Effect of Sarwala operation on the performance and yield of some sorghum cultivars in rainfed areas

Lotfie A. Yousif

Agricultural Research Corporation, Agricultural Engineering Program, Gedarif Research Station, Gedarif, Sudan.

ABSTRACT

Field experiments were conducted in the mechanized rainfed areas of Gedarif State during two consecutive seasons, 2001 and 2002, in one site in the first season and two sites in the second season. The objective was to study the effect of Sarwala operation on the performance of some sorghum cultivars, namely, Gadambalia Bloom, Um Baneen, Arfa Gadamak, Tabut and Wad Ahmed. Seeds were sown at the rate of 7.5 kg/fed in both seasons. However, in the second season, additional sowing was done at the rate of 3.2 kg/fed for hand weeding. A randomized complete block design with four replicates was used. Sowing was carried out during the third and the fourth week of July for the first and the second seasons, respectively. Sarwala operation was done after 25-30 days from crop emergence. Crop plants were counted immediately before Sarwala, two weeks later and at harvest. Percent reductions in plants as well as the number of heads and grain yield were determined. Results showed that plant population before Sarwala depended on seed size. Sarwala significantly reduced sorghum stand. Irrespective to sorghum cultivars, Sarwala significantly increased grain yield compared to hand weeding; however, Tabut cultivar resulted in the lowest yield. Moreover, the results showed that Sarwala increased rain efficiency. The overall average rain efficiency for Sarwala was 2.54 kg/fed/mm while it was 1.63 kg/fed/mm for the hand weeding. The productivity of sorghum cultivars Gadambalia Bloom, Um Baneen, Arfa Gadamak and Wad Ahmed increased significantly with Sarwala compared to hand weeding in the mechanized rainfed areas of eastern Sudan.

INTRODUCTION

Sarwala is a mechanical operation to control striga and other weeds on rainfed sorghum. This operation comprises two steps. The first step is to sow (by broadcasting) sorghum at a high seed rate with the use of the wide level disk implement (WLD). The second step is to introduce the WLD after crop emergence but this time at different disk angle. This second operation thins sorghum plants, striga as well as other weeds and cultivates the soil in one operation.

Farmers can obtain satisfactory sorghum yield by practicing Sarwala operation. This operation was first invented by farmers in the rainfed areas of eastern Sudan; and it has been tested and recommended by Yousif (2004) and approved by the National Crop Husbandry Committee. Detailed description and specifications for optimum Sarwala performance were mentioned by Yousif (2004). The advantages and disadvantages of Sarwala operation were identified and reported by Yousif *et al.* (2006). Also, the effect of Sarwala operation on soil physical properties was reported by Yousif and Dawelbeit (2003). Moreover, Yousif *et al.* (2008) studied the effect and the time of adding urea on the grain yield of rainfed sorghum when planning to practice Sarwala operation. Taha and Babiker (1995) reported that Sarwala practice significantly reduced striga population and increased sorghum grain yield in rainfed areas.

Different sorghum cultivars, e.g. local and improved cultivars, are usually grown by farmers in rainfed areas of the Sudan. These cultivars differ in the period to maturity, annual water requirements, resistance to striga, grain yield and other characteristics. In the mechanized rainfed areas of eastern Sudan, sorghum constitutes a large portion (85%) of the total cultivated area (3.4 million hectares); which indicates that mono-cropping of sorghum is a common practice. The consequences of the repeated sorghum cultivation are depletion of soil fertility, striga infestation and low yield. Hamdoun and EL Tigani (1977) reported that striga can cause total crop loss in heavily infested fields and it is difficult and expensive to control (Babiker and Hamdoun, 1983). There are many methods to control striga, including hand pulling, chemical control, resistant varieties and Sarwala operation. The relative advantages of Sarwala operation convinced most of the farmers in the area to adopt it. However, the effects of Sarwala on the performance of different sorghum cultivars need to be investigated.

The objective of this research was to assess the performance of different sorghum cultivars with the use of Sarwala operation under rainfed cultivation.

MATERIALS AND METHODS

Description of the study area

The area of mechanized rainfed agriculture in Gedarif State lies in the eastern part of the central clay plain of the Sudan. It is the biggest producer of sorghum in the country. It is divided into farms of 420 to 630 hectares each, which are cultivated and managed by private farmers. The soil is heavy cracking clay characterized by shrinking when dry and swelling when moistened. Rainfall is in summer (June to October), its distribution is erratic within the rainy season and from year to year. According to the annual rainfall totals, the area could be divided into three zones, northern, central and southern areas, with annual rainfall varying from < 500 mm, 500 to 600 mm and > 600 mm for the three areas, respectively. The land is continuously cultivated using the wide level disk (WLD) which is the most popular machine used for seedbed preparation, sowing and Sarwala operations. This machine tills the soil at shallow depths of 5 cm to 8 cm and broadcasts crop seeds at variable seeding depths.

Experiments and collected data

Experiments were conducted during two consecutive rainy seasons (2001 and 2002) at one site (Alazaza) in the first season, and two sites (Alazaza and Towawa) in the second season. Alazaza and Towawa are located in the central and northern parts of the mechanized rainfed areas of Gedarif State, respectively. In the first season, the sorghum cultivars Gadambalia Bloom (G.B), Tabut (T), Arfa Gadamak (A.G) and Wad Ahmed (W.A) were tested. In the second season, the cultivars Gadambalia Bloom (G.B), Um Baneen (U.B) and Arfa Gadamak (A.G) were tested at Towawa site, and Wad Ahmed (W.A), Tabut (T) and Arfa Gadamak (A.G) at Alazaza site. Cultivars were sown at the rate of 7.5 kg/fed in both seasons. However, in the second season, additional sowing was done at the rate of 3.2 kg/fed for hand weeding.

In both seasons, the treatments were arranged in a randomized complete block design with four replicates. Plot size was 4 m x 30 m. Sowing was carried out during the third and fourth weeks of July in the first and second seasons, respectively. Plants were counted immediately before Sarwala application, two weeks later and at harvest. Then reduction percent, due to Sarwala operation, in plant population was calculated according to the methods described by Yousif *et al.* (2006). Yield and yield components were determined at crop maturity by taking three random samples of 1m x 1m from the middle 20 meters of the plot. Data were subjected to analysis of variance using Mstat-C software program. Duncan's Multiple Range Test (DMRT) was used for means separation.

Execution of the Sarwala operation and implement adjustments

Sarwala was done after 25-30 days from crop emergence. The WLD of Massey Ferguson type which was used to execute the Sarwala operation, has 24 disk blades arranged in four gangs. Each disk was 40 cm in diameter. Spacing between disks was 18 cm. Total implement width was 407cm. Sarwala was executed at a disk angle of 10º and 8 cm depth of cut. The disk angle is the angle of the disk gangs made from a line perpendicular to the direction of motion, counter clockwise. It is a function of width of cut; as the width of cut increases the angle of cut decreases. The adjustment of the disk angle is based on the width of cut. The depth of cut was measured by a ruler at the furrow wall taking the untilled side as a reference. To adjust the depth of cut, the ratchet jack of the implement, which raises and lowers the disks, was used. Shortening the ratchet jack increases the depth of cut and *vice versa*. The leveling front crank was adjusted to give an even depth of cut throughout the width of the implement.

The amounts of rain during both seasons were recorded from rain gauges located at the experimental sites (Table 1). The concept of rain productivity (kilograms of grain per unit area per mm of effective annual rainfall) was used for the evaluation of Sarwala operation on the tested sorghum cultivars. It was calculated as follows:

Rain productivity (R.P.) = Yield (kg/fed) / effective total rainfall (mm)

The effective total rainfall was calculated according to the method described by Adam (2008) as fallows:

Effective total rainfall (mm) = 125 + 0.1 total rainfall (mm)

Table 1. Monthly, total and effective rainfall (mm) at the experimental sites for both seasons.

Sites and seasons	June	Jul	Aug	Sep	Oct	Total rainfall	Effective rainfall
Alazaza, 2001	56	199	239.2	131.0	56.7	681.9	193.2
Alazaza,2002	42	84	250.0	40.0	Nil	416.0	166.6
Towawa,2002	63.5	160	157.6	66.3	43.7	491.1	174.1

RESULTS AND DISCUSSION

Results of the measured parameters in the first season (2001) are shown in Table 2. Highly significant differences (P > 0.01) in plant population before Sarwala operation were detected. Wad Ahmed cultivar obtained the highest plant population, while Gadambalia Bloom and Arfa Gadamk obtained the lowest plant population. This could be due to the differences in seed size of the cultivars; Wad Ahmed had a smaller seed size compared to the other cultivars, hence higher plant density. There were also highly significant differences (P > 0.01) in plant population after Sarwala operation. Wad Ahmed cultivar resulted in a higher plant population. Tabut cultivar resulted in a higher reduction in plant population (44%) due to Sarwala operation followed by Arfa Gadamk (38.5%), Wad Ahmed (35.3%) and Gadambalia Bloom (33.5%). However, another study showed that reduction in sorghum plant population due to Sarwala operation was 59.5% (Yousif, 2001).

No significant differences were observed in plant population at harvest between the cultivars; however, Wad Ahmed cultivar resulted in a higher plant population compared to the other cultivars. Plant population at harvest was lower than that after Sarwala operation. Similar results were found by Yousif (2001). This could be due to the natural competition between plants or due to injuries caused by Sarwala operation on plants or due to both reasons. The differences in crop stand after Sarwala operation and at harvest were 15.8%, 39.1%, 21.1% and 35.5% for Gadambalia Bloom, Tabut, Arfa Gadamk and Wad Ahmed cultivars, respectively.

Table 2. Effect of Sarwala operation on crop stand, yield and rain productivity of some sorghum cultivars at Alazaza site (season 2001).

Measured parameters	Cultivars				S.E.(±)	C.V. (%)
	G. B.	Tabut	A.G.	W.A.		
Plant pop./m^2before Sarwala	30.0b	42.0ab	31.0 b	48.0a	3.0 **	15.9
Plant pop. /m^2after Sarwala	19.0b	23.0ab	19.0 b	31.0a	2.4 **	20.8
Reduction in pla population (%)	33.5	44.0	38.5	35.3	6.8	35.9
Plant population/m^2at harvest	16.0	14.0	15.0	20.0	1.4	17.6
Number of heads/m^2	12.0	9.0	12.0	14.0	1.4	23.2
1000 seeds weight (g)	32.5a	26.4bc	31.6 b	21.0c	1.3 **	9.3
Grain yield (kg/fed)	638.4	430.8	495.2	596.0	115.5	42.8
Rain productivity (kg/fed/mm)	3.3	2.2	2.6	3.1	-	-

G.B. = Gadambalia Bloom, A.G. = Arfa Gadamk and W.A. = Wad Ahmed.

Means in the same rows followed by the same letter are not significantly different according to DMRT.
** Significant at P = 0.01.

Wad Ahmed cultivar resulted in a higher number of heads/m^2 while Tabut resulted in the lowest. It was observed that the number of heads was lower than the number of plants at harvest. The reductions in number of heads compared to crop stand at harvest were 25%, 35%, 20% and 30% for Gadambalia Bloom, Tabut, Arfa Gadamk and Wad Ahmed cultivars, respectively. There were significant differences between the cultivars in seed weight. Gadambalia Bloom and Arfa Gadamk cultivars had the highest seed weight, whereas Wad Ahmed cultivar had the lowest. These results confirmed the results of plant population before the Sarwala operation. However, Elasha *et al*. (2005) found that Wad Ahmed resulted in significantly lower 100 seeds weight compared to Tabut cultivar. No significant differences were observed between the cultivars in sorghum grain yield (Table 2). The highest yield was obtained by Gadambalia Bloom (638.4 kg/fed), and the lowest yield was obtained by Tabut (430.8 kg/fed).

Table 3 shows the measured parameters in season 2002 for Alazaza site.

There was a significant difference in plant population before and after Sarwala operation. Arfa Gadamak and Tabut resulted in the lowest plant population before and after Sarwala operation. No significant differences between the tested cultivars in plant population at harvest were found. Irrespective of cultivar, there was a reduction in plant population after Sarwala and at harvest for both Sarwala and hand weeding plots. This reduction might be due to the injury caused by Sarwala operation, natural competition and unintentional hand weeding. Moreover, the number of heads for Sarwala and hand weeding plots was lower than the plant population at harvest. This means that not all plants formed heads. Sarwala operation significantly increased sorghum grain yield compared to hand weeding. Wad Ahmed cultivar resulted in significantly higher grain yield compared to Tabut. However, Hassan (2005) reported that Wad Ahmed gave higher yield than Tabut, but the difference was not significant.

The results of the measured parameters at Towawa site, season 2002, are shown in Table 4. There were no significant differences between the tested sorghum cultivars in all measured parameters. This means that Sarwala operation affected all sorghum cultivars similarly and none of the tested cultivars was superior over the others. There were significant differences between Sarwala and hand weeding plots in all measured parameters, except in the number of heads at harvest. Sarwala operation significantly reduced plant population initially and at harvest compared to hand weeding. Plant population at harvest was lower than that after Sarwala operation for both Sarwala and hand weeding treatments.This reduction was 25% for Sarwala and 15% for hand weeding. Also, Sarwala operation resulted in significantly higher crop yield compared to hand weeding. The average increase in sorghum grain yield due to Sarwala operation was 66% over hand weeding. Taha and Babiker (1995) reported that Sarwala operation increased sorghum grain yield by 6 to 7 folds over control plots.

Rain productivity in the first season varied with sorghum cultivar (Table 2). Gadambalia Bloom resulted in the highest value (3.3), meaning that each one mm of the effective rainfall produced 3.3 kg/ fed. The cultivar Arfa Gadamak with Sarwala operation resulted in a consistent rain productivity of 2.5 kg/ fed /mm in both seasons; while Tabut resulted in the lowest value in both seasons (2.0 kg/fed/mm).

Table 3. Effect of Sarwala operation on crop stand, yield and rain productivity of some sorghum cultivars at Alazaza site season (2002).

	Wad Ahmed	Tabut	Arfa Gadamk	Mean
Plant population /m^2 before Sarwala (C.V. % = 18.7) (S.E. ±1.1)				(S.E.±0.63)
Sarwala	17.0	17.0	13.0	15.7
Hand weeding	8.5	8.3	6.3	7.7
Plant population /m^2 after Sarwala (C.V. % =27.2) (S.E.± 0.9)				(S.E.± 0.5)
Sarwala	8.3 a	5.5 b	7.0 ab	6.9
Hand weeding	5.0 b	7.3 ab	5.3 b	5.8
Plant population /m^2 at harvest (C.V.%=21.7) (S.E.± 0.6)				(S.E.± 0.4)
Sarwala	5.3 b	4.8 b	5.8 ab	2.5
Hand weeding	5.0 b	7.3 a	5.3 b	5.8
Number of heads /m^2 (C.V.%=19.0) (S.E. ± 0.5)				(S.E.± 0.3)
Sarwala	4.5	3.8	5.8	4.6
Hand weeding	4.3	5.0	5.8	5.0
Grain yield (kg/fed) (C.V.%=26.4) (S.E.± 42.0)				(S.E.±26.0)
Sarwala	455.4	306.0	408.2	389.8 a
Hand weeding	337.6	226.8	309.5	291.3 b
Rain productivity (kg/fed/mm)				
Sarwala	2.7	1.8	2.5	2.3
Hand weeding	2.0	1.4	1.9	1.8

Means in the same row followed by same letter are not significantly different according to DMRT.

Rain productivity, for both sites in the second season, was higher for Sarwala operation compared to hand weeding. The overall average rain productivity for Sarwala was 2.54 kg/ fed /mm while it was 1.63 kg/ fed /mm for the hand weeding.

This was because the Sarwala operation improved the water holding capacity of the soil by loosening the soil surface, and rain water was stored rather than lost as runoff (Yousif, 2001). This explains why sorghum plants in the Sarwala plots remained green till the harvesting date, whereas the control plots were yellow. These results indicated that Sarwala operation increased rain productivity.

Table 4. Effect of Sarwala operation on crop stand, yield and rain productivity of some sorghum cultivars at Towawa site (season 2002).

Treatments	G. B.	Um B.	A. G.	Mean
Plant population /m^2 before Sarwala (C.V.%=10.2) (S.E. ± 1.0)				(S.E.± 0.6)
Sarwala	25.5	25.8	25.3	25.5 a***
Hand weeding	14.0	13.8	10.5	12.8 b
Plant population /m^2 after Sarwala (C.V.%=19.5 (S.E.± 0.8)				(S.E. ± 0.5)
Sarwala	6.8	4.0	7.3	6.0 b***
Hand weeding	10.3	11.3	10.3	10.7 a
Plant population /m^2 at harvest (C.V.%=13.9) (S.E. ± 0.5)				(S.E. ± 0.3)
Sarwala	5.0	3.5	5.0	4.5 b***
Hand weeding	7.8	10.5	9.0	9.1 a
Number of heads /m^2 (C.V.%=21.94) (S.E. ± 0.9)				(S.E. ± 0.5)
Sarwala	7.3	6.3	9.3 e	7.6
Hand weeding	7.3	10.0	8.5	8.6
Grain yield (kg/fed) (C.V.%=18.8) (S.E.± 31.8)				(S.E. ± 18.3
Sarwala	417.9	422.1	419.0	419.7 a***
Hand weeding	200.6	259.4	312.9	253.4 b
Rain productivity (kg/fed/mm)				
Sarwala	2.4	2.4	2.4	2.4
Hand weeding	1.2	1.5	1.8	1.5

G.B. = Gadambalia Bloom, Um B. = Um Baneen and A.G. = Arfa Gadamk.
Means in the same row followed by same letter are not significantly different according to DMRT.
******* Significant at P = 0.001.

CONCLUSIONS

The following conclusions could be drawn from this study:

1. Plant population before Sarwala operation depends on cultivar seed size.
2. The Sarwala operation had the same affect on plant population for all cultivars.
3. Irrespective to the sorghum cultivar, Sarwala operation reduced plant population.
4. Irrespective to the sorghum cultivar, Sarwala operation significantly increased grain yield compared to hand weeding.
5. All tested sorghum cultivars performed successfully with Sarwala operation. However, Tabut resulted in the lowest yield.
6. Sarwala operation improved rain productivity compared to hand weeding. The overall average rain productivity for Sarwala was 2.54 kg/ fed /mm while it was 1.63 kg/ fed /mm for hand weeding.

REFERENCES

Adam, H. S. 2008. Agroclimatology, Crop Water Requirement and Water Management. Gezira Printing and Publishing Co. Wad Medani, Sudan.

Babiker, A. G. T. and A. M. Hamdoun. 1983. Factors affecting the activity of ethephon in stimulating germination of *Striga hermonthica* (Del) Benth. Weed Research 23:125-131.

Elasha, A. E., I. N. Eldin; A. M. Ali, N- E. A. Amir, and M. S. Mohammed. 2005. Response of improved sorghum cultivars to plant spacing under irrigation. Proceeding of the 37th meeting of the national crop husbandry committee. Pp.14-23. Edited by El-Siddig, K. Agricultural Research Corporation, Wad Medani, Sudan.

Hamdoun, A. M. and K. B. El Tigani. 1977. Weed Control Problems in the Sudan. PANS 32 (2): 190-194.

Hassan, A.E. 2005. Effect of plant population on grain yield of sorghum in South Kordofan. Proceeding of the 37th meeting of the national crop husbandry committee. Pp.6-13. Edited by El-Siddig, K. Agricultural Research Corporation, Wad Medani, Sudan.

Taha, M.B. and A.G.T. Babiker. 1995. Effect of Sarwala on striga control. Gedarif Research Station Annual Report. Agricultural Research Corporation, Wad Medani, Sudan.

Yousif, L. A. and Mamoun I. Dawelbeit. 2003. Sarwala: A novel dry land tillage practice to control striga in dry land sorghum in the Sudan. P. 1391-1395. In International Soil and Tillage Research Organization (ISTRO), 16th Triennial Conference on 13-18 July 2003. University of Queensland, Brisbane, Australia.

Yousif, L.A. 2001. Evaluation and optimization of Sarwala operation for Striga control on rainfed sorghum. Unpublished M.Sc. Thesis, Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan.

Yousif, L.A. 2004. Sarwala operation: A new method for striga and weed control on rainfed sorghum eastern Sudan. A paper submitted to the Crop Husbandry Committee Meeting (26 January 2004). Agricultural Research Corporation, Wad Medani, Sudan.

Yousif, L.A., M.A. Ali and M.I. Dawelbiet. 2006. Effect of seed rate, disk angle and time of application of Sarwala on weed control and crop yield of rainfed sorghum. Gezira Journal of Agricultural Science 4(1): 100-111.

Yousif, L.A.; M.B. Taha, H.A. Sulman and A.O. Hassan. 2008. Effect of urea and its time of application with Sarwala on sorghum production in Gedarif rainfed area. Gezira Journal of Agricultural Science 6(2): 158-170.

تأثير عملية السرولة على أداء وإنتاجية بعض أصناف الذرة الرفيعة في المناطق المطرية

لطفي عبد الرحمن يوسف

هيئة البحوث الزراعية، برنامج بحوث الهندسة الزراعية، محطة بحوث القضارف، القضارف، السودان.

الخلاصة

نفذت هذه التجارب الحقلية في مناطق الزراعة المطرية الآلية بولاية القضارف خلال موسمين متتاليين 2001 و 2002م، في موقع واحد في الموسم الأول و موقعين في الموسم الثاني. يهدف هذا البحث لدراسة تأثير عملية السرولة على أداء وإنتاجية بعض أصناف الذرة الرفيعة الآتية: زهرة القدمبلية، أم بنين، أرفع قدمك، طابت و ود أحمد. زرعت الأصناف في الموسمين بمعدل بذور 7.5كجم/الفدان بالإضافة لزراعتها بمعدل 3.2 كجم/الفدان كشاهد (بدون سرولة – عزيق يدوي) في الموسم الثاني. استخدم في التجربة تصميم القطاعات العشوائية الكاملة بأربعة مكررات. تمت الزراعة خلال الأسبوع الثالث والرابع من شهر يوليو لكل من الموسم الأول والثاني على التوالي. أجريت عملية السرولة بعد مضي 25 – 30 يوم من الإنبات. تم حساب عدد النباتات في المتر المربع ثلاث مرات قبل السرولة مباشرة، بعد مضي 15 يوم من السرولة وعند الحصاد. كما تم تحديد نسبة النقصان في عدد النباتات، بالإضافة لعدد القناديل والإنتاجية. أوضحت النتائج أن عدد النباتات قبل السرولة (عند التأسيس) يعتمد على حجم البذرة. السرولة أدت إلى تخفيض عدد النباتات بصورة معنوية. زادت السرولة الإنتاجية معنوياً مقارنة بالشاهد بغض النظر عن الصنف ، بيد أن الصنف طابت أعطى أقل إنتاجية. كما أوضحت النتائج أن السرولة زادت من فاعلية الأمطار، فالمتوسط العام لإنتاجية الأمطار كان 2.54 كجم/الفدان/ م م في حالة السرولة بينما كان 1.63 كجم/الفدان/م م في حالة الشاهد. زادت إنتاجية أصناف الذرة الرفيعة زهرة القدمبلية، أم بنين، أرفع قدمك و ود أحمد معنويا مع السرولة مقارنة بالعزيق اليدوي في مناطق الزراعة المطرية الآلية بشرق السودان.