Effects of sowing method and herbicide application on growth, yield and water productivity of two wheat cultivars

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ABSTRACT

Water management and weed control are crucial components in maximizing wheat yield and water productivity. Little research work has been done on the relationship between sowing methods, chemical weed control and wheat varieties. Field experiments were conducted during 2013/14-2014/15 seasons to evaluate the effect of four sowing methods and herbicide application on the performance of two wheat cultivars at the Gezira and New Halfa Research Stations. The experiment was arranged in a split-split plot design with four replicates, the main plots were assigned to herbicide application (sprayed and unsprayed), sub-plots were allocated to sowing methods (broadcasting + ridging, bed-planting, seed drill and wide level disc), and sub-sub-plots were assigned to wheat cultivars (Bohaine and Imam). Results showed that herbicides did not affect the yield and yield components of wheat for both seasons in the Gezira. Irrespective of herbicide application, seed drill resulted in the highest wheat yield for the two seasons. New Halfa results revealed that the crop growth and yield components were significantly affected. However, the two wheat cultivars resulted in higher yield with bed-planting method under sprayed condition. The interaction of herbicide application and bed-plating methods resulted in higher water productivity, which could be attributed to the lower amount of water applied compared to the other treatments. These results indicated that in the Gezira, unsprayed seed drill and wide level disc sowing methods can be used without yield reduction of wheat. Moreover, herbicides application with bed-planting sowing method in both sites can be used to improve water use efficiency.

INTRODUCTION

Wheat is traditionally grown as a winter crop in northern Sudan, but with the availability of adapted cultivars to heat stress, wheat production has been expanded into the central clay plain of the Sudan. The winter season in central Sudan is shorter and warmer compared to the traditional wheat producing areas in northern Sudan, thus water loss by evapotranspiration (ET) and competition by weeds are very high during the growing season. Different sowing methods are used by farmers in the Sudan to fulfill various objectives such as increasing grain yield, improving water use efficiency (WUE) and controlling weeds. In Pakistan, Hassan *et al*. (2005) reported an increase of 30% , 32% and 65% in maize grain yield , water saving and water productivity, respectively, under permanent raised beds compared to basin. Similarly, permanent raised beds demonstrated 13%, 36% and 50% higher grain yield, water saving and water productivity, respectively, for the wheat. Weed infestation was also 24% and 31% lower for maize and wheat crops, respectively, under permanent raised beds, which maintained lower soil bulk density and high infiltration rates.

In the Sudan, Dawelbeit and Babiker (1997) found that in the irrigated Vertisols of the Rahad Scheme, drilling in rows as well as ridging after broadcasting resulted in significantly greater yield than broadcasting alone. Elamin *et al*. (2011) concluded that Rahad Scheme had the highest water use efficiency compared to Gezira and New Halfa Schemes. Abdelhadi *et al*. (2006) concluded that wheat bed planting could be adopted in the irrigated Vertisols of the Sudan with reduced seed rate and more efficient irrigation water utilization. Additionally, they added that bed planting with a suitable machine and low seed rate (92 kg/ha) could improve water management, reduce time of seeding and reduce seed rate by 36% below the recommended 143kg/ ha. Many studies have examined the effects of different sowing methods on grain yield, however, only a few researchers have discussed the effect of each method on grain yield, WUE and weed infestation. Hence, the objective of this study was to investigate the effects of sowing methods and herbicide application on growth, yield and water use efficiency of two wheat cultivars.

MATERIALS AND METHODS

Site description

The study was performed in Gezira Research Station (GRS) and New Halfa Research Station (HRS) during 2013/14 and 2014/15 seasons. The climate is semi-arid with annual precipitation of about 280 mm (30-year average), most of it occurring between July and October. Temperatures are hot in summer, reaching an average of 41.5 $^{\circ}$C in May, while the minimum temperature is 14.1 $^{\circ}$C in January. The average relative humidity, sunshine duration and solar radiation are 41.5%, 9.3 hr and 22.1 MJ/m^2/d, respectively. The soil type is heavy clay Vertisols ($\geq$ 60%) with low organic matter (0.03$\approx$0.04%), available phosphorous is 3 ppm and nitrogen is around 350ppm for both sites.

Experimental design

The experiments were arranged in a split-split plot design. Herbicide application was assigned to the main plots. Four planting methods were tested (broadcasting + ridging (BR), bed-planting (BP), seed drill (SD) and the wide level disc (WLD)) and assigned to the sub-plots. In the sub-sub-

plot, two wheat cultivars were used which were Bohaine and Imam. Each main plot was 8 x 10 m in size and replicated four times. Wheat was sown at the rate of 143 kg/ha on the first week of December in both seasons. The seeds of both cultivars (Imam and Bohaine) were treated with Gaucho at the rate of 0.5 g/kg of seed before sowing against early season pests and diseases. At the time of sowing, 96kg/ha of triple superphosphate (P_2O_5) were added. Nitrogen fertilizer at the rate of 86 kg N/ha was added in split doses after second and fourth irrigation. Other cultural practices were applied as recommended by the Agricultural Research Corporation.

Herbicide application

Traxos@ herbicide was applied three weeks after sowing at the rate of 0.067 kg a.i./ha (1.48 l/ha) for grasses control, followed by 2,4-D a week later at 1.43 kg a.i./ha (1.98 l/ha) to control broad leaved weeds. Herbicides were applied by a Knapsack sprayer at a volume of 238 l/ha. Weed data were assessed by counting total and individual weed species in 5 fixed quadrates (25 x 40 cm) and percent ground covered by weeds was recorded.

Measurements

Growth and yield parameters

Ten plants were randomly selected per plot and tagged for the determination of plant height and weight of seeds per spike. Plant height was measured from the soil surface to the tip of the uppermost leaf using a meter ruler. The ten tagged plants were manually harvested, threshed and cleaned to remove trashes then weighed using electronic balance. Average seed weight of each spike per plot was recorded. From the threshed samples 1000 seeds per plot were randomly taken to obtain the 1000 seed weight. The above ground biomass and grain yield were recorded based on a net harvested area of 24 m^2 of each sub-sub plot.

Water use efficiency

Total applied water (m^3/ha) refers to the sum of the measured quantities of water applied during the entire season using a water flow-meter in m^3/ha. For computation of water productivity (water use efficiency), grain yields of wheat (kg/ha) in different treatments were divided by the respective total applied water (m^3/ha) and expressed as kg m^{-3} (Molden, 1997, Zhang *et al*., 2007 and Neal *et al*. 2011).

Data analysis

Data were analyzed using the standard analysis of variance procedure. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS

Growth and yield analysis

Tables 1 and 2 show the combined effect of herbicide application and sowing methods on two wheat cultivars during 2013/14 and 2014/15 growing seasons at GRS and HRS, respectively. Herbicide application did not affect crop growth and yield parameters at GRS. However, HRS results revealed that growth and yield components were significantly affected by herbicide application. However, the respective values of weight of seeds per spike, 1000 seed weight, dry biomass and grain yield were found to be 25%, 16%, 19% and 19% higher in sprayed plots compared to unsprayed ones. Moreover, plants treated by herbicides were found to be 8 cm taller at harvest than untreated (Table 2).

In GRS, biomass and the grain yield were significantly affected by wheat cultivars. Imam cultivar resulted in the highest values of the above mentioned attributes (7278 kg/ha and 2593 kg/ha, respectively). The same trends were observed in HRS. In GRS, the conventional sowing methods (SD and WLD) were found to result in higher grain yield (2979 and 2450 kg/ha, respectively) followed by bed-planting method (2289 kg/ha), while BR resulted in the lowest yield (2178 kg/ha). However, these trends were not observed in HRS. Bed-planting resulted in significantly higher yield (3702 kg/ha), while WLD and SD were found to result in 2450 and 2119 kg/ha, respectively (Table 2). Results also showed that, higher value of 1000 seed weight was achieved by BR followed by BP, SD and WLD. Furthermore, average weed count after spraying in HRS showed that the lowest number of weeds (50 weeds/m^2) was obtained with WLD followed by BR, BP and SD, with respective values of 57, 61 and 71 weeds/m^2. In GRS, sowing methods recorded similar number of weeds/m^2 three to six weeks after spraying.

Based on the results of both seasons, at HRS, BP was resulted in the most appropriate sowing pattern; however, though the results were not consistent SD appeared to perform better under well-leveled land.

Table 1. Combined effect of herbicide application and sowing methods on growth and yield parameters of wheat at GRS.

Treatments	Plant height (cm)	Wt of seeds/ spike (g)	1000 seed wt (g)	Biomass (kg/ha)	Yield (kg/ha)
Herbicide application					
Sprayed	68.1	1.42	37.7	6705	2512
unsprayedde	69.2	1.23	36.6	7187	2436
SE ±	0.98	0.05	0.503	56.5	46.3
Sig. level	NS	NS	NS	*	NS
Wheat cultivars					
Imam	74.0	1.26	33.3	7278	2593
Bohaine	63.3	1.39	40.9	6614	2355
Sig. level	***	NS	***	*	***
SE ±	1.01	0.05	0.805	208.0	30.3
Sowing methods					
SD	70.6	1.21	35.9	7927	2979
WLD	68.1	1.32	35.8	7351	2450
BP	68.0	1.25	36.6	6081	2289
BR	67.7	1.50	40.2	6425	2178
Sig. level	NS	**	*	***	***
SE±	1.36	0.04	1.01	201.9	107.2
CV%	10.2	28.4	15.0	20.8	8.5

*,**, *** Significant at p= 0.05, 0.01 and 0.001 levels, respectively.

Table 3 shows significant interaction effects of herbicide application, sowing methods and wheat cultivars on yield for the two seasons (2013/14 and 2014/15) at HRS.

Grain yields were maximum when Imam and Bohaine cultivars were sown under bed-planting and sprayed with herbicides. Results also showed that under unsprayed condition, the two wheat cultivars gave higher yield with bed-planting method in both seasons. The lowest interaction values were obtained by Imam with SD (1231 kg/ha) and BR (1276 kg/ha) during the two growing seasons. All sowing methods and cultivars recorded higher values of yield under sprayed plots compared with unsprayed ones.

Table 2. Combined effect of herbicide application and sowing methods on growth and yield parameters of wheat at HRS.

	Plant height (cm)	Wt of seeds/ spike (g)	1000 seed wt (g)	Biomass (kg/ha)	Yield (kg/ha)
Herbicide application					
Sprayed	70.6	1.6	58	5050	2802
unsprayed	62.7	1.2	49	4102	2281
Sig. level	**	**	**	**	**
SE ±	0.3	0.018	0.37	98.6	52.6
Wheat cultivars					
Imam	67.5	1.4	53	4802	2593
Bohaine	65.8	1.4	54	4350	2533
Sig. level	NS	NS	NS	*	*
SE ±	0.82	0.017	0.232	90.9	54.8
Sowing methods					
SD	66.7	1.4	53	4479	2119
WLD	67.9	1.3	52	4398	2450
BP	65.6	1.7	54	4910	3702
BR	67.0	1.3	56	4524	1895
Sig. level	NS	**	**	NS	**
SE±	1.29	0.025	0.388	194.5	84.8
CV%	3.3	3.0	1.3	7.4	5.8

*, ** Significant at p=0.05 and 0.01 levels, respectively.

Table 3. Interaction effects of herbicide application (H), sowing method (M) and wheat cultivar (V) on yield (kg/ha) at HRS.

Sowing method	Sprayed		Unsprayed		Mean
	Imam	Bohaine	Imam	Bohaine	
SD	2141	3161	1231	2648	2295
WLD	1551	3245	1400	3150	2337
BP	2553	4277	2601	3713	3286
BR	1460	3223	1276	2440	2085
Mean of herbicide	2702		2307		
Mean of cultivars	1777		3232		
Factors	H	M	V	H*M*V	
SE±	57.3	85.2	161.8	269.7	
CV%	15.9				

Table 4 revealed that the number of weeds (broad leaves and grasses) was significantly affected by herbicide application in both sites. Sprayed treatment at GRS and HRS gave less number of weeds (16 and 27 weeds/m^2, respectively) compared to untreated plots (45 and 93 weeds/m^2, respectively). In both sites, sowing methods and wheat cultivars did not differ significantly with respect to number of weeds after spraying.

Table 4. Effect of herbicide application, wheat cultivars and sowing methods on number of weeds.

Treatments	GRS	HRS	GRS	HRS
Herbicide application				
Sprayed	44.5	99.0	15.5	26.6
Unsprayed	60.1	85.5	45.4	92.8
Sig. level	**	***	**	***
SE +	5.31	1.68	4.63	2.7
Wheat cultivars				
Imam	48.6	91.7	28.9	60.2
Bohaine	56.0	92.8	32.0	59.2
Sig. level	NS	NS	NS	NS
SE ±	3.23	1.68	2.02	4.68
Sowing methods				
SD	51.3	99.7	30.3	71.1
WLD	54.8	82.9	34.2	50.2
BP	51.6	94.7	27.1	60.7
BR	51.4	91.7	30.1	57.0
Sig. level	NS	***	NS	NS
SE±	5.63	2.38	3.14	6.73
CV%	30.2	8.9	32.5	19.5

L.S. = level of significance **, *** Significant at p=0.01 and 0.001 levels, respectively.

Irrigation water applied

Figure 1 shows the effects of herbicide application and sowing methods on applied irrigation water at GRS. Total water supplied is the summation of all irrigation cycles except the first one which is difficult to be measured due to the cracking nature of the heavy clay soils. Total water supplied varied from 5232 m^3/ha with bed planting (BP) to 8378 m^3/ha with wide level disc (WLD). However, BP and BR sowing methods resulted in lower amount of water compared to SD and WLD. Moreover, herbicide application had no significant effects on amount of water for the same sowing method.

Figure 2 shows water productivity (WP), which refers to the ratio of grain yield to total irrigation water supplied, which varied from 0.29 to 0.45 kg/m^3. With increased amount of water supply, the water productivity decreased. The result indicated that although BP and BR resulted in lower yield compared to SD and WLD, the former treatments resulted in higher WP compared to the latter. On the other hand, irrigation water supplied and WP were neither affected by sowing methods nor herbicide application.

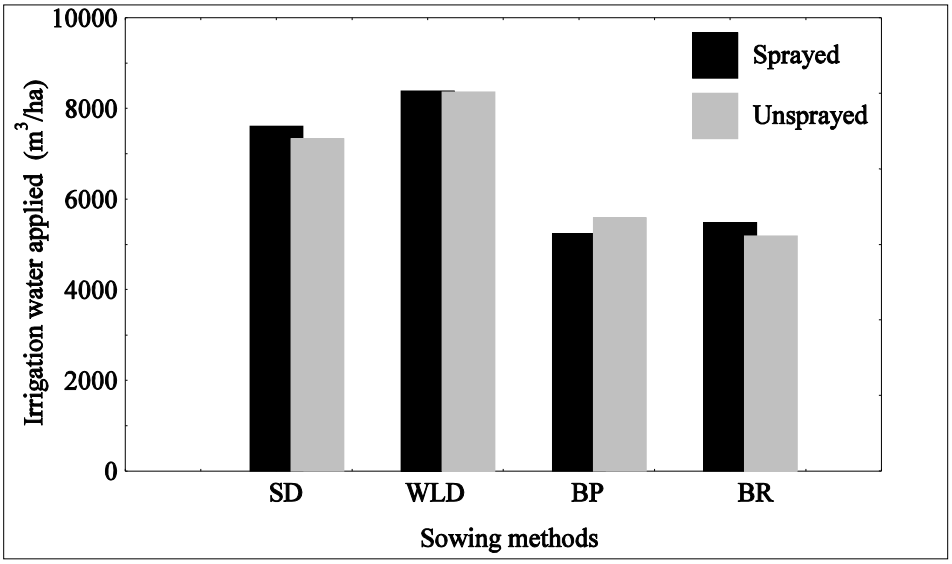

Figure 1. Effect of herbicide application and sowing methods on irrigation water applied at GRS.

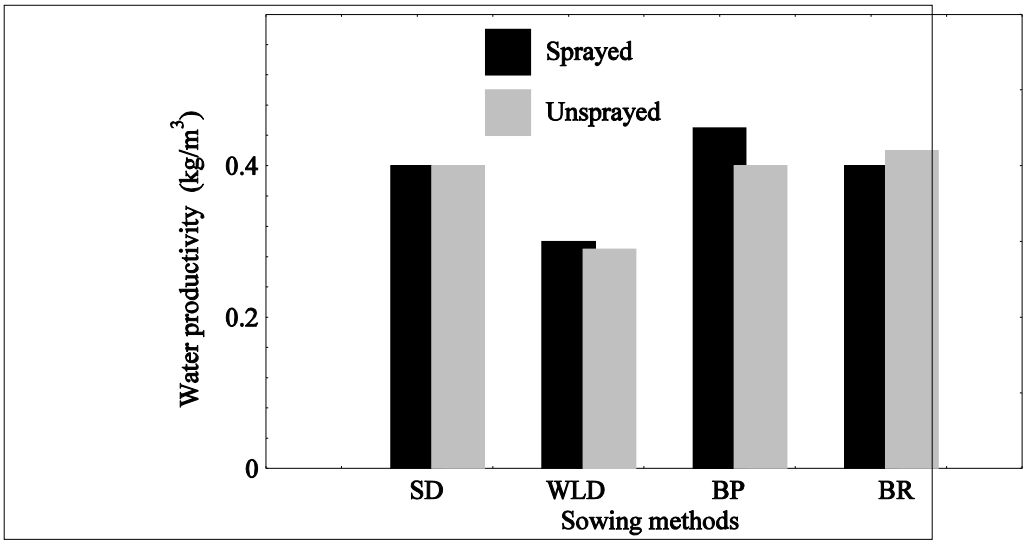

Figure 2. Effect of herbicide application and sowing methods on irrigation water productivity at GRS.

DISCUSSION

In GRS, similar results of grain yield and other traits were obtained under sprayed and unsprayed treatments, however, the results of HRS site did not follow the same trend. These results could be attributed to high infestation of weeds in HRS in comparison with less number of weeds in GRS. However, the number of weeds after spraying in HRS was observed to be 50% higher than GRS (Table 4). Moreover, the distribution of weeds on the soil surface resulted in competition with the crop for water and light. The lowest population density of weeds in GRS farm (Table 4) did not necessitate herbicides application; in such circumstances sowing methods could play a great role in

weed control, which encouraged research on alternative measures of integrated crop management (ICM) for controlling weeds in order to increase crop productivity and farmer's return.

In GRS, irrespective of herbicide application used, conventionally sowing method (SD) gave significantly higher yield compared to other sowing methods. The results could be attributed to the less weeds density and high competition of wheat crop. In HRS, though all sowing methods performed better under sprayed compared to unsprayed treatments (Table 3), BP resulted in significantly higher grain yield compared to other treatments.

If water productivity is given priority, the grain yield per unit of water was more with BP, it gave considerably higher output from irrigation water consumed, and with 36% higher than WLD. These results could be attributed to the less water applied, which agreed with the results obtained by Abdelhadi *et al*. (2006). On the other hand, water productivity obtained by BP under herbicides application was 10% higher than untreated plots. This indicated that the competition of weeds with wheat crop resulted in poor growth and high yield reduction. Yield reduction from weed competition depends on weed species, time of infestation, weed density and climatic conditions.

CONCLUSION

The similarities between sprayed and unsprayed treatments in GRS indicated that unsprayed seed drill and wide level disc sowing methods for wheat production could be used without yield reduction. However, bed-planting method with herbicides improved water use efficiency and might also increase grain yield. In HRS, grain yields were maximum when wheat was sown under bed-planting and sprayed with herbicides; this will not only enhance food security but save water as well.

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REFERENCES

Abdelhadi, A.W., S.E. A. Elawad, M.A. Bashir, and H. Takeshi. 2006. Evaluation of wheat bed planting system in irrigated Vertisols of the Sudan. Agricultural Mechanization in Asia, Africa and Latin America 37(3): 62-67.

Dawelbeit, M.I. and E.A. Babiker. 1997. Effect of tillage and method of sowing on wheat yield in irrigated Vertisols of Rahad, Sudan. Soil and Tillage Research 42 (1-2):127-132.

Elamin, A.W.M., A.B. Saeed and A. Boush. 2011. Water use efficiencies of Gezira, Rahad and New Halfa irrigated schemes under Sudan dryland condition. Sudan Journal of Desert Research 3(1): 62-72.

Hassan, I., Z. Hussain and G. Akbar. 2005. Effect of permanent raised bed on water productivity for maize - wheat cropping system. Evaluation and performance of permanent raised bed cropping system in Asia, Australia and Mexico. In: Proceedings of a workshop held in Griffith, NSW, Australia, 1-3 March 2005.

Molden, D. 1997. Accounting for water use and productivity. SWIM Paper 1. Colombo, Sri Lanka, International Water Management Institute (IWMI)).

Neal, J.S., W.J. Fulkerson and B.G. Sutton. 2011. Differences in water-use efficiency among perennial forages used by the dairy industry under optimum and deficit irrigation. Irrigation Science 29: 213-232.

Zhang, J, J. Sun, A. Duan, J. Wang, X. Shen and X. Liu. 2007. Effects of different planting patterns on water use and yield performance of winter wheat in the Huang-Huai-Hai Plain of China. Agricultural Water Management 92: 41-47.

تأثير طرق الزراعة ومبيد الحشائش علي نمو و انتاجية وكفاءة مياه الري لصنفين من القمح

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الخلاصة

إدارة مياه الري ومكافحة الحشائش هي أحدى العوامل الأساسية لتعظيم انتاجية القمح وزيادة كفاءة مياه الري. أجريت تجارب حقلية خلال موسمي 14/2013 و 15/2014 لتقييم أثر أربعة طرق للزراعة ومبيد الحشائش على انتاجية صنفين من القمح بمحطتي بحوث الجزيرة وحلفا الجديدة. تم استخدام تصميم القطع المنشقة مرتين بأربع مكررات. وضعت معاملات مبيد الحشائش في الأحواض الرئيسية ووضعت طرق الزراعة في الأحواض الفرعية بينما وضعت الأصناف في الأحواض الفرعية . أوضحت النتائج أن مبيد الحشائش لم يؤثر على الإنتاجية ومكوناتها خلال الموسمين بمحطة بحوث الجزيرة. بغض النظر عن مبيد الحشائش، الزراعة في سطور أعطت أعلى انتاجية خلال الموسمين. كذلك أوضحت النتائج بمحطة بحوث حلفا الجديدة أن النمو ومكونات الانتاجية تأثرتا بصورة معنوية، حيث وجد أن صنفي القمح سجلتا أعلى انتاجية باستخدام الزراعة في مساطب والمكافحة الكيميائية للحشائش. إن أثر تفاعل الزراعة في مساطب والمكافحة الكيميائية للحشائش انتجت أعلى كفاءة مياه ري وذلك يمكن مرده لقلة كمية مياه الري المضافة مقارنةً بالمعاملات الأخرى. النتائج أعلاه تشير إلى أن الزراعة في سطور والزراعة باستخدام الدسك العريض يمكن استخدامهما بالجزيرة لإنتاج القمح دون نقص يذكر في الإنتاجية. اضافةً الي ذلك، فان اضافة مبيد الحشائش لطريقة الزراعة في مساطب يمكن أن تحسن من كفاءة استخدام مياه الري في كلا الموقعين.