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Comparison of Bed Planting-furrow Irrigation with Conventional Planting-flood Irrigation in Durum Wheat (*T. durum* Desf) in Southeastern Turkey

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Abstract: There is no clear consensus regarding the advantages of bed planting with furrow irrigation over conventionally irrigated cropping. This 3-year study from Southeastern Turkey aimed to assess the limits to some input savings in bed planting-furrow irrigation in terms of yields and profitability of durum wheat. Field trials were carried out using a randomized complete block design with six treatments and tree replications: T_1: Conventional Planting-Flood Irrigation (CP-FI) with recommended practices for seed rate, chemical fertilizers and chemical weed control; T_2: Bed Planting and Furrow Irrigation (BP-FI) with recommended input rates as in T_1; T_3: BP-FI with 10% input reduction; T_4: BP-FI with 20% input reduction; T_5: BP-FI with 30% input reduction; T_6: BP-FI with 40% input reduction. The trial had four replications at each location over three cropping seasons, i.e., Akçakale (2004-05, 2005-06) and Koruklu (2006-2007). Individual and combined analysis of variance were performed for grain yields, market prices based on quality assessment, protein content and both 1000-kernel and hectoliter weights. Profitability was assessed with partial budget analysis. Except for yields, there was little effect of treatments on the other variables. Based on yields and economic analysis, the conventional system with flood irrigation was superior to the bed and furrow system, even when the inputs were reduced in such a system. The work demonstrates the site-specific nature of any new technology as there are several local biological and economical factors to be considered.

Key words: Bed planting-furrow irrigation, durum wheat, input saving, profitability

INTRODUCTION

The environment of the Mediterranean region is characterized low and erratic rainfall (Kassam, 1981). While, agricultural production is practiced during the relatively moist cool season from late fall to early summer, drought invariably limits crop yields (Cooper *et al*., 1987); cropping is only possible during the dry hot summer season with irrigation. However, the past few decades have witnessed an expansion of irrigated agriculture from the river valleys where irrigation was practiced for ages to areas where formerly only rain fed agriculture was possible (Oweis *et al*., 1998); this expansion was driven by exploitation of groundwater and the development new irrigation sources, such as the harnessing of the waters of the Euphrates through the Atatürk Dam under the authority of the GAP Project and other irrigation projects in the Middle East, with attendant social and political concerns (El-Fadel *et al*., 2002).

Regardless of whether agriculture was based on rainfall or irrigation, the limitations of the environment dictated that efficient use should be a guiding principal (Pala *et al*., 2007). The management of water in semiarid agricultural regions of the world determines their long term sustainability for food production (Johnston *et al*., 2002). Consequently, strategies such as supplemental irrigation (Oweis *et al*., 1998) and an increasing shift from less efficient traditional flood irrigation to more efficient sprinkler and drip systems gradually emerged.

The new paradigm included looking at other alternatives to the traditional flood irrigation approach such as the bed and furrow irrigation system which is designed to improve crop water management under limited irrigation water. A further advancement to the bed and furrow system is development of permanent beds, replacing the practice of post-harvest tillage and re-shaping of beds for each crop rotation. After harvest, the permanent beds are reshaped the crop residues

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retained on the field are chopped and uniformly distributed with a little delay for seeding of next crop (Sayre, 2000).

Bed planting and furrow irrigation emerged in Sonora in Northwest Mexico in the early 1980's and was promoted by the International Wheat and Maize Improvement Center (CIMMYT) mainly for wheat followed by corn. The technique spread over America first, then to West Asia and North Africa, Pakistan, India, Bangladesh and Central Asia, including China. The system was adopted for some other crops such as legumes, oilseeds, cotton, sugar cane and rice rotating with wheat (Hobbs *et al*., 2000; Sayre and Hobbs, 2004; Tripathi *et al*., 2004). The bed planting and furrow irrigation system has been used in different countries with varying degrees of success.

The use of permanent beds was seen as an alternative practice for wheat allowing for the timing of N fertilizer to increase efficiency and lower production costs (Limon-Ortega *et al*., 2000). The new approach was shown to be effective for wheat in China as it resulted in a savings in water use and an increase in water-use efficiency compared to the conventional flood system (Fahong *et al*., 2004); it also reduced lodging and diseases and increased grain quality. A key feature of the comparison of the raised bed system with traditional flood irrigation involved crop N response and N efficient use. Research in Bangladesh showed that maximum wheat yields occurred with bed planting and furrow irrigation combined with 140-150 kg ha^{-1} (Hossain *et al*., 2006; Alam *et al*., 2007). In contrast to these findings, research from Oklahoma in the semi-arid Midwest USA showed that the conventional system was superior to the raised bed system and also showed a greater response to N (Freeman *et al*., 2007), a difference that was attributed to row configuration.

Despite the absence of yield advantages of bed planting and furrow irrigation over conventional flood irrigation, the former system offers some advantages in wheat growing: such as short turn around time for wheat/corn crop rotations, ease in water management, allowing for more effective drainage and reduced risk of water-logging; pre-planting irrigation and weed control; lower seeding rates; better placement of N fertilizer and easier application of herbicides (Sayre, 2004; Aquino, 1998).

Turkey is among the ten largest wheat producers in the world (Braun, 1999). Wheat is grown 9.4 million ha, yielding 18 to 20 million tons; 25 to 30% of total wheat area and production is devoted to durum wheat, with average annual production of 5 m tons (Özberk *et al*., 2005a). Wheat is the major cereal crop for Southeastern Anatolia with a weighted annual production averaging over 2 million ton $year^{-1}$ from the harvested area of 1 million ha. Average wheat yield is 6 ton ha^{-1} under supplementary irrigated conditions (Özberk *et al*., 2005a). Southeastern Anatolia is considered Turkey's the durum wheat belt, with conventional planting and flood or border irrigation being commonly used. Although, bed planting and furrow irrigation has been introduced the system has not been adopted yet due to inadequate agricultural machinery (drill) and inadequate adoption of wheat/corn rotation and relatively low irrigation water charges (approximately 134.6 $US ha^{-1} per one wheat growing season). Furthermore, relatively large bare strips (furrows) in the newly emerging wheat field may have contributed to farmers hesitating to adopt this new planting system; the perception was that low grain yields were inevitable due to large non-planted patches in the field. Consequently, field research was needed to validate the new system and promote adoption.

The first research results on the bed and furrow system in Sanliurfa indicated that in terms of grain yield the new system was not superior to conventional planting. However, irrigation management was found to be homogenous and easy in bed planting (Kabakçı, 1999). The recent increase in salinity and an escalation in input prices (certified seed, fertilizers, pesticides, labor) provided the rationale for the present evaluation of conventional practice with the bed and furrow system with varying inputs in order to identify a package of production practices economically acceptable to the region's farmers.

This study aimed to give a rapid answer to farmers' questions about bed planting and furrow irrigation assessing the limits to input savings in bed planting-furrow irrigation in terms of yields and profitability of durum wheat in South-East Anatolia.

MATERIALS AND METHODS

Field trials were carried out at Akcakale (clay loam; pH = 7.92, P_2O_5 = 26.9 kg ha^{-1}, $CACO_3$ = 24.7%, Organic matter = 1.08-1.69%, Total N = 27 kg ha^{-1}, Salinity = 0.062-0.082%) and Koruklu (clay) in the Harran Plain in Sanliurfa (2004/05, 2005/06 and 2006/07 cropping seasons) at the experimental field of GAPEYAM (GAP Training Extension and Research Center) as a part of cotton (first year)-[wheat + corn] (second year) rotation. Annual rainfall was 218 and 229 mm in Akcakale (long term average = 303 mm) in 2004/05 and 2005/06 cropping seasons (no rain fall during the grain-filling period) and 195 mm in Koruklu in 2006/07. A randomized complete block design with 4 replications was used.

Treatments were as follows: T_1: Conventional Planting (CP) with recommended seed and fertilizer rate and herbicide use; T_2: Bed-planting and furrow irrigation with inputs as in CP (BP-FI); T_3: BP-FI with 10% reduction for inputs; T_4: BP-FI with 20% reduction for inputs; T_5: BP -FI with 30% reduction for inputs; T_6: BP-FI with 40% reduction for inputs.

Conventional planting can be characterized as follows; after cotton harvest all stalks are chopped by special equipment (rotating chain mounted to track) then ploughed. After second tillage by disk harrow or cultivator, field is ready for planting.(response to Q1 of first reviewer via web page) The recommended seed rate was; 500 grains m^{-2} (270 kg ha^{-1} for durum wheat variety of Firat-93, fertilizer rate was 140 kg ha^{-1} N, 50% at sowing and 50% at shooting stage, 80 kg ha^{-1} of P applied at sowing, 2 L ha^{-1} herbicide for narrow-leaf weeds (grasses) such as wild oats (*A. fatua*) (active ingredient; Fenoxyprop-p-ethyl), 60 mL ha^{-1} herbicide for broad-leaf weeds (active ingredient; 100 g L^{-1} pyrimidine + 2-sulfonamide and 75 g L^{-1} florasulam).

Irrigation was applied twice at the grain- filling stage; giving 150 mm m^{-2} at each application for all treatments. The drilled plot size was 10 m×6 rows (1.2 m) for CP and 10 m×2 beds (1.40 m) for BP-FI plots. Isolation plots were also placed among treatments to avoid any bias scoring, caused by water joining of neighboring plots with different N fertilizer ratios. A plot combine harvester (Hege-140) was used for harvest. After dockage-cleaning to separate chaff and other light material by air flow and sieving, grain yields were calculated and samples from each replication were scored for hectoliter and 1000 kernel weights, vitreous kernels and protein content % (Williams *et al*., 1986). Individual year and combined (all factors for the three years) analyses of variance were performed employing TARIST (Açıkgöz *et al*., 1994).

Grain samples from each treatment from each year were presented to the four randomly selected grain purchasers in the local commodity market for price estimations. Individual (year-based) and combined analyses of variances of market price data were also performed using TARIST (Açıkgöz *et al*., 1994). An economical analysis was further performed to identity the best profitable treatment, where net income ($US ha^{-1}) = [grain yield (kg ha^{-1}) x market prices ($US ton^{-1}) - (total varying costs of inputs under study)].

RESULTS

Results for Akcakale 2004-2005 cropping season: Due to the malfunction of deep well pump, first irrigation was missed and this resulted in low average grain yield. Analysis of Variance (ANOVA) for grain yield indicated that treatments were non significant (Table 1, p<0.05). However, treatments for 1000-kernel weight were significant (p<0.05), indicating that the various bed-furrow treatments were higher than CP (CV 2.6%). Treatments for hectoliter weights and protein content (%) were non significant (CV, less than 1%).

Table 1: Means and LSD range test on of some characteristics of treatments based on individual analysis of variance for three growing seasons in Sanliurfa, Southeastern Turkey

Treatments	2004-2005	2005-2006	2006-2007
Protein content (%)			
CP-FI[1]	19.2	16.0ab	17.9
BP-FI[2]	19.2	16.5a	17.4
BP-FI-10[3]	19.4	16.5a	17.5
BP-FI-20[4]	19.3	16.0ab	17.7
BP-FI-30[5]	19.1	15.8ab	17.8
BP-FI-40[6]	19.1	15.7b	17.6
Statistical significance	$p \leq 0.05$		
1000 kernel weights (g)			
CP-FI[1]	44.2b	52.0	53.0
BP-FI[2]	46.2a	51.3	51.2
BP-FI-10[3]	47.3a	52.1	53.9
BP-FI-20[4]	46.6a	51.2	53.2
BP-FI-30[5]	46.7a	52.1	52.1
BP-FI-40[6]	45.8ab	51.7	51.5
Statistical significance	$p \leq 0.05$		
Hectoliter weights (kg hL^{-1})			
CP-F[1]	84.6	87.8	83.6
BP-FI[2]	83.3	87.6	83.9
BP-FI-10[3]	83.8	87.6	83.9
BP-FI-20[4]	83.8	87.6	83.8
BP-FI-30[5]	83.5	87.7	83.8
BP-FI-40[6]	83.7	88.1	83.7
Grain yield (kg ha^{-1})			
CP-F[1]	3460	6190a	4970a
BP-FI[2]	3390	4840b	4560b
BP-FI-10[3]	3035	5110b	4620ab
BP-FI-20[4]	3770	5230b	4670ab
BP-FI-30[5]	3340	5010b	3970c
BP-FI-40[6]	3440	5170b	4100c
Statistical significance	$p \leq 0.01$		
Market price ($ US ton^{-1})			
CP-F[1]	318d	318ab	355b
BP-FI[2]	318cd	320a	356a
BP-FI-10[3]	321bc	319ab	356ab
BP-FI-20[4]	319bcd	319ab	356ab
BP-FI-30[5]	324a	316b	356ab
BP-FI-40[6]	321b	318ab	356a
Statistical significance	$p \leq 0.01$		

[1]Conventional flood irrigation; [2]Bed Planting and furrow irrigation+full inputs; [3,4,5,6]Bed planting and furrow irrigation with 10, 20, 30 and 40% reduction in inputs, respectively

Results for Akcakale 2005-2006 cropping season: In contrast to the previous year: Rain distribution was quite satisfying and relatively adequate. No problem rose for irrigation as well. Analysis of variance for grain yield

Table 2: Means and LSD range test on of some characteristics of treatments and years based on combined analysis of variance over three growing years in Sanliurfa, southeastern Turkey

Treatments	Market price ($US ton^{-1})	Protein content (%)	1000-kernel weight (g)	hectoliter weight (Kg hL^{-1})	Grain yield (Kg ha^{-1})
CP-F[1]	335b	17.7	49.7b	85.3	4877a
BP-FI[2]	337ab	17.7	49.6b	84.9	4247bc
BP-FI-10[3]	337ab	17.8	51.1a	85.1	4359bc
BP-FI-20[4]	336ab	17.7	50.3ab	85.1	4556ab
BP-FI-30[5]	337a	17.5	50.3ab	85.0	4103c
BP-FI-40[6]	337a	17.5	49.7b	85.2	4238bc
Statistical significance				p<0.01	p<0.01
Years					
1	320b	19.2a	46.1b	83.8b	3449c
2	318b	16.1c	51.7a	87.8a	5259a
3	356a	17.6b	52.5a	83.8b	4481b
Statistical significance		p<0.01	p<0.01	p<0.01	p<0.01

[1]Conventional flood irrigation; [2]Bed Planting and furrow irrigation + full inputs; [3,4,5,6]Bed planting and furrow irrigation with 10, 20, 30 and 40% reduction in inputs, respectively

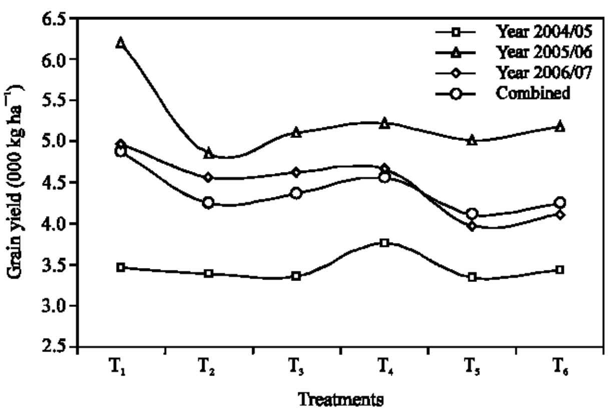

Fig. 1: Comparisons of grain yields for different treatments (1: Conventional flood irrigation; 2: Bed Planting and furrow irrigation+inputs; 3, 4, 5, 6: Bed planting and furrow irrigation with 10, 20, 30 and 40% reduction in inputs, respectively)

were significant ($p<0.05$), with the CP yielding highest (6200 kg ha^{-1}) and significantly outranking the original and reduced-input bed and furrow treatments. All other parameters were non-significant in terms of treatment effects.

Results for Koruklu 2006-2007 cropping season: This season was quite unusual. After sowing, there was no rain following 40 days. Permanent electricity cut off at deep well pump blocked us to irrigate experiment for early germination. Late germination and a-three-day hot winds at grain filling period resulted in relatively low grain yield. However, as in the second year at Akcakale, ANOVA for grain yield indicated that treatments were significant ($p<0.01$), again with the conventional practice out yielding the alternative bed and furrow treatments. Various treatments had no significant effect on the other independent variables. Given that variation in seasonal rainfall and related environmental conditions have a significant influence on crop yields despite the input of irrigation, there was a marked effect of season on yields (Fig. 1) but the treatment differences followed the same pattern.

Combine analysis of variance: Combined ANOVA for grain yield indicated that treatments, years and treatments x year interactions were significant. The analysis showed that the conventional (CP) treatment yielded highest, but that the reduced input bed and furrow treatment (BP-FI-20) ranked only marginally less than the conventional system. Average yields for 2005/06, 2006/207 and 2004/05 were 5258.3, 4500 and 3500 kg ha^{-1}, respectively. The analysis showed no significant effects for the other parameters but the year effect was significant. Despite non significance of some parameters, all characteristics under study were grouped by LSD test and results are given Table 2.

Year-based and combined ANOVA's for marketing prices: Analysis of variance for marketing price estimates for the first year of experiment indicated that both purchasers and treatments were significant. Grain samples, obtained from the bed and furrow treatments such as T_5 (BP-FI-30), T_6(BP-FI-40) and T_3(BP-FI-20), received higher marketing price offers. In the second and third year of the experiment, the ANOVA for marketing price estimates showed that only purchasers were significant ($p<0.01$). However, the combined ANOVA for marketing price estimates for all three experimental years indicated non significance. Despite non significance, the reduced-input treatments (T_5, T_6 and T_3) ranked highest in economic terms (Table 2).

Correlation analysis: Coefficients of correlation among grain yields, 1000 kernel weights, protein content and market prices (Table 3) were non significant, but the

Table 3: Coefficients of correlation between some of the quality characteristics vs. grain yields and market prices

Parameters	Market prices ($US ton^{-1})	Grain yield (kg ha^{-1})
Protein content (%)	-0.450^{NS}	0.416^{NS}
1000-kernel weight (g)	0.353^{NS}	-0.105^{NS}
Hectoliter weight (kg hL^{-1})	-0.645^{NS}	0.783^{NS}
Market price ($US ton^{-1})	-1.000	-0.934**
Grain yield (kg ha^{-1})		-1.000

**p<0.01, NS: Not significant

Table 4: Net incomes of treatments calculated by subtracting varying costs from total income ha^{-1}

Treatments	Grain yield (Kg ha^{-1}) (1)	Market price ($US t^{-1}) (2)	Total income ($US ha^{-1}) (3) = (1)×(2)	Seed cost ($US ha^{-1}) (4)	Fertilizer cost ($US ha^{-1}) (5)	Herbicide cost (broad levels) ($US ha^{-1}) (6)	Herbicide cost (narrow levels) ($US ha^{-1}) (7)	Total varying cost ($US ha^{-1}) (8) = (4+5+6+7)	Net production income ($US ha^{-1}) (9) = (3)-(8)
1 CP-FI	4877	335	1634	98.4	47.9	7.4	71.8	225.5	1408
2BP-FI	4247	336	1429	98.4	47.9	7.4	71.8	225.6	1203
3 BP-FI-10	4359	337	1469	88.6	43.2	6.7	64.6	203.0	1266
4BP-FI-20	4556	336	1532	78.7	38.4	5.9	57.4	180.5	1352
5BP-FI-30	4103	337	1384	68.9	33.6	5.2	50.2	157.9	1226
6BP-FI-40	4238	337	1429	59.0	28.8	4.5	43.1	135.3	1293

1: Conventional flood irrigation; 2: Bed Planting and furrow irrigation+inputs; 3, 4, 5, 6: Bed planting and furrow irrigation with 10, 20, 30 and 40% reduction in inputs, respectively

negative correlation between grain yields versus market prices was highly significant. Market price offers increased for grains with plumpness due to the low seed rates in BP treatments. However, market price offers also did not correlate significantly with protein content, 1000 kernel weights or hectoliter weights.

Economical analysis: Net income (Table 4) for Conventional Planting with Flood Irrigation (CP-FI) was the highest at $US1408 ha^{-1}, while the bed and furrow reduced systems ranked second (BP-FI-20) at $US1352 and (BP-FI-40) ranked third rank at $US1293 ha^{-1}. Conventional planting-flood irrigation yielded a net income increase of $US56 ton^{-1} over the most profitable of the nearest bed planting-furrow irrigation treatment. Although they received higher marketing price offers, net incomes of bed planting treatments were reduced gradually due to the lower grain yields. Comparison of net returns for CP-FI vs BP-FI-40 was performed by partial budget analysis. Only chancing inputs were considered and the others were constant. It means that the cost 40% input saving treatment has already been taken into account for net income calculation.

DISCUSSION

Notwithstanding the potential benefits of the relatively new bed planting and furrow irrigation system (Akhtar, 2006; Limon-Ortega *et al*., 2000; Fahong *et al*., 2004) this series of field trials showed that at least under conditions prevailing in southeastern Turkey, the conventional planting with flood irrigation with some recommended inputs (seed, fertilizer and chemical herbicide) was still the most acceptable in terms of yields and economic profitability. The hypothesis that the reduced bed system, along with conventional inputs, would be better than the traditional system was not borne out as shown elsewhere (Freeman *et al*., 2007). Consequently, recommendation packages that involved sequentially reduced inputs were not demonstrated in this study. Indeed, there were indications that decreasing inputs in bed planting and furrow irrigation could result in lower yields.

There was little in the study to suggest that any quality parameters were factors in the assessment of the practices; grain yields and market price offers are the only considerations. Increasing amounts of input saving reduced grain yield and increased the grain plumpness and subsequently market price offers. In the Sanliurfa local commodity market, purchasers do not offer high market price for high quality grain (Ozberk *et al*., 2006). There was only a $ US 2 ton^{-1} marketing price differences between the highest and lowest quality grain in this study. But this may not be true for some other countries such as Canada and USA. Durum wheat must fulfill certain quality requirement of protein content, sedimentation value, yellow berry percentage carotene content, test weight etc (Traccoli *et al*., 2000; Sardana, 2000). Although, there are many other quality requirements for durum wheats in the international marketing, some physical characteristics such as high test weights influence buyer decision strongly rather than protein content and amylase activity in USA (Lee *et al*., 2000). Findings of this study indicated that grain yield is the major factor affecting high net return. The results obtained from this study for grain yield were similar to that of present study (Kabakçı, 1999). Except for the yield advantages of bed planting and furrow irrigation in wheat-cotton crop rotation study in Diyarbakir there is not any study carried out recording bed planting and furrow irrigation out yields the conventional planting and flood irrigation in wheat production in Turkey. Research findings of this study overlapped those of previous studies in terms of grain yielding. But Özberk *et al.* (2005b) claimed that net return per se must be taken into account for treatment (variety) preference. None of the earlier study carried out in Turkey considered the market prices of experimental crop. Several of them took into account for input prices only. In dealing mainly with yield and to a lesser extent grain quality, our study was less comprehensive than those of Aquino (1998) who considered irrigation water savings and some operational costs in the bed and furrow system.

The outcome of this study raises the question as to why there should be discrepancies between the traditional approach and innovative ones such as bed and furrow irrigation. Clearly, in retrospect, inputs cannot be logically reduced by a given fraction uniformly. For example, reducing pesticide levels below the effective threshold would render the reduction meaningless. Similarly, while reductions in fertilizer use can be made in a step-wise fashion, these have to be related to the soil levels of available nutrients and their impact on crop growth; in addition, as each nutrient, i.e., nitrogen and phosphorus, has a different effect on growth, reductions of each have a differential effects. In such cases, the experiment should have been conducted with variable rates of one factor and others held constant. As water use and its efficiency is fundamental to assessment of the bed and furrow system (Fahong *et al.*, 2004), this aspect was ignored in this comparison. Although, being aware of the importance of irrigation water saving, the amount of irrigation water was not taken as a factor in this experiment. It costs quite cheap for farmers in the region. They only pay for 134.6 \$US ha^{-1} in one wheat growing season. They could irrigate their fields more than 5 times giving 100 mm in each in a growing season.

Under the conditions of the present field trials in southeastern Turkey, there was little indication that the bed and furrow system could replace the traditional flood irrigation system unless high quality grains are given high premium. Grain yields are the only basis for comparing the two systems since neither is likely to influence grain quality parameters. In terms of grain yield farmers are not keen to adopt new system as the way we suggest. But they tend to employ this system to enlarge the planting area by planting both beds and furrows so that they can extend the acreage of field by 10%.

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