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Research paper

Effect of Tillage Methods on Yield and Yield Components of Wheat (*Triticum aestivum* L.) Under Tropical High Terrace Soil Conditions, Northern Sudan

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ABSTRACT

This study was conducted for two consecutive winter seasons (2009/10-2010/11) at the Experimental Farm of the Faculty of Agriculture, Nile Valley University, Darmali, Sudan. The experimental design was randomized complete block with three replications. The treatments consisted of conservation tillage treatments disc plow followed by land leveler (DP), disc harrow followed by land leveler (DH) and zero tillage (ZT). The wheat variety Imam performance was studied. Results showed that, the maximum seedling emergence percentage (82%) was recorded in disc harrow (DH) treatment in the first season compared to 80 and 79 % for disc plow (DP) and zero tillage (ZT) treatments, respectively. Plant height and 1000-Kernel weight were not markedly influenced by tillage treatments over the two seasons. The harvest index was significantly affected by tillage methods; disc plow recorded the highest value (20.4%). However, the grain yield was significantly affected by tillage treatments over the two seasons. Conventional tillage systems (DP and DH) significantly improved grain yield as compared to conservation tillage system (ZT). The maximum grain yield recorded by conventional tillage system DH (1450 kg ha^{-1}) followed by DP system (1326 kg ha^{-1}) and ZT system (1098 kg ha^{-1}). The economic cost of soil preparations of different tillage methods to produce one tone of grain was higher for DH and DP than ZT by 1456 and 2838 SDG for DH and DP, respectively. It can be concluded that, with an economic concern, zero tillage can be recommended for wheat cultivation under tropical high terrace soil conditions.

Keywords: Zero-tillage; Grain yield; conventional tillage; conservation tillage.

تأثير طرق الحرث في الإنتاجية ومكوناتها في القمح تحت ظروف مناطق التروس العليا شمال السودان

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أجريت هذه الدراسة خلال الموسمين الشتويين 10/2009 و11/2010 بالمزرعة التجريبية لكلية الزراعة جامعة وادي النيل، دارمالي، السودان. استخدم تصميم القطاعات العشوائية في ثلاث مكررات. المعاملات تتكون من طرق الحرت بالمحراث القرصي يتبعه آلة التسوية، والمشط القرصي وبعده آلة التسوية، وبدون حرث. تم دراسة محصول القمح الصنف امام. أوضحت النتائج أن معاملة المشط القرصي أعطت اعلي نسبة لبزوغ البادرات (82%) خلال الموسم الأول مقارنة بمعاملة المحراث القرصي وبدون حرث (80) و(79) علي التوالي. كذلك أعطت النتائج عدم وجود تأثير للمعاملات في طول النبات ووزن الإلف حبة خلال الموسمين. دليل الحصاد تأثر معنوياً بمعاملات الحرث، أعطى المحراث القرصي اعلي قيمة (20.4%). الإنتاجية من الحبوب تأثرت معنوياً في الموسمين بمعاملات طرق الحرث. نظم الحرث التقليدية (المحراث القرصي والمشط القرصي) حسنت من الإنتاجية من الحبوب مقارنة بالمعاملة دون حرث. أعطت معاملة المشط القرصي اعلي إنتاجية من الحبوب (1450 كجم/هكتار) تليها معاملة المحراث القرصي (1326 كجم /هكتار) ثم المعاملة بدون حرث (1098 كجم/هكتار). أوضحت النتائج الخاصة بالتكلفة الاقتصادية لعملية تحضير التربة لمختلف طرق الحرث لإنتاج طن واحد من الحبوب انها كانت اعلي في معاملة المشط القرصي ومعاملة المحراث القرصي مقارنة بالمعاملة بدون حرث بحوالي 1456 و2838 جنية سوداني علي التوالي. ومن ذلك وبالأخذ في الاعتبار الناحية الاقتصادية يمكن التوصية بزراعة القمح بدون حرث تحت ظروف التروس العليا.

Introduction

Poverty alleviation and food security are the most important challenges facing governments in developing countries which can be achieved if sustainable land and soil management practices are applied. The total area of Sudan is about 188.2 million hectares. Arable lands are estimated to be 84 million hectares representing 44% of the total area (Alsayim and Saeed, 2013).

The area of Sudan can be described as marginal arid land. It is estimated that agriculture contributes to 33 % of GDP and employs more than 80 % of the total population (Lee *et al*., 2013). Traditional farming accounts for 60-70% of the agricultural output and is largely subsistence production based on shifting cultivation and livestock rearing (Badri, 2012).

Although 50 years passed from the beginning of mechanized agriculture in Sudan, until now the technology which was usually used is of low level concerning agricultural mechanization. One of the most important agronomic practices in agricultural production is tillage. Thus applying appropriate tillage is essential to avoid soil structure destruction, maintain optimum crop yield as well as ecosystem stability (Greenland, 1981; Lal, 1985 and Barut and Celik, 2017).

Lal (1983) defined tillage as physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. In arable crops growing, soil tillage is usually marked as one of the greatest energy and labour consumer. The primary tillage operations require 75% of the total energy spent before the seeding time (Pelizzi *et al.*, 1988). A current trend in modern arable farming is the elimination of excessive cultivation by reducing tillage practices. In general, reduced tillage systems give lower operation costs and offer greater economic returns compared with conventional tillage (Smart and Bradford, 1999). Perviz *et al*. (2013) concluded that, conservation tillage practices such as zero-tillage and minimum tillage increase grain yield due to better nutrients and water use efficiency, less soil erosion, less weed infestation and better crop establishment.

Niamatullah *et al.* (2015) reported that in conventional tillage treatments almost all the growth and yield parameters of bread wheat were higher. However, the marginal return (economic benefits) was greater for reduced treatment than conventional and no tillage treatments. Therefore, it is recommended for bread wheat cultivation to replace conventional tillage with conservation tillage which can improve crop yields and reduce operational costs (Oleary and Connor, 1997; Gicheru *et al*., 2004; Fabrizzi *et al*., 2005). However, Larney and Lindwall (1994) stated that in semi-arid regions wheat yields may benefit from a reduction in tillage intensity due to the resulting water conservation. Similarly, Taa *et al.* (2004) observed that wheat yields from minimum and no-tillage, sometimes, were lower than those from conventional tillage. Studies on winter wheat, under minimum and zero tillage systems are few and the results are not consistent because of different experimental conditions. Therefore, the objective of this study was to examine the effects of different tillage methods on yield and yield attributes of wheat variety Imam under tropical high terrace soil conditions of River Nile state (Sudan).

Materials and Methods

Field experiments were conducted during 2009/10 and 2010/11 seasons at the Experimental Farm of the Faculty of Agriculture, Nile Valley University, Darmali, Sudan (17°48" N; 34°00" E; altitude 346.5 meters). Soil physical and chemical characteristics for the experimental site were analyzed in Hudeiba Research Station Laboratory (Table 1).

The climate data during growing seasons was obtained from Atbara Meteorological Station as average of 30 years (1971 – 2000) as presented in Table 2.

The experiment was laid out in completely randomized block design, having three blocks with net plot size of 4 × 6 m^2. Treatments include three conservation tillage treatments: disc plow (DP) followed by land leveler, disc harrow (DH) followed by land leveler and zero tillage (ZT). The depth of plowing was mostly within the range of 20-25 cm and the harrowing within the range of 8-10 cm. The wheat variety Imam was sown on 21^{th} November, 2009 and 25^{th} November, 2010 at a seed rate of 120 kg ha^{-1}. Sowing was carried by driller 2 m width. Irrigation intervals were 7-10 days with total crop water requirements of 400 m^3, total number of irrigations were ten. Coast of each land preparation treatment per hour was determined.

Table 1: Physical and chemical characteristics of soil at the study site

Soil properties	Value
Calcium Carbonate (%)	15
Organic matter (%)	0.042
Nitrogen (ppm)	140
Phosphorus (ppm)	1.1
Exch. Sodium percent	1.2%
Electric conductivity (ds/m)	0.85
Soil texture	
Sand (%)	35
Clay (%)	63
Silt (%)	02
pH	7.4

Table 2: Climatology data (1971 – 2000) Atbara Station

Mon.	Air temperature °C				Bright sunshine duration		Relative humidity %	Wind mean speed at 2 m (km hr^{-1})
	Maximum		Minimum					
	MEAN	HST	MEAN	LST	HRS	%	MEAN	
NOV	34.9	40.7	20.1	11.7	10.2	90	36	6.9
DEC	31.1	38.5	16.0	6.5	9.7	88	40	6.9
Jan	29.8	39.1	14.2	6.3	9.9	88	36	8.0
Feb	31.8	41.4	15.1	5.5	10.3	90	31	8.0
Mar	35.7	45.7	18.4	10.8	10.1	84	24	8.0
Year	**37.7**	**48.0**	**22.3**	**5.5**	**9.6**	**79**	**31**	**-**

Source: Sudan Meteorological Authority, Atbara Station

For the two experiments urea (46% N) was applied in split dose as a source of nitrogen, half-dose applied at sowing and the rest four weeks after sowing. Triple super phosphate (48% P_2O_5) was applied as a source of phosphorous before sowing. The crop was kept clean by hand weeding two and three weeks after sowing, respectively.

For the crop germination (%), two rows were randomly selected within each plot. Hence the average number of plants per plot was calculated as follows:

$$G\% = \frac{Pc}{Pp} \times 100$$

Where:

Pc = plants count per plot, Pp = presumed plant count/plot, and G = germination

Plant height was measured at two weeks intervals; one plant was randomly selected within two rows in each plot.

Plants were harvested as they dried up. Shoots were removed manually by cutting at the soil surface. Plants were harvested, bound and air dried before threshing and measuring seed yield per unit area.

Ten plants samples randomly selected from the harvested area. Parameters assessed include; plant height (from the ground surface to tip of growing point) and 1000-kernel weight (g). Harvest index was calculated as the average grain yield per plot divided by the average dry biomass per plot. Seed yield per unit area was obtained from the three center rows of each plot. To avoid border effect, 0.5 m of every side in each plot was not considered when harvesting, then grain yield was determined in kg ha^{-1}.

The data were statistically analyzed using analysis of variance to test the significance of treatment effects using the SPSS statistical program.

Results and Discussion

Seedling emergence (%)

Effect of different tillage methods on seedling emergence percentage two weeks after irrigation for both seasons was presented in Fig 1. The results showed that, the highest seedling emergence (82%) was recorded by disc harrow (DH) treatment at the first season compared to 80 and 79% for disc plow (DP) and zero tillage (ZT) treatments, respectively. However, for the second season, the results showed lower seedling emergence (73%) for the DH treatment and gave comparable ratio of 77 % for DP and ZT. Acceptable percentage ratio for seedling emergence under ZT treatment for the second season may be caused by organic matter which may improve soil physical and chemical characteristics particularly soil water holding capacity. These results were supported by Sayre and Ramos (1997) who concluded that zero-tillage can provide enough water for germination of wheat seeds.

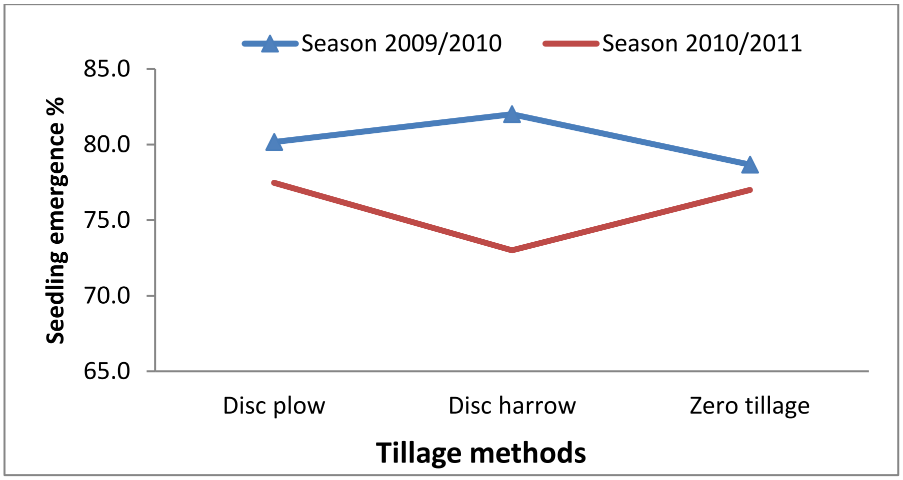

Fig.1: Effect of tillage methods on seedling emergence percentage two weeks after irrigation for the two seasons 2009/2010 and 2010/2011

Plant height (cm)

Plant height was not significantly different among the treatments during both seasons. The order of plant height from the lowest to the highest was ZT, DH, and DP (Table 3). Similar results were obtained by DeVita *et al.* (2007).

The 1000- kernels weight (g)

The 1000 kernels weight recorded under different tillage treatments over the two seasons as shown in Table 3. The results indicated that, the 1000- kernels weight was not affected by tillage treatments during both seasons. The maximum 1000-kernel weight (42.1g) was recorded under conventional tillage, and it decreased under reduced tillage (40.7g) and no tillage (38.3g). These results agreed with results obtained by Perviz *et al*. (2013).

Harvest index (%)

Harvest index was significantly affected by tillage methods (Table 3). The results showed that, the highest harvest index (20.4%) was recorded by DP, which could be due maximum translocation of assimilates towards grain formation. On the other hand, DH and ZT attained lower harvest index; 18.6 and 18.2%, respectively. These results were similar to the findings of DeVita *et al.* (2007).

Grain yield (kg ha^{-1})

Grain yields under different tillage treatments over two growing seasons were recorded and the results are shown in (Table 3). Conventional tillage systems (DP and DH) significantly improved grain yield as compared to conservation tillage system (ZT). The maximum grain yield was recorded by DH conventional tillage system (1450 kg ha^{-1}) followed by DP system (1326 kg ha^{-1}) and (1098 kg ha^{-1}) for the ZT system. However, in the ZT compared to DP and DH systems, the grain yield showed reduction by 50 and 776 kg ha^{-1} for DP and DH, respectively. This different yield may be attributed to soil properties improvements as a result of increases in soil fertility. It may be due to greater inorganic N and N uptake. These results agreed with those obtained by Zamir *et al.* (2010) and Niamatullah *et al.* (2015). They found that conventional tillage produced significantly higher grain yields compared to others conservation tillage systems.

Table 3: Effect of tillage method on wheat yield and yield components over two seasons (2009/2010 and 2010/2011).

Tillage Methods	Plant height (cm)	1000 KW (g)	Harvest index (%)	Grain yield kg ha^{-1}
Disc plow	96.2 a	40.9 a	20.4a	1326ab
Disc harrow	67.3 a	42.1 a	18.6 b	1450a
Zero tillage	71.1 a	38.3 a	18.2b	1098b

Means within the same column having the same letter are not significantly different at P = 0.05

Economic cost

The economic cost of different tillage methods was presented in Table 4. The results showed that, the total conservation tillage systems cost (seed drill and ditcher) under zero tillage recorded low values (270 SDG ha^{-1}) compared with disk plow, land leveling, seed drill and ditcher (920 SDG ha^{-1}) and disk harrow, land leveling, seed drill and ditcher (730 SDG ha^{-1}). Likewise, the results indicated that the economic cost of soil preparations to produce one ton of grain yield was higher for DH and DP than ZT by 1456 - 2838 SDG for DH and DP, respectively.

Table 4: Economic cost (SDG) of different tillage methods

Tillage Methods	Tillage cost SDG	Total cost of ton (grain yield) SDG
Disk plow + Land leveling + Seed drill + Ditcher	920	3932.6
Disk harrow + Land leveling + Seed drill + Ditcher	730	2854.0
Seed drill + Ditcher	270	1394.5

Conclusion

It can be concluded that, grain yield was affected by different tillage methods. Therefore, zero tillage with economic concern can be recommended for wheat cultivation under tropical high terrace soil conditions (Northern Sudan).

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