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Full Length Research Paper

The effect of planting methods on yield and yield components of irrigated spring durum wheat varieties

Hasan Kiliç

Department of Field Crops, Faculty of Agriculture, Bingöl University, 12000, Bingöl, Turkey. E-mail: hkilic@bingol.edu.tr.

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A field experiment was carried out during three consecutive years: 2004 - 2005, 2005 - 2006 and 2006 - 2007 in South-eastern Anatolian, Turkey. The objective of the study was to compare planting methods and varieties of spring durum wheat (*Triticum turgidum* var. durum Desf.) for grain yield, yield components, some grain qualities and black point disease. An experiment was conducted as a randomized complete block design with four replications using a split plot treatment arrangement. The result revealed that planting methods had significant effect on yield and yield contributing characters except harvest index, vitreousness, protein content and black point disease. Interactions between planting methods and varieties were also significant for most yield components. Although the mean grain yield (6.29 t ha^{-1}) in flat planting method was 4% higher than bed planting method (6.04 t ha^{-1}), the Sarıçanak-98 produced the highest grain yield (6.77 t ha^{-1}) with bed planting method. However, Aydın-93 produced the lowest (4.97 and 5.26 t ha^{-1}) with bed and flat planting, respectively. All the yield components were significantly influenced by cultivars. Among the varieties, Sarıçanak-98 was the best performer in bed planting system owing to desired yield components. Also, an appropriate genotype for bed planting should have broad leaf area and ground cover due to protection the evaporation from soil in South-eastern Anatolia irrigated area. Percentage of black point disease was much less severe in wheat plants grown on bed planting than in those on flat beds. Furthermore, bed planting decreased black point disease by more than 19%. It may be concluded that bed planting method is suitable for wheat in irrigated area when appropriate genotypes are used.

Key words: Bed planting, black point disease, durum wheat, chlorophyll content, quality traits, yield, yield components.

INTRODUCTION

Wheat is one of the world's three most important cereal crops (the other two are maize and rice) and it has the widest distribution of any cereal. The crop is primarily grown for its grain, which is consumed as human food. It is the first important cereal crop of Turkey and now accounts for about 75% of the total cereal production with coverage of 11.9 million hectares (Anonymous, 2008). Durum wheat is a minor crop, grown in only 15% of all the wheat cultivated area in Turkey. Per capita water resource is reduced from 4.000 to 1.430 m^3 last decade in Turkey (Anonymous, 2010). This problem is occurred in other places in the world. The increase in irrigation application causes serious environmental problems. Therefore, it is urgently needed to improve the planting methods such as bed planting system which have efficiency of irrigation water for sustainable production. Most of areas of wheat in South-eastern Anatolian, Turkey are flood irrigated, which results in adverbs affect such as lodging and higher water consumption.

Bed planting systems have been used in cultivation for centuries (Ghane et al., 2009). The origin of raised-bed cultivation has traditionally been associated with water management issues, either by providing opportunities to reduce the impact of excess water in rainfed conditions, or to more efficiently deliver irrigation water in high production irrigated systems (Sayre, 2004). Over the past 20 years, farmers in the irrigated areas in the northwest state of Sonora in Mexico have adopted an innovative system by which wheat is planted in defined rows on top of beds with irrigation supplied in furrows between the beds. With more than 95% farmer acceptance of this planting method for wheat as well as all other crops in the cropping systems, dramatic improvements have occurred in productivity of irrigation water. Farmers are also taking

Table 1. Sum of total precipitation and average of maximum, minimum temperatures and relative humidity in each year.

Year	Total Precipitation (mm)	Relative humidity (%)	Temperatures (°C)		
			Max.	Min.	Mean
2004 - 2005	389.4	44.0	25.3	8.7	16.1
2005 - 2006	534.2	50.2	23.2	8.7	16.2
2006 - 2007	534.2	63.7	22.0	7.6	14.9
Long term	494.4	53.9	22.5	8.8	15.9

Table 2. List of varieties and pedigree.

Code	Varieties	Pedigree	Lodging rating
V1	Aydın-93	OMRABİA “S”	Susceptible
V2	Sarıçanak-98	“Daki “S”	Tolerant
V3	Omruf-2	ICD86-0436-ABL-0TR-9AP-0TR-4AP-0TR	Tolerant
V4	Eyyubi	CD86603-7M-030YRC-040PAP-4Y-1PAP-0Y	Susceptible
V5	Artuklu	CD84785-3B-030YRL-040PAP-1Y-0PAP	Moderately susceptible
V6	Şahinbey	ICD.86-0471-ABL-0TR-8AP-0TR-20AP-0TR	Tolerant

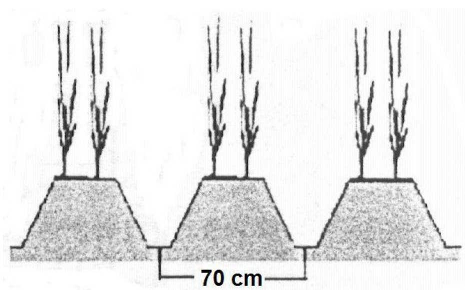

Figure 1. Schematic plan of bed planting.

advantage of the field access provided by this planting method to improve N management (Sayre and Ramos, 1997; Limon-Ortega et al., 2000).

Among different planting methods used for wheat cultivation, bed planting is a new technique in farming system of Turkey. However, a new system of planting with inadequate research of wheat production technology may not advisable and always may not increase wheat productivity since bed planting and conventional planting may have significant interaction with other components of wheat agronomic technology like genotype. Systems the same as or similar to the ridged bed in Turkey are also practiced in many other areas for different crops such as cotton, maize, soybean etc. Many benefits from the bed planting have been reported (Kumar et al., 2007; Holland et al., 2007). Likewise, there are some benefits of this planting system such as low seed rate, decrease of field traffic, better irrigation management facilities, reduce of crop lodging and herbicide dependence, the control of rot diseases, better usage of chemical application machines, and better control of excess water in heavy soil condition (Sayre and Ramos, 1997).

According to results obtained from researches, demonstration and farm practices, this method could be applicable in South-Eastern Anatolian Region (Kılıç, 2007). 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 (Özberk et al., 2009). Therefore, our objectives were to compare bed planting method using furrow irrigation and conventional flat planting method using flood irrigation and to determine the potential interactions between planting methods and genotypes on grain yield, yield components and some quality traits in South-eastern Anatolian in Turkey.

MATERIALS AND METHODS

The experiments were conducted in 2004 - 2005, 2005 - 2006 and 2006 - 2007 at the South-eastern Anatolian Agricultural Research Institute in Diyarbakır, Turkey (Latitude:37° 56'36"N, longitude: 043°15'.13"E at an elevation of 602 m above sea level). The soil of the experimental area is silty loam and slightly alkaline (7.83) in reaction, low in organic matter (1.45%), medium in available phosphorus (P) (4.3 kg/da^{-1}), high in potassium (K) (95 kg/da^{-1}). The weather conditions during the crop cycles are presented in Table 1. There was lower rainfall after planting in 2004 - 2005 as compared to 2005 - 2006 and 2006 - 2007. Each year an experiment was conducted as a randomized complete block design with three replications using a split plot treatment arrangement. The planting methods were randomized in the main plots and cultivars in the sub-plots. The cultivars used were grown widely in South-eastern Anatolian region (Table 2). The sub-plots for flat seeded consisted of 10 m length with twelve rows per plot, 20 cm apart, providing a plot area of 24 m^2 (Figure 1). Similarly the bed planted, sub-plots included the same 6 varieties which were planted on top of two 70 cm wide beds x 4 (furrow to furrow) with two rows per bed, spaced 20 cm apart. Each plot was 10 m long providing a 28 m^2 plot

Table 3. Effects of planting method and variety on some quality traits and black point disease of wheat

Treatments	Plant height (cm)	Spikes per m^{-2}	Grains per $spike^{-1}$	WGS (g^{-1})	Harvest index (%)	Lodging rate (%)	Grain yield ($t\ ha^{-1}$)
Planting method							
Flat planting	94.1	548.8 a[a]	51.0 b	2.3 b	43.9	30.4 a	6.29 a
Bad Planting	93.5	358.1 b	53.8 a	2.4 a	44.2	11.4 b	6.04 b
LSD (0.05)	ns	15.8	1.61	0.08	1.33	4.68	0.13
Variety							
Aydın-93	100.7a[a]	447.3c	49.1d	2.1c	38.1c	40.0a	5.11d
Sarıçanak-98	88.7d	428.2cd	58.1a	2.6a	46.8a	2.5d	6.71a
Omruf-2	88.4d	477.4b	53.1b	2.3b	46.4a	13.1c	6.15c
Eyyubi	96.5c	508.3a	51.6bc	2.2bc	45.1ab	34.4ab	6.41b
Artuklu	99.4b	445.1 c	52.1 bc	2.3 b	42.8 b	29.7 b	6.05 c
Şahinbey	89.2d	414.5d	50.3cd	2.5a	45.3a	5.6cd	6.57ab
LSD (0.05)	1.1	28.8	2.4	0.1	2.3	8.1	0.22

[a] = Means in a column with the same letter are not significantly different at the 5% level; ns = Not significant.

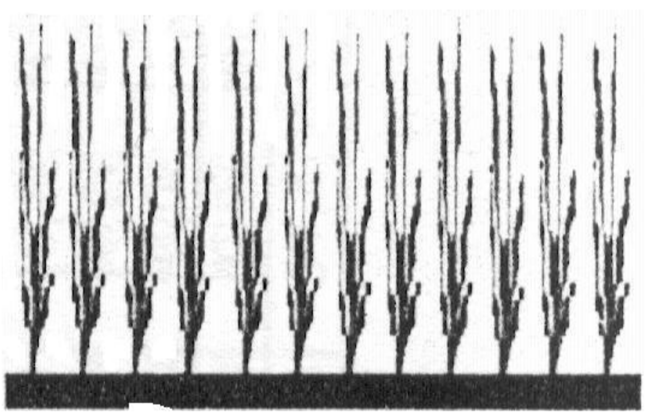

Figure 2. Schematic plan of flat planting.

area (Figure 2).

In every three years, the experiments were planted with a plot drill in the last week of November into let soil at a rate of 100 kgha^{-1} (Kabakçı, 1999) for raised bed and 200 kgha^{-1} (Alagöz, 1993) for conventional flat bed. The whole dose of P (100 kg P ha^{-1}) with half dose of nitrogen (80 kg N ha^{-1}) were applied at sowing time and the remaining nitrogen (70 kg N ha^{-1}) was top-dressed as urea with first irrigation. All other agronomic practices like irrigation, weeding etc. were kept normal and uniform for all the treatments.

Data was recorded for plant height, spikes per m^{-2}, grains spike^{-1}, weight of grains spike^{-1} (WGS), harvest index, lodging rate, thousand grain weight (TGW), vitreousness, grain protein content and percentage of black point disease at the end of the season. Grain yield (t ha^{-1}) was harvested by harvester machine. Leaf chlorophyll content was measured and recorded using the chlorophyll meter device (Minolta SPAD–502). To measure this trait, plant leaves were put between the two blades of the device and the content of the three sections of flag leaves including the beginning, the middle and the end of the samples were recorded by selecting the 15 individual plants.

Data on growth and yield components were collected using standard procedures and were analyzed statistically by using Fisher's analysis of variance technique. Least significance difference (LSD) tests were performed to determine the significant differences between individual means. Regression analysis was also run on grain yield and yield components (Steel and Torrie, 1980). All statistical analysis was performed using the SAS program (SAS Institute, 1999).

RESULTS AND DISCUSSION

Effect of planting method

Planting method was found significant on yield and contributing characters of wheat and the results are presented in Tables 3 and 4, and Figure 3. TGW, grains per spike^{-1} (53.8), WGS (2.4 g) and chlorophyll content (49.9) were highest in the bed planting method while spikes per m^{-2} (548.8) and lodging (30.4%) were highest in flat planting method. However, there were no significant differences for plant height, harvest index, vitreousness, grain protein content and percentage of black point between flat planting and bed planting method. Another words, bed planting reduced over grain yield (4%) compared with the flat planting. The highest grain yield (6.29 t ha^{-1}) was obtained from flat panting where the lowest (6.04 t ha-1) was in bed planting method. This result is supported by the study of Özberk et al. (2009), Kabakçı (1999), Tripathi et al. (2002) and Alam et al. (2007),which reported that bed planting showed significantly higher grain spike than conventional method. Fahong et al. (2004) reported that bed-planting reduced plant height, lodging and some disease incidences, while increased the grains per spike and grain weight. At the same time, in a study at the same region, Özberk et al. (2009) stated that planting methods for TGW were significant while treatments for hectoliter weights and protein content were non significant.

Table 4. Effects of planting method and variety on some quality traits and black point disease of wheat.

Treatments	Chlorophyll content (SPAD)	TGW (g^{-1})	Vitreousness (%)	Grain protein content (%)	Black point disease (%)
Planting method					
Flat Planting	48.73 b[a]	43.9 b	95.12	12.17	13.92
Bad Planting	49.91 a	45.4a	95.93	12.26	11.25
LSD(0.05)	0.57	0.42	ns	ns	ns
Variety					
Aydın-93	49.6b[a]	52.3a	97.8a	13.0a	19.38a
Sarıçanak-98	49.7b	44.2b	96.0ab	12.3b	15.25ab
Omruf-2	46.7d	44.1b	92.7c	11.7b	14.25bc
Eyyubi	53.3a	43.5bc	96.1ab	12.2b	4.25e
Artuklu	48.1c	42.7c	96.1ab	12.1b	11.37cd
Şahinbey	48.5c	41.1d	94.5bc	11.9b	11d
LSD (0.05)	1.00	1.0	2.5	0.5	3.4

a: Means in a column with the same letter are not significantly different at the 5% level; ns = Not significant

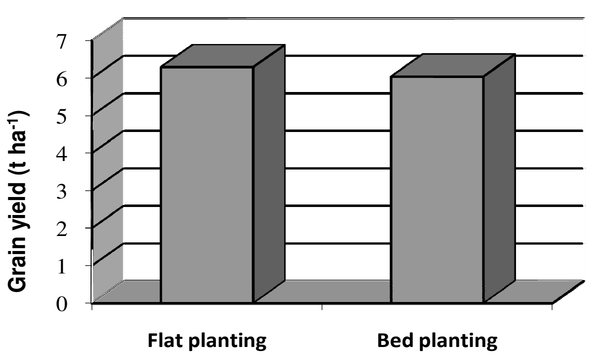

Figure 3. Effect of planting method on grain yield of wheat.

Effect of variety

Variety had significant effects on the all yield, yield contributing characters and quality traits (Tables 3 and 4, Figure 4). The highest value for most of the growth and yield parameters was obtained from the variety Sarıçanak-98. On other hand, Aydın-93 showed lowest performance. The reasons for differences in producing growth and yield components might be because of genetic structure of the cultivars primarily affected by heredity.

Interaction effect of planting method and variety

Interaction between planting method and variety were found to have significant effect on all characters except grain yield, grain protein content and black point disease (Tables 5 and 6). The highest grain yield (6.77 and 6.65 t ha^{-1}) was observed in Sarıçanak-98 for both bed and flat planting methods, respectively.

This trial also shows an overall yield advantage for flat planting but again identifies cultivars such as Sarıçanak-98 and Şahinbey as demonstrating remarkable yield stability across planting systems and with consistently less lodging. Sarıçanak-98 had particularly the least lodging for both planting methods and produced stability. Also, these cultivars have broad leaf area and ground cover due to protection of soil from evaporation from inter top of beds (Figure 6). On the other hand, Aydın-93 showed lowest performance. Probably, this was due to the most lodging in either planting systems and has smaller and upright leaf area and ground uncover. Such genotypes may be unsuitable for bed planting (Figure 5). Besides, Kılıç (2007) reported that appropriate wheat genotypes have greater broad leaf area, covering the ground and protecting the soil against evaporation with bed planting when compared with genotypes which have narrow leaf area and upright growth habit.

Genotypes, which demonstrated superior performance across the different planting systems, exemplified a more "farmer friendly" choice and characterized the plant type that plant breeders should strive to develop (Triphati et al., 2005). Results show that not all wheat varieties are appropriate for bed planting. Also, Sayre and Ramos (1997) reported that there can be variety interactions for bed-width, number of rows per bed, and seed rates within different bed planting systems.

Meisner et al. (1992) reported that the growth and grain yield of wheat were significantly influenced by planting methods. In a study at CIANO, Sayre and Ramos (1997) further concluded from comparing a large number of randomly chosen advanced lines planted on the flat and on beds, that the average grain yield for the lines planted on the flat was 5% more than in bed planting. The authors, however, further noted that, while it was common to observe genotypes that performed well under

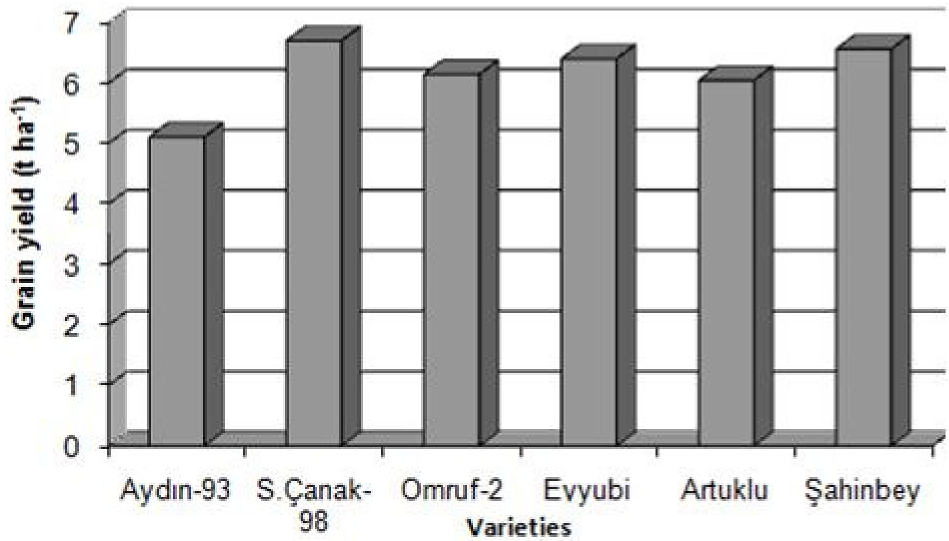

Figure 4. Effect of variety on grain yield of wheat.

Table 5. Interaction effects of planting method and variety on yield and yield contributing characters of wheat.

Interaction (Planting method×Variety)	Plant height (cm)	Spikes per m^{-2}	Grains per $spike^{-1}$	WGS (g^{-1})	Harvest index (%)	Lodging rate (%)	Grain yield (t ha^{-1})
FP x V1	100.6ab[a]	581.5a	47.3d	2.2fg	33.8f	53.8a	5.26
FP x V2	88.6ef	506.8b	56.7ab	2.6ab	45.7bcd	3.8e	6.65
FP x V3	89.1ef	576.0a	49.9cd	2.3c-f	43.3cde	23.8c	6.36
FP x V4	98.1c	608.2a	51.7c	2.3def	43.3cde	51.3a	6.54
FP x V5	99.8bc	528.5b	53.0bc	2.3def	40.7e	41.3b	6.23
FP x V6	88.3f	492.1b	47.2d	2.7a	45.8bc	8.8de	6.73
BP x V1	100.7a	313.1f	50.8cd	2.0g	42.5de	26.3a	4.97
BP x V2	88.9ef	349.6def	59.4a	2.5bc	47.8ab	1.3e	6.77
BP x V3	87.8f	378.7cd	56.4ab	2.2ef	49.4a	2.5e	5.95
BP x V4	94.9d	408.4c	51.5c	2.1fg	46.8ab	17.5cd	6.29
BP x V5	99.1bc	361.7de	51.3c	2.4cd	44.8bcd	18.1c	5.86
BP x V6	90.0ef	336.9ef	53.4bc	2.4cde	44.7bcd	2.5e	6.41
LSD (0.05)	1.6	38.6	3.9	0.18	3.3	8.8	ns
CV%	2.13	10.4	9.14	10.3	7.55	41.3	6.7

a: Means in a column with the same letter are not significantly different at the 5% level; V: Variety; Ns: Not significant; FP: Flat planting method; BP: Bed planting method; CV: Coefficient of variation.

flat planting but did not perform well with bed planting, it was rare to find the reverse, lines that performed well on beds but did poorly on the flat, unless markedly differential lodging was involved. These results are confirmed that of Kabakçi (1999) and Özberk et al. (2009) who stated that wheat genotypes produced lower yield under bed planting system in same region. On the contrary, Hossain et al. (2006); Hobbs et al. (2000), Talukder (2003) and Fahong et al. (2004) reported that bed planting ensured higher grain yield when compared with flat planting.

Black point disease

Percentage of black point disease was much less severe in wheat plants grown on bed planting than in those on flat beds. Bed planting decreased the black point disease by more than 19% (Table 4). The reduced risk of disease incidence might be attributed to the integrated improvements characterized by good soil aeration, unwetted soil surface and low air humidity and good light penetration inside the canopy. Within the optimum range, soil water potential was slightly lower in ridged beds than

Table 6. Interaction effects of planting method and variety on some quality traits and black point disease of wheat.

Interaction (planting method × variety)	Chlorophyll content (SPAD)	TGW (g^{-1})	Vitreousness (%)	Grain protein content (%)	Black point disease (%)
FP x V1	48.9 b [a]	39.6 h	96.3 bc	13.1	13.5
FP x V2	49.7 b	41.8 g	95.6 bcd	12.3	13.3
FP x V3	46.7 c	43.3 def	92.5 e	11.7	13.8
FP x V4	53.0 a	43.0 ef	97.6 ab	12.1	4.5
FP x V5	47.2 c	44.1 d	95.3 bcd	12.0	11.0
FP x V6	46.9 c	51.5 b	93.4 de	12.4	11.5
BP x V1	50.3 b	42.6 fg	99.2 a	12.9	25.3
BP x V2	49.7 b	43.7 de	96.3 bc	12.2	17.3
BP x V3	46.8 c	43.6 def	92.8 e	11.8	14.8
BP x V4	53.7 a	45.3 c	94.7 cde	12.4	4.0
BP x V5	49.0 b	44.2 d	97.0 ab	12.3	11.8
BP x V6	50.1 b	53.2 a	95.6 bcd	11.5	10.5
LSD (0.05)	1.4	1.0	2.3	ns	ns
CV%	3.46	2.80	2.42	7.1	25.6

a:Means in a column with the same letter are not significantly different at the 5% level; V:Variety;ns: Not significant; CV : Coefficient of variation; FP: Flat planting method; BP: Bed planting method.

Figure 5. Narrow and upright leaf area and erect growth habit (Aydın-93).

Figure 6. Greater leaf area and ground cover (Sarıçanak-98).

in flat beds, leading to un-wetted soil surface conditions even after rainfall and irrigation (Xu et al., 2009). Fahong et al. (2004) reported that bed planting reduced crop lodging and decreased the incidence of some wheat diseases. The authors, however, additionally noted that these advantages, interacting together, were found to improve grain quality and increase grain yield by more than 10%.

Conclusions

Bed planting with furrow irrigation for wheat, a new production system in South-eastern Turkey, produced dramatic reductions in crop lodging for all lodging- tendency varieties. Yields of genotypes were at par or better with flat planting compared with bed planting. However, in most cases, these lines also demonstrated less lodging with bed planting. Results clearly demon-strated that some varieties were not appropriate for bed planting. Varieties such as Aydın-93 which was unsuit-able for bed planting could generally be characterized as possessing an extreme upright, uncovering the earth and compact growth habit (Figure 5). However, it was identified that varieties such as Sarıçanak-98 which had high yields for both bed and flat planting combined with consistent, lower incidences of lodging for both planting systems (Figure 6).

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