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Full Length Research Paper

Effect of seeding rate on yield and yield components of durum wheat cultivars in cotton-wheat cropping system

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This research was carried out in experimental field of Southeastern Anatolia Agricultural Research Institute in randomized split bloc design with three replications for three years (2004 - 2005, 2005 - 2006 and 2006 - 2007 growing seasons). The objective of this study was to determine the effects of seeding rates on grain yield and yield components of two durum wheat cultivars (Aydin-93 and Firat-93) under permanent bed planting in cotton–wheat cropping system. Six seeding rates (50, 150, 250, 350, 450 and 550 seed per m^{-2}) were tested. Seeding rate affected grain yield and yield components except for protein content, but its effects is being altered from year to year. The results revealed that 253 seed per m^{-2} (111 kg ha^{-1}) proved as predicted optimum seed rate; producing highest grain yield (5162 kg ha^{-1}) as regards averages of all years. Among varieties, significant differences were found for yield and yield parameters.

Key words: Chlorophyll content, durum wheat, grain yield, grain quality, seeding rate, permanent bed planting.

INTRODUCTION

Wheat is one of the important cereal crops in the world and it has the widest distribution among cereal crops. 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 grown account for about 15% all the wheat cultivated area in Turkey.

In South-Eastern Anatolian, wheat is planted through broadcasting on a large area after cotton is harvested. Broadcasting do not only requires higher seed rate but also results in untidy plant population. On the other hand, drill sowing method is recommended because of its uniform seed distribution and planting at desired depth, which usually results in higher germination and uniform stand. Seeding rate is one of the important production factors. Higher wheat grain yield with better quality requires appropriate seeding rate for different cultivars. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique et al., 2010). The optimum seed rates for wheat by altering with variety, location and method of planting. Larson and Watson (2010) reported that more and more producers are growing wheat and other small grains in no-tillage cropping systems because no-till systems produce major ecological and economic benefits. If growers can achieve adequate stands in no- till systems, grain yields usually are similar to conventional wheat systems. The optimum seed rates for wheat by altering with variety, location and method of planting. Carefully conducted experiments have shown that seed rates as low as 15 - 25 kg ha^{-1} to as high as 200 kg ha^{-1} can give similar yields on raised beds (Sayre and Moreno, 1997). The authors, however, further noted that seed rates have tendency to decline as bed planting increased and as better planters have become available, some farmers are using seed rates as low as 50 - 75 kg ha^{-1}. On the other hand, Kabakçi (1999) reported that a seeding rate of 100 kg ha^{-1} led to maximum grain yield under bed planting system.

Although effect of seeding rate on performance of genotypes has been studied widely on conventional planting method, but little work has been published on seeding rate effect under planting method of permanent beds. Due to its importance, present study was planned to evaluate the effect of different seed rates on growth

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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

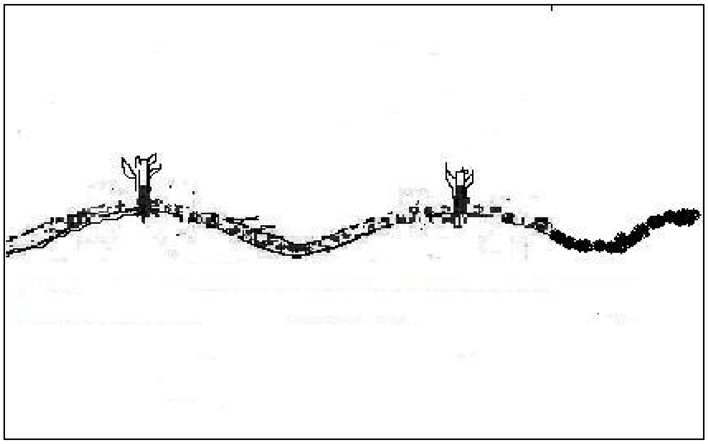

Figure 1. Stalks cut after harvest of cotton.

and yield of two durum wheat cultivars; 'Aydin-93 and Firat-93' on permanent beds under irrigation conditions of South-Eastern Anatolian, 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 Diyarbakir, 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 siltyl loam and slightly alkaline (7.83) in reaction, low in organic matter (1.45%), medium in available P (4.3 kg/da^{-1}) and high in 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 cultivars were randomized in the main plots and seed rate in the sub-plots. The net plot size was 2.8 × 10 m. The seeding rates were 50, 150, 250, 350, 450 and 550 seeds m^{-2} and the cultivars used were Aydin-93 and Firat-93, which are widely grown in South-Eastern Anatolian region

Wheat was grown in rotation following cotton. Cotton as a summer crop was planted in May and harvested in October. Wheat as a winter crop was planted in the optimum period of late November to early December and harvested in late June and early July. New raised beds were prepared for cotton and after harvesting of cotton, wheat was grown in winter season under zero tillage following a required repairing of the beds (Figures 1 and 2). Planting was carried out with a planter modified for planting two rows of seed on the top of permanent bed. The width of the ridge was 70 cm from furrow bottom to furrow bottom. The space between each row on ridge was 15 cm.

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. 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 analyses were performed using the SAS program (SAS Institute, 1999).

RESULTS AND DISCUSSION

Plant height

Table 2 indicated that plant height was significantly affected by different seeding densities and different cultivars in both 2004 - 2005 and 2006 - 2007. However, plant height was not significantly affected relating to both

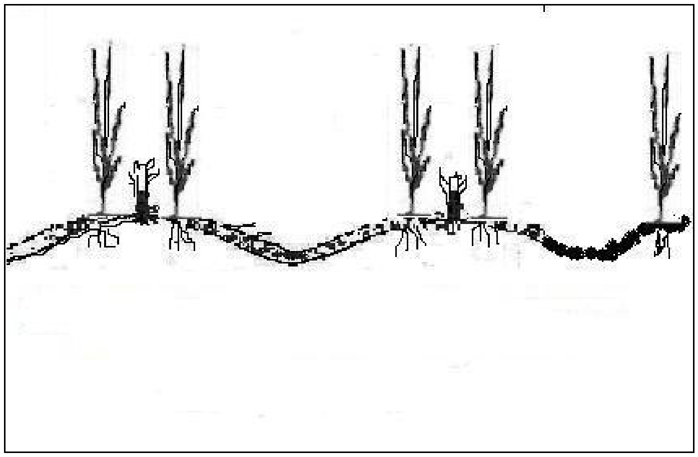

Figure 2. Wheat planted after cotton on permanent beds.

Table 2. Effect of different seeding rates on plant height, spikes per m^{-2} and chlorophyll contents of two durum wheat cultivars.

Treatment	Plant height (cm^{-1})			Spikes per m^{-2}			Chlorophyll content (SPAD)		
	2004 -05	2005-06	2006-07	2004-05	2005-06	2006-07	2004-05	2005-06	2006-07
Cultivars									
Aydin-93	109.1	107.6	106.4	393.9	445.2	339.1	46.1	48.1	48.7
Firat-93	91.5	92.7	89.8	379.9	456.3	425.0	48.3	45.3	44.5
LSD(0.05)	3.75	ns	3.11	ns	ns	ns	ns	0.93	2.66
Seed rate (seed m^{-2})									
50	97.8d	98.3	96.7 b	297.3c	340.0d	311.2c	48.8a	50.0a	46.0
150	99.3cd	101.4	100.0 a	337.6bc	406.9cd	365.2bc	47.9ab	47.8b	47.1
250	98.7cd	100.2	98.7 ab	407.1ab	431.0bc	372.9ab	47.9ab	46.9bc	46.4
350	100.3bc	101.1	98.5 ab	406.1ab	495.0ab	402.9ab	47.8ab	45.8cd	46.8
450	101.8ab	100.5	97.3 b	418.6ab	509.0ab	400.0ab	45.8bc	45.3cd	46.3
550	103.8a	99.4	97.3 b	454.6a	522.4a	440.2a	44.9c	44.4d	46.8
LSD (0.05)	3.75	ns	2.06	90.4	78.4	59.4	3.43	1.97	ns
Cultivar x seed rate	**	ns	*	ns	ns	*	ns	ns	ns

Means in a column with the same letter are not significantly different at the 5% level, NS = Non-significant. *: Significant at the 0.05 level of probability for the cultivar x seed rate interaction. **:Significant at the 0.01 level of probability for the cultivar x seed rate interaction.

treatments in 2005 - 2006. The interaction between the two factors was also non-significant in 2005 - 2006, while significantly affected in 2004 - 2005 and 2006 - 2007. Aydin-93 produced the tallest plants for all three years. The difference in plant height of the cultivars was attributed to difference in their genetic make up. These findings were in line with those of Khokhar et al. (1985), Khaliq et al. (1999) and Hussain et al. (2001). The greatest of plant height was observed with seed rate 550 seed m^{-2} (103.8 cm) in 2004 - 2005, while the shortest plant height (96.7 cm) was recorded with 50 seed m^{-2} seed rate in 2006 - 2007. Hussain et al. (2001) reported that seed rate did not have significant effect on plant height in bed planting method, while Soomro et al. (2009) showed that wheat sowing at higher seed rate, that is, 175 kg ha^{-1} produced greater plant height, that is, 101.25 cm. According to regression analyses, there was neither linear nor quadratic relationship between plant height and seed rate for all three years (Table 5).

Spikes (m^{-2})

Table 2 revealed that different seeding densities significantly affected the spikes per m^2, while cultivars did not significantly affect the spikes m^2 in both 2004 - 2005 and 2005 - 2006. Besides, the interaction between the two factors was non-significant except for the 2006 - 2007

Table 3. Effect of different seeding rates on the harvest index, number of grain spike and thousand grain weight of two durum wheat cultivars.

Treatment	Harvest index (%)			Number of grain per spike^{-1}			Thousand grain weight (g^{-1})		
	2004-05	2005-06	2006-07	2004-05	2005-06	2006-07	2004-05	2005-06	2006-07
Cultivars									
Aydin-93	40.6	34.1	42.7	46.2	48.6	55.6	39.4	44.2	39.6
Firat-93	45.8	43.5	43.9	44.0	41.3	47.0	50.8	51.6	45.3
LSD (0.05)	ns	2.54	ns	ns	0.63	4.94	1.99	1.81	2.52
Seed rate (seed m^{-2})									
50	44.6ab	40.8	45.1a	50.8a	50.5a	55.6	46.6a	48.4	44.1a
150	48.7a	40.9	43.9abc	46.9a	49.5ab	52.5	46.6a	48.8	43.9a
250	43.7bc	38.2	44.9ab	47.7a	44.1bc	50.5	44.7b	48.4	43.1ab
350	43.9bc	37.3	43.1bc	42.7b	43.0c	50.4	45.2ab	48.3	42.4b
450	39.9cd	38.7	42.2cd	42.8b	40.7c	49.8	44.1b	47.8	40.9c
550	38.7d	36.9	40.6d	39.5b	42.1c	49.1	43.5b	45.8	40.4c
LSD (0.05)	4.04	ns	1.82	3.91	5.62	ns	1.87	ns	1.44
Cultivar x seed rate	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means in a column with the same letter are not significantly different at the 5% level, NS = Non-significant. Cultivar x seed rate interaction among all parameters are non significant.

growing season. Althoug 550 seed m^{-2} produced the maximum number of spikes per unit area; it was statistically at par with that recorded with 450 and 350 seed m^{-2} seed rate for all three years. These results were in agreement with those of Khokhar et al. (1985), Nazir et al. (1987) and Hussain et al. (2001). The regression analysis revealed that the number of spikes per square meter increased linearly with seeding rates for all years (Table 5). The lower numbers of spikes per unit area compared with reports from north-central Europe and the USA are likely relevant to the production characteristic of Mediterranean wheat. Mediterranean types of wheat normally have a lower tiller in capacity and a shorter growing season (Slafer and Whitechurch, 2001; Lloveras et al., 2004). These varieties grown under relatively high temperatures have fast development rate and low tiller rates (Loss and Siddique, 1994; Satorre, 1999).

Leaf chlorophyll content

Statistical analysis of the data showed that different seeding densities as well as the varieties significantly affected the leaf chlorophyll content except for cultivars in 2004 - 2005 and for seed rate in 2006 - 2007. However, the interaction between the two factors was non-significant (Table 2). It was found that as density increased, this trait was decreased so that the most and the least one was observed in 50 and 550 seed m^{-2}, respectively for 2004 - 2005 and 2005 - 2006. As in lower populations, the fewer plants grow so well, inter plant spaces increased more and ability of plants to absorb the light and nutrient elements is improved and the chlorophyll content is increased (Jamaati et al., 2009). The regression analysis revealed that leaf chlorophyll content decreased linearly with seeding rates in 2004 - 2005 and 2005 - 2006, while regression equation was not significant in 2006 - 2007 (Table 5).

Harvest index

Seed rate had significant effect on harvest index of wheat in both 2004 - 2005 and 2006 - 2007, while there was no significant effect in 2005 - 2006 (Table 3). On the other hand, cultivars significantly affected the harvest index only in 2005 - 2006. Firat-93 produced significantly higher harvest index than Aydin-93. Seed rate 50 and 150 seed m^{-2} produced the maximum harvest index for all three years. The higher harvest index obtained in the lowest seed rate can be attributed to more light penetration through plant canopy and nutrient elements are improved. However, Mollah et al. (2009) reported that seed rate did not have significant effect on harvest index of wheat in bed planting condition. The interaction between the two factors was non-significant for all three years. The regression analysis revealed that harvest index decreased linearly with seed rates increasing in 2004 - 2005 and 2005 - 2006, while regression equation was not significant in 2006 - 2007 (Table 5).

Number of grain per spike

The results revealed that the differences among two varieties in both 2005 - 2006 and 2006 - 2007 and seeding rates in 2004 - 2005 and 2005 - 2006 significantly affected the number of grains spike (Table 3). The

Table 4. Effect of different seeding rates on the test weight, grain yield and protein content of two durum wheat cultivars

Treatment	Test weight (Kg hl^{-1})			Protein content (%)		Grain yield (kg ha^{-1})			
	2004-05	2005-06	2006-07	2004-05	2005-06	2004-05	2005-06	2006-07	Means
Cultivars									
Aydin-93	82.9	82.0	83.1	12.7	12.5	4786.8	5039.8	4681.5	4836.0
Firat-93	82.1	81.8	82.6	12.8	12.9	5169.4	5237.8	5140.1	5182.4
LSD(0.05)	ns	ns	0.31	ns	ns	ns	ns	ns	244.4
Seed rate (seed m^{-2})									
50	82.9a	81.7	82.6c	13.1	13.2	4861.7	4811.3c	4156.3b	4861.7 b
150	82.3b	81.8	83.1ab	13.0	13.2	5032.9	5343.3a	4963.2a	5032.9a
250	83.1a	82.0	83.5a	12.8	12.5	4997.3	5242.7ab	5030.2a	4997.3a
350	82.2b	81.8	83.1ab	12.9	12.7	5020.5	5274.0ab	5281.6a	5020.5a
450	82.2b	82.0	82.8bc	12.5	12.1	5022.2	5112.4abc	4976.7a	5022.2a
550	82.3b	82.0	82.3c	12.2	12.5	4933.9	5049.2bc	5056.6a	4933.9a
LSD (0.05)	0.62	ns	0.48	ns	ns	ns	307.8	485.1	192.3
Cultivar x seed rate	ns	ns	**	ns	ns	ns	ns	ns	192.3

Means in a column with the same letter are not significantly different at the 5% level, NS = Non-significant. **:Significant at the 0.01 level of probability for the cultivar x seed rate interaction.

interaction between the two factors was, however, non-significant. There was a consistent decrease in number of grains produced per spike with increasing seed rate. Seed rate 50 seed m^{-2} produced the highest number of grains per spike followed by 150 seed m-^{2} for all three years. The higher grain number obtained in the lowest seed rate can be attributed to more light penetration through plant canopy (Hussain et al., 2001). Aydin-93 produced significantly higher number of grains spike in 2005 - 2006 and 2006 - 2007. These results were in line with those of Kalita and Choudhury (1984) and Hussain et al. (2001). According to regression analysis, number of grain spike decreased linearly with seed rates increasing for all three years (Table 5).

Thousand grain weight

Table 3 showed that difference in thousand grain weight related to cultivar were significant for all three years, while interactions of cultivar and seed rate were non-significant. Firat-93 produced significantly higher thousand grain weight than Aydin-93. The difference in thousand grain weight among the wheat cultivars was attributed to their variable inherent potential. These results are in agreement with Khokhar et al. (1985) and Hussain et al. (2001). Seed rates had a significant impact on the thousand grain weight of wheat in both 2004 - 2005 and 2006 - 2007, while it had no significant impact on the TGW in 2005 - 2006. Among the seed rates, the maximum thousand grain weight was recorded with 50 seed m^{-2}, while the minimum thousand grain weight was recorded with 550 seed m^{-2} in both the years (Table 3). Higher seed rate produced significantly lower thousand grain weight for all three years. These results were in agreement with those of Hussain et al. (2001) and Soomro et al (2009). According to regression analysis, number of grain spike decreased linearly with seed rates increasing in 2006 - 2007, while regression equation was not significant in 2004 - 2005 and 2005 - 2006 (Table 5).

Test weight

Table 4 indicated that test weight was only significantly affected by the cultivars in 2006 - 2007. On the other hand, seed rate significantly affected the test weight in 2004 - 2005 and 2006 - 2007 growing seasons. Interactions of cultivar and seed rate were only significant in 2006 - 2007. Among the seed rates, the maximum test weight was recorded with 250 seed m^{-2}. On the contrary, Anonymous (2010) reported that there were no differences observed between seeding rates for test weight of wheat. The regression analysis revealed that test weight had quadratic relevance with seed rates in 2006 - 2007, while regression equation was not significant in both 2004 - 2005 and 2005 - 2006 (Table 5).

Protein content

Table 4 indicated that protein contents of grains were non-significantly affected both by the varieties as well as by the seeding densities. Similarly, the interaction between the two factors was also non-significant. These results were supported by the findings of Mazurek (1984),

Table 5. Best-fit regression equations for response of grain yield and yield components for each year.

Year	Plant height	R^2	Spikes per m^{-2}	R^2
2005	Regression equation was not found significant		Y=298.73907 + 0.293829x	0.34**
2006	Regression equation was not found significant		Y=49.702905 - 0.0097068 x	0.37**
2007	Regression equation was not found significant		Y=313.37042 + 0.2329579 x	0.22**
Year	**Chlorophyll content**	R^2	**Harvest index**	R^2
2005	y=49.442857 - 0.0074762 x	0.23**	Y=48.008095 - 0.0159714 x	0.25**
2006	y=49.702905 - 0.0097068 x	0.37**	Regression equation was not found significant	
2007	Regression equation was not found significant		Y=45.734619 - 0.0079491 x	0.31**
Year	**Grain per spike**	R^2	**Test weight**	R^2
2005	Y=51.405317 - 0.0211381 x	0.53**	Regression equation was not found significant	
2006	Y=50.731532 - 0.0187477 x	0.23**	Regression equation was not found significant	
2007	Y=55.006474 - 0.0128474 x	0.12*	$Y=83.281369 - 0.0000453 x - 0.0000122 (x-285.294)^2$	0.20*
Year	**TGW**	R^2	**Grain yield**	R^2
2005	Regression equation was not found significant		Regression equation was not found significant	
2006	Regression equation was not found significant		$Y=5305.8216 + 0.0046899 x - 0.0057224 (x-313.158)^2$	0.20*
2007	Y=44.755449 - 0.0075449 x	0.14*	$Y=4704.9237 + 1.5942764 x - 0.0094883 (x-285.294)^2$	0.39**
		Means	$Y = 5013.9039 + 0.5348558 x- 0.0056836 (x-300)^2$	0.16**
Year	**Protein content**	R^2		
2005	13.257827 - 0.0016326 x	0.11*		
2006	13.251366 - 0.0018595 x	0.14*		

*: Significant at the 0.05 level of probility for regression equation, **: Significant at the 0.01 level of probility for regression equation.

Khaliq et al. (1999) and Hussain et al. (2001). However, the regression analysis revealed that protein content decreased linearly with seed rates increasing in both years (Table 5).

Grain yield

Effect of seeding rate on grain yield was significant (Table 4) in both 2005 - 2006 and 2006 - 2007 but not in 2004 - 2005. On the other hand, no significant interaction for grain yield was detected between cultivars and seeding rates as well as cultivars for all three years. Data regarding wheat grain yield showed that in 2005 - 2006, maximum wheat grain yield (5343.2 kg ha^{-1}) was obtained from seed rate of 150 seed m^{-2} followed by 350 seed m^{-2} seeding rate (5274.0 kg/ha). During growth period of 2006 - 2007, higher grain yield (5281.6 kg ha^{-1}) was attained at seeding rate of 350 seed m^{-2} followed by 250 seed m^{-2} (5030.2 kg ha^{-1}). Higher grain yield at lower seed rate might be due to more thousand grain weights and number of grain spike in lower seed rate. The regression analysis revealed that grain yield had quadratic relevance with seed rates in both 2005 - 2006 and 2006 – 2007, while regression equation was not found to be significant in 2004 - 2005 (Table 5).

Average of all years depicted that seeding rate had significant effect on grain yield. Overall maximum grain yield (5022.2 kg ha^{-1}) was obtained at seeding rate of 150 seed per m^{-2}. Minimum grain yield (4861.7 kg ha^{-1}) was produced at 50 seed per m^{-2} rate. Using the regression equations of average of all years in Table 5 and Figure 3, the grain yield for the optimum seeding rate was estimated at 253 seed m^{-2} (approximately 111.4 kg h^{-1}) for the permanent bed planting method. Sayre and Moreno Ramos (1997) and Mollah et al. (2009) reported that seed rate did not have significant effect on grain yield of wheat in bed planting conditions. However, Sayre and Moreno Ramos (1997) reported that some farmers had been using seed rates as low as 50-75 kg ha^{-1}, while Kabakçi (1999) suggested that 100 kg ha^{-1} seeding rate was appropriate for wheat on bed planting system.

Conclusion

From the three years results, it may be concluded that the grain yield for the optimum seeding rate was estimated at 253 seed per m^{-2} (approximately 111.4 kg h^{-1}) for wheat grown successfully on permanent bed in cotton-wheat cropping system.

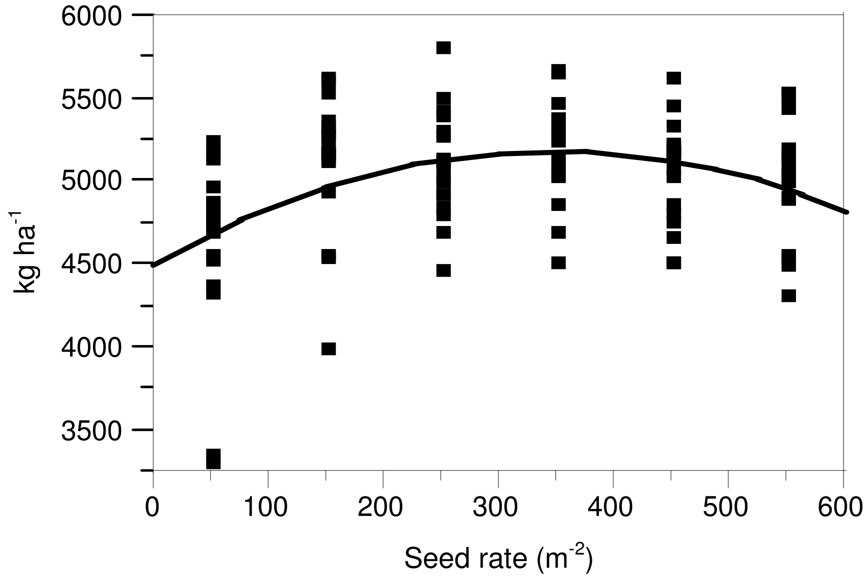

Figure 3. Relationship between seed rate and grain yield of average of all years.

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