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Research Article

Increasing Crop Profitability through Adoption of Ridge Planting of Rice Crop in Punjab, and Wheat & Banana Crops in Sindh Province of Pakistan

Abid Hussain[1*], Mohsin Ali Khathian[2], Sami Ullah[1], and Saad Ullah[1,3]

[1]Social Sciences Research Institute, PARC-National Agricultural Research Centre, Islamabad, Pakistan
[2]PARC-Social Sciences Research Institute, Agricultural Research Institute, Tandojam, Pakistan
[3]Department of Agriculture and Resource Economics, University of Agriculture, Faisalabad, Pakistan

Abstract: Ridge sowing of crops has clear advantages over traditional irrigation practices; specifically reduces use of water and other inputs, helps better crop management, and delivers higher crop productivity. The study analyses adoption and cost-benefit of ridge planting of rice crop in mixed cropping zone of Punjab, and wheat and banana crops in mixed cropping zone of Sindh province of Pakistan. It is based on primary data collected from 120 adopter farmers of the technology, including 40 farmers each planting rice crop on ridges in central Punjab (Toba Tek Singh district), sowing wheat crop on ridges in central Sindh (Shaheed Benezirabad district) and planting banana crop on ridges in lower Sindh (Tando Allahyar district) during crop season 2017-18. Field surveys for the study were conducted in March to May, 2018. It is found that adoption of the technology results into increase in land preparation cost of rice, wheat and banana crops by about 13, 2 (excluding cost of ridge sowing through drill) and 47 percent, respectively. Adoption of the method resulted into productivities of rice, wheat and banana crops of 56.5, 48.9 and 666.4 mound per acre, respectively. Though, productivities of wheat and banana crops were higher than traditional sowing practices of the crops by about 22 and 20 percent, respectively. While that of rice crop was less than conventional flat sowing method by three percent. Adoption of ridge sowing method resulted in decrease in irrigation cost by 25, 36 and 40 percent in rice, wheat and banana crops, respectively. The method resulted in decrease in total cost of production of rice and wheat crop by about two and seven percent, respectively; while, increase in that of banana crop by four percent. Benefit cost ratios of the technology for rice, wheat and banana crops are 1.03, 1.41 and 2.26, respectively; against 1.04, 1.08 and1.97 obtained through traditional flat sown/ flood irrigation of crops, respectively. Thus adoption of the technology is beneficial in case of wheat and banana crop, but at par in financial gains with conventional sowing in case of rice crop.

Keywords: Ridge planting, Rice, Wheat, Banana, Punjab, Sindh, Productivity, Benefit-cost ratio

1. INTRODUCTION

The agrarian economy of Pakistan is continuously under stress due to the low yield productivity of almost all the crops that is constrained with many problems. One of the most important issues of crop farming is water shortage, severity of which is increasing with the passage of time. So much so, that it has become a major challenge of the day. Therefore, water saving becomes the utmost need of the hour. In the country, adopters of new water saving technologies/ practices typically have more favorable resource base and tend to variously outperform non-adopters. More access to education and other social amenities increase the chances to adopt new technologies by the farming community. However, small farmers can also be benefited from these technologies, if they are provided with proper knowledge and access through effective social mobilization. This would result in conservation of scarce and valuable farm resources [1]. The technique of wheat sowing on flat beds raised between irrigation furrows started in mid 1970s in Mexico [2]. Its adoption increased from few farms

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*Corresponding Author: Abid Hussain < abid.parc@gmail.com >

in 1981 to 75 percent farms in 1994 [3]. Similarly, there are several reports on the performance of crops grown on ridges in India going back in the 1970s. Ridges/ furrow-beds are similar to raised beds which were introduced in the mid-1990s [4]. The technique was tried for rice crop for the first time in Haryana, India in 2000, and in Parwanipur, Nepal in 2001 [5]. It is believed that the technique not only helps to save water but also diversify cropping systems. The method is particularly considered more appropriate for growing high value crops that are more sensitive to temporary water logging stress. Farmers often raise crops such as cabbage, carrot, radish, okra, onion, brinjal, cauliflower, colocasia, turmeric, cotton, maize, wheat on the raised beds. It also helps to improve the physical properties of soil [6]. While, conventional crop raising though open flood irrigation and puddling for rice crop have been leading to deterioration of soil health and declining farm profitability due to high inputs of water and labour [3, 7].

On the other hand, establishment of rice on non-puddled flat land or raised bed is promising. However, weeds are a serious problem and micronutrient deficiency is conspicuous when rice is direct seeded in non-puddled soil [5]. While, furrow-bed planting of crops results into better aeration, saving in irrigation quantity and application time with intermittent irrigation, less crop lodging, higher water use efficiency, non-crusting & little cracking of soil surface thereby decreasing moisture loss through evaporation and improve aquifer recharge [8]. Likewise adoption of the technology results in lesser adverse effects on the environment through reduced methane emissions, effective use of applied nitrogen and reduction in nitrous oxide emissions [3]. It helps to overcome drudgery of transplanting & management of subsoil composition, reduced tillage in rice, makes possible timely sowing of wheat crop, prevents clod formation during land preparation for proceeding crops and higher returns [9]. Similarly, furrow-bed planting with residue retention is considered as a form of conservation agriculture. It results in increase in C and N content of the silt and clay fraction of the soil and improves the soil structure [10]. Advantages of the technique over traditional sowing also include mechanical weeding, placement of fertilizers, opportunities for relay cropping etc. Furthermore, in case of rice crop adoption of the technique can improve soil structure to the benefit of ensuing wheat crop. Thus, even if rice yield remains the same or reduces to some extent through adoption of the practice, real benefit could be increase in wheat productivity [11]. Wheat yield can further increased through possibility of higher N application rates and later irrigation because of reduced risk of lodging on beds [12].

It improves photosynthetic parameters & water use efficiency, enhances root number & antioxidant enzyme activities, it also increase panicle number in rice and the crop yield by 15 percent. Furthermore, use of residue mulching is considered to have potential to increase both crop productivity and profitability [13]. It is also recommended to plant nutrient responsible cultivars of rice in non-saturated soil with sufficient external inputs to reach yield of sufficiently high input (70-80% more than ridge sowing) requiring flooded rice. Trails for optimizing dose and timing of N fertilizer and improvement in water regime are also suggested to reduce crop water stress in case of ridge sowing [14]. Conversely, conventional basins to irrigate crops through open flooding are commonly used in Pakistan. The irrigation system is highly inefficient resulting in loss of precious and costly canal & pumped water as well as nutrients, that results in poor crop yield. Sowing wheat and other crops on ridges has clear advantages over traditional irrigation practices *viz*. reduces water use, saves electricity (energy) used for pumped water, reduces seed rate, results into better conservation of rain water, improves fertilizer use efficiency, provides better control on weeds by keeping furrows flooded in early stages as well as possibility of mechanical weeding, reduce insect- pest infestation, helps reduce crop lodging and increases crops' productivity. In the country, after its use for wheat crop, the method is also gaining acceptance for rice and banana crops. [15].

Specifically, in case of rice crop farmers have options for doing away with the practice of flat/puddled sowing by adopting different direct seeding methods *viz*. broadcasting soaked seed in moist soil condition, broadcasting of dry seed in dry soil and applying irrigation afterwards, broadcasting of dry seed in wattar condition, broadcasting soaked seed in dry soil followed with immediate irrigation, broadcasting sprouted seed in wattar condition, drilling of dry seed in wattar

condition, and drilling of soaked seed in wattar condition etc. [16]. However, in case of dry-seeded rice on beds, seed germination and initial crop establishment appear to be problematic [5]. The rice crop can also be sown through transplanting methods *viz*. on flat irrigated land or ridges, and through mechanical transplanters on puddled soils. However, mechanical transplanting could not achieve success in the country due to skill & training requirement for raising mat-type nurseries, mud flows & burying of one row of new planted seedlings, machine access at reasonable costs and amount of time available of services providers etc. [9].

Wheat and rice are ranked third and fourth by global production of food times, respectively [17]. Pakistan shares 2.65 percent in world population. The country shares 3.40 and 0.92 percent in the global wheat and rice production, respectively. While, wheat is the main staple food crop in Pakistan followed by rice. During 2017-18, cultivated area under wheat crop was 8.734 million hectare with production of 25.492 million ton. It contributed 9.1 % to the value added in agriculture and 1.7 to the national GDP [18]. Out of total wheat area, 7.8 million hectare (89% of total wheat area) is planted through broadcast method and irrigated through low-efficiency basin irrigation methods [19]. Sindh province is the 2nd largest wheat producing province in the country. It shares about 13% in wheat production, with 1.11 million hectare area under the crop. Rice is an important food as well as cash crop in the country. Rice is second major exportable commodity after cotton. During 2016-17, cultivated under rice crop was 2.724 million hectare with production of 6.849 million ton [20]. Banana is second largest fruit crop produced in the world by volume after watermelons [21]. Pakistan shares one percent in world banana production. Banana is tasty fruit, which is liked throughout the world. It remains available year round. It contains many fruit nutrients like, vitamin B-6, vitamin C, copper, potassium, manganese, soluble dietary fiber, carotenoids and short fatty acids. Other fruits do not compete with banana in these vitamins, salts and other nutrients. Furthermore, it produces more per unit area than other fruits [22]. Banana crop was planted on 28,200 hectare in the country in the year 2014-15. Total production of the fruit was about 1.19 million ton. Sindh province shares 93 percent in area (26,300 hectare) and 86 percent (1.02 million ton) in total production of the fruit [20].

In Sindh province, Badin, Shaheed Benezirabad, Hyderabad, Tando Allahyar, Mirpur Khas, Tando Muhammad Khan, Matiari, Thata, and Khairpur are major banana producing districts, where good varieties of banana are cropped. Banana is planted in February-March and August-September; however February-March is considered the best period as plants planted in these months grow better. In the country, average productivity of the crop is 42.2 ton per hectare (427 mounds per acre); however, production potential of the crop is 60-80 ton per hectare (607-809 mounds per acre). Thus, there is a big gap in average and potential yield of banana crop in the country. One of the main reasons of this yield gap is over irrigation of the crop than required level. Farmers mostly irrigate the crop through conventional method due to which water resource get wasted and increase in water logging and soil salinity occur. While, banana crop is very sensitive to these soil issues. Drainage and Reclamation Institute of Pakistan (DRIP), Tandojam, which is subsidiary of Pakistan Council of Research in Water Resource (PCRWR) has reported that in case of banana crop 50% water goes waste through traditional irrigation method that can be saved by adoption of ridge planting of the crop along with obtaining increased productivity [20].

Thus, planting of crops on ridges/ beds is one of the practices which can potentially improve yields and water use efficiency (WUE). In case of ridge or bed planting of rice, soil is prepared through ploughing and then laser leveled, ridges (12" x 12") are made using ridge maker. Field are irrigated through the furrows up to three-fourth (75%) height and after two to three hours rice nursery is transplanted on ridges or beds manually by keeping pant to plant distance to 5 inch and row to row distance of 8 inch. In this way, minimum number of plants per acre should be 80,000 [23]. In ridge planting of wheat, seed and fertilizer are broadcasted in the fields after land preparation; it is followed by making ridges (12" x 12") by a ridge maker. In this way, seed and fertilizer come on the ridges and the water is applied in furrows [24]. Land should be selected and prepared in January for banana ridge sowing. Loamy soil, well

drained up to 4-5 feet depth and having 1.5-2.0% organic matter should be selected. It should be first deeply ploughed with Raja plough/ large sized disc plough and then with ordinary cultivator. Then it should be laser leveled. On well prepared soil, 36 inch wide furrows are made at 84 inch space. In this way 36 inch wide furrow and 48 inch wide beds are prepared. In each furrow, 24 square inch holes are digged, and total number of plants per acre come to 888 [22]. WUE in the conventional flood irrigation practice of growing crops is low. In the backdrop of increasing water scarcity, the farmers and researchers are looking for new methods and techniques to improve crops' yield and WUE. As stated earlier that planting of crops on ridges is one of the technologies which can potentially lead to improve productivities and WUE. Keeping all this in view, the study has been designed to analyze cost-benefit analysis of ridge planting of rice in mixed cropping zone of Punjab province, and wheat and banana crops in mixed cropping zones of Sindh province.

2. MATERIALS AND METHODS

The study is based on cross-sectional data collected for rice crop from tehsil Kamalia of Toba Tek Singh district of the Punjab province, for wheat crop from tehsil Sakrand of Shaheed Benezirabad district of the Sindh province, and for banana crop from southern districts of the Sindh province *viz*. Badin, Matiari and Tando Allahyar. Rice ridge planting technology is being promoted by PCRWR Regional office Lahore in Punjab. Rice-wheat zone of the province was actual target area to encourage farmers to adopt the technology. However, in the year 2017 early rains at the start of sowing season in the rice-wheat zone made it impossible for the farmers to prepare land and practice ridge sowing of the crop. Thus, the technology was promoted in Toba Tek Sindh district through scrupulous efforts of Regional Office of PCRWR (Lahore). A field survey was conducted in March, 2018 and forty farmers who practiced ridge/ bed planting of rice were interviewed. They were also asked about production practices, cost of production, and productivity of flat sowing practice to make comparison of the technology with general practice. The farmers were belonged to 710-GB, 711-GB, 712-GB, Jevan Veroana, 714 GB, 718 GB, 733-GB and 743-GB. Land preparation methods are covered in details as the main focus of the study was comparison of bed sowing technique with conventional technique. While other items of production cost are briefly narrated to avoid longevity.

Similarly, in case of wheat crop, list of adopter farmers were obtained from Agriculture Training Institute, Agricultural Extension Department, Sakrand who promoted ridge sowing technology for the crop in Sindh province. Cross-sectional data was collected in April, 2018 from forty farmers. Sample farmers were belonged to Ali Bux Sanjrani, Qaim Khan Sanjrani, Phull Lakho, Nazar Muhammad Unar, Dodo Khaskheli, Nakar, Mian Shoro villages of Sakrand tehsil of Shaheed Benezirabad district. Similarly, cost-benefit analysis of banana ridge/bed planting is based on cross-sectional data collected from forty adopter farmers. Field survey was conducted in Badin, Matiari and Tando Allahyar districts in May, 2018. In the first step DRIP, Tandojam was approached to obtain list of the adopters. Then, farmers were randomly interviewed for comparison of the technology with general practices of banana production. They were also asked about normal sowing of the crop on flat beds. The farmers were belonged to Allah Bux Bhurgri and Tando Ghulam Ali villages from Badin district, Masu Bhurgri village from Matiari district, and Nawazabad village from Tando Allahyar. The data was analyzed through software SPSS-22 for descriptive statistics. Thereafter, for cost-benefit analysis of ridge planting of selected crops/ fruit and to make comparisons with conventional practices, costs of production were computed by using MS-Excel.

3. RESULTS AND DISCUSSION

3.1 Farmer Characteristics and Adoption by Technologies

Sample farmers planting rice in Punjab and wheat in Sindh on ridges were in young age group, with mean ages of 41 and 40 years, respectively. While, sample farmers planting banana through the technology in Sindh province were in middle or old age groups with mean age of 59 years (Table 1). Sample farmers practicing ridge planting were substantially educated with mean education of eight to ten years across crops. They were well experienced in crop farming in case of both rice crop in Punjab and wheat

crop in Sindh. In case of banana ridge/ bed planting farmers were much experienced, having mean experience in crop farming of 35 years. Sample farmers have medium family sizes, six members in wheat-Sindh, eight members in Banana-Sindh and nine members per household in rice-Punjab. There were huge differences in operation land holding of the farmers across regions, in rice-Punjab adopters of the technology were large farmers, in wheat-Sindh medium farmers and in Banana-Sindh very large farmers. Similarly, livestock holdings were different across regions, with mean of 10 and 15 in rice-Punjab and wheat-Sindh, respectively, and highest of 95 animals per farm in Banana-Sindh. Sample adopters of the technology reported to have non-diversified income sources (Table 2).

Farmers of ridge/bed planting of rice in Punjab and wheat in Sindh are mainly dependent on crop and livestock farming income, with small enterprises, agriculture services, trade and remittances are minor income sources. While in case of banana ridge/bed planting, crop farming is the main source of income of the adopter farmers.

3.2 Awareness and Adoption Experiences of the Farmers

Agricultural Extension Department (AED) has played a very effective role in promotion of rice ridge planting in Punjab province. Farmers reported that few years back, head of the tehsil government i.e. Assistant Commissioner took personal interest in promotion of the technology in the study area. Under this initiative AED financed Agricultural Service Providers (ASPs) to provide land preparation and ridge making services to area farmers free of cost. Fellow farmers and technical persons of AED and PCRWR are main awareness sources about the technology, as reported by 67% and 33% of the adopters, respectively. Adopter farmers reported to have awareness about the technology since last two years (2016-17). Farmers are taking keen interest in the technology, as all the sample adopters reported to visit other adopters' farms. Most of the sample farmers (80%) reported that their fellow farmers convinced them to adopt the technology. While remaining farmers (20%) were convinced for the adoption of ridge planting

Table 1. Demographic characteristics of sample adopter farmers (n=120)

Characteristics	Rice-Punjab (n=40)	Wheat-Sindh (n=40)	Banana-Sindh (n=40)
Age of the farmer (year)	41.2 (11.0)	39.9 (9.8)	59.0 (8.9)
Education of the farmer (year)	9.8 (2.9)	10.1 (4.3)	8.2 (8.6)
Farming experience	19.3 (12.6)	18.2 (8.9)	35.0 (3.5)
Family size (number)	8.6 (3.7)	6.3 (2.2)	7.8 (1.3)
Operational holding (acre)	29.2 (25.2)	17.3 (20.0)	291.3 (299.0)
Livestock holding (number)	10.3 (8.2)	13.5 (14.3)	94.8 (130.0)

Note: Figures in parenthesis are standard deviations

Table 2. Sources of income of adopters (n=120) (Rs./year)

Sources	Rice-Punjab (n=40)	Wheat-Sindh (n=40)	Banana-Sindh (n=40)
Crops	1169167 (68.4)	996333 (78.7)	3244000 (98.8)
Livestock	454166 (26.6)	166233 (13.1)	380000 (1.2)
Small enterprises/ Agricultural services & trade	30000 (1.8)	41667 (3.3)	0 (0.0)
Job	55000 (3.2)	22800 (1.8)	0 (0.0)
Remittance	0 (0.0)	38667 (3.1)	0 (0.0)
Total	1708333 (100)	1265700 (100)	3624000 (100)

Note: Figures in parenthesis are percentages

of rice by technical persons/ extension agents. Farmers reported to adopt the technology on their own, without any financial support/ subsidy. Each of the farmers reported to have access to services of at least one ASP. However, all the farmers expressed that number of ASPs are insufficient to meet the requirement of area farmers for ridge planting of rice. Keeping in view performance of the technology in the study area, sixty percent of the farmers reported to continue practice of rice planting on ridges. They reported that two-third of their fellow farmers are taking medium level of interest in the technology, and remaining one-third are quite convinced and expressed high level of interest in the adoption of the technology. Adopter farmers of the technology for wheat crop in Sindh province reported to become familiar with the technology about two and half year ago, and adopted it since year 2016-17. Most of them (77%) reported that their fellow farmers informed them about the benefits of the technology adoption while 16 and 7 percent of the farmers became cognizant of it through electronic media and technical people, respectively. Forty percent of the adopters visited farmers of their fellow adopters to get know-how about the technology and observe performance of the crop sown on ridges. Two-third of the sample farmers (67%) reported that their fellow farmers convinced them to adopt the technology. Half of the farmers were of the view that their fellow farmers are highly interested in adoption of the technology, 40 percent reported to have medium and 10 percent low levels of interest by their fellow growers in adoption of the technology.

Adopter farmers of the technology for banana reported to have knowledge about the technology since last two years, and were practicing it since then. Fellow farmers and technical staff of DRIP convinced adopters to take over the practice of ridge planting of banana, as reported by 60 and 40 percent of the farmers, respectively. Adopter farmers of banana ridge planting have good access to input markets, as mean distance of farms from these markets was five kilometers. However, output markets were far away, at a mean distance of 143.8 kilometers from their farms. Thus, pre and post-harvest contractors play their role by facilitating farmers in the study area in production, harvesting and marketing of the crop. However, sample farmers reported to perform farm operations mostly on their own, as they are large farmers and mostly do not need services of ASPs. Farmers also reported that technology is not being promoted in the study area by any development project or local support organization.

3.3 Area Allocation, Land Preparation Practices and Costs

On an average, farmers in mixed cropping zone of Punjab allocated 57.7 percent (13.8 acre) of their operational land holding to rice crop in Kharif season 2017, out of this 42.5% (5.8 acre) was under ridge/bed planting and 57.5% (8.0 acre) was under conventional flat sowing.

Land preparation cost was higher in case of ridge planting of the crop by about thirteen percent than flat sowing, due to more number of ploughings for proper seedbed preparation and ridge making (Table 3). However, number of ploughings & planking in combination was less in case of ridge planting of rice than traditional method of soil puddling. On an average, sample farmers in Sindh province sowing wheat on ridges allocated 63 percent of their operational land holding in Rabi season 2016-17 to the wheat crop. They allocated 11.12 acre to wheat crop and adopted ridge sowing practice of wheat on 4.69 acre, 42 percent of wheat area. There was nominal increase in land preparation cost in case of ridge sowing of wheat crop by about two percent, excluding ridge making cost as it is considered as part of crop sowing, seed is broad casted first and then ridges are made. Banana crop is cultivated on large scale in lower Sindh. In the year 2017, at sample farms on an average forty percent of the operational holding was under banana orchards (114.7 acre out of operational area of 291.3 acre per farm). While, mean banana area planted on ridges was 12.1 acre, 10.6% of total area under banana orchards and 4.2% of operational holding per farm. Adopters of ridge planting of banana, generally better prepare land than flat sowing of the crop. Generally they give one additional ordinary and deep ploughing each for land preparation than flat sowing.

3.4 Cost of Production, Productivity, Profitability and Adoption Prospects of Rice Crop in Punjab

In rice ridge planting nursery cost was lower than flat sowing by 20 percent, however labour cost for bund making was more than double, higher by 104 percent and cost of transplanting was higher than flat sowing by 32 percent (Table 4). Similarly, weeding/weedicide and fertilizer application costs were 11 percent and seven percent higher than flat sowing method, respectively. Adoption of ridge sowing for rice crop results into considerable saving of irrigation water. There was a decrease in irrigation cost by one-fourth (25.02%) than conventional sowing. Labour as well as operators of mechanical harvesters prefers to harvest the crop sown by conventional method, as they consider it difficult and time consuming to harvest the crop planted on ridges. Thus, they charge higher in case of ridge planted crop by 61.4% than conventionally planted crop.

Total cost of production of the crop planted on ridges was less than that planted on flat land by about two percent while the productivity of crop sown through ridge planting methods was less than that of flat sowing by 2.25%. Thus, furrow/ridge sowing method does not result in remarkable increase in crop productivity. The findings are in line with that of Aslam et al. [25], as they reported that though the technique results into higher number of tillers per unit than conventional planning (207 vs. 200), while paddy yield through adoption of the technique was lower than conventionally planted rice in rice-wheat zone of Punjab under research station conditions by 6.1%. However, in case of direct seeded rice in shallow furrows higher productivity of the crop by 3.2% than flat sowing was reported by Ashraf [15], in rice-wheat zone of Punjab. Mean crop productivities in case of ridge and flat planting of rice at the sample were 56.5 and 57.8 mounds per acre, respectively. Though, few farmers achieved higher yield than their counterparts by adopting complete recommended production package of ridge sowing. The highest yield achieved through the practice was 78 mounds per acre. Profitably of ridge sowing practice is higher than flat sowing by 14.04%. While, cost-benefit ratios of both ridge and flat sowing practice of rice crop are found to be 1.03 and 1.04, respectively. Thus, it is perceived that ridge planting of rice may perform better in main rice-wheat zones in the country. As soil in the zone is medium to fine-textured (having 10-40% clay) with better moisture retention capacity in case of alternate wetting and drying.

It has been reported that soil having clay content in this range may require varying intensities of puddling [26]. Furthermore, it is stated that sodic soils that form crusts on ridge tops and disperse quickly, resulting in poor emergence and infiltration, saline soils, shallow saline water table situations, and irrigation with saline water may be unsuited for ridge sowing of rice. Some soils would require amelioration and careful management for beds to function; for example sodic soils could be improved by the addition of gypsum and/ or organic matter [11]. Similarly, there is a need to identify new 'aerobic' rice varieties that are more competitive with weeds, and other crops that can grow well on ridges [3]. In bed planted rice crop, weeds are kept suppressed by keeping furrows flooded in early growth stage of the crop, and spraying weedicides after emergence of weeds. As chemical weed control is more effective than mechanical method. Furthermore, hand weeding and hoeing of the crop sown on beds are not possible due to short plant to plant distance (5") and row to row distance (8"), as well as wet field conditions.

3.5 Cost of Production, Productivity, Profitability and Adoption Prospects of heat Crop in Sindh

Seed use in ridge sowing and flat sowing of wheat were 56.0 and 40.3 kg per acre respectively. Thus, seed rate was higher in ridge sowing of the crop, resultantly cost was higher than flat sowing method by 39 percent (Table 5). Land preparation and sowing cost for ridge sowing of wheat was 20 percent higher than flat sowing method. Use of farm yard manure was higher at the adopters' farm than their counterparts with 25.2 percent higher cost. While, costs of fertilizers and labour for water course cleaning were lower at adopters' farms than non-adopters by 8.3 and 25.6 percent, respectively. Wheat planted on ridges results into saving of irrigation water and its application time. At the sample farmers it resulted into decrease in irrigation water cost by 36.0 percent as compared to conventional flat sowing method. Similarly,

Table 3. Land Preparation Costs (Rs. per acre)

Operations / Inputs	Bed/Ridge Sowing (Average No. of oprs/units/ acre)	Flat Sowing (Average No. of oprs/ units/ acre)	Cost (Rs. per unit)	Bed/Ridge Sowing Cost	Flat Sowing Cost
a. Rice Crop-Punjab (n=40)					
Deep Ploughing	1.67	1.50	1712	2859	2568 (11.33)
Ploughing	4.90	4.30	926	4537	3982 (13.94)
Ploughing& Planking	0.33	0.50	850	281	425 (-33.88)
Planking (Dry/Wet)	1.17	2.00	450	527	900 (-41.44)
Laser Levelling	1.00	1.00	1233	1233	1233 (0)
Ridge Making	1.00	-	833	833	0
Total	10.7	9.3	-	10270	9108 (12.75)
b. Wheat Crop-Sindh (n=40)					
Deep Ploughing	1.97	2.00	1047	2063	2094 (-148)
Ploughing	1.00	1.00	1000	1000	1000 (0)
Ploughing& Planking	0.47	0.47	1057	497	497 (0)
Planking (Dry/Wet)	0.47	0.47	1043	490	490 (0)
Laser Levelling	0.10	0.00	1000	100	0
Total	4.01	3.94	-	4150	4081(1.69)
c. Banana Crop-Sindh (n=40)					
Deep Ploughing	4.00	3.00	1200	4800	3600 (33.33)
Ploughing	3.00	2.00	1000	3000	2000 (50.00)
Laser Levelling	1.00	1.00	1200	1200	1200 (0)
Ridge Making	1.00	-	1000	1000	0
Total	9.00	6.00	-	10000	6800 (47.06)

it is reported that wheat bed planting in rice-wheat system in Bangladesh resulted in saving of irrigation water by 41-48 percent [27]. Total cost of wheat production was less than flat sowing method by 6.0 percent. Productivity of the crop sown on ridges was higher than flat sowing method by 8.9 mounds per acre. Mean productivities of the crop in case of ridge and flat sowing methods were 48.9 and 40.0 mound per acre, respectively. Thus, adoption of raised bed technology resulted in increase in the crop productivity by 22.3 percent. Similarly, increase in wheat yield by 21.0 percent through adoption of 28 inch wide beds was observed in Bangladesh [27].

Profitability of the crop sown on ridges was higher by almost four times than flat sowing method. Benefit-cost ratios of ridge and flat sowing of wheat in the study area are 1.41 and 1.08, respectively. Furthermore, ten percent of the sample farmers reported to intercrop sugarcane in the wheat crop sown on ridges in month of March, which resulted into additional benefits due to savings in land preparation cost, basal dose of fertilizer (DAP) and one or two irrigations for sugarcane crop. Usual costs of land preparation for sugarcane crop, five bags of DAP and two irrigations are more or less Rs. 11100, 6149 and 4880 per acre, respectively. Thus, expenditures on these operations or inputs

Table 4. Cost of production, productivity and profitability of rice crop in Punjab (n=40) (Per Acre)

		Adopters (Ridge Sowing) A	Non-Adopters (Flat Sowing) B	Difference (A-B)
a. Land preparation cost		10270	9108	1161 (12.75)
b. Nursery cost		1125	1415	-290 (-20.49)
C. Uprooting, transporting and transplanting cost		4157	3150	1007(31.89)
d. Labour for bund making etc.		990	485	505(104.12)
Land preparation and sowing cost (a+b+c+d)		**16542**	**14158**	**2384 (16.89)**
Weeding/weedicide cost		2460	2220	240 (10.81)
Plant protection cost		3197	3892	-695 (-17.86)
Farm yard manure including transport cost		4484	5416	-932 (-17.20)
Fertilizer cost		9077	9067	10 (0.11)
Labour used for fertilizer application		1258	1174	84 (7.16)
Irrigation water cost		17033	22716	-5683 (-25.02)
Labour used for irri. and water course cleaning		3889	4895	-1006 (-25.86)
Harvesting		7669	4751	2918 (61.40)
Land rent for 6 months (Rs/acre/annum)		24167	24167	0 (0)
Avg. land tax @ 326.18/ha/annum for 6 months		66	66	0 (0)
Straw disposal		3587	3587	0 (0)
Marketing cost (Rs. per acre)		1130	1156	-26 (-2.25)
Total Cost of production (Rupees)		**94559**	**96026**	**-1467 (-1.53)**
Productivity (mound/ 40 kg)	**Mean**	**56.5**	**57.8**	**-1.3 (-2.25)**
	Standard deviation	12.8	6.6	-
	Minimum	42.0	50.0	-
	Maximum	78.0	65.0	-
Price per (mound / 40 kg)		1727.5	1727.5	-
Gross Income		**97604**	**99849**	**-2246 (-2.25)**
Profitability (Rupees)		**3045**	**2670**	**375 (14.04)**
Benefit-cost ratio		**1.03**	**1.04**	**-**

Note: Figures in parenthesis in the last column are percentages

if sugarcane crops are cultivated separately are Rs. 22129 per acre. Considering two-third of these costs as savings, results into additional benefits to the tune of Rs.14605 per acre.

3.6 Cost of Production, Productivity, Profitability and Adoption Prospects of Banana Crop in Sindh

Adopters of ridge planting of banana, generally better prepare land, well mange weeding, hoeing and earthling up, and apply higher dosages of fertilizers, than non-adopters (Table 6). Cost of land preparation & plantation, weeding/hoeing & earthling up, and fertilizers including labour for application were higher in case ridge planting of banana than flat sowing by 5.5, 39.1 and 25.7, respectively. Adoption of banana ridge planting results in decrease in irrigation cost by 40.6 percent. Though number of irrigations remains same, but

Table 5. Cost of production, productivity and profitability of wheat crop in Sindh (n=40) (Per acre)

		Adopters (Ridge Sowing) A	Non-Adopters (Flat Sowing) B	Difference (A-B)
a. Land preparation and sowing cost		7900	6329	1571 (20.0)
b. Weeding/weedicide cost		1003	1003	0 (0.0)
c. Farm yard manure including transport cost		3408	2549	859 (25.2)
d. Fertilizer including labour for application		8453	9157	-704 (-8.3)
e. Irrigation water cost		11295	**15363**	-4068 (-36.0)
f. Labour used for irri. and water course cleaning		1985	2493	-508 (-25.6)
g. Harvesting		2371	2371	0 (0.0)
h. Land rent for 6 months (Rs/acre/annum)		10967	10967	0 (0.0)
i. Avg. land tax @ 326.18/ha/annum for 6 months		66	66	0 (0.0)
Production cost per hectare		**47448**	**50287**	**-2839 (-6.0)**
Value of wheat straw/ bhoosa		9375	9375	0 (0.0)
Net production cost		**38073**	**40912**	**-2839 (23.0)**
Productivity (mound/ 40 kg)	**Mean**	**48.9**	**40.0**	**8.9 (22.3)**
	Standard deviation	4.5	3.7	-
	Minimum	40.0	33.9	-
	Maximum	55.0	46.6	-
Price per (mound / 40 kg)		1124	1124	
Gross Income (Rupees)		**54964**	**44960**	**9925 (18.1)**
Marketing cost (Rupees)		977	800	176 (18.1)
Total cost (Rupees)		39050	41712	-2662 (-6.8)
Profitability (Rupees)		**15914**	**3248**	**12588 (388)**
Benefit-cost ratio		**1.41**	**1.08**	-

Note: Figures in parenthesis in the last column are percentages *(+ve higher, –ve lower cost for adopters)

considerable decrease in irrigation time for banana orchards planted on ridges occurs. Similarly, there was a considerable decrease in use of labour for irrigation application and water course cleaning. Total cost of banana orchards planted on ridges was higher than that planted on flat land by 4.3 percent while productivity of the crop sown on ridges was higher than flat sowing method by 95.3 mounds per acre (20%). Mean productivities of the crop in case of ridge and flat sowing methods were 571.9 and 476.6 mound per acre, respectively. Banana produce wholesale market prices ranged from Rs. 600 to Rs. 800 per 40 kg during normal harvesting season but reached to a maximum of Rs. 1400 per 40 kg during the month of Ramazan. Mean whole sale market prices were Rs. 840 per mound. Profitability of the crop sown on ridges was higher than flat sowing method by about 36 percent. Benefit-cost ratios of ridge and flat sowing of banana in the study area are 2.26 and 1.97, respectively. In addition to highly profitable fruit production, about 950 mound banana leaves are produced per acre which can be used for making compost by using banana residue chopper. The use of the compost helps in ameliorating soil physical and chemical properties, and enhance fertility to obtain higher productivity of vegetables and make it conducive to plant high value crops for diversifying cropping system in the study area. All the sample adopters reported to continue the practice of ridge planting of banana. They reported to extend area under banana ridge planting by about 3.5 times, to 42.40 acre per farm in next three years. Interest of their fellow farmer in the adoption of the practice was also high. Thus, it is expected that promising technology of ridge planting of banana will gain scale in lower Sindh.

Table 6. Cost of production, productivity and profitability of banana crop (n=40) (Per acre)2

		Adopters (Ridge Sowing) A	Non-Adopters (Flat Sowing) B	Difference (A-B)
a. Land preparation and plantation		9017	8548	468 (5.5)
b. Weeding/hoeing & earthling up cost		18360	13203	5157 (39.1)
c. Cost of de-sucking & removing old leaves		10800	10800	0 (0.0)
d. Fertilizers including labour for application		77608	61768	15841 (25.7)
e. Irrigation water cost		26772	45075	-18304 (-40.6)
f. Labour for irri. and water course cleaning		4837	6288	-1451 (-23.1)
g. Fruit picking cost		9375	9375	0 (0.0)
h. Land rent for one year (Rs/acre/annum)		20000	10967	0 (0.0)
i. Avg. land tax @ 264/acre/annum (for 6 months)		132	66	0 (0.0)
Production cost per hectare (Rupees)		176901	9375	1711 (1.0)
Transportation and marketing cost (Rupees)		35503	40912	7115 (25.1)
Total cost (Rupees)		212404	40.0	8826 (4.3)
Productivity (mounds/acre)	**Mean**	571.9	40.0	95.3 (20.0)
	Standard deviation	330.3	3.7	-
	Minimum	385.0	33.9	-
	Maximum	686.8	46.6	-
Price per (mound / 40 kg)		840	1124	-
Gross Income (Rupees)		**480396**	**44960**	**80052 (20.0)**
Profitability (Rupees)		**267992**	**800**	**71226 (36.1)**
Benefit-cost ratio		**2.26**	**41712**	**-**

Note: Figures in parenthesis in the last column are percentages *(+ve higher, –ve lower cost for adopters)

4. CONCLUSION AND RECOMMENDATIONS

Ridge planting of rice in mixed cropping zone of Punjab results into considerable saving of irrigation water; however, it does not generate very high financial returns for the farmers than conventional planting practice. It is observed that farmers were not fully conversant with the complete production package of ridge sowing method. Even, they are not planting required number of plants per unit area i.e. eighty thousand per acre, as it is difficult for the labour to plant nursery on ridges than on wet puddled flat land. Thus, there is need to create awareness among the farmers about complete production package of the practice. Furthermore, bed planting of rice may result into substantial savings of water and generate higher returns for the farmers if practiced in the main rice producing area i.e. rice-wheat zones of Punjab and Sindh, than in the mixed cropping zone due to differences in soil characteristics, specifically in soil water retention capacities. Similarly, monitoring of soil and biotic factors and socioeconomic survey are needed to assess the longer-term benefits of the practice. Based on findings of the study it is recommended that Agricultural Extension Department should generate awareness among farming community about complete production package of rice sowing on ridges. The technology should also be tested in main rice producing areas of Punjab and Sindh province to come up with solid findings about the performance of the technology. Plant breeders should develop rice varieties that can perform well on ridges considering their desired yield components. Plant scientist should finalize water and weed management strategies for the technology. Similarly shallow ridges, having half height than normal ones can also be experimented, as these could help in easing planting and harvesting practices. Planting of wheat crop on ridges in mixed cropping zone of Sindh province results in saving of irrigation water and fertilizers and hence generates better financial returns for the farmers than flat sowing method. Farmers in the study area are well conversant with

production package of wheat sowing on ridges. Furthermore, sugarcane sowing intercropping in wheat planted on ridges results into additional savings and hence financial benefits for the farmers. Similarly, ridge planting of banana in lower Sindh results in considerable saving of irrigation water and higher crop productivity. The method produces considerable profits over traditional flat sowing method. It is expected that technology will be adopted on large scale in near future. There, is a need to convince provincial agricultural extension department, Government of Sindh to include the practice of ridge sowing of wheat and banana in approved production technologies of major crops for wider dissemination, demonstration and adoption in the province.

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