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RESEARCH ARTICLE

Effects of Tillage and Mulching over Two Seasons on Grain Yield of *Sorghum bicolor* at Matopos, Zimbabwe

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Abstract

A field trial was carried out to determine the combined contribution of tillage, mulching and season to crop productivity. The tillage treatments used were conventional tillage, basin and ripper tine tillage. The experiment was set up in 2013/14 and 2014/15 seasons as a split plot with treatment plots arranged in a randomized complete block design with three replications. Three mulching levels were used; zero mulch application, 2t and 4t (mulch) of crop residue application for each tillage treatment. There were significant differences between the tillage systems used over the two seasons. The first season of 2014 gave average yield of 2544kg/ha and the second season of 2015 gave mean yield of 2113kg/ha, which were significantly different ($p<0.05$). The tillage method of basin, conventional and ripping resulted in mean yields over two seasons of 2465kg/ha, 2555kg/ha and 1966kg/ha respectively and showed significant difference ($p<0.05$). The seasons varied considerably in their rainfall amount and distribution, 403.4mm was realised in 2014 and 417.5 mm in 2015. Different mulching levels did not show significant difference over the two seasons of the trial. However the interaction of tillage and season showed significant difference in the yield of sorghum. The effect of mulching was the weakest of the combined contribution from tillage, season and mulching perhaps due to the limited number of seasons.

Keywords: Ploughing; Conservation Agriculture; Sorghum Yield; Rainfall

Introduction

Conservation tillage practices simultaneously conserve soil and water resources, reduce farm energy usage and increase or sustain crop production [1]. There is need to shift from conventional tillage to minimum and zero tillage for the purpose of protecting soil degradation, increasing water use efficiency, reducing the cost of production of summer crops and improving crop productivity.

Sorghum as a grain crop can complement wheat, rice, maize and other grain crops, as it is a staple food for millions of people in semiarid regions of the World [2]. However, research on tillage requirements and the effect of tillage methods on soil physio-chemical properties is scarce in Zimbabwe and farmers use conventional tillage practices. Use of excessive and unnecessary tillage operations is harmful to the soil and increases the cost of production. Intensive conventional tillage is known to degrade soil structure [3].

Sorghum is grown mainly as a rain fed crop in the semi-arid areas. In these areas, sorghum production is limited by water stress due to low and variable rainfall between and within seasons induced by the ongoing climate change. Sorghum yields vary considerably between years and show a close dependence on rainfall perhaps management practices like mulching and conservation tillage may improve crop productivity in a year with poor rainfall.

While substantial information on crop yield benefits of Conservation Agriculture (CA) practices has been generated, there is a dearth of information on the impact of season on the crop yields. The sorghum crop requires development of a soil management package that could conserve soil moisture. This attribute is expected to enhance crop productivity.

The objective of study was to investigate the effects of tillage and mulching on sorghum yield over two seasons under semi-arid on the general yield of sorghum.

Materials and Methods

Site

The experiment to determine the tillage, mulching and season effects on grain yield of sorghum (Sorghum bicolor L.) was conducted during the summer seasons of 2014 and 2015 in a fixed plot at Matopos, Zimbabwe. Matopos Research Institute is located 30 km south of Bulawayo between latitude 20^0 24′ S and 28^0 29′ E longitude. Its altitude is approximately 1340 m and it lies in agro-ecological region 4 of Zimbabwe. Rainfall is both low and variable (250-650 mm per year, median 573 mm) and occurs between October and April. October is the hottest month (mean maximum 29.4 ºC) [4]. Sorghum variety Macia was sown in both the two trial seasons. The soil at Matopos is a Chromic- Leptic Cambisol derived from basaltic greenstone [5].

Experimental Design

The experiment was laid out in a split plot arrangement (tillage being the main plot and mulching being subplots) having three replications with net plot size of 8.0 m × 4.0 m. Seedbed was prepared by cultivating the field as per treatment requirement. Sowing was done with a hand drill maintaining inter-row spacing of 90 cm and in row spacing of 20 cm after thinning on ripper and conventional tillage, while basins had spacing of 90 x 60 cm (with three plants per basin). The basins were hoe dug with 15 cm x 15 cm x15 cm length, width and depth dimensions respectively. Ripper lines were simulated by digging a deep line in the trial plots using hoes. Mulching levels of 0, 2 and 4 t/ha was applied according to treatment and previous season sorghum crop residues were used as mulch in each growing season. The mulch was applied at the same time in all plots at the sowing stage of the trial. In the conventional tillage, land preparation was by ploughing using an oxen-drawn plough (farmer's practice) to prepare the seedbed.

Data collection

Data collected included 50% physiological maturity. Physiological maturity was determined by the presence of a black layer where the grain attaches to the heard. Rainfall records were collected throughout the two growing seasons. Weight of grain per net plot after harvest was collected.

Statistical analysis

Trial data were subjected to the analysis of variance appropriate to the experimental design [6]. Genstat 14 was used to analyse the data. Least significant differences were used for means separation at the 0.05 probability level.

Results

Grain yield is an important component of sorghum performance under a set of growing conditions (Figure 1).

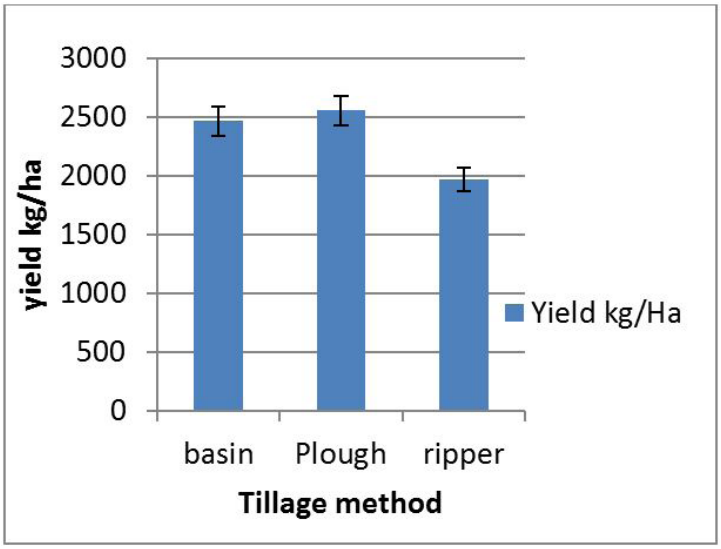

Figure 1: Sorghum grain yields in kg/ha from conventional, basin and ripper tillage in the two seasons combined

Tillage method over the two seasons showed significant effect on the grain yield of sorghum ($p<0.05$). The basin and conventional method produced better grain yield than the ripper tillage method in the overall two seasons.

The interaction between tillage and season was significant at $p<0.05$ as shown in Table 1 below.

Among the three tillage treatments basin method produced the best sorghum yield in 2013/14 growing season while conventional tillage had best yield in 2014/15 season. The interaction of tillage and season showed significant difference on sorghum grain yield ($p<0.05$) (Table 1).

	Tillage Yield Kg/ha		
Season	Basin	Plough	Ripper
2014	2570b	2018a	1752a
2015	2361b	3091c	2180a
LSD	607.8		
P- value	0.017		

Table 1: Effect of the interaction of season and tillage method on sorghum grain yield

The effect of mulching in any particular season and between the two seasons showed no significant difference in grain yield.

The rainfall average for the two seasons at Matopos was 410mm with the first season of 2013/14 having 403mm and in 2014/15 about 417mm of rainfall was received.

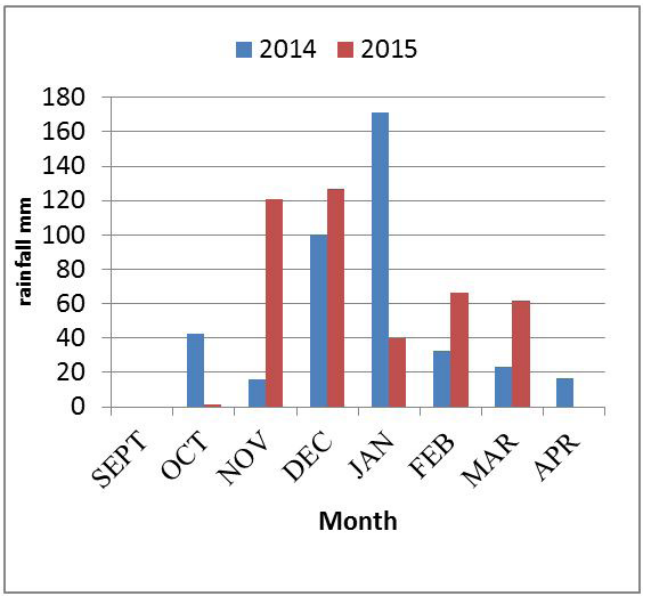

Figure 2: Monthly rainfall received and season rainfall distribution

Total annual rainfall (based on the July June calendar) varies from 573mm at Bulawayo the two seasons in Figure 2 had rainfall below average; the season effect resulted in significant yield difference [4]. The area of Matopos research station where the trial was conducted lies in natural farming region IV, which has limited rainfall with the average rainfall declining over the years perhaps due to climate change.

During the 2014/15 season the average sorghum yield was significantly different at $p<0.05$ from that for the 2013/14 season. An average yield of 2544kg/ha of sorghum was produced in 2014/15 as compared to 2113kg/ha of sorghum which was realized in the season of 2013/14 as shown in Figure 3 below.

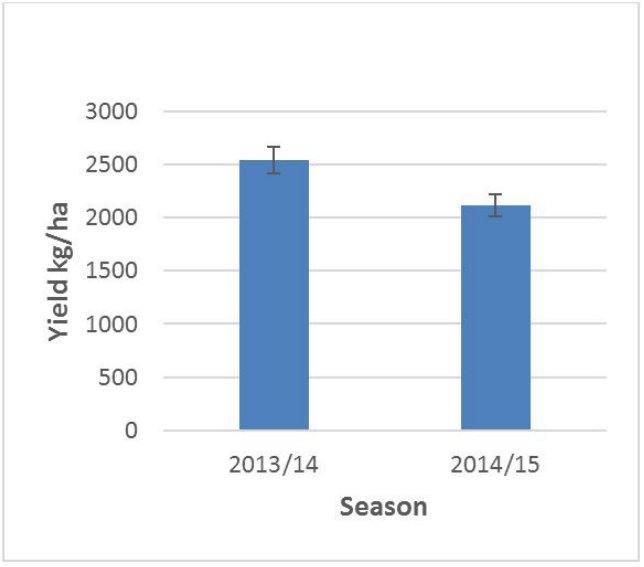

Figure 3: Sorghum mean yield for the two seasons

A comparatively better sorghum grain yield was obtained in the first season of the trial.

Discussion

The lowest yield was realized from zero-tillage, particularly ripper tine plots at all levels of mulch application (Figure 1). This result is in agreement with [6,7]. Where zero-tillage was found to give lower yield because, perhaps, of restricted root growth. From existing literature, there is considerable evidence existing for unlikely poor performance of the zero-tillage associated with the influence of climate, soil and management practices. Minimum tillage performance in terms of enhancing yield could be limited, especially at the earlier few years where minimum tillage persists. It was also observed that the minimum tillage did not increase yield when the precipitation was reasonably ample or increased [9,10]. Sorghum crop has shown to perform well with about 300mm rainfall which is well distributed in the season. Other studies have shown no, or variable difference in crop yield between minimum tillage and conventional tillage [11]. In our trial the simulation of the ripper did not provide the good depth for the root development in the two seasons resulting in ripper tillage producing the least yield results from other tillage practices.

The total rainfall amount received in the two seasons was below the average rainfall (570 mm) usually received at Matopos. Moreover, rainfall distribution was poor after February 2014, which coincided with the late growth stage of the crop (March 2014) (Figure 2). The crop was stressed during the late grain filling stage affecting the yield. Much of the rains in December and January did not help the crops much, as some of the water was lost as runoff in the heavy rainstorm. The season tail of 2015 had effective precipitation (Figure 2). The first season of the trial received low grain filling period precipitation as compared to the second year of the trial. The two months, February and March of 2014 had a total rainfall of 56.1 mm while for the same time in 2015 a total of 128.7 mm of rainfall was received. Rainfall amount during the grain filling period is critical in determining the sorghum crop grain yield.

The studies by also suggested that sorghum responded positively to growing season precipitation when increasing amounts of residue remain on the soil during the growing season [13].

The effect of mulching and other interactions effects with tillage on the grain yield of sorghum could have been more sharp and pronounced when mulch was applied early or left in the field the previous season. The different rates of mulch in this trial were applied at planting time, the effect could have been different if the crop residues used as mulch were to be applied early in the season or left on the trial plots over the season. The two seasons perhaps were not enough to show the mulching effect on yield of sorghum.

Several research results from the long-term field experiments demonstrated the advantage of zero tillage and straw mulch management from greater water use efficiency in regions receiving annual precipitation of more than 250 mm [12]. The good yield performance of sorghum crop in basins can be attributed to the moisture conservation effect of the planting basins [13]. According to sorghum grain yields varied for a given level of precipitation during a growing season undoubtedly because of difference in initial soil water contents and distribution of the precipitation.

The sorghum grain yield from the current trial was higher than that normally realized by the small scale farmers (national sorghum average 0.8t/ha) possibly due to the effect of crop management. Most of the small scale farmers use unimproved retained seed which compromise sorghum yield even where soil and water conservation techniques would have enhanced crop performance.

Lack of grain yield response to mulching suggested that soil water conserved by the mulch was just adequate to impact positively on stover production and not enough for the conversion of accumulated biomass into grain (Mupangwa et al, 2012). Sorghum can survive dry conditions because of its ability to extract water from the subsoil (0.45–1.35 m depth) [14]. When sorghum is exposed to soil water stress its roots grow deeper into the profile thereby increasing the volume of moist soil explored in search of water [14].

The crop residue applied as mulch was broke down by soil microorganisms as was observed in the mulched plots limiting the mulching effect in soil and moisture conservation.

The first season of the trial received lower precipitation during the grain filling period relative to the second year of the trial. The two months; February and March of 2014, had a total rainfall of 56.1mm while for the same time in 2015 a total of 128.7mm of rainfall was received. Rainfall amount during the grain filling period is critical in determining grain yield. The rainfall distribution in the two season coupled with crop management may have resulted in different sorghum yield performance.

Conclusion

Minimum tillage especially the use of basins can be adopted by farmers in the dry areas for soil and water conservation in sorghum production to ensure household food security in the face of climate change and variability.

Despite the yield benefits from tillage method and season effect observed in our study, long term studies under different soil, climatic and socio-economic conditions are still required to substantiate the crop responses. There is also need to do further research on the effect of ripping depth since the simulation of a ripper using the hoes carried out in the trial resulted in significant lower yields.

The effect of precipitation during the grain filling period on the yield of sorghum need also to be looked into, to see potential yield differences as a result of season quality in terms of amount of rainfall received and its distribution over the season.

Recommendations

Minimum tillage may result in a sustainable soil management with reduced soil loss to erosion.

Mulching is the most omitted conservation agriculture practice by small holder farmers; however it is very important for farmers especially on light soils to mulch. Significant benefits from mulching depending on soil may, be realised after numerous cropping seasons.

The preparation of CA should be done on time to effectively maximize the utilization of rainfall in a particular season; the delay may result in reduced yields similar to those from conventional tillage.

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