1996).

5.2. Assessing The Differences In Plant Density And Crop Development

In order to determine whether the average plant density may have an influence on the average crop production figures for the bed-and-furrow and basin irrigation methods, the plant density has been determined, based on the counting of plants per square meter, whereby 9 samples (each sample covering 1 square meter) were taken at random in the sample fields. The average results are presented in Table 5.3. The results reveal that on an average 5% more plants were counted for the

[6] 1 Bale ≈ 13 maunds.

bed-and-furrow field as compared to the basin fields. Although, the difference may have influenced the production results, yet, there is insufficient evidence to support this hypothesis for the experiment.

Table 5.3. Plant density for the bed-and-furrow and basin fields (Kharif 1998).

	Bed-and-furrow	Basin	Bed-and-furrow	Basin
	Avg. number of Plants /m2	Avg. number of plants /m2	Avg. number of plants /acre	Avg. number of plants /acre
Average:	6.1	5.8	24761	23613
Sample size:	n =31	n = 23	n = 31	n = 23
Standard deviation:	2.2	2.1	8731.9	8474.4
Minimum value:	3	3	12141	12141
Maximum value:	10.4	9.9	42089	40020

Overall the crop development, i.e. the start of the different stages was faster for the basin sample fields. On an average, however, the total crop growth duration till the last picking was about the same. The average sowing time was for the bed-and-furrow field May 25 (ranging between May 18 and June 21). For the basin fields, the average sowing time was 6 days later, May 25 (ranging from May 17 to June 19). The last picking took place 181 days after sowing, whereas it was for the bed-and-furrow field 184 days after sowing. Table 5.4 summarized collected information regarding the crop development.

Table 5.4. Crop development in number of days after sowing for the bed-and-furrow and basin fields (Kharif 1998).

Bed-and-furrow	First flowers	Boll appearance	Boll opening	First picking	Last picking
Average:	89.1	91.6	108.3	148.3	184.2
Sample size:	n = 18	n = 18	n = 17	n = 18	n = 18
Standard deviation:	9	6.7	11.1	10.8	9.6
Minimum value:	61	72	90	131	159
Maximum value:	95	105	128	165	202
Basin	First flowers	Boll appearance	Boll opening	First picking	Last picking
Average:	63.5	65.8	80	145.2	180.5
Sample size:	n = 15	n = 15	n = 14	n = 15	n = 15
Standard deviation:	9.8	8.5	11	14.2	13.1
Minimum value:	42	43	71	120	153
Maximum value:	72	75	108	171	207

5.3. WATER USE EFFICIENCY

The water use efficiency (WUE), an indicator for water productivity, and defined as the ratio of the production per unit area and the total amount of water applied to a unit area (kg/m^3). The WUE is calculated for those sample farmers, for which irrigation data was complete as well as yield data. Table 5.5 presents the analyzed WUE.

The average WUE is about the same for the bed-and-furrow and the basin irrigation method, with values of 0.251 and 0.254, respectively, resulting in only a 1.2 percent difference. Based on previous studies (Iqbal 1997, also mentioned in Kalwij 1998), it was expected that the WUE would be clearly higher for the bed-and-furrow irrigation method. However, earlier analysis in this report, already show a clearly higher total water use for the bed-and-furrow irrigation method, whereas the yield was on an average higher when using the bed-and-furrow irrigation method. A clear comparison, however, can only be made when the yield is representative, i.e. not severely affected by different factors.

Table 5.5. Water use efficiency for the bed-and-furrow and basin irrigation methods (Kharif 1998).

	Bed-and-Furrow			Basin		
Farmer #	Volume of water applied m^3	Production kg / acre	WUE kg / m3	Volume of water applied m^3	Production kg / acre	WUE kg / m3
1.4	1550.0	672	0.43	845.6	130	0.15
1.7	2099.3	524	0.25	1938.7	636	0.33
1.8	2680.5	332	0.12			
3.13	1474.8	520	0.35	1632.6	560	0.34
3.14	1282.3	371.5	0.29	1156.4	40	0.03
4.34	1210.8	498	0.41			
5.37	2122.2	470	0.22	1254.4	583	0.46
5.38	1937.6	567	0.29			
5.39	1780.2	360	0.20	1332.0	330.7	0.25
5.40	1979.2	50	0.03	1070.2	72	0.07
5.41	2781.2	78	0.03	1203.0	520	0.43
5.42	1560.4	680	0.44	2812.8	624	0.22
5.43	1536.2	305	0.20	1420.6	350	0.25
Average	1845.7	417.5	0.251	1466.6	384.6	0.254
Sample size	n = 13	n = 13	n = 13	n = 10	n = 10	n = 10
Standard deviation	488.7	196.4	0.14	561.4	234.4	0.14
Minimum value	1210.8	50	0.03	479.6	40	0.07
Maximum value	2781.2	680	0.44	2812.8	624	0.46

5.4. UNCERTAINTIES IN THE CROP PRODUCTION

The occurrence of pests and diseases affecting the crop production always has been a main problem for many farmers. During Kharif 1998, the most frequent occurring diseases were white fly (Bemisia) and the American Bollworm (Helothis). Thrips also occurred in several fields. Diseases like Jassids (Amrasca), Black headed cricket (Gryllus) were only observed and reported a few times. Table 5.6 summarizes the status of occurrence of the major diseases.

Table 5.6. The status of occurrence of the major diseases.

	Bed-and-furrow fields (n = 32)			Basin fields (n = 23)		
	Continuous	Sporatic	Non	Continuous	Sporatic	non
White fly	21	9	2	16	4	3
Bollworm	18	9	5	11	3	9
Thrips	4	12	16	4	6	11
Continous: more than 3 weeks continuing.						
Sporadic: 3 weeks or less or reported only once or twice.						

During the final interview, however, all the farmers claimed to have faced problems with the American Bollworm. Undoubtedly, diseases like white fly and the American Bollworm have an effect on the crop development and, consequently, the yield, which is confirmed by farmers' perceptions. Despite the effort and money spent on sprays, for farmers it is very hard to control a disease, once it occurs. They have a sincere interest in how to take preventive measures in the future. One farmer (from the Hasilpur area) related the severe occurrence of the American Bollworm to the extinction of a particular bird. He might be correct.

5.5. THE EFFECT OF THE LASER-LEVELING ON THE YIELD AND WATER USE EFFICIENCY

Table 5.7 presents the analysis pertaining to the production performance and WUE for the fields, which have been laser-leveled prior to the preparation of the beds-and-furrows. Significant differences (49.2% increase) can be observed in yield when the production data of the laser-leveling users are compared against those farmers who did not use the laser-leveling. With respect to the WUE a similar tendency is observed, resulting into a 26.3 percent increase. Carefully, it can be stated that the WUE is better for the fields when laser-leveled, though the analysis may be biased due to the conglomeration of the laser-leveler users in one sub system (SS5); knowing that these farmer had easy access to tubewell water, and which may have influenced the analysis. Similarly, the better yields are most probably related more to the good access to water.

Table 5.7. The effect of the laser-leveling on the yield and WUE.

Farmer number	Yield	WUE
	maund / acre	
3.14	9.3	0.29
3.15	2	
5.37	11.8	0.22
5.38	14.2	0.29
5.42	17	0.44
5.43	7.6	0.2
5.44	28	
Average (ll)	12.84	0.29
Sample size	n = 7	n = 5
Standard deviation	8.24	0.09
Average non-users of		
laser-leveling (nll)	8.61	0.23
Ratio (ll/nll)	1.49	1.26
Increase (%)	49.19	26.27

6. FINANCIAL ANALYSIS

6.1. Expenses

During the irrigation season, expenses pertaining to cultural practices were collected for the sample farmers. The results of the analysis are presented in Table 6.1, and Figure 6.1 presents the results graphically. Expenses pertaining to picking and harvesting are excluded from the analysis. Further, for farmers whose seed-related costs were unknown, the average cost as calculated for the bed-and-furrow and basin irrigation methods separately, is included for these farmers. The major differences occur for the sowing activity, seed usage and hoeing activities, with an increase in expenditures of 112, 68.8 and 68.8 percent, respectively, for the bed-and-furrow use. Whereas, a reduction in expenditures for the bed-and-furrow use occurred for the land preparation activity and application of pesticides, valued at 8.9 and 20.5 percent, respectively. When comparing the total costs, it can be concluded that the difference may be considered negligible; only a difference of 4 percent between the expenditures on cultural practices arises, whereby for basin fields the average expenditures is slightly higher.

Table 6.1. Average Expenditures for the Bed-and-Furrow and Basin Fields pertaining to Cultural Practices (*Kharif* 1998).

Bed-and-furrow *Costs / acre*	Land preparation	Laser leveling	Sowing Shaper + tractor	Seeds kg/acre	Seed Costs	Hoeing	Inter-culturing	Fertilizer	Pesticides
Average	410.9	392.5	142.6	5.7	241.3	338.5	116.4	632.1	1869.2
Sample size:	n = 27	n = 6	n = 27	n = 15	n = 15	n = 27	n = 11	n = 26	n = 26
Standard deviation:	277.4	514.1	53.8	2.2	89.7	470.2	59.4	364.2	974.5
Min. value:	25	160	50	4	200	50	20	227	450
Max. value:	1200	1440	250	13	520	1450	200	1069	3745
Basin *Costs / acre*	Land preparation		Sowing Tractor + drill	Seeds kg/acre	Seeds costs	Hoeing	Inter-culturing	Fertilizer	Pesticides
Average	451		66.9	4	108	201	100	607	235-1
Sample size:	n = 18		n = 18	n = 6	n = 6	n = 18	n = 10	n = 18	n = 18
Standard deviation:	304		43.1	1	29	145	60	326	1181
Min. value:	90		20	3	200	100	30	180	721
Max. value:	1400		100	5	250	560	200	1260	5275

With respect to irrigation practices, possible labor pertaining to the irrigation application is excluded from the analysis; similarly, is the *abiana* (water fee). Irrigation-related costs pertain to the tubewell operation. The rent rate is assumed to be Rs. 50 to 75 per hour, and the estimated fuel expenses are Rs. 18 to 22 per hour. A total amount of Rs. 1777.17 has been spent on tubewell operation for the bed-and-furrow fields (9 farmers) and Rs. 693.67 has been spent on tubewell operation for the basin sample fields (2 farmers).

The total amount of money spent on the irrigation and cultural practices, as calculated above, is Rs. 3770.47 and Rs. 3872.51 per acre, for the bed-and-furrow and basin fields, respectively, which gives the ratio (bed-and-furrow / basin) of 0.97. In other words, the analysis shows that there may not be a significant difference in the expenses for the bed-and-furrow irrigation method in comparison to the basin irrigation method.

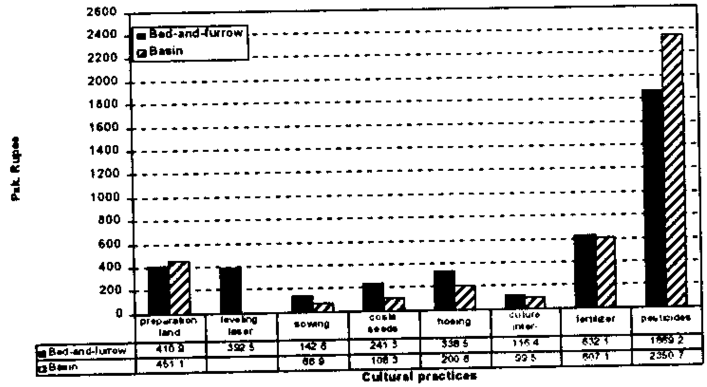


Figure 6.1. Average Expenditures for the Bed-and-Furrow and Basin Fields Pertaining to Cultural Practices (*Kharif* 1998).

6.2. REVENUE

The total expenditures pertaining to irrigation and cultural practices and the benefits received from the cotton yield sold at the market are summarized in Table 6.2, and the revenue has been calculated accordingly (revenue = benefits - expenditures).

Table 6.2. Total Expenditures, Benefits and Revenue for the Bed-and-Furrow and Basin Fields (Kharif 1998).

Bed-and-furrow irrigation method				**Basin irrigation method**			
Farmer number	Total Expenses	Yield Sold	Revenue	Farmer number	Total expenses	Yield sold	Revenue
1.1	3661	5497	1836	1.1	2538	4549	2011
1.2	4661	5746	1084	1.2	4738	5576	838
1.3	6289	6259	-30	1.3	4462	3355	-1108
1.4	6389	16430	10041	1.4	5098	3180	-1919
1.5	4664	15920	11256	1.5	7953	1244	-6710
1.6	4500	6757	2256	1.6	-	-	-
1.7	4411	13231	8820	1.7	4028	-	-
1.8	4960	8300	3340	1.8	-	-	-
1.9	6461	6900	439	1.9	5118	7500	2382
2.11	5513	10098	4585	2.11	5910	9465	3556
3.13	2820	6338	3518	3.13	4188	14700	10512
3.15	2910	2000	-910	3.15	3208	12600	9392
3.16	3682	10697	7015	3.16	2413	12216	9803
4.29	3824	4860	1036	4.29	2871	3932	1061
4.31	2801	4654	1853	4.31	-	-	-
4.32	2981	12928	9947	4.32	-	-	-
4.33	2465	201	-2264	4.33	-	-	-
4.34	4073	11579	7506	4.34	-	-	-
4.35	1572	119	-1453	4.35	-	-	-
5.38	1771		-	5.38	-	-	-
5.39	1876		-	5.39	1924	-	-
5.4	3161	1213	-1949	5.4	1638	1782	144
5.41	5129	1950	-3179	5.41	4855	12870	8015
5.42	3456		-	5.42	2808	-	-
5.43	2216	7625	5409	5.43	1935	8313	6378
5.44	5555	28000	22445	5.44	4003	19000	14997
Average:	4117	8144	**4026**	Average:	4062	8019	**3957**
Sample size:	N = 23	n = 23	n = 23	Sample size:	n = 15	n = 15	n = 15
B/C ratio:	**0.98**			**B/C ratio:**	**0.97**		

The calculations are performed on a per-acre basis. Revenue-wise, the revenue ratio does not show much difference between the bed-and-furrow and basin irrigation methods (bed-and-furrow / basin), which has a value of 1.02. The benefit - cost ratio (B/C) are 0.98 and 0.97 for the bed-and-furrow and basin irrigation methods, respectively. With respect to losses, 4 farmers had losses; 3 farmers had severe losses on bed-and-furrow fields. Three farmers incurred losses on the sample basin fields. The average loss on the bed-and-furrow field was Rs. 1164.25, whereas, the average loss for the basin field was Rs. 3245.67.

The implementation of the bed-and-furrow irrigation, assuming the required implements are purchased on a rental basis, is economically feasible for the farmers and does not have a negative impact on the revenue in comparison to the basin irrigation method. Further, the magnitude of financial losses appears less for the bed-and-furrow irrigation method according to the presented figures.

When comparing the level of expenses and revenue sub-system-wise, a variation can be observed (Table 6.3). Overall, better revenue is achieved for the farmers in Sub-system 5. For this sub-system, the yield is high and the expenses are of an average value when compared with other systems. Again, the performance in terms of obtained revenue might be related to their relatively more frequent use of tubewell water in order to guarantee water supply at the time of the crop need. Negative revenue only occurs for the sample basin fields of Sub-system 1; the yield is low, whereas, the expenditures are on an average high. On the contrary, the obtained revenue in Sub-system 1 for the bed-and-furrow fields is reasonable.

Table 6.3. Sub-system -wise Average Values for Expenses, Yield and Revenue (Kharif 1998).

Bed-and-furrow irrigation method				**Basin irrigation method**		
	Expenses	Yield	Revenue	Expenses	Yield	Revenue
	Rs. / acre	Rs. / acre	Rs. / acre	Rs. / acre	Rs. / acre	Rs. / acre
Sub-sytem 1						
Average	5111.0	9448.9	4338.0	4848.2	4234.0	-750.8
Standard Deviation	1014.5	4465.0	4429.0	1630.2	2163.1	3375.3
Sample size	n = 9	n = 9	n = 9	n = 7	n = 6	n = 6
Sub-sytem 2						
Average	5512.8	10098	4585.2	5909.8	9465.5	3555.7
Standard Deviation	-	-	-	-	-	-
Sample size	n = 1	n = 1	n = 1	n = 1	n = 1	N = 1
Sub-sytem 3						
Average	3137.3	6344.7	3207.4	3270.0	13172.0	9902.0
Standard Deviation	473.8	4348.3	3971.4	889.1	1337.1	566.6
Sample size	n = 3	n = 3	n = 3	n = 3	n = 3	N = 3
Sub-sytem 4						
Average	2952.7	5723.4	2770.8	-	-	-
Standard Deviation	914.6	5477.0	4918.5	-	-	-
Sample size	n = 6	n = 6	n = 6	-	-	-
Sub-sytem 5						
Average	3309.1	9696.9	5681.6	2860.5	10491.1	7383.4
Standard Deviation	1528.3	12533.9	11801.4	1305.0	7272.2	6104.3
Sample size	n = 7	n = 4	n = 4	n = 6	n = 4	N = 4

7. FARMERS' PERCEPTIONS

7.1. Bed-And-Furrow Irrigation Method And Farming Aspects

At the end of the *kharif* season, farmers who have been using the bed-and-furrow irrigation method were interviewed in which mainly farmers' experience and perceptions pertaining to the implementation of the bed-and-furrow irrigation method, farm implements, irrigation and cultural practices, cotton production, crop development, pest management, etc. were discussed. This chapter elaborates farmers' experiences and perceptions on the issues cited above. The total number of farmers interviewed are 44 (including farmers from outside the Hakra-4R command area).

7.2. Implementation Of The Bed-And-Furrows

7.2.1. Accessibility Of The Bed-And-Furrow Shaper

As there was only on set available at the initial stage of the season, which was also not provided on time by the manufacturer, a delay in sowing occurred and was experienced by most of the farmers. Mostly farmers insisted to take the machinery first and try to use the bed-and-furrow shaper as early as possible. It was noted that time was wasted during the machinery conveyance from one place to another place; hence, a delay in sowing for the next farmer occurred. The problems in machinery conveyance mainly occurred due to tractor unavailability.

The bed shaper was perceived as easily available to 16 farmers out of 50 farmers interviewed. It was, - for these farmers -, due to the easy availability of a tractor for the bed-and-furrow shaper. Most of the other farmers mentioned that the bed-and-furrow shaper was difficult due to some problems in tractor arrangement and conveyance problems. In fact, the major problem with the accessibility of the shaper was of the tractor arrangement. Most of the farmers do not have their own tractor and also of a proper horsepower.

Three farmers prepared the beds-and-furrows by tractor by themselves due to their keen interest in making the beds-and-furrows. One of them prepared the beds-and-furrows by a traditional ridger after making some adjustments. He took this initiative due to the non-availability of the bed-and-furrow shaper, whereas he had a keen interest in the bed-and-furrow experiment. He experienced nice preparation of the beds-and-furrows, however, with some lesser deep furrows.

7.2.2. Occurred Difficulties During The Implementation

Some difficulties were faced during preparation. It was due to some less extent in soil preparation, and inexperience with the bed-and-furrow shaper, and, initially, a tractor size problem. This latter was solved by using the tractor of OFWM for Rs. 50 per acre. Figure 7.1 shows the farmers comments on the preparation phase of the bed-and-furrow irrigation method. Out of 50 farmers, 17 farmers faced no kind of problem during preparation. Remaining farmers faced the following problems (the number in brackets refers to the number of farmers who made the respective comment)

- Metering wheel halted problem due to soil wetness (13);
- Non straight B/F prepared due to tractor size or soil wetness (5);
- Seed was not covered by soil due to sowing time or wet soil (4);
- Tractor arrangement problem (3);
- Some manual seed planting (3);
- Collects soil at the end of the round (2); and
- Difficulties in its seed adjustment (2).

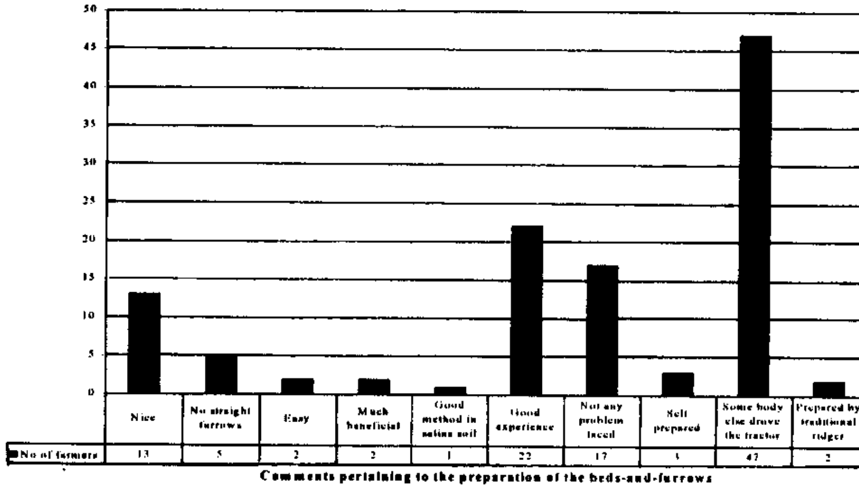


Figure 7.1. Comments by the farmers regarding the preparation and implementation of the bed-and-furrow irrigation method.

7.2.3. Comments On The Bed-And-Furrow Shaper

Most of the farmers commented that the bed-and-furrow shaper is *reasonable / suitable for bigger sized tractor*, and was considered as too weighty for smaller tractors. The bed-and-furrow shaper created difficulties for the hydraulic system of the tractors. The performance, however, was also perceived as being dependent on the tractor driver's expertise about the implement's operation. Some farmers commented that the bed-and-furrow shaper is suitable for smaller sized tractor. In fact, some mentioned that the shaper is about the same weight as the commonly used rotavator. It has been observed that in the wetted soil, difficulties were faced for the operating of implements, whereby more hydraulic power is required in that type of soils. Figure 7.2 presents the comments from farmers pertaining to the bed-and-furrow shaper as such.

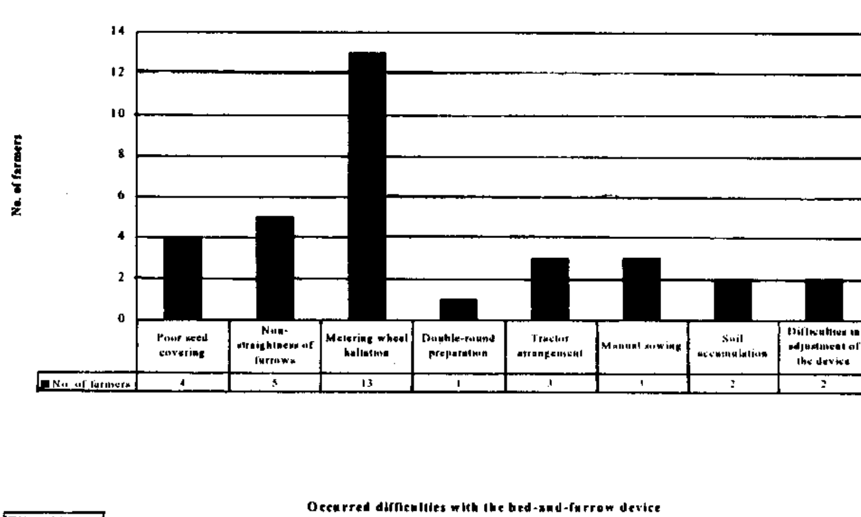


Figure 7.2. Occurred difficulties with the bed-and-furrow shaper.

Farmers categorized a smaller tractor as having less than 50 horsepower (hp) and bigger as more than 50 hp.

It has been observed by both farmers and IIMI staff that mostly some breakdown occurred in the bed-and-furrow shaper parts, it was either due to some manufacturer fault or the lack of experience in the machinery operation or the ignorance of precautions.

In order to find the faults in the implement, farmers also have been questioned about the material of the bed-and-furrow shaper. About 24 farmers commented it has good material, 3 commented it has medium quality material and the remaining 23 commented it has poor quality material both in parts and in the welding joints. Some farmers who have visited Bilal Farm, Khanpur commented that it is not the same implement as they have seen during their visit.

Most of the farmers used bigger sized tractors i.e. MF-375, Russian (BALARUS), FIAT-640, which belong to the OFWM Directorate. It was easy for operation and pull/conveyance by these types of tractors. It has been also observed that it was easy for operation with a smaller sized tractor MF-285 and difficult by FIAT-480 and MF-240. Figure 7.3 shows the type of tractor used and the implement's operation.

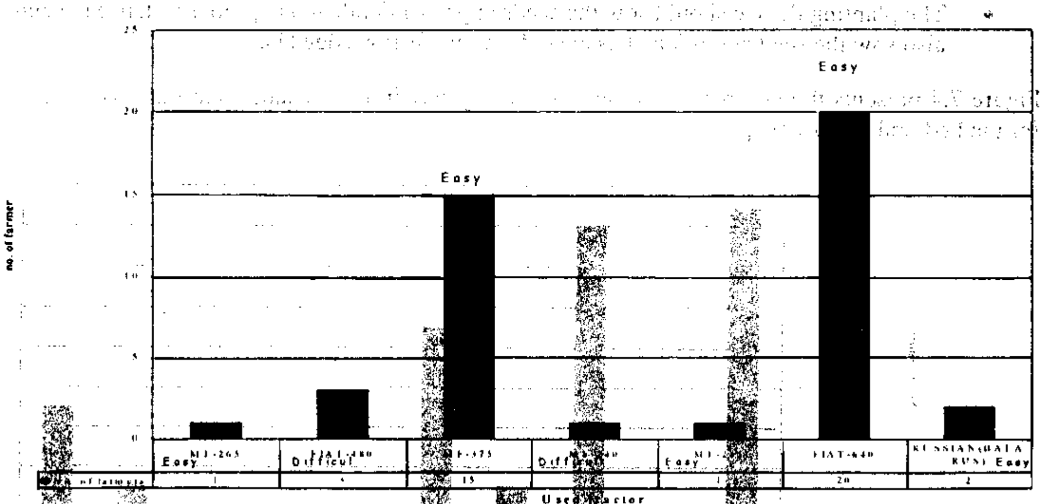


Figure 7.3 Different tractors usage.

Also, some manufacturer faults were observed in the sowing seedling device. 28 farmers observed it as not working properly; the fault was in its seeding tines. Most of the farmers complained about the performance of the seedling device. They said that the seed was entrapped in the seed tubes due to the clogged ends of the pipes facing the soil. Some of the farmers also regarded the position of the seed placement to be improper. Some farmers faced seed covering by the soil, the seed was not properly covered by the soil in the plantation row, it was either some wetness in the soil and/or some manufacturer designing faults in the sowing tines. Some times the metering wheel halation problem occurred during operation, it was observed due to the wet soil clogging in the metering chain. It was due to the uncovering of chain and improper chain lubricant system. Five farmers commented about the fluctuation in the seed quantity. The remaining farmers were satisfied and felt no kind of problem with the sowing device. Some farmers performed manual gap filling as due to fault discrepancies in drilling parts and they felt satisfaction as it is only possible for gap filling in bed-and-furrow method and also plant density or number of plant per field can be better controlled, which is not possible in the traditional basin method (drilling method).

With respect to the required maintenance during the operation of the bed-and-furrow shaper, farmers mentioned the following issues:

- Requires lot of maintenance in its welding parts (6);
- Maintenance in sowing device (5)
- Frequent lubrication in metering chain (1);
- Maintenance in sowing parts (1); and
- Maintenance in shaper plank (1).

Further, the following modifications were suggested by the farmers:

- Machine should be lighter in weight but should have stronger material (17);
- Improvement in the function of metering wheel (16);
- Improvement in the sowing device (16);
- Cover the metering chain, shock absorber and improve the seedling device (3);
- The planting tine should cover the seed by soil (3);
- Weight and width should be reduced (2); and
- The planting device should sow the seeds at proper depth and at proper distance (1) and also sow the seed about 3 inches away from the furrow edge (1).

Figure 7.4 presents the number of farmers expressing certain maintenance and improvement issues for the bed-and-furrow shaper.

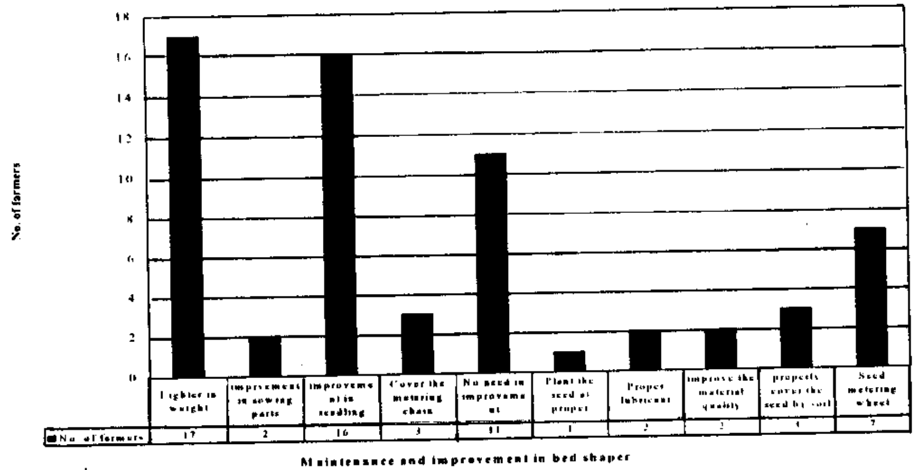


Figure 7.4. Maintenance and improvement suggestions for the bed-and-furrow shaper.

7.2.4. Hoeing Device

Most of the farmers could not use the hoeing machine due to its unavailability. Only two farmers out of fifty farmers could use the hoeing device and mentioned that it was too big and heavy, complicated in its adjustment, and difficult in its use. Also, the machine was available very late and the crop was in fruiting stage, so most of the farmers avoided using it, while some farmers took it to their field but could not use it due to the same problems. The late availability was due to late manufacturing and late supply from the manufacturer. The machine user recommended that there should be easy adjustment in its weeding tines and earthing up blades so it can be easily adjustable according to the plant heights. Five farmers controlled the weeds by making some adjustment in their traditional ridger according to the bed-and-furrow shape and they easily did this job and controlled the weeds. Seven farmers applied weedicide (Stamp, cotoguard) just after crop sowing by manual spray and they succeeded in this way to control the weeds. The remaining farmers controlled the weeds by manual hoeing with *khurpa, kasi and kadola* (traditional manual implements). Farmers felts easy hoeing in the bed-and-furrow fields due to less weed germination on the bed sides and easy weed control in furrows with their traditional implements. Figure 7.5 presents farmers' strategies on dealing with the weeds and comments on the hoeing machine.

Of the few farmers who used the hoeing device, the following improvements were suggested:

- It should be easily operated (2);
- Weeding tines and adjustments in hoeing parts should be easy (1) and can be adjusted according to plant height (2);
- Material quality should be improved (1);
- Strong and strengthen parts applied to weed cutting discs (1); and
- It should be lighter in weight (1).

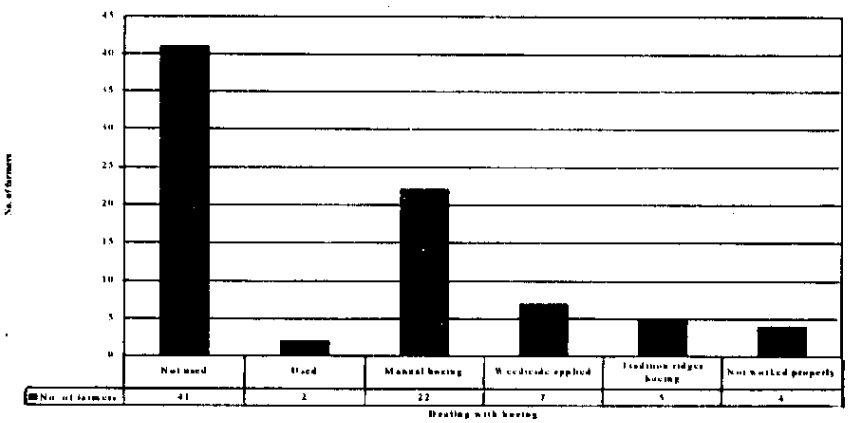


Figure 7.5. Dealing with weeding and the use of the hoeing machine.

7.2.5. Laser Leveling Device

Eleven farmers used the laser leveling device and commented on its use as a good and accurate method for soil leveling, especially before bed-and furrow use, easy for irrigation applications, and good for leveling the lengthy plots i.e. plots more than one acre which could not be possible in any traditional method, either for soil leveling or to irrigate such a long plots by the traditional basin method. The remaining farmers did not use the laser leveling device due to its non or late availability, or there was only a short time left for soil preparation.

7.3. AGRONOMIC ASPECTS

7.3.1. Germination Rate

Table 7.1 shows the comments of the farmers regarding the germination rate for the bed-and-furrow and basin irrigation methods. Eight farmers observed a germination rate of 100% in bed-and-furrow fields and commented that it is a good method for controlling the plant density and manual gap filing is easily possible for this method.

Overall, a better germination rate was observed for the bed-and-furrow irrigation method. The criteria for judging the germination rate by farmers was to visually and thoroughly see the crop germination in beds-and-furrows and compare it with the germination in basins. Due to less germination and disturbance by the rainfall at the sowing time, four farmers re-sowed the crop on the bed-and-furrow method instead of the basin method and were satisfied about the germination rate.

Table 7.1. Comparison of germination rate for the bed-and-furrow and basin irrigation methods.

Germination rate (%)	Number of farmers	
	Bed-and-furrow	Basin
100	8	6
80-95	22	3
70-80	7	14
50-70		8
40-50	1	6

7.3.2. Occurred Disturbances

Most of the farmers felt that more disturbances occurred for the crop germination in the basin fields, whereas the crop remained safe from flooding and rain in the bed-and-furrow fields. They concluded that after rain a thin and hard soil crust was formed on the soil surface. If rain would occur just after sowing, it would be almost impossible to break through this soil crust by a newly germinated embryo; also, it would be impossible to irrigate the basin field just after rain. It was, however, possible to irrigate the bed-and-furrow fields. Beds-and furrows have as a provision the ability to irrigate the field after rainfall and the crusted soil gets soaked and ultimately softens again, and the plant germination would not get disturbed.

Thirty-four farmers did not face any disturbance by rainfall at the germination stage for the bed-and-furrow irrigation method. Four farmers felt some bit of disturbance by rainfall and the remaining ten farmers found crop failure by heavy rainfall in beds-and-furrows. In basins, thirteen farmers experienced not any disturbance due to rainfall, whereas the other farmers felt some disturbances in basin fields after rainfall.

7.3.3. Differences In Crop Development And Fruit Formation

With respect to the crop growth, twenty-six farmers commented that the growth was faster for the crops sown in the bed-and-furrow fields, whereas seven farmer indicated that they could not observe any difference; and four farmers experienced a better growth in the basin fields. The latter farmers related the slower crop growth to neglecting of the hoeing.

Farmers felt easiness in controlling the crop height by adjusting the irrigation applications in the bed-and-furrow fields, and which is difficult to control for basin fields. It was observed that when the crop was sown even 10 to 15 days later, still the crop in the bed-and-furrow field would achieve the same height as for the earlier sown crop in the basin field.

Thirty farmers observed more fruit formation for the cotton grown in the bed-and-furrow fields as compared to the basin fields. The farmers commented that there was less intranode distance, resulting into more branches, closer fruit formation, more stem thickness, fat and weighty bolls and early boll opening, observed for the cotton in bed-and- furrow fields. Seven farmers felt almost the same fruit formation and three farmers felt lesser fruit formation in bed-and-furrow crop as in basin crops, the reason was due to non-hoeing and disturbance by heavy rainfall.

7.3.4. Seed Usage

Figure 7.6 shows the farmers' trend about the seed usage for both of the irrigation methods. Two farmers used 10 kg of seed per bed-and-furrow field. This high quantity was a result of the first time using for the bed-and-furrow shaper and some difficulties occurred in adjusting the sowing device. Twenty farmers used 6 to 9 kg of seed per acre for the sowing in the bed-and-furrow fields; and seventeen farmers used 3 to 6 kg of seed per acre. This includes the used seed for gap filling. The range of seed used for the basin fields was 6 to 8 kg per acre for thirteen farmers, and seventeen farmers used 3 to 6 kg of seed per acre. Overall, more seed was used for the bed-and-furrow fields; only one farmer mentioned to have used about the same quantity for both of the fields. Figure 7.6 presents the used quantity of seeds for the bed-and-furrow and basin fields.

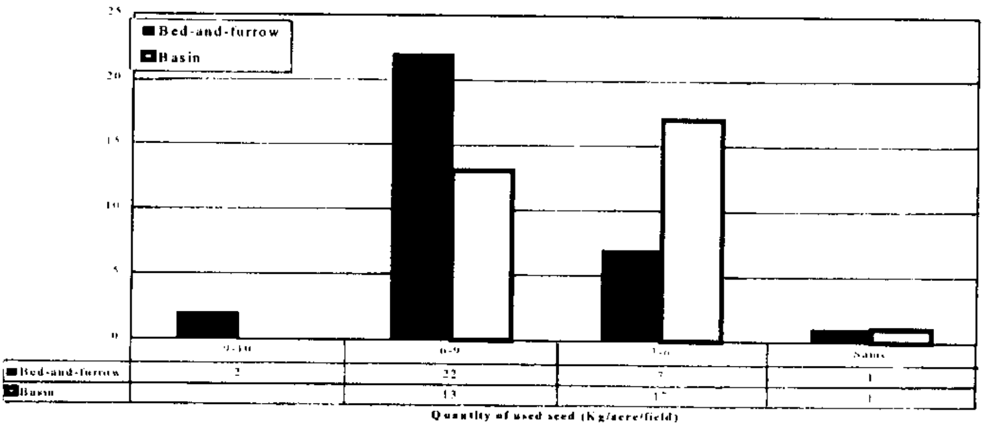


Figure 7.6. Comparison of the used seed quantity for the bed-and-furrow and basin fields.

7.4. Water Management Aspects

Although during the initial stage of the season some farmers showed their concern for the number of irrigation applications, by passing the season farmers became more at ease on this matter. Six farmers mentioned during the final interviewing that only for the first three to four irrigation events an interval of about a week was required, later on the interval could easily be increased. Though, a few farmers raised the issue of needing more irrigation applications. Sixteen farmers indicated that there was not any real change in their irrigation strategy. Several observations were indicated by a number of farmers. Figure 7.7 presents a bar diagram with on the x-axis the comments and on the y-axis the number of farmers who made that particular statement.

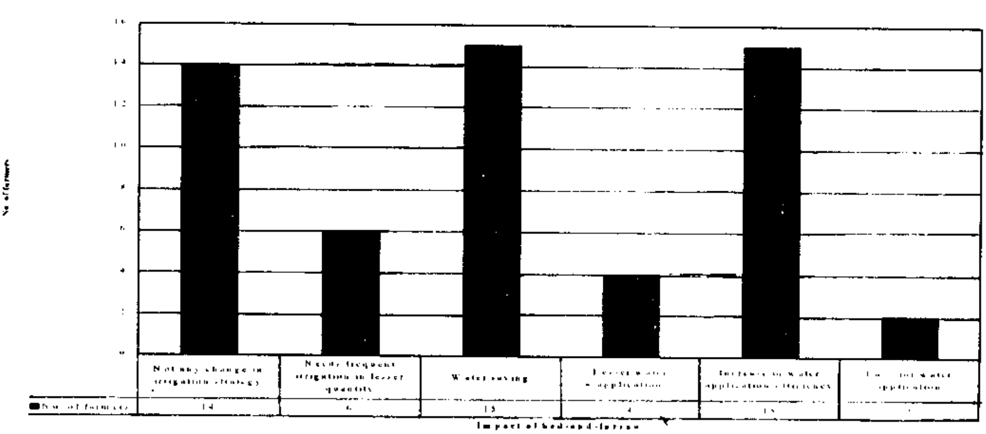


Figure 7.7. Farmers comments pertaining to irrigation practices and the bed-and-furrow use.

Fifteen farmers mentioned that irrigation efficiency increased, to which farmers refer to as *peecha bara*. They reasoned that since the water only flows through the furrow, hence less time is spent and less water is used. Also, farmers could easily use their advance volume of water (*nikkal*), since the furrow would convey this water easily across the field; something which is not possible with the basin fields. Other comments were that the bed-and-furrow irrigation method needs more frequent irrigation, though in less quantity (mentioned by 6 farmers), and that the method is easy and allows a quicker water application (mentioned by 2 and 4 farmers, respectively). It was observed that water saving takes place (observed time-wise)and, hence, more land could be irrigated during the *warabandi*. This was mentioned by fifteen farmers.

Regarding the time saving aspect, this was observed by all the interviewed farmers, except for two. Nine farmers mentioned that about 0.5 to 1.5 acres more could be irrigated during the same warabandi, since they saved time on the bed-and-furrow field. Two farmers mentioned a time saving of 15 to 20 minutes. Seven farmers indicated that the bed-and-furrow irrigation method yields 50% saving over the season, though it could be not clearly derived whether they referred to time or water application. Questioning farmers about the time required to irrigate an acre, on an average their replies resulted into a 50% time saving when the bed-and-furrow method is used. Comparing this to the quantitative analysis, presented in Table 4.2, event wise, the time saving occurs indeed (on an average 35.87% for event 1 to event 6, excluding the rouni for this analysis), but on an average season-wise, it was derived that more time for irrigation is spent on the bed-and-furrow irrigation method. In other words, farmers' statements and analysis are in contradiction. Farmers, however, provided also information about the estimation to fill a field with water; farmers mentioned that it took about 0.5 to 1.5 hours to fill the bed-and-furrow field and 1 to 3 hours to fill a basin field, which coincides fairly with the results of the analysis.

With respect to water saving, thirty-one farmers observed water saving for the whole season, since, as they reasoned, less time and consequently water was applied to the bed-and-furrow fields. Two farmers mentioned that water saving only occurred event-wise and five farmers mentioned that they did not observe any water saving due to the increase in irrigation frequency. The latter two groups of farmers are closer to the results of the analysis of Chapter 4.

With respect to tubewell water, about fifteen farmers felt an increasing dependence on tubewell water because of the increase in irrigation frequency, whereas twenty-two farmers commented that there was no need or dependence on tubewell water at all, despite the use of the bed-and-furrow irrigation method.

During the discussion on water management aspects, some other advantages and constraints than discussed above were mentioned, such as:

- The water drains easily from the field due to the furrows (2);
- Water saving in terms of rouni, and thus no time be spent on rouni (1).

7.5. APPLICATION OF CHEMICALS AND FERTILIZERS

Questions pertaining to the application of chemicals and fertilizers had a two-fold reason, which is to obtain insight in how farmers manage the respective application and whether there was a significant difference in the application practices of chemicals and fertilizers between the bed-and-furrow and basin irrigation methods.

Figure 7.8 presents when farmers apply either fertilizers or chemicals (x-axis) and the number of farmers representing each comment are presented on the y-axis. Farmers have their knowledge about the use of chemicals and fertilizers, often based on years of experience, though they do not have a control on the quality of the products, for which they are dependent on the local shopkeepers.

With respect to both, the application of fertilizers and chemicals, farmers maintain that the main criteria is the crop condition, also further described as either crop growth or crop health. Only a very few farmers commented that fertilizers are applied after seeing the fruiting. Mostly, fertilizers are applied in the early stages of the crop development. DAP fertilizers are applied during the preparation time, and Urea is applied in conjunction with an irrigation application, mostly up to the fourth irrigation. The application of chemicals relates mostly to the occurrence of diseases. Most of the farmers (i.e. 32 farmers) mentioned that they apply chemicals after the observance of a pest attack. Depending on the kind of pest attack, and in consultation with the pesticide dealers, the choice of chemical is decided upon.

This season several major diseases occurred, as explained in section 5.4. The interviewed farmers mentioned that the American Bollworm was a real problem (mentioned by 39 farmers). Foremost because they appeared resistant for any kind of (costly) pesticide and in fact were uncontrollable. Some farmers indicated that it was a new kind of breed of American Bollworm, which contains spots like the Spotted Bollwurm (identified by 5 farmers). The uncontrollable pest attack was also ascribed by 4 farmers to the unfavorable weather conditions. Diseases, such as White Fly, Thrips and Jassid were also mentioned, but were less severe as compared to the American Bollwurm. Farmers indicated that there was little difference in the measure of the diseases for the bed-and-furrow and basin fields; though several farmers commented that the White Fly attack was more severe for the basin fields due to the presence of a more favorable micro-climate for the virus (more humidity and warm temperature above the soil surface between the crops). Various farmers ascribed the occurrence of diseases to either seed quality (mentioned by 5 farmers), climate (mentioned by 4 farmers), or consider it as a natural process (mentioned by 2 farmers).

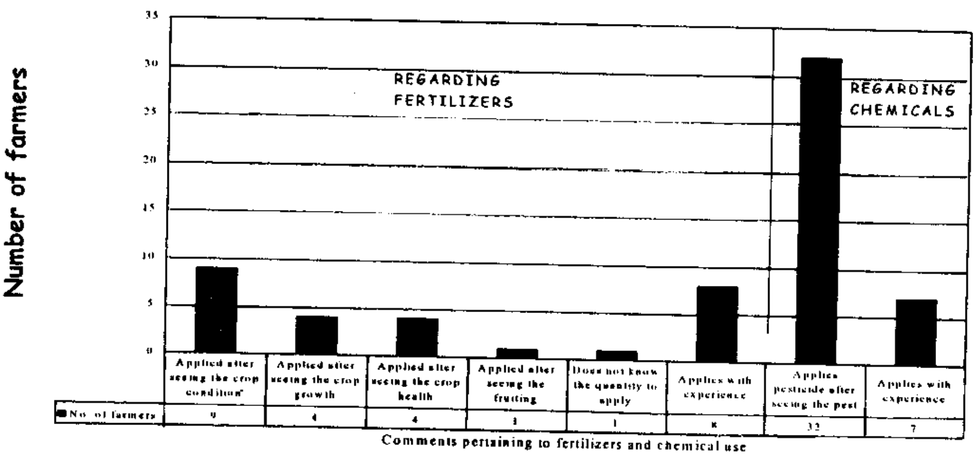


Figure 7.8. Comments pertaining to the use of fertilizers and chemicals.

The various diseases were considered as having a negative impact on the yield. The main disease considered as yield affecting was the American Bollworm. Nineteen farmers mentioned that also White Fly had its negative impact on the yield; five farmers mentioned that the Spotted Bollworm had a negative impact on the yield and five farmers mentioned that Jassid and Thips had a negative effect, though not severe.

With respect to the quantity used on chemicals and fertilizers, thirty farmers were of the opinion that the same quantity of each was used for the bed-and-furrow and basin fields. Seven farmers mentioned that they saved in quantity on the application of chemicals and fertilizers for the bed-and-furrow field.

7.6. Farmers' Feedback On The Cotton Production

Farmers expected for Kharif 1998 a cotton yield of 20-35 maunds per acre, with an average of 26.10 maunds per acre. In reality, however, the yield was much lower. As described in section 5.1, the average farm cotton production was 8.24 maunds per acre (for 33 sample farmers) and an average 6.9 maunds per acre when all the farmers are included (49 farmers), though comparing the bed-and-furrow with the basin fields, a 15% higher yield is analyzed. When the expected yield is compared with the actual yield, a great loss can be observed. Farmers ascribed the low yield to the severe pest attacks and unfavorable weather conditions. More specifically, the following reasons were mentioned:

- Occurrence of rainfall along with wind during the fruiting stage (10)/ unfavorable weather conditions (11);
- Drought during the monsoon period (20);
- Severe attack of diseases (pests and virus) (13);
- Flower shedding (due to wind and rainfall) (5);
- Shortage and ambiguous canal water supply (2);
- Late sowing (2);
- Not taking good care of the crop (2);
- Forger pestices (2); and
- Non availability of fertilizers (1).

With comparison to last year, thirty farmers viewed their current yield as low in comparison to last year (Kharif 1997) and were not satisfied with the yield. Four farmers mentioned that they received about the same yield. Two farmers mentioned that they received a better yield due to the bed-and-furrow method. Several farmers commented that they have lost interest in cotton cultivation as being the main *kharif* crop, mainly due to the low yield and consequently financial losses and the increase of waterlogging and salinity; though they are hoping that the bed-and-furrow irrigation method gives better prospects. Most of the farmers were of the opinion that the bed-and-furrow irrigation method provides an increase in reliability of a good cotton production.

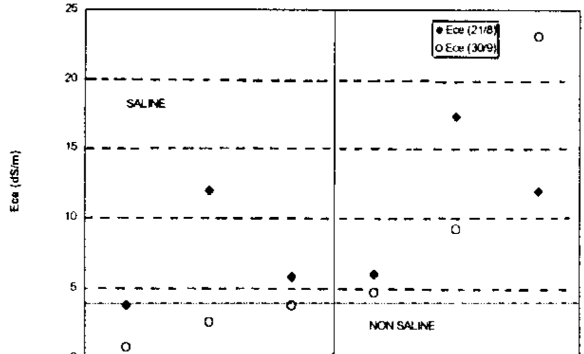
During the harvesting, twelve farmers mentioned that the picking went easy, since the pickers can follow the little path on the bed, while picking, which also facilitated a reduction in the breaking of branches of the cotton crop while moving through the field.

7.7. Effect Of Waterlogging And Salinity

Although farmers did not make a direct inference to waterlogging and salinity problems during the question pertaining to the motivation of lower crop production, later on, however, during the interview, the discussion dealt with waterlogging and salinity. Many farmers faced difficulties in cotton cultivation where the soil is either waterlogged or saline of nature. Twenty-eight farmers mentioned having problems with the soil quality, of which three mentioned to have real problems in terms of waterlogging and salinity; thirteen felt some problems; and nine farmers mentioned facing few problems pertaining to soil quality.

Twenty-seven farmers mentioned that the bed-and-furrow irrigation method is good for saline or waterlogged land, mostly because of less water use during an irrigation event. Four farmers were indifferent in this regard. Twenty-four farmers mentioned that they did not observe a noticeable or severe increase of salinity on the bed. This is an issue farmers were told about in the beginning of the season, and, thus, showed a concern for this earlier in the season. Thirteen farmers observed some increase in salinity on the beds, and one farmer noticed salinity occurrence in the furrow. Farmers also commented that they were not really worried on the salinity occurrence, since they gather that the salts will be removed once a good *rouni* is applied prior to the cultivation of *rabi* crops. In this regard, farmers do not feel any difficulties for the *rabi* season, though eleven farmers were a bit worried on leveling the field (into basins).

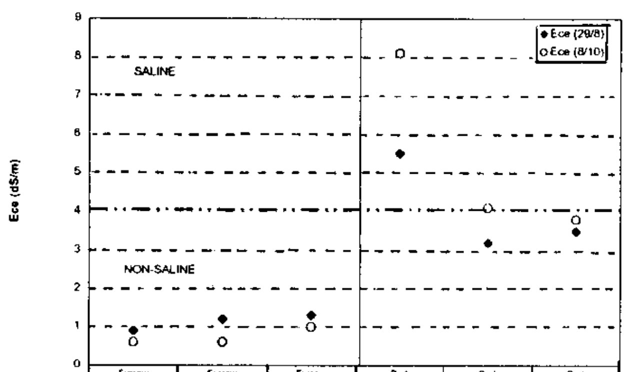
However, in order to illustrate the magnitude of differences in soil salinity accumulation for the furrow and the bed, soil samples were collected and next analyzed by MREP, WAPDA though from another distributary command area (Bahaderwah Minor, part of Sirajwah Distributary command area). At two farms, classified as waterlogged and saline areas, soil samples were taking at two different timings during *Kharif* 1998. The Figures 7.9 and 7.10 present graphically the measure of salinity (with EC_e in dS/m as the indicator), while below the x-axis the depicted values are given.



	Furrow	Furrow	Furrow	Bed	Bed	Bed
◆ Ece (21/8)	3.8	11.9	5.8	6	17.3	11.9
O Ece (30/9)	0.8	2.6	3.8	4.7	9.2	23.1

Sample location in the field (i.e. furrow or bed)

Figure 7.9. Soil salinity Farm 1 (Kharif 1998).



	Furrow	Furrow	Furrow	Bed	Bed	Bed
◆ Ece (28/8)	0.9	1.2	1.3	5.5	3.2	3.5
O Ece (8/10)	0.6	0.6	1	8.1	4.1	3.8

Sample location in the field (i.e. furrow or bed)

Figure 7.10. Soil salinity Farm 2 (Kharif 1998).

SSoP assessed the initial salinity status of the bed-and-furrow sample fields in July 1998. The EC_e was found to be 5.9 and 7.74 dS/m; and 0.88 and 0.85 dS/m, respectively, for the bed-and-furrow sample field of Farm1 and Farm 2 (SSoP 1999). The sample field of Farm 1 was found to be saline, whereas the sample field of Farm 2 was typified as non-saline. Comparing this with the data of MREP, it can be observed that in time the salinity has increased significantly for the beds for the sample field of Farm 1. A similar tendency occurred for the sample field of Farm 2 (i.e. an increase in Ece), though the values do not indicate severe salinity. In fact, only two values exceed the upper boundary for the non-saline condition of 4 dS/m. For the furrows, the increase in salinity is much less consequential as compared to the initial condition, and thus, it can be concluded that the soil of the bed is more subjected to increased salinity as compared to the soil of the furrow. Spatial variability of soil salinity, however, occurs for the furrow as well as bed location.

7.8. LABOR REQUIREMENT

In general, farmers did not really experience a difference in labor requirement for the bed-and-furrow irrigation method in comparison to the basin irrigation method, except for the hoeing activity, for which the labor demand was high, though not really perceived as a burden. It is expected that with the use of the hoeing device, the hoeing will be much easier and quicker, and in addition, would allow a quick application of fertilizers, due to a provision built in the hoeing device for fertilizer purpose. Some farmers mentioned, with respect to hoeing, that they did not experience any difficulties or burden on labor due to the application of weedicide just after sowing; they only spent some time in cleaning the furrows.

7.9. OPERATION AND MANAGEMENT OF THE BED-AND-FURROW SHAPER

As indicated in Chapter 3, the bed-and-furrow shaper was available to the farmers upon paying a rent of Rs. 50/- . An additional Rs. 100/- had to be paid if a tractor was rented. Twenty-four farmers perceived this as a reasonable rent and felt it as almost the same amount of money spent when the drill is used for sowing of the basin field. Farmers observed that if they would use a ridger for making the furrows and perform manual sowing, more money would be spent (i.e. Rs. 150/- to Rs. 200/- per acre for the ridger and Rs. 250/- to Rs. 300/- for manual sowing, charged by local persons working on a rental basis). Sixteen farmers recommended that the rent rate (including all the expenses) should be at a rate of Rs. 20 to Rs. 50 per acre for the next few seasons.

With respect to the total price for the bed-and-furrow shaper and hoeing device, Rs. 50,000/- and Rs. 40,000/-, respectively, which is perceived as being too costly to purchase individually by twenty-four farmers, especially after experiencing several faults in the devices. Twelve farmers consider the price for each device as reasonable, considering the weight. Several farmers suggested that attempts should be made to fabricate such implements at lower costs, i.e. prices mentioned ranged from Rs.15,000/- to Rs. 30,000/- for the bed-and-furrow shaper and Rs. 15,000/- to Rs. 35,000/- for the hoeing device. Devices were perceived as affordable for the common farmer if the price would be around Rs. 15,000/- to Rs. 16,000/-.

Thirty-eight farmers are not willing to make personal investment for either or both the devices, considering the current costs. Five farmers are considering to make a personal investment in this regards, though the first want to wait and see for the next few season how the bed-and-furrow irrigation method prospers.

With respect to the concept of having a common arrangement in purchasing the respective devices, eleven farmers were willing to join hands with the WUF and to share costs on an installment basis and subsidized basis. Twenty-six farmers were not willing to share costs for the purchasing of the devices with the WUF and they recommended that the WUF should be responsible for purchasing the implements. This, however, is a confusing statement, since the WUF represents the water users and financially is dependent on the water users.

Several suggestions came with respect to the management side. Twenty-four farmers felt that the responsibility falls under the finance secretary of the WUF. Nine farmers suggested that it should be jointly between IIMI and the WUF. Further, farmers suggested that a set of both devices should be available for each sub-system separately for easy availability during sowing (bed-and-furrow shaper) and hoeing (hoeing device). Also, it was recommended that the devices are available on booking basis for which a separate committee should evolve that registers the bookings (mentioned by 15 farmers), the devices should be available within the subsystems on a rotational basis, mentioned by 7 farmers (then of course, the booking principle does not work). One farmer mentioned that a bigger size tractor should be arranged.

7.10. Future Interest

Certain factors disturbed this years cotton production and the effect of the bed-and-furrow irrigation method could not be clearly observed due to factors such as late sowing, late availability of the bed-and-furrow shaper and hoeing device, unfavorable weather conditions and uncontrollable crop diseases. Nevertheless, among farmers who used the bed-and-furrow irrigation method, enthusiasm was generally expressed. All the interviewed farmers, except two, have an interest in continuing the use of the bed-and-furrow irrigation method (both farmers experienced severe crop failure and difficulties in hoeing). The following reasons (incentives) were mentioned by the farmers for continuing with the bed-and-furrow irrigation method next year:

- Better germination (11);
- Water saving (12);
- Safety from rainfall (11);
- Better yield expectation (2);
- Efficient use of water for more acres (2);
- Good crop growth rate (2);
- Easy for pesticide applications (2);
- Fertilizer and pesticide saving (2);
- Increase in the average yield (1);
- Increase in soil fertility for the next crop (1);
- Less labor work (1);
- Less input expenses (1);
- Easy for hoeing (1); and
- Good for waterlogged and saline soils (1).

7.11. Extension Services

Although the topic "Extension Services" does not explicitly relate to the bed-and-furrow use, yet several questions were asked to the farmers in order to obtain insights in how the farmers feel about the performance of the existing extension services (Agricultural Extension Directorate) and whether farmers make use of radio and television to listen or watch agricultural related programs.

It could be inferred from the answers of the farmers that there is hardly any interaction between farmers and the Extension Directorate. Only seven farmers mentioned having contact with this Organization due to IIMI and the WUF. These farmers mentioned discussing issues pertaining to crop diseases, seeds, fertilizer and pesticide use and pest control.

In general, the farmers criticized the behavior of the extension workers in terms of providing hardly any updated information pertaining to crops, seeds, fertilizer and pesticides, and the location of the field trials, which are mostly near the main road. It is said that some extension workers hardly visit the field and meet with farmers.

With respect to the use of media facilities for extension purposes, fourteen farmers commented that they rarely watch or listen to media broadcasting regarding agricultural programs, since anyhow little time is allocated by the media on these issues, and further the quality of the programs are not perceived as good and informative. Twenty-three farmers mentioned seldom watching or listening to agricultural related programs. It was suggested, however, by some farmers that the broadcast should be on prime time, i.e. between 8 pm to 10 pm. The following suggestions were given by the farmers pertaining to improvement of extension services:

- Extension personnel should punctually visit the farmers, listen to the farmers and solve the farmers' problems (20);
- They should visit farmers' fields and check the crop frequently (4);
- They should maintain their rotational schedule (4);
- They should give information pertaining to agriculture to each and every farmer (3);
- They should make strict checks on forger fertilizer and pesticides (2);
- The Directorate should provide seeds, fertilizers and pesticide for cheap prices (subsidized) or should be made available based on paying in installments or loans should be made possible (2).
- Provision of a pamphlet on agriculture and crop cultivation (1); and
- The Directorate should provide agricultural implements on cheaper prices or they should be made accessible by allowing payment in installments (1);

8. SYNTHESIS AND CONCLUSIONS

8.1. Impact of the Bed-and-Furrow Irrigation Method on the Irrigation, Cultural Practices, Cotton Production and Farmers' Revenue

8.1.1. Impact on Irrigation Practices

Irrigation practices for the bed-and-furrow irrigation method showed several significant differences with the basin irrigation method. A first observation from the farmers was that the irrigation frequency increases, and thus, a reduction in the time interval between two successive irrigation events. Quantitative analysis, - based on a sample size of 32 and 21 for the bed-and-furrow and basin fields, respectively -, confirms this observation. On an average, the number of irrigation applications for cotton during the *kharif* season increased by two, with average values for the number of irrigation applications of 7 and 5 for the bed-and-furrow and basin fields, respectively. The minimum and maximum number of irrigation applications for the basin field was found to be two and seven, respectively, whereas for the bed-and-furrow fields these value were four and ten, respectively.

The average irrigation duration accumulated for the kharif season results in a 30.6% increase in time spent on irrigation applications for the bed-and-furrow irrigation method. Event-wise, however, less time (on an average 35.9%, by comparing the first six irrigation events) is spent on irrigating one acre of cotton sown in a bed-and-furrow field, hence more area can be irrigated during the warabandi. The event-wise time saving is considered by farmers as a real advantage, and for this the irrigation method is appreciated. Though farmers expressed that water and time is saved, yet this statement causes distraction in what is really meant with this statement when the total water application depth or volume of water applied for the bed-and-furrow irrigation method is compared with the basin irrigation method. The analysis shows that season-wise, on an average, more water is used for the bed-and-furrow fields, typified by a 15.5% increase in water application depth. Only two farmers felt that event-wise water saving has occurred but not season-wise.

The evaluation on the irrigation requirement and the water application depth reveals that for both the irrigation methods, season-wise the irrigation applications have been deficit and the irrigation requirements are not fulfilled. An irrigation requirement of 743 mm is calculated for the period May 19 (average sowing date) to November 5 (average last applied irrigation). The average irrigation application depth is 563 mm and 436 mm for the bed-and-furrow and basin irrigation methods, respectively, and which results into a season-wise deficit of 24 percent for the bed-and-furrow irrigation method and 41 percent for the basin irrigation method. There is a significant difference in deficit between the two methods; hence, it can be hypothesized that the lighter, but more frequent irrigation applications for the bed-and-furrow method not only allows the farmer to irrigate more bunded fields during a warabandi, but also results in lower crop water deficits as compared with the basin irrigation method, which results in higher farm productivity over the season.

A relationship between irrigation practices and the landholding size and physical factors could not clearly be established. With respect to irrigation frequency, farmers with different land holding size appear to maintain a similar kind of strategy. The only noticeable difference appeared for farmer with large landholding sizes (i.e. between 25-50 acres), for which the difference in irrigation frequency between the bed-and-furrow and basin irrigation methods appeared less as compared to the irrigation strategy of farmers of smaller landholding sizes. With respect to irrigation practices in relation to soil quality, it was observed that the average irrigation application depth was more for the bed-and-furrow fields that are classified as saline-sodic soils. For the basin fields, it appeared that more water is applied per irrigation event for the non-saline sodic and saline non-sodic fields. It appeared that more water is applied to fields subjected to sodicity problems.

More tubewell water has been applied for the bed-and-furrow fields than for the basin fields (1540 and 460 hours, respectively), which may correlate with the increase in irrigation frequency, that cannot always be complemented by canal water use.

8.2. Impact On Cultural Practices

A significant difference in time spent on specific cultural practices occurred for the hoeing activities and thinning activities. An increase in time spent of 33.7 percent and 48.7 percent occurred for the hoeing and thinning, respectively. The main reason for the increase in time spent on hoeing pertains to the performance of manual hoeing. This in contrary to the basin fields, where farmers can use the traditional method of hoeing by using the tractor or animal traction and a plough-type of implement. Though, it can be noted that a considerable time on hoeing is also spent for the basin fields; it was noted that farmers also conduct manual hoeing for the basin fields next to the use of a farm implement. Although, a hoeing device was made available to the farmers to hoe the bed-and-furrow fields, only two farmers used the device. The main reason was the late delivery of the hoeing implement, at a stage when the crop was already of considerable height and fruiting, and, since farmers did not want to wait for the implement, they already started hoeing while the implement had not reached the area yet. Overall, the two farmers who used the hoeing device were not satisfied with the device, it was considered as being too heavy and difficult to use. The reason for the increase in thinning could not clearly be identified, however, the most logical reason would be that a denser sowing occurred by using the bed-and-furrow shaper, since the sowing device has not been calibrated to maintain a specific plant-to-plant distance.

The total time spent on cultural practices is 3787 and 2850 hours, respectively, for the bed-and-furrow and basin fields, which results in a 32.9 percent increase in time. The average time spent on irrigation and cultural practices is 4700.6 hours and 3549.3 hours, which is about 19 hours of time difference. Using the bed-and-furrow irrigation method has resulted in an increase in spent time on irrigation and cultural practices of 32.4 percent. It is expected that the time difference will be reduced when mechanical hoeing is applied.

8.2.1. Impact On Cotton Production

The average cotton production was found 15 percent higher for the bed-and-furrow irrigation method, with average values of 9.48 maunds per acre and 8.1 maunds per acre for the bed-and-furrow and basin fields, respectively. Overall, the yield was low, mainly due to the weather and the occurrence of severe diseases of which the American Bollworm was the major disease identified. Farmers, however, perceived the bed-and-furrow irrigation method as a method that provides an increase in the reliability or good cotton production.

The various diseases, such as American Bollworm, White Fly and Thrips, are considered by farmers the main cause of low cotton production next to the often unpredictable climate (i.e. early high temperatures, sudden rainfalls and droughts). Farmers have their knowledge and experience in what and when to apply when it comes to chemicals and fertilizers. However, the magnitude of diseases attacks were considered as uncontrollable. Further, farmers are familiar with controlling measures but not with preventive measures, and in fact, when the disease is noticed in reality, the farmer is already too late to properly control the crop disease or virus attack. It was perceived, though, by a few farmers that the magnitude of White Fly was more for the basin fields as compared to the bed-and-furrow field and ascribed the difference to the unfavorable climate which arises in basin fields due to the ponding of water and high temperature.

The water use efficiency, an indicator for the water productivity, was found to be about the same for the bed-and-furrow and basin fields, with values of 0.251 kg/m3 and 0.254 kg/m3, respectively. The WUE, however, is expected to be higher, and thus higher water productivity, when the irrigation requirements are actually met, rather than having a crop water deficit.

8.2.2. Impact On The Farmers' Revenue

The financial analysis reveals that the difference between the bed-and-furrow and basin fields pertaining to the total input costs is negligible (4% difference only). Major differences in expenses occurred for the seed purchasing, hoeing and pesticides application, of which the expenses for the latter were higher for the basin fields, whereas the expenses of the other items were higher for the bed-and-furrow fields.

A similar tendency occurred for the revenue, for which a negligible difference is calculated. The benefit - cost ratio for the bed-and-furrow and basin fields are 0.98 and 0.97, respectively. The average losses (i.e. a negative valued revenue) were higher for the basin fields (Rs. 3245.67) as compared to the bed-and-furrow fields (Rs. 1164.25), which makes the bed-and-furrow irrigation method less sensitive for financial losses.

Based on the analysis, it can be concluded that the bed-and-furrow irrigation method does not impose a financial burden on the farmers under the condition that the required farm implements are available on a rental basis. Also, the magnitude of financial losses, - when this occurs- appears less for the bed-and-furrow irrigation method and make it a dependable irrigation method.

8.2.3. Impact On Salinity

A concern, raised by farmers, especially at the beginning of the kharif season, was the effect of the bed-and-furrow irrigation method on salinity. During the season, however, most of the farmers, though they observed salinity on the beds, did not consider it as a real hazard.

Quantitative data collected from another distributary command area (Sirajwah Distributary) shows that the ECe increases more for the soil samples taken from the bed side than from the furrow side over the season. Fields affected with salinity are subjected to a severe salinity increase on the bed, whereas fields free from salinity also have a modest increase in the ECe, and the hazard for salinity (i.e. ECe > 4 dS / m) could not clearly be identified. For the furrow side, soil samples showed the increase in salinity was found less consequential for the saline, as well as non-saline, fields. It was found that the bedside is more subjected to increases in ECe as compared to the soil from the furrows, and thus confirms the farmers' concern.

8.3. Impact Of Precision Laser Leveling On Irrigation Duration And Water Use

A total of twelve farmers (out of the 50 farmers) used the bed-and-furrow irrigation method in conjunction with the precision laser leveling, covering an area of 28.75 acres. For seven sample farmers, the irrigation practices (duration and water use) were analyzed. Based on this small sample size, it could be concluded that there is a significant difference in irrigation performance when the precision laser leveling is used prior to the implementation of the beds-and-furrows. The total irrigation duration, total water depth applied and average water depth applied per irrigation events is reduced by 45.4%, 54.4% and 32.4%, respectively, which is quite dramatic.

From a water saving point of view, the laser leveling technology has potential. The farmers who have been using this were satisfied and considered this as a good and accurate method for soil leveling, especially before implementing the bed-and-furrow irrigation method.

8.4. ADAPTABILITY OF THE BED-AND-FURROW IRRIGATION METHOD

8.4.1. Major Advantages And Constraints

With respect to agronomic aspects, based on farmers' feedback on either qualitative or quantitative information, it was found that:

- The germination rate is better for the bed-and-furrow fields, of which the maximum encountered germination rate was 80% to 95% for the bed-and-furrow fields and 70% to 80% for the basin fields.
- Farmers perceived a better resistance of the crop towards rain and flood of the crop sown in the bed-and-furrow field, since the soil covering the crop was not subjected to permanent crusting, but would soften again. Also, 26 farmers indicated that the crop growth was faster for the crops of the bed-and-furrow field and more fruit formation was observed.
- An increase in seed usage per acre was observed for the bed-and-furrow field. This includes seed usage for gap filling, an activity that only took place for the bed-and-furrow fields.

With respect to the water management and irrigation practices it was found that:

- Fifteen farmers felt that the *peecha bara* (irrigation efficiency) increased;
- Fifteen farmers mentioned that water saving takes place, hence more acres of land are irrigated *during the warabandi*;
- Although farmers indicated also water saving season-wise, this was found to be in contradiction with the analysis. Event-wise, there is a water and time saving, but not season-wise;
- An decrease in the irrigation interval for definitely the first four irrigation events and (consequently) an increase in the irrigation frequency increased, but less quantity of water is used.

Overall, the constraints were mostly felt with the farm implements (the bed-and-furrow shaper and hoeing device) and the implementation phase of the beds-and-furrows.

- The bed-and-furrow shaper was perceived as too heavy to be pulled by an average tractor (e.g. MF 240), however, this problem and the accessibility to a heavier horsepower tractor was solved by using (on rent) a tractor from On-Farm Water Management;
- Due to soil wetness, the metering wheel did not function properly (halted);
- Difficulties occurred in preparing straight furrows, which in a later stage made the use of the hoeing machine difficult, since the crop would be damaged; and
- Seed was not covered by the soil due to the sowing tine or wet soil and some problems in the sowing device occurred.

Further, 23 farmers commented that the quality of the bed-and-furrow shaper was not so good in terms of material and also the welding joints were not properly fabricated. The maintenance of the bed-and-furrow shaper then mostly pertained to fixing the welding parts in addition to the maintenance of the sowing device. Farmers' main suggestions were that the bed-and-furrow shaper should be lighter in weight, but the material should be stronger, and improvements in the metering wheel and sowing device should be made.

The hoeing device was hardly used by the farmers due to the late delivery; at the time of delivery most of the farmers had commenced with manual hoeing. The two farmers who used this device mainly commented that it was too big and heavy, and complicated in its adjustments and use. They recommended that the device should be easier in operation, should be adjustable according to the crop height, should be lighter in weight, and made of better quality material.

8.4.2. Role of the WUF

To delegate responsibilities to the Water Users Federation in the bed-and-furrow dissemination process proved to be very efficient for Hakra-4R Distributary. When the plan of the bed-and-furrow irrigation method was explained to the farmers, they were very receptive towards the idea. The Federation put a lot of effort in awareness building activities for the farmers in the command areas, such as village lectures, study tours were made, and trainings were organized in collaboration with MREP. The WUF established a committee that was responsible for the booking and rent acquiring of the implements. Despite several drawbacks pertaining to the late delivery of the implements, the weather, and organizing properly the rotation of the bed-and-furrow shaper, it has been very encouraging to observe that farmers have the ability to organize activities collectively, and foremost their keen interest in experimenting with improved irrigation practices. However, it was experienced that the WUF needs to learn how to operate and act independently. During the dissemination process of the bed-and-furrow irrigation method, IIMI still remained the driving force in many instances.

In the future, the role of the WUF has to be clearly defined, and also the role of the farmers. Based on the final interviews, it became clear that most of the farmers (26) are not willing to join hands with the WUF with respect to sharing costs for the implements and considered the WUF as responsible for this. This, however, implied that farmers consider the WUF as independent from the farmers with their own financial sources, instead of farmers' representatives who are dependent on farmers' contributions. If the WUF has to bear the costs, then still the money has to come technically speaking from the users, which are the farmers. The management of the bed-and-furrow shaper was perceived as the task of the WUF (finance secretary) and a few farmers mentioned that both IIMI and the WUF should manage the bed-and-furrow use. This indicates that IIMI is still considered as a potential actor in the process, which actually should not be the case. Being organized should give the farmers the strength and willingness to undertake any activity themselves.

8.4.3. Farmers' Attitude

Overall, the attitude of the farmers towards the bed-and-furrow irrigation method has been very receptive, expressed in an enthusiasm and interest in using the irrigation method in the next *kharif*. The three main reasons for continuing with the bed-and-furrow irrigation method are:

- Better crop germination;
- Water saving; and
- Safety from rainfall.

Only two farmers were very negative towards the bed-and-furrow irrigation method due to crop failure.

8.5. CONCLUSIONS

Comparing analytical results and farmers' reactions, there are no major reasons to identify what would make the bed-and-furrow irrigation method not appropriate for the farming community. The irrigation method can be adopted, but a certain experience in operating the implements and organizing the use of the implements should be improved, which has been recognized by the WUF. Further, it needs to be a requisite for farmers to have access to a proper tractor. Otherwise, many farmers will be exempted from the bed-and-furrow use and then, in the end, it will become only an instrument for a selected group of farmers (mainly the rural elite), a tendency which occurred with the laser-leveling technology several years back, that was totally confiscated by the large farmers.

Further, the bed-and-furrow irrigation method could only become truly successful if other aspects of irrigation management and farming management are considered. A requisite for using this method is that the farmer can rely on the water supply from the main system. During the period mid-May 1998 to mid-December 1998, 64 days were counted of which there was no water in the distributary. Since the bed-and-furrow irrigation method requires frequent water supply, an unreliable water supply shall remain constraining for farmers when it comes to scheduling irrigation events and applying the required amount of water. This may result in farmers not using the bed-and-furrow irrigation method, especially those who do not have access to good quality tubewell water.

During the data collection activities and analysis, it became apparent that the current farming system is far from productive, which too a large extent can be ascribed to the occurrence of the fatal diseases. Preventive measures are requisites and as long as there is no serious and effective pest management program, farming cannot become a productive enterprise in this area.

The bed-and-furrow irrigation method is a mean to facilitate on-farm water management. However, it is still an option for which a farmer is free to choose and it is by no means imposed on them. But with introducing this irrigation method to the farmers, an achievement has been to make farmers realize that they have a choice when it comes to managing their irrigation water at the field and farm level.

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APPENDICES

APPENDIX A. ROTATIONAL PROGRAMME FOR THE HAKRA CANAL DIVISION BAHAWALNAGAR

Hakra Canal Division Bahawalnagar
Rotational Programme for the Fassal Kharif, 1998 of E.S.
Canal/Hakra Branch for the Period 20-04-1998 to 20-10-1998

GROUP "A"	3-R, 5-R, 2-L, 7-R, 8-R, Hakra Right, 3-L, 4-L.
SUBGROUP "A1"	3-R, 2-L, 3-L, 4-L
SUBGROUP "A2"	5-R, 7-R, 8-R.
SUBGROUP "A3"	HAKRA RIGHT DISTY
GROUP "B"	4-R, 1-L, 6-R, 9-R, HAKRA LEFT, FLOOD CHANNEL.
SUBGROUP "B1"	4-R, HAKRA LEFT, FLOOD CHANNEL.
SUBGROUP "B2"	1-L, 9-R.
SUBGROUP "B3"	6-R

Note: Bakhu Shah Mior, 1-R/Hakra Branch, 2-R/Hakra Branch Are Not Included In This Programme Due To High Level Channels

PERIOD		GROUP		SUBGROUP					
From	To	1st	2nd	1st		2nd			
20/4/1998	27/4/1998	A	B	A2	A3	A1	B2	B3	B1
28/4/1998	5/5/98	B	A	B1	B2	B3	A1	A2	A3
6/5/98	13/5/1998	A	B	A3	A1	A2	B3	B1	B2
14/5/1998	21/5/1998	B	A	B2	B3	B1	A2	A3	A1
22/5/1998	29/5/1998	A	B	A1	A2	A3	B1	B2	B3
30/5/1998	6/6/98	B	A	B3	B1	B2	A3	A1	A2
7/6/98	14/6/1998	A	B	A2	A3	A1	B2	B3	B1
15/6/1998	22/6/1998	B	A	B1	B2	B3	A1	A2	A3
23/6/1998	30/6/1998	A	B	A3	A1	A2	B3	B1	B2
1/7/98	8/7/98	B	A	B2	B3	B1	A2	A3	A1
9/7/98	16/7/1998	A	B	A1	A2	A3	B1	B2	B3
17/7/1998	24/7/1998	B	A	B3	B1	B2	A3	A1	A2
25/7/1998	1/8/98	A	B	A2	A3	A1	B2	B3	B1
2/8/98	9/8/98	B	A	B1	B2	B3	A1	A2	A3
10/8/98	17/8/1998	A	B	A3	A1	A2	B3	B1	B2
18/8/1998	25/8/1998	B	A	B2	B3	B1	A2	A3	A1
26/8/1998	2/9/98	A	B	A1	A2	A3	B1	B2	B3
3/9/98	10/9/98	B	A	B3	B1	B2	A3	A1	A2
11/9/98	18/9/1998	A	B	A2	A3	A1	B2	B3	B1
19/9/1998	26/9/1998	B	A	B1	B2	B3	A1	A2	A3
27/9/98	4/10/98	A	B	A3	A1	A2	B3	B1	B2
5/10/98	12/10/98	B	A	B2	B3	B1	A2	A3	A1
13/10/1998	20/10/1998	A	B	A1	A2	A3	B1	B2	B3

NOTE:- 1) The Group in 2nd preference will run subject to availability of supply
2) The programme can be changed accroding to the increase/decrease of supply.
3) The Sub-Divisional Officers (Incharge) are responsible for implementation of this programme.
4) The Sub-Divisional Officers are authorised to change the programme in un-avoidable circumstances.

Source: Punjab Irrigation Department

APPENDIX B: PRODUCTION DATA FOR THE BED-AND-FURROW AND BASIN FIELDS

		Bed-and-Furrow				Basin				Total Farm Production		
		Area	Yield	Yield	Yield		Yield	Yield	Yield	Cotton Area	Yield Maund	Yield
1	1.1	1	221	221	5.5	1	186	186	4.7	12	54	4.5
2	1.2	1	235	235	5.9	1	228	228	5.7	29	235	8.1
3	1.3	1	256	256	6.4	1	142	142	3.6	4.5	32	7.1
4	1.4	1	672	672	16.8	0.5	65	130	3.3	6.13	78	12.7
5	1.5	1	640	640	16.0	1	50	50	1.3	4.88	44	9.0
6	1.6	0.5	143	286	7.2	no sample basin				3.25	21	6.5
7	1.7	1	524	524	13.1	0.5	318	636	15.9	3	52	17.3
8	1.8	0.5	166	332	8.3	no sample basin				1.5	19	12.7
9	1.9	1	276	276	6.9	1	300	300	7.5	6.5	48	7.4
10	2.10	2	301	150.5	3.8	no sample basin				12	28	2.8
11	2.11	1	408	408	10.2	1	381	381	9.5	26	110	5.2
12	3.13	0.5	260	520	13.0	1	560	560	14	5	30	6.0
13	3.14	2	743	371.5	9.3	1	40	40	1	6	64	10.7
14	3.15	1	80	80	2.0	1	480	480	12	4	20	5.0
15	3.16	1	415	415	10.4	1	480	480	12	18	131	7.3
16	3.18	1	280	280	7.0	no sample basin				22	96	4.4
17	3.21	1	400	400	10.0	no sample basin				7	73	10.4
18	3.24	1	160	160	4.0	no sample basin				4.5	25	7.1
19	4.28	1	170	170	4.3	0.5	97	194	4.9	2.5	21	8.4
20	4.29	1	216	216	5.4	1	160	160	4	8.5	36	4.2
21	4.30	0.375	67.5	180	4.5	0.375	43.5	116	2.9	2.5	6	2.4
22	4.31	0.5	193	386	9.7	no sample basin				-	-	-
23	4.32	1	525	525	13.1	no sample basin				2	21	10.5
24	4.33	1	8	8	0.2	no sample basin				1	0.2	0.2
25	4.34	1	498	498	12.5	no sample basin				12	70	5.8
26	4.35	1	5	5	0.1	no sample basin				3	4	1.3
27	5.36	0.25	111	444	11.1	0.25	104	416	10.4	1.5	25.5	17.0
28	5.37	0.5	235	470	11.8	0.5	291.5	583	14.6	17.5	150.75	8.6
29	5.38	0.75	425	567	14.2	no sample basin				2.5	17.5	7.0
30	5.39	0.375	135	360	9.0	0.375	124	330.7	8.3	1.25	19	15.2
31	5.40	1	50	50	1.3	1	72	72	1.8	15	170	11.3
32	5.41	1	78	78	2.0	1	520	520	13	35	206	5.9
33	5.42	0.25	170	680	17.0	0.25	156	624	15.6	10	67	6.7
34	5.43	1	305	305	7.6	1	350	350	8.8	4	43	10.8
35	5.44	1	1120	1120	28.0	1	800	800	20	12	155	12.9
36	5.45	1	615.38	615.38	15.4	no sample basin				8	108	13.5
	5.46									15	185	12.3
	0.47									100	650	6.5
	0.48									22.5	418.75	18.6
	0.49									45	402.5	8.9
	0.5									150	900	6.0

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R-83	Disseminating the Bed-and-Furrow Irrigation Method for Cotton Cultivation in the Hakra-4R Distributary in Collaboration with the Water Users Federation (Joint Research Dissemination Program)	Ineke Margot Kalwij Zafar Iqbal Mirza Anjum Amin Ahdul Hameed	May 1999