RAISED BED TECHNOLOGY FOR CROP WATER PRODUCTIVITY OF MAIZE AND COTTON

TECHNOLOGIE DE PARTERRE SURELEVE POUR LA PRODUCTIVITE EN EAU DES CULTURES DU MAÏS ET DU COTON

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ABSTRACT

Raised bed technology is a land configuration where irrigation water is applied in furrows with plants on the raised beds. The technology increases water application and distribution efficiencies and gives better crop yields. Researchers reported that increase in crop yield is because of higher fertilizer use efficiency, reduced weed infestation, improvement in root proliferation and smaller lodging of the crops. The irrigation water saving depends on size of bed-furrow system where larger bed means lesser number of furrows, less irrigation application time and finally more saving in irrigation water. However, number of beds should meet plant population per unit area and furrows to meet crop water demand and row to row distance of plants. Machine designed for wheat planting on bed–furrow system by University of Agriculture, Faisalabad (UAF), Pakistan was used to develop bed-furrow systems for maize and cotton on farmer's fields for water saving and increasing crop productivity.

Results indicated that bed-furrow system (60 cm bed and 30 cm furrow) suited both maize and cotton (variety 121) when plant to plant distance was maintained at 20 cm and 30 cm, respectively. The selected geometries of bed-furrow planting of maize and cotton were further evaluated for water saving in comparison with traditional practices. Farmer's organizations were involved for the experiments and demonstrations of comparative studies made at various farmers' fields. Soils on sites are sandy loam, clay loam and sandy clay loam. Irrigation water saving, crop growth and yields were observed for calculating crop water productivity. Results indicated that grain yield of maize under bed-furrow planting was 19% higher than the that obtained from traditional practices whereas water application efficiency increased from 50% to 75%, saving considerable irrigation water as compared to the traditional ridge-furrow irrigation practice. The minimum water saving was observed from fields which had not been leveled using laser land leveler but with traditional wooden or tractor planers. The range of water

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saving highlights the role of leveling in water saving and according to the reported studies; leveling contribution in water saving was 10 to 15%. Other than water saving, more grain yield was observed in leveled field than non-leveled fields. Although leveling encourages water saving, especially crop water productivity but still cannot be pre-requisite as bed-planting alone saves irrigation water by 35 to 40%. Water saving results obtained from cotton fields showed 40% water saving and 10 to 15 per cent increase in yield. The results of studies concluded that raised bed technology has enough potential of water saving and improving water productivity of maize and cotton.

Key words: *Raised bed, Crop water productivity, Maize and cotton, Irrigation water saving, Lower Chenab Canal System.*

RESUME

La technologie de parterre surélevé est une configuration du terrain où l'eau d'irrigation est appliquée dans des sillons à côté des plantes sur les plates-bandes surélevées. La technologie accroît l'utilisation d'eau, l'efficacité de la distribution et donne des meilleures récoltes. Les chercheurs montrent que l'augmentation des rendements des cultures est due à l'utilisation élevée des engrais, les infestations de mauvaises herbes réduites, l'amélioration de la prolifération des racines et des petits logements des cultures. L'économie d'eau d'irrigation dépend de la taille du système parterre-sillon où un grand parterre implique la présence de moins de sillons, moins de temps pour l'irrigation et donc plus d'économie des eaux d'irrigation. Cependant, le nombre de parterres devrait répondre à la population végétale par unité de surface et aux sillons pour satisfaire la demande en eau des cultures et la distance des plantes selon les rangs. L'Université de l'Agriculture, Faisalabad (UAF), Pakistan a conçu une machine pour les semis de blé sur le système parterre-sillon. Cette machine a été utilisée pour développer des systèmes parterre-sillon pour le maïs et le coton sur les champs agricoles pour économiser l'eau et pour augmenter la productivité des cultures.

Les résultats indiquent que le système parterre-sillon (le parterre de largeur 60 cm et le sillon de 30 cm) convenait à la fois au maïs et au coton (la variété 121) où la distance entre les plantes a été maintenue à 20 cm et 30 cm respectivement. Ces formes géométriques sélectionnées du semis parterre-sillon de maïs et de coton ont encore été évaluées pour l'économie de l'eau en comparaison aux pratiques traditionnelles. Les organisations paysannes ont été inclues pour exécuter les expériences et les démonstrations des études comparatives, effectuées à différents champs des agriculteurs. Les sols sur les sites sont la marne sableuse, le limon argileux et le limon sablo-argileux. Pour calculer la productivité en eau des cultures, le taux de l'eau d'irrigation économisée, la croissance des cultures et les rendements ont été observés.

Les résultats indiquent que le rendement en grain de maïs sous la plantation parterre-sillon était de 19% plus que celui obtenu à partir des pratiques traditionnelles. L'efficacité d'application de l'eau a augmenté de 50% à 75%, économisant considérablement l'eau d'irrigation par rapport à la pratique de l'irrigation traditionnelle crête-sillon. L'économie d'eau a été minimale dans les champs qui n'avaient pas été portées à l'aide d'une machine laser pour le nivellement, mais avec des rabots traditionnels en bois ou en tracteur. La gamme de l'économie d'eau met en évidence le rôle de nivellement des parterres et selon les études rapportées, la contribution de nivellement à l'économie d'eau était de 10 à 15%. A part les *économies d'eau, le rendement de grain a été observé plus dans le champ nivelé que dans les champs non nivelés. Bien que le nivellement encourage l'économie d'eau, en particulier la productivité de l'eau, pourtant ceci ne peut toujours pas être un pré-requis puisque la plantation-parterre seule aide à économiser l'eau d'irrigation de 35 à 40%.*

Les résultats des économies d'eau obtenus dans les champs de coton ont montré que l'économie d'eau était 40% et a mené à l'augmentation de 10 à 15 pour cent de rendement. Les résultats des études ont conclu que la technologie du parterre soulevé a suffisamment de potentiel d'économiser l'eau et d'améliorer la productivité de l'eau du maïs et du coton.

Mots clés : *Parterre surélevé, productivité de l'eau des cultures, maïs et coton, économie d'eau d'irrigation, Basse-système du canal Chenab.*

1. INTRODUCTION

Irrigated agriculture is the mainstay of Pakistan's economy as it is contributing over 43% of the gross national product. Out of 21.0 million hectares cultivated area, about 4 million hectares are non-irrigated. There is a huge irrigation network to carry water stored in two mega reservoirs or found in the form of river's runoff to irrigate lands. However, the available water supplies during certain times of the year are either less or more than the crop water requirements. Water storage capacity is less than water availability, resultantly, irregular flow of water in rivers causes irregular surface water supply in the canal network and finally results in low crop and water productivity per unit area. In addition, the country's most suitable areas for agriculture are located in arid and semi-arid regions, which does not receive sufficient rainfall to make up the water deficit and in some periods of the year even do not receive any rainfall. All this together, is resulting in low farm output and discouraging the farming community.

On the other hand, increasing trend in population and their food requirements has increased both the cropping intensity and cropped area and the gap between surface water supplies and demands has been increasing. The situation has mounted its pressure on water equity issues among provinces, within the provinces and even among farmers. To meet the surface water shortages against demands, irrigated areas are becoming more dependent on the groundwater and consequently, resulting in its over-exploitation. The Government of Pakistan has tried to address irrigation water shortage by launching various water management projects, which include lining of minors and watercourses, command area water management and groundwater development projects etc.; however, these alternatives are still dependent upon a limited available water supply. There is a need to look for water saving option in irrigation and improve water productivity.

Countries facing irrigation water shortages have replaced their traditional flood irrigation methods with high efficiency drip and sprinklers irrigation. Although the high efficiency irrigation methods are imperative need for sustainable agriculture in Pakistan, however, it is difficult to introduce these methods due to high cost, economic level of farmers, provision of energy on the farms, and low farm return etc. Low-cost technologies of relatively high efficiency are the need of the hour for the farmers of Pakistan. One of such alternative methods is the

Raised Bed Technology. Raised bed Technology increases water productivity by increasing yield of corps on beds through better nutrient management and saving water due to lesser area of spreading irrigation water (Ahmad et al 2009). The risk of crop lodging is reduced in this method (Syre and Moreno Ramos 1997). Bed planting has shown improved water distribution and efficiency, fertilizer use efficiency, reduced weed infestation and lodging (Hobbs et al 2000; Syre et al 2000). Peries et al (2001) reported that the technique requires reduced seed rate without sacrificing crop yield as compared to flat sowing. Ahmad and Mahmood (2005) reported that greater root proliferation in bed planting ensures better crop stand and yield. Above all, bed planting promises a considerable saving of water (by almost 35 to 45 %) as compared to conventional sowing method, eliminating the formation of crust on the soil surface (Fahong et al 2003, Ahmad et al 2009).

To introduce Rasied Bed Technology, Water Management Research Centre (WMRC) of the University of Agriculture, Faisalabad (UAF) designed and developed a 4-row bed-planting machine for wheat. A modified and improved version of the machine was tested to sow cotton and maize on bed-furrow system over a laser-controlled leveled land for improving their water productivity under a technology transfer project funded by UAF.

2. EXPERIMENTAL PROCEDURES

Experimental Site. It was the pre-requisite of the project to demonstrate the proposed technology in tail area of Lower Chenab Canal System of the Indus basin Irrigation System. The area is suffering from severe shortage of irrigation supplies with marginal to low quality groundwater. The area is famous for cotton-wheat rotation with all others as minor crops. Reconnaissance survey was conducted for the irrigation practices, cropping intensity and awareness of farmers regarding raised bed Technology for cotton and maize. Farmers were interviewed for the size of their farms, crops at their farms and planting practices etc. Moreover, information was gathered for the sources of irrigation water and general irrigation practices. Research team visited different villages, had meetings with farmers, developed farmer's groups and made them aware of objectives of the project. Farmers were asked for their awareness regarding use of laser land leveler and its availability on their farms. Farmers were also inquired for the agricultural implements they have for their routine agricultural practices like tractor, cultivator, furrow opener, land leveling equipment and other implements.

Cotton and Maize Bed Planting. The UAF wheat bed planting machine has the provision to make a bed-furrow system from (30 cm bed x 20 cm furrow) to (180 cm bed x 60 cm furrow) whereas, the most common size of bed-furrow system for cotton is 90 cm or 75 cm bed with 60 cm furrow, and it is 60 cm x 30 cm for maize. Moreover, cotton can also be sown on 60 cm to 30 cm bed-furrow system by changing planting geometry and maintaining its row to row distance at 60 cm by crosswise planting at plant to plant distance of 60 cm. It is important to mention that it is the number of plants per unit area that is maintained by changing the plant to plant and row to row distances. It has been observed that usually the plant population is greater in bed-furrow system than in the traditional flat and ridge planting practices. To adjust or check the general plant population under different planting geometry of bed furrow system following relationship could be applied:

Plant population = area / plant to plat x row to row distances

For example:

Cotton Population

Case = 1 Bed-furrow system of

75 cm x 60 cm or 2.5 ft x 2ft

Plant to plant (9in x 9in) and row x row (2ft x 2ft): 19360

Case = 2 Bed-furrow system of

60 cm x 30 cm or 2ft x 1 ft

Plant to plant (1ft x 1ft) and row x row (1.5 ft x 1.5 ft): 19360

Demonstration Fields. The Project activities were started in January, 2008 to grow winter maize. As the project area is located in the crop zone of cotton-wheat, most of the farmers grow cotton while maize is grown only by the progressive farmers in a limited scale.

A number of farmers were selected in different villages for the project activities including all levels of farm size. The criteria for the selection of demonstration fields included easy access to the site and its visibility for the passerby's and farmers' meeting places. The selected farmers were convinced not only to grow cotton under bed-furrow planting practices and but also be a leader for the extension of the proposed technologies.

Farmers were inquired if they are using only canal water or both canal and groundwater for irrigation. About demand and supply of irrigation water, area is suffering from severe canal water shortage. Farmers were involved for irrigation water saving in bed-furrow planting in comparison with traditional irrigation method. Irrigation application time was observed by the farmers for both the flat and bed-furrow plantings. Irrigation depth was calculated on the basis of 50% irrigation depletion from field capacity of soil on the site.

3. RESULTS AND DISCUSSION

As a result of reconnaissance survey, it was found that most of the farmers in the area have the farm size of 6 acres[4] (small) to 12 acres (medium) whereas a few farmers have more than 12 acres. The research team observed that most of the farmers were keen to adopt new technologies especially, the improved seed varieties. Farmers were well aware of the use of laser land leveler for increasing yield and saving water but they do not have bed-furrow planting machine at their farms.

3.1 Maize

In 2008, two farmers were selected for the maize trials while there were four farmers for each of two cropping seasons of 2009 (Table 1). Farmers were helped by providing bed planting machine and other required guidelines regarding maize verities, proper land preparations

4 1 acre = 0.4047 ha

and irrigation schedules. The soil on the sites is sandy loam and clay loam; pH greater than 8 and with low organic matter up to 1%.

Table 1 shows data of plant height and grain yield of maize obtained from the two planting practices. In addition to measure plant height and yield data, observations made on the sites included plant vigor, crop stand and health under the both the planting practices. Results are similar to that as reported by Peries et al (2001). Although germination under both the planting practices was good but there was clear difference in growth of plants showing better response under bed planting. Plant height data revealed that crop on bed-furrow system performed better than the traditional planting of maize on ridge-furrow system. Plant height on beds was higher at all sites for all verities of maize in all the three cropping seasons.

Table 1: Detail of Maize Bed planting for plant growth parameters and yield.

Site #	Year	Variety	Date of sowing	Plant height (cm) after 2 months of sowing		Maize yield (Kg/ha)		Increase in yield (% age)	Water saving (% age)
				Bed Planting	Ridge Planting	Bed Planting	Ridge Planting		
1	2008	Hybrid	15-2-08	70	62	6400	5600	15	40.00*
2	2008	Hybrid	18-2-08	65	57	5900	4700	22	35.15*
3	2009	TS-631	14-3-09	80	69	8150	6700	22	33.26
4	2009	HB-6524	04-3-09	79	68	9584	8002	19	32.54
5	2009	TS-919	04-7-09	80	68	7904	6718	17.65	30.27
6	2009	TS-619	07-7-09	78	70	7410	6422	15.38	28.53
7	2009	HB-6515	10-7-09	82	72	8102	7410	10	33.33
8	2009	HB-107	11-7-09	85	73.5	8398	6521	29	25.00
Average				77.10	67.36	7731	6509.14	18.75	32.26

*Laser leveled fields

The grain yield data are also presented in Table 1, which indicate that grain yield obtained from maize planting on beds was higher than that obtained from the ridge planting. Analysis of the data show that the average grain yield obtained under bed planting was 7731 kg/ha whereas the same under ridge planting was 6509 Kg/ha. On the average there was 19 % increase in grain yield under bed planting than ridge planting method. The maximum grain yield among all the sites was 22% higher under bed planting than in traditional planting of maize.

Farmers were involved for irrigation water saving per unit area under same size of stream flow. The table show that there was 32% water saving in bed planted fields than ridge planted fields with maximum saving of water up to 40% in the laser leveled fields.

3.2 Cotton

The sites being in the cotton growing area, many farmers took keen interest in raised bed planting of cotton using the University-developed bed planting machine. About one hundred acre of cotton was planted, out of which a few farmers were selected for data collection (Table

2). Traditional planting practices of cotton on sites included both the flat and ridge-furrow methods. It was observed that BT121 was the most common cotton variety in the area. The new variety introduced in the area was BT 601, 703 and 802. It is important to note that plant population and geometry of bed-furrow size changes with the variety.

Soil samples were collected from all fields prior to the sowing of cotton. The prominent texture of the soil in the area is loam. Some farms have sandy loam soil whereas some farms have clay loam and sandy clay loam soils. The information was used to calculate irrigation depth and plan its schedule.

Cotton yield. Tables 2 and 3 show the number of bolls for different verities and their yield response for ridge and bed planting in 2008 and 2009, respectively. The Tables indicate that there was higher number of bolls after a specific growth period in bed planted cotton than the ridge planted cotton in almost all cotton verities tested here. Moreover, the bolls under bed planting practices were healthier than the bolls obtained under ridge planting. BT 802 yielded the highest number of bolls under both practices; however, bed planting practice again gave 14% higher yield than the ridge planting for this variety.

The Tables also present yield data of cotton. Comparing cotton planting time under bed planting, the Tables reveal that early sowing of cotton yielded better than the late planted. Comparing bed panting with the flat/ridge planting of cotton, data in the tables show that there was not a single sites which yielded less from the bed planted cotton. The maximum increase was 25% while the minimum was 7.4% during 2008 with average percentage increase in yield of 12.21. In 2009 (Table 3), data show that maximum increase in yield in bed planting was 14.29% while minimum increase was 7.98% with average increase of 10.96%.

Table 2: Cotton Yield and Number of bolls per plant for different varieties under bed and ridge planting practices (*Kharif*[5] 2008).

Sr. #	Variety	Date of Sowing	Number of bolls per plant			Cotton Yield (kg/ha)		
			Bed Planting	Ridge Planting	% increase	Bed Planting	Ridge Planting	% increase
1	BT-802	10-04-08	45	40	12.50	4347.2	4050.8	7.32
2	BT-703	13-06-08	39	37	5.41	4050.8	3754.4	7.89
3	BT-601	16-06-08	36	33	9.09	3062.8	2766.4	10.71
4	BT-601	09-06-08	38	36	5.56	2964	2667.6	11.11
5	BT-703	09-06-08	37	34	8.82	3655.6	3359.2	8.82
6	BT-703	28-05-08	36	35	2.86	4001.4	3556.8	12.50
7	BT-802	10-06-08	48	42	14.29	3705	3260.4	13.64
8	BT-703	29-05-08	37	34	8.82	3902.6	3458	12.86
9	BT-121	29-05-08	40	37	8.11	3952	3161.6	25.00
Average			**39.56**	**36.44**	**8.38**	**3737.93**	**3337.24**	**12.21**

5 *Kharif* or *Kharif* season is the monsoon cultivation season.

The results in the Table show that on two year average basis, there was 11.1% more yield in bed planting than the flat/ridge planting of cotton. The results are in line as reported by Ahmad; 2004. The difference in cotton yield among the sites within bed planting could be due to farmers on farm managements i.e. time of irrigation, time fertilizers, type of fertilizers and amount of fertilizers.

The t- test was applied to compare bed planting with ridge planting (Table 4). It showed that bed planting practices differed significantly from each other for the final cotton yield. On 2-year average basis, there was 11.1% more yield in bed planting than the flat/ridge planting of cotton. The results are in line as reported by Ahmad; 2004. The difference in cotton yield among the sites within bed planting could be due to differences in on- farm managements i.e. time of irrigation, time and type and amount of fertilizer applications. It is important to report that cotton on beds has been adopted quicker than the other crops.

Table 3: Cotton Yield and Number of bolls per plant for different varieties under bed and flat planting practices (*Kharif* 2009).

Sr. #	Variety	Date of Sowing	Number of bolls per plant			Cotton Yield (kg/ha)		
			Bed Planting	Flat Planting	% increase	Bed Planting	Flat Planting	% increase
1	BT-121	28-03-09	43.7	40.8	7.11	4246	3851	10.26
2	BT-121	30-03-09	41	37	10.81	3952	3458	14.29
3	BT-703	30-03-09	44.1	40.5	8.89	4640	4297	7.98
4	BT-121	13-04-09	42	38.3	9.66	4446	4051	9.75
5	BT-601	13-04-09	37.7	34	10.88	3574	3191	12.00
6	BT-121	22-04-09	40	36	11.11	3914	3496.9	11.93
7	BT-121	25-04-09	41.3	36	14.72	3952	3458	14.29
8	BT-121	30-04-09	39	35	11.43	3754	3468	8.25
9	BT-802	30-04-09	38.7	35.3	9.63	4070.6	3705	9.87
Average			**40.83**	**36.99**	**10.47**	**4060.96**	**3663.99**	**10.96**

3.3 Irrigation water saving

The main objective of the project was to address water shortage on one hand and improve crop productivity on the other. As reported by various researchers that raised bed technology is an improved irrigation method, which not only improves water use efficiency, but also increases yield, results of the study firmly confirm the findings of previous researchers. The studies conducted on raised bed technology for water saving showed that this technology has potential saving more than 50% water against traditional flood irrigation/flat sowing. Comparison between bed and ridge planting under this study (Table 5) shows that water saving difference was within the range of 30 to 40% as compared to ridge planting method. Comparatively lesser water saving could be attributed to the ridge-furrow planting, as it itself saves water in comparison with the flat sowing as reported by Fahong et al 2003.

The Table presents the data regarding irrigation time collected at different farms, which indirectly indicate irrigation water saving. The variation in irrigation time in bed-planting was due to the leveling status of fields. It was observed that leveling could enhance water saving by 10-15% and of course improves crop productivity.

Table 4: Detail of irrigation water saving

Sr. #	Irrigation water saving (2008)			Irrigation water saving (2009)		
	Time under Bed Planting (h)	Time under Ridge Planting (h)	% water saving	Time under Bed Planting (h)	Time under Ridge Planting (h)	% water saving
1	13.8	17.6	21.59	16.41	27.72	40.80
2	14.15	21.7	34.79	17.63	28.34	37.79
3	14	20.7	32.37	17.65	28.35	37.74
4	15.5	22.6	31.42	16.22	27.65	41.34
5	18.4	25.7	28.40	16.30	27.70	41.16
6	13.3	18.5	28.11	14.5	22.38	35.21
7	15.2	21	27.62	15.3	23.25	34.19
8	15	22	31.82	15.86	25.08	36.76
9	14.15	20.6	31.31	15.90	25.16	36.80
Average	**14.83**	**21.16**	**29.71**	**16.20**	**26.18**	**37.98**

4. CONCLUSIONS

- Project activities revealed that raised bed technology improved crop yield of both maize and cotton by 19% and 11.1%, respectively, confirming the results reported by previous researchers.
- Irrigation water saving from bed planting in comparison with ridge planting was within the range of 30 to 40% for both maize and cotton.

REFERENCES

Ahmad, N. (2004) Water and Disasters: Innovative Water Saving Techniques for Sustainable Agriculture. Proceedings of one day Seminar on World Water Day held on April 8, 2004 at University of Agriculture, Faisalabad, Pakistan. pp 56-64.

Ahmad, N and N Mahmood (2005). Impact of Raised Bed Technology on Water Productivity and Lodging of Wheat. Pakistan Journal of Water Resources. Vol. 9(2).

Ahmad, N., M. Arshad and M.A. Shahid. 2009. Bed-furrow system to replace conventional flood irrigation in Pakistan. Proceedings of 59th IEC Meeting and 20th ICID Conference held at New Dehli, India from December 6-11, 2009.

Fahong, W., W. Xuquing and K.D. Sayre. 2003. Comparison study on two different planting methods for winter wheat in China. Bed Planting Course, CIMMYT, Mexico.

Hobbs, P.R. and R.K. Gupta. 2000. Rice-wheat cropping systems in the Indo-Gangetic Planes: Issue of water Productivity in relation to new resource-conserving technologies. :239-253.

Peries, R., B. Chris and B. Wightman. 2001. Raised bed cropping leading to improved root proliferation in heavy duplex soils prone to water logging. Proceedings of the 6th symposium of The International Society of the Root Research, Nagouya, Japan, November 2001.

Sayre, K.D. and O.H. Moreno Ramos. 1997. Application of raised bed planting system to wheat. Wheat Special Report No. 31. Mexico, DF: CIMMYT.

Sayre, K.D. 2000. Effects of tillage, crop residue retention and nitrogen management on the performance of bed-planted, furrow irrigated spring wheat in northwest Maxico. Proceedings of the 15th Conference of the International Soil Tillage Research Organization, Fort Worth, Texas, USA. July 2-7, 2000.