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Effect of Planting Methods and Seeding Rates on Grain Yield and Yield Components of Durum Wheat (*Triticum durum*) in Harran Plain

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Abstract: This study was conducted in Sanliurfa, SE-Turkey to identify suitable Planting methods and seeding rates for durum wheat to be grown under irrigated conditions in the Harran Plain. Seeding rates were 100, 150, 200 and 250 kg ha^{-1} respectively. Sowing methods were: 1) Conventional system (CP): Sowing on flat seedbeds with small grain seeders, 2) Raised bed planting (RBP): Sowing in two rows with 20 cm distance on previously prepared 70 cm wide beds. 3) Furrowed Planting (FP): Broadcast sowing on flat seedbeds and preparation furrow 70 cm distance after sowing. The cultivar used was Diyarbakir 81, the dominating durum wheat variety. The irrigated trials were conducted in 1994 and 1997 at Tatlica and in 1998 at two locations (Akçakale, Tatlica). In 1996, the same experiment was conducted under rainfed conditions at Akçakale and Tatlica. Traits measured were: Number of plants/ m^{-2}; number of spike/ m^{-2}; grain yield $spike^{-1}$; TKW and grain yield.
Under rainfed conditions, CP resulted in a significantly higher grain yield, number of plants m^{-2}, number of spike m^{-2}, and lowest grain yield $spike^{-1}$. No significant difference was recorded for TKW. No differences were observed between RBP and FP for any of the traits. In the seeding rate experiment, the lowest seeding rate resulted in the highest grain yield $spike^{-1}$ and TKW but the lowest number of plants m^{-2}. No significant differences were observed for number of spike m^{-2} and grain yield.
Under irrigated conditions, RBP and FP resulted in a significantly lower number of plants m^{-2} and number of spike m^{-2} and the higher grain yields $spike^{-1}$ compared to CP. However, no statistically significant differences could be observed for grain yield and TKW. No significant differences were observed between RBP and FP. In the seeding rate experiment, the lowest seeding rate produced the highest grain yields $spike^{-1}$ and TKW, but the lowest number of plants m^{-2} and spikes m^{-2}. Seeding rate had no significant effect on grain yield.
The results suggest that grain yield of RBP and FB are similar to CP in irrigated condition. However, the RBP and FP are more water use efficient, less labor intensive, consequently more economic than the CP and irrigation system presently used by farmers in the Harran Plain.
Key words: Conventional seedbeds. Raised bed planting, Furrowed planting, Seeding rate, Durum Wheat

INTRODUCTION

There is an increasing need to produce more food in order to feed the ever-increasing population in the world. This is also true for cereal production. As it is not possible to increase the land cultivated, the only solution is to increase grain yield and productivity. And this needs to be done in a sustainable way.

South Eastern Anatolia, part of the Fertile Crescent, is a very important region in Turkey and for Turkish agriculture. There is strong evidence civilization started there. Einkorn (Triticum monococcum) was domesticated in what is now southeastern Turkey around 10,000 years B.P., close to the Karacadağ mountains (Heun et al., 1997), from where einkorn and cultivated emmer (Triticum turgidum var. dicoccum) spread through the Fertile Crescent and beyond. Also barley and several legumes were domesticated here. South Eastern Anatolia occupies 11% of the 27.4 million hectares total cultivated land in Turkey. The region produces 10% of the total production of wheat, and 15% of barley in Turkey. Wheat occupies 49% and barley occupies 27% share in the total production of field crops. Most of the cultivated land (38%) is in one province, Sanlıurfa. Wheat is the number one crop

produced in Sanlıurfa with an acreage of around 360 000 ha followed by barley with 220 000 ha. The yield of wheat is lower (1.3-1.5 t ha-1) in Sanliurfa than the average in Turkey (1.92 t ha-1). (GAP, 1986).

In order to develop South East Anatolia, the Government of Turkey has launched the South East Anatolian Development Project (GAP). Upon completion of the project, about 1.7 million ha will be brought under irrigation. At present around 300 000 ha are already irrigated. As a consequence of this, the old wheat varieties adapted to rainfed conditions will be replaced with new wheat varieties suitable for irrigation. Aside identifying high yielding cultivars, there is also a need to carry out research on agronomic aspects of irrigation in the region.

Several reports have suggested that the benefits of bed planting systems are significant and more and more farmers are using them. Sayre and Moreno Ramos, (1997) has listed the advantages of the Bed planting system, which also apply to the GAP area. These are:

- Water management is better and easier
- Increased water use efficiency
- Pre-sowing irrigation allows weeds to emerge; this makes weed control more effective.
- Easy mechanical weed mechanically in early growing periods of wheat.
- Hand weeding is possible
- Less amount of herbicide is used; less pollution.
- Reduced seeding rates saves seed and results furthermore in less lodging.
- Fertilizer can be applied to root region directly and at later growth stages.
- The same beds can be used again for the following crop.

Sayre and Moreno Ramos (1997) have reported that bed planting method has been increasingly implemented by the farmers in Mexico under irrigated conditions and that as a result the Yaqui Valley where the Green Revolution has started; could play a very important role in the wheat production again. They also concluded that bed planting has advantages in weed control, nitrogen use efficiency, regulation of tillering and increases water use efficiency compared to flat sowing.

This study compares different planting methods and seeding rates in wheat production both under irrigated and rainfed conditions.

MATERIAL AND METHOD

Variety:

Diyarbakır-81, the dominating durum wheat variety, was used in the experiment.

Location and soil characteristics:

Experiments have been carried out at the Tatlica experimental site in Sanlıurfa. The soils belong to the red-chestnut soil groups with the following characteristics: pH 7.80, lime 17.4%, total salt 0.065% and organic matter 1.85%.

Climatical Data:

Most of the rainfall is received in winter and spring. Summers are hot and dry. Average annual rainfall at the experimental site is 303 mm. Long term annual maximum temperature is 45.1 ^{o}C, minimum is -10.4 ^{o}C and the annual mean temperature is 18 ^{o}C. Average relative humidity is 57.4.

Fertilizers applied:

80 kg pure N ha-1 and 80 kg pure P2O5 ha-1 have been applied at sowing. An addition of 80 kg pure N ha-1 has been applied at tillering.

Experimental Design:

Split plot design with four replications was used in the experiment. Each treatment was in sub plots of 5 m. Length. Seeding Rates of 100, 150, 200 and 250 kg ha-1 were investigated.

Planting Methods:

Three planting methods were compared

1. **CP: Conventional planting:** Seeds were sown with a conventional planter using inter spacing of 20cm.
2. **FP: Furrowed Planting:** Seeds were broadcast sown and then the furrow were prepared. Spacing between the furrow were 70 cm. Each treatment had 4 beds.
3. **RBP: Raised bed planting:** Beds with a distance of 70 cm were prepared before planting. Seed was sown in two rows on each bed with 20 cm row distance. Each treatment had 4 beds.

RESEARCH RESULTS

Number of plants m^{-2}:

There were statistically significant differences in number of plants m^{-2} between planting methods both under rainfed and irrigated conditions. The highest number of plants m^{-2} was obtained in CP (263), whereas no significant difference was observed between RBP (199 plants m^{-2}) and FP (195 plants m^{-2}) under rainfed conditions. Under irrigated conditions however, there were significant differences between all the planting methods. The highest number of plants was obtained in CP (406 plants m^{-2}) followed by FP (350 plants m^{-2}) and RBP (303 plants m^{-2}). Seeding rate also affected the number of plants m^{-2} both under rainfed and irrigated conditions. As the seeding rate increased so did the number of plants m^{-2}. All four treatments differed significantly under irrigated conditions whereas 20kg/da and 25kg/da seeding rates did not differ significantly under rainfed conditions.

Number of Spikes m^{-2}:

The highest number of spikes m^{-2} was obtained with CP, which was significantly different ($P<0.01$) from both RBP and FP. However, RBP and FP did not differ under both rainfed and irrigated conditions. The number of spike m^{-2} was under rainfed conditions 412 in CP, 322 in FP and 310 in RBP respectively. The number of spike m^{-2} was under irrigated conditions 478 in CP, 404 in RBP and 363 in FP, respectively. Seeding rate did not affect the number of spikes under rainfed conditions but the difference was significant ($P<0.01$) under irrigated conditions. As the seeding rate increased so did the number of spike m^{-2}

Grain yield $spike^{-1}$:

Planting method resulted in statistically significant differences for grain yield $spike^{-1}$ ($P<0.01$) both under rainfed and irrigated conditions (Table 1 and 2). The highest value was 1.342 g $spike^{-1}$ in RBP followed by 1.281 g $spike^{-1}$ in FP and 1.150 g $spike^{-1}$ in CP under rainfed conditions. Under irrigated conditions, the highest value was 1.560 g $spike^{-1}$ in FP followed by 1.385 g $spike^{-1}$ in RBP and 1.224 g $spike^{-1}$ in CP. Seeding rate also affected the grain yield $spike^{-1}$ ($P<0.05$ under rainfed and $P<0.01$ under irrigated conditions). The highest value was obtained with the lowest seeding rate (Table 3 and 4).

Thousand Kernel Weight (TKW):

Planting methods did not affect TKW under both rainfed and irrigated conditions (Table 1 and 2). However seeding rate affected TKW both under rainfed ($P<0.05$) and irrigated ($P<0.01$) conditions. The highest TKW was obtained with seeding rates of 100 kg ha^{-1}, 150 kg ha^{-1} and 200 kg ha^{-1}. 250 kg ha^{-1} has decreased the TKW (Table 3 and 4).

Grain Yield:

Significant differences were obtained between all three planting methods ($P<0.01$) under rainfed conditions. The highest yield was 4530 kg ha-1 in CP followed by 4060 kg ha-1 in FP and RBP (Table 1). However, no significant differences were obtained under irrigated conditions (Table 2). Although the yield has decreased with seeding rates higher than 200 kg ha-1, the differences obtained were not statistically significant (Table 3 and 4).

DISCUSSION AND CONCLUSION

Planting Methods:

Planting methods have affected significantly number of plants m^{-2}, number of spikes m^{-2} and grain yield $spike^{-1}$ under both rainfed and irrigated conditions. However, TKW was not affected. The highest number of plants m^{-2} and spikes m^{-2} was obtained in CP, and the highest grain yield $spike^{-1}$ were obtained in RBP and FP (Table 1 and 2).

Results obtained under rainfed conditions:

Grain yield was significantly higher in CP than RBP and FP under rainfed conditions (Table 1). FP and RBP did not differ significantly. This could be explained by the assumption that the surface area exposed to sunshine is higher in bed planting systems resulting in loss of more water from the soil.

Tewolde, et al., (1993) reported that Dryland sorghum and wheat production in areas where a significant fraction of the annual rainfall is received during the fallow period may be improved by fallow period or year-round furrow diking.

Day, Jackson and Alemu (1978) investigated different planting methods and seed rate (29, 58 or 87 kg seed/ha) and reported that Flat and bed methods of sowing gave similar grain yields and TKW. The lowest sowing rate gave most wheat seed/ear and fewest ears/unit area. Row orientation in the

beds produced changes in seed/ear, ears/unit area and yield/row, more marked in the E.-W. than in the N.-S. beds. Choice of sowing method, yields being equal, turned on individual farming conditions and operations. Costs could be reduced by using the lowest of the 3 sowing rates.

Results obtained under irrigated conditions:

Number of plants m^{-2} and spikes m^{-2} were the highest in CP under irrigated conditions (Table 2). The highest the grain yield $spike^{-1}$ and TKW on the other hand were obtained in RBP and FP. However, no significant differences were obtained between all three planting methods under irrigated conditions.

Khan-MB, Gill-MA and Zia-MS (1987) investigated different planting methods and nitrogen applications and reported that yield in bed planting was much higher (5.3t ha-1) than in conventional planting (4 t ha-1) and that the yield increased as the amount of nitrogen applied increased. Mascagni et al. (1995) compared different raised bed planting methods with conventional planting system between 1986-1991. Wheat yield was highest in the center of the raised beds.

In a field trial at Hisar, Haryana, wheat was sown using a ridge and furrow system and the crops were irrigated 21 + 42 d after sowing using furrow or border strip irrigation methods, respectively. The 2 irrigation methods gave similar wheat yields (4.69 and 4.85 t/ha in furrow and border strip methods, respectively). Furrow irrigation resulted in a 25% saving in post-sowing irrigation water compared with border strip irrigation. The capillary contribution meeting the evapotranspiration requirement of the crop was estimated to be 43.65 and 34.25% under furrow and border strip irrigation, respectively (Singh and Singh. 1995).

Results of Different Planting Densities

As a general observation in all three methods the number of plants m^{-2} and number of spikes m^{-2} increased and grain weight $spike^{-1}$ and TKW, though latter mostly not statistically significant, decreased with increasing seeding rate (Table 3 and 4). This compensation of the yield components is responsible that seeding rate did not result in statistically significant differences for grain yield,

When yields were compared within each sowing method and water regime, no significant differences were found. But in all experiments, highest yields were obtained for seeding rates of 150 and 200 kg ha^{-1}. This trend was found independent of the water regime or the planting method.

Seed rate studies have clearly indicated that an extremely wide range of seed rates is compatible with planting wheat on beds. Carefully conducted experiments have shown that seed rates as low as 15-25 kg/ha to as high as 200 kg/ha can give similar yields. Extremely low seed rates are feasible when other production factors such as weed and pest control, stand establishment, and water are managed with precision. They also require more precise planters (K.D. Sayre, and O.H. Moreno Ramos. 1997).

Table 1: Yield and yield component obtained with three planting methods under rainfed conditions at Akcakale, Turkey.

Planting Methods	Plant m^{-2}	Spike m^{-2}	Grain weight $spike^{-1}$ (g)	TKW (g)	Yield (kg ha^{-1})
Conventional Planting (CP)	263 a	413 a	1,150 b	39,1 a	4530 a
Raised bed Planting (RBP)	199 b	310 b	1,342 a	39,6 a	4060 b
Furrowed Planting (FP)	195 b	322 b	1,281 ab	39,1 a	4060 b

Table 2: Table 1: Yield and yield component obtained with three planting methods under irrigated conditions at Akcakale, Turkey.

Planting Methods	Plant m^{-2}	Spike m^{-2}	Grain weight $spike^{-1}$ (g)	TKW (g)	Yield (kg ha^{-1})
Conventional Planting (CP)	406 a	478 a	1,224 b	41,0 a	5580 a
Raised bed Planting (RBP)	303 c	404 b	1,385 ab	42,4 a	5320 a
Furrowed Planting (FP)	350 b	363 b	1,560 a	41,7 a	5380 a

Although experiments have been carried out under conventional planting system, researchers in Turkey have reported a wide range of optimum seeding rate to maximize yield. The results reflect the growing and climatic conditions under which these experiments have been carried out. For example 300-350 grains m^{-2} gave the best result in Erzurum (Barutçu 1971), a very cold winter wheat growing area, whereas 150-300 grains m^{-2} was the best seeding rate in Cukurova, a high yielding coastal fall sown spring wheat area. Contrary, Tugay (1973) reports that the highest yield were obtained with a seeding rate of 300 grains m^{-2} in Menemen, with similar climate like Cukurova. Alpturk (1975) has reported that the best rate was 400grains m^{-2} in Konya, a winter wheat area. The crops grown before wheat also affect seeding rate. Keklikçi (1998) reported for Cukurova, that the following rates resulted in the highest wheat yields: 433 grains m^{-2}, after cotton, 389 grains m^{-2} after soybean, 380 plants grains m^{-2} after maize, and 398 plants m^{-2} after watermelon.

Sayre and Moreno Ramos report that this method was used in the Yaqui Valley in Northern Mexico for the first time in 1978. The rate of acceptance was 6% in 1981 but 90% in 1990. The main reason behind this high level of adoption was easier weed control and less amounts of seed used as well as decrease in the cost of soil bed preparation.

In a survey in 1994, 47 farmers in the Yaqui Valley in N-Mexico using bed planting got an average yield of 5615 ha^{-1} compared to 4923 kg ha^{-1} of 17 farmers using conventional planting systems. The income was 1216 Mex. Pesos ha^{-1} and 561 Mex. Pesos ha^{-1} respectively (Aquino, 1998).

Table 3: Yield and yield components obtained with three planting methods under rainfed conditions for four different seeding rates at Akcakale, Turkey.

PLANTING METHODS	SOWING DENSITY	Plant m^{-2}	Spike m^{-2}	Grain weight spike $^{-1}$ (g)	TKW (g)	Grain Yield (kg ha^{-1})
Conventional Planting (CP)	100 kg/ha	179 c	393	1,31 a	41,3	4530
	150 kg/ha	253 b	405	1,19 ab	39,4	4720
	200 kg/ha	284 ab	441	1,05 b	39,6	4620
	250 kg/ha	337 a	412	1,05 b	36,3	4260
Raised bed Planting (RBP)	100 kg/ha	135 d	274 b	1,51	40,7	4050
	150 kg/ha	187 c	323 a	1,30	39,2	4160
	200 kg/ha	220 b	331 a	1,25	39,4	4160
	250 kg/ha	255 a	312 ab	1,30	39,2	3870
Furrowed Planting (FP)	100 kg/ha	126 c	309	1,28	40,7 a	3940
	150 kg/ha	192 b	323	1,30	39,8 a	4130
	200 kg/ha	233 a	310	1,36	39,3 ab	4140
	250 kg/ha	231 a	345	1,18	36,8 b	4040

Table 4: Yield and yield components obtained with three planting methods under irrigated conditions for four different seeding rates at Akcakale, Turkey.

PLANTING METHODS	SOWING DENSITY	Plant m^{-2}	Spike m^{-2}	Grain weight spike $^{-1}$ (g)	TKW (g)	Grain Yield (kg ha^{-1})
Conventional Planting (CP)	100 kg/ha	275 c	378 b	1,49 a	45,3 a	5410
	150 kg/ha	402 b	412 b	1,36 a	40,9 b	5620
	200 kg/ha	411 b	554 a	1,09 b	40,7 b	5750
	250 kg/ha	534 a	568 a	0,95 b	37,2 b	5540
Raised bed Planting (RBP)	100 kg/ha	224 d	325 c	1,63 a	42,6	5100
	150 kg/ha	279 c	395 b	1,46 ab	42,7	5570
	200 kg/ha	324 b	439 ab	1,27 bc	42,4	5500
	250 kg/ha	387 a	458 a	1,18 c	41,8	5100
Furrowed Planting (FP)	100 kg/ha	249 d	327 b	1,68 a	43,5 a	5160
	150 kg/ha	305 c	334 b	1,63 ab	43,3 a	5410
	200 kg/ha	388 b	377 ab	1,54 ab	42,4 a	5400
	250 kg/ha	460 a	414 a	1,39 b	37,7 b	5560

The experiment has been conducted on an experimental station with good infrastructure. Flat bed Irrigation (CP) was performed much better than it is usually the case in farmers' fields. It is most probable that the grain yield is lower in farmers field using CP. Farmers using the bed system should have less problems to obtain yields comparable to that obtained on the experimental station. The beds will be much longer in farmers' fields and irrigation will be more uniform resulting in less amount of labor and water. Beds will also deliver the water more evenly to wheat plants than it is the case in CP. The grain yield obtained in both bed-planting systems was similar to that of CP. Therefore, farmers will have a higher income when they use the bed system. In our experiments we observed that the bed system does not need as careful soil leveling as is the case for good CP irrigation systems. It also needs to be mentioned that we used only one cultivar. Sayre (1997) has shown that some varieties are better adapted to CP than to RBP or FP. There is a need to identify the most suitable durum wheat varieties for the bed planting system under GAP conditions. Many farmers at present do not irrigate wheat in the GAP area. But in the near future, water will be available to irrigate 1.6 mlln ha of crops such as maize, cotton and wheat. I believe, that bed planting would bring an advantage for the farmers under irrigated conditions. In places whit high rainfall or a high water table, the bed planting system would help to drain the excess water and give the plants a better environment to grow. In summary, I believe that bed-planting system has a future and great potential for the GAP region of Turkey when all irrigation facilities are fully in use.

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