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Full Length Research Paper

A comparative analysis of yield performance of maize (*Zea mays* L.*)* under different tillage methods in Musana communal area, Zimbabwe

Nyakudya I. W.[1]*, L. Jimu[2], V. Muripira[1] and T. J. Chikuvire[1]

[1]Department of Agriculture, Bindura University of Science Education, P. Bag 1020, Bindura, Zimbabwe.
[2]Department of Environmental Science, Bindura University of Science Education, P. Bag 1020, Bindura, Zimbabwe.

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In order to reduce the negative effects of conventional tillage there is need to develop or adopt alternative tillage systems. A comparative study on the effects of three tillage methods on the yield performance of a maize cultivar SC633 was conducted in Musiiwa ward of Musana Communal Area, Mashonaland Central Province in Zimbabwe. The experiment was conducted on existing farmers' fields. A randomized complete block design with three treatments (direct seeding, ripping and conventional mouldboard ploughing) replicated four times was used. The data were subjected to analysis of variance using SPSS for Windows, Version 15.0 (2006). Results showed that there was no significant difference (P>0.05) in maize grain yield mouldboard ploughing and ripping. Mouldboard ploughing out-yielded (P<0.05) direct seeding. Stover yields and harvest indices under the three tillage methods were not significantly different (P>0.05). It was concluded that ripping can perform perfectly well just like the conventional mouldboard ploughing. In view of the comparative advantages of conservation tillage in terms of carbon sequestration and the subsequent soil quality improvement, mitigation of greenhouse gas emissions, and reduced soil erosion, adoption of conservation tillage is recommended.

Key words: Tillage, maize, communal area, conservation farming, grain yield.

INTRODUCTION

Zimbabwe has an agrarian based economy with more than 1.2 million peasant farmers in the communal sector (Matarira et al., 2004). The major field crops grown include maize (*Zea mays*), soybeans (*Glycine max*), cotton (*Gossypium hirsutum*), groundnuts (*Arachis hypogaea*), wheat (*Triticum aestivum*), tobacco (*Nicotiana tabacum*), sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*). Maize is both a staple food and a cash crop. According to Mashingaidze (2006), maize ranks first in terms of producers, area grown and total cereal production in Zimbabwe. Being a strategic crop, maize quantities must be maintained at adequate levels in order to ensure food security and self-sufficiency at both household and national level. However, the past decade has seen a decline in the production of maize in communal areas mainly as a result of inefficient management practices like burning of crop residues and inappropriate tillage practices (Blevens and Fry, 1993). Organic matter is involved in the enhancement of soil quality since it acts on soil structure, nutrient storage and biological activity (Melero et al., 2009). Burning of crop residues therefore implies that its beneficial effects will not accrue to the soil. In addition, burning crop residues leaves the soil bare and pre-disposes it to agents of soil erosion that remove the productive top soil. Throughout the world, soil erosion on cultivated land causes on-site as well as off-site damage, generating profound economic consequences (Raclot et al., 2009). On-site damage includes soil and nutrient loss while the off-site damages include siltation and eutrophication of water bodies and air pollution.

According to Van Straaten (1999), soil degradation has

*Corresponding author. E-mail: pupunege@yahoo.com. Tel: +263 912 773 746.

increased dramatically over the last decades, affecting millions of hectares of land, posing a threat to maize productivity particularly in areas with fragile ecosystems. The realization that agricultural production causes alteration of natural ecosystems, producing disturbances in abiotic and biotic components (Melero et al., 2009) should be accompanied by deliberate efforts to minimize negative. In Zimbabwe, smallholder farmers have been practicing conventional tillage through the use of the ox-drawn mouldboard plough. Conventional tillage includes practices that leave less than 15% of the soil surface covered with stubble (Baker et al., 2007). Usually, it involves both primary and secondary tillage, with the former being associated with the inverting of the plough furrow, lifting and moving all the soil in the plough layer, usually to a depth of 0.1 to 0.2 m (Morgan, 1986) and the later, being applied to control weeds. The mould board plough cuts a rectangular slice of soil, turns it over, loosens it and buries weeds and organic matter on or near the surface. However, this method has been blamed for soil degradation and requiring an investment to buy oxen and the plough which most farmers cannot afford. According to Wang et al. (2006), soil carbon loss and tillage-induced CO_2 emissions associated with conventional tillage affect not only productive capacity but also global environmental quality. As a result, the farmers have been urged to adopt conservation tillage to save the planet's soil (Grarcia-Torres et al., 2001).

Conservation tillage is a way of farming that allows the soil-water resources to maintain its natural ability to produce crop today and in the future (Papendick et al., 1983). Conservation agriculture and conservation tillage are the collective umbrella terms that usually denote the retention of at least 30% ground cover by residues (Baker, 2007). Conservation tillage has the following multiple functions: carbon sequestration (increase soil carbon storage for carbon trading), mitigation of greenhouse gas emissions and improvement of soil quality for economic crop production (Chatskikh et al., 2008; Sainju et al., 2008). As early as the late eighties, Wilhelm et al. (1987) had noted that in dryland cropping systems, enhanced water storage from conservation tillage results; theoretically, in greater yield potential than conventional tillage systems. Data of grain yield indicates that maize well tolerates simplified tillage systems including no-tillage with retained annual chopped straw on both loamy sand and sandy loam (Pabin et al., 2006). Melero et al. (2009) also showed that long-term soil conservation management improved the quality of both sandy clay loam (Entisol) to heavy clays (vertisols) through enhancing organic carbon fraction and biological status especially at upper layers. This implies that the benefits of conservation tillage are not restricted to specific soil types, thus, widening the scope for experimentation.

The objective of this study was to compare maize grain and stover yield under ripping, direct seeding and conventional ploughing.

MATERIALS AND METHODS

Description of study area

The research was conducted in Musiiwa communal area (31° 15' E, 18°15' S; 1250 m.a.s.l) during the 2007/2008 croppi ng season. The area is located at 65 km along Harare-Shamva Road in Bindura district of Mashonaland Central Province of Zimbabwe. Musiiwa is in Natural Region II (b) with an annual rainfall of 700 to 1000 mm and mean annual temperature of 26 to 28℃. The area lies in a dissected plateau with 30 to 50% of the land area comprising rock outcrops of the bornhardt and castle koppie type (Anderson et al., 1993). A catenary association of soils occurs on the pediment slopes. The upperslope section is adjacent to rock outcrops and has well-drained, moderately shallow to deep, coarse-grained sand to sandy loam over yellowish red to red coarse-grained sandy clay loams. Mid to lower slopes have well to moderately well drained, moderately shallow to deep coarse grained sands or loamy sands over strong brown to reddish similar sands often with mottling at about 1m depth (Anderson et al., 1993).

Experimental design

The experiment was conducted on fields under the Development Aid from People to People (DAPP) Farmers Club. Systematic sampling was used to select four farmer participants and the distance between the furthest farmers was 4 km. A randomised block design comprising three treatments (ripping, direct seeding and conventional ploughing) replicated four times was used. Each farmer's field was regarded as a block and the three treatments were assigned at random to the three plots in each block (Neeley et al., 1991) using random numbers.

Description of experimental sites

All the four fields were on mid-slope positions with an identical pH ($CaCl_2$) of 4.6 and textural classes ranging from coarse sandy loam to coarse sandy clay loam. During the 2006/2007 cropping season, all the fields were planted to maize under similar treatments to those studied in the 2007/2008 cropping season.

Field operations

The land was pegged to form blocks measuring 30 × 30 m and plots measuring 30 × 10 m. Footpaths of 1 m were left between plots in each block. Conventional ploughing was done in one plot of each block using a mould board plough at a depth of 0.2 m. Seeding furrows were 0.90 m apart. In the other plot, only the seeding furrows were made using an ox-drawn ripper at a depth of 0.3 m. Hand planting was then done using a hoe. A calibrated planter was used in the final plot to rip lines at a depth of 0.15 m, and plant maize at a spacing of 0.90 × 0.15 m. Planting was done on the 1st of December 2007. Hand seeding at two pips per station was done in mouldboard-ploughed and ripped plots at a spacing of 0.90 × 0.30 m. In the third plot, ripping of lines, sowing, fertilizing and seed covering was done simultaneously at a spacing of 0.90 × 0.15 m and one seed per station was sown. The 0.30 × 0.90 m spacing is commonly used by local farmers when planting manually because there is considerable saving in terms of labour if fewer stations with more plants are used. The 0.90 × 0.15 m spacing is recommended for machine planning because with this method fertilizer application is precise and labour saving is less important. The maize hybrid seed SC 633 was sown in all the plots. The hybrid seed is a long season variety with a yield potential which ranges from 10 to 12 tons per hectare and takes about 136 days to maturity. Basal fertilizer compound D (7% N: 14% P_2O_5: 8% K_2O) fertilizer was applied at a rate of 176 kg/ha. The fertilizer was banded ±7.5 cm to the side of the seed and covered with soil. The application was according to Grant (1996).

Weed control was done using hoes, slashers and hands. Uprooted weeds were left in between the rows to maintain soil cover. The first weeding operation was done at planting in all the plots. First post emergence weeding was done on the 3rd week in ripped and direct seeded plots only. Second post emergence weeding was carried out on the 7th week when new weeds appeared in all the plots. Lastly, there was pre harvest weeding on the 11th week in all the plots again whereby spot weeding was done after the dough stage of the maize plants. Scouting for pests was done after every fortnight and stalk borer and cutworms were commonly seen. Spot stalk borer control was done through application of dipterex at the rate of 4 kg/ha as soon as the caterpillar feeding damage was seen in the maize funnel (Agritex, 1993). Ammonium nitrate was applied in all the plots at a rate of 222 kg/ha (5 g/station) based on regional recommendations.

Rainfall data collection

Rainfall was measured using a rain gauge at Mhumhurwi Primary School. The site was considered to be central with the furthest fields being 2 km away.

Harvesting and data collection

Harvesting was done on the 23rd of April 2008. Areas to be harvested were chosen from the centre of each plot to cater for boarder effects during data collection. Four sub-plots were harvested per plot at an interval of 2 m and each of the sub-plots covered 9 m^2. Thus, maize plants were harvested from a total area of 36 m^2 per plot. Two plants were then drawn randomly from each sub-plot making up a sample of 8 plants per plot. Cobs were removed from the 8 stalks, placed in small plastic bags and the wet weight of the cob was measured. The mass of the 8 stalks was also measured. The samples (8 stalks and 8 cobs) per plot were air-dried separately.Cobs were shelled using hands and the grains were weighed. . In Zimbabwe the maximum moisture content normally recommended for maize storage is 12.5 percent. The weight of maize was adjusted to 12.5% moisture content after determination of the sample grain moisture. All the measurements were done using a balance to the nearest 0.01 kg and were recorded.

Determination of harvest indices

Harvest index was calculated using the formula (Shamsi et al., 2003):

$$\text{Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Data analysis

Data were analysed through one way analysis of variance (ANOVA) using SPSS for Windows Version 15.0 (2006). The differences between means were calculated using the least significant difference (LSD) post hoc tests at 5% significance level.

RESULTS

The rainfall received for the 2007/2008 cropping season was as follows: The rainfall was well distributed during the crop growing season. The mid-season dry spell which normally occurs in January was virtually non-existent. The seasonal total was significantly different ($p<0.05$) from the mean for the nine years of 2000/2001 to 2008/2009. Monthly, totals for all months exceeded the mean monthly totals except for January and February.

Yield comparisons

Table 2 shows a comparison of maize grain and stover yields produced under ripping, direct seeding and conventional mouldboard ploughing. There were no significant differences ($P>0.05$) on maize grain yield produced through direct seeding and ripping as well as ripping and conventional mouldboard ploughing. However, the grain yield of maize produced through conventional ploughing outperformed ($P<0.05$) those produced through direct seeding. The stover yield of maize plants produced through the three tillage methods did not significantly vary ($P>0.05$).

Comparison of harvest indices

Maize harvest indices for the three tillage methods were as follows: ripping (0.45 ± 0.10), direct seeding (0.46 ± 0.07) and conventional ploughing (0.44 ± 0.09). The harvest indices were not significantly different at P = 0.05.

DISCUSSION

Maize grain yield produced under conventional mouldboard ploughing out-yielded that under direct seeding because in the first seasons conventional mouldboard ploughing loosens the root zone, allowing plant roots easy access to soil-water and plant nutrients. Direct seeding which involves little disturbance of the soil through opening a rip line with coulters, somehow restricted the lateral and downward movement of the roots (Baker et al., 2007). However, with time it can be assumed that "biological tillage" will improve root growth. Conservation tillage methods like stubble mulch, ripping, strip, and direct seeding result in better returns during dry years compared to conventional tillage (Wang et al., 2006). Thus, the significance of conservation tillage is highly proven in drier seasons than in wetter seasons. In this study, the season was wetter than normal for the area and this could have resulted in inferior performance

Table 1. Decadal rainfall totals (mm) for the 2007/2008 rainy season for Mumhurwi Primary School in Musiiwa Communal Area, Zimbabwe.

Decade of month	October 2007	November 2007	December 2007	January 2008	February 2008	March 2008	April 2008
First	0.0	33.5	78.7	79.0	21.5	60	20
Second	0.0	58.5	242.4	35.0	58.9	100.0	0
Third	0.0	84.5	175.8	160.3	19.8	0	0
Total	0.0	176.5	496.9	274.3	100.2	160	20

Table 2. Comparison of maize grain and stover yield produced under direct seeding, ripping and conventional mouldboard ploughing during the 2007/2008 in Musiiwa Communal Area, Zimbabwe.

Tillage method	Mean yield (SD)(t/ha)	
	Grain	Stover
Ripping	3.67(0.86)[ab]	4.10(2.10)[a]
Direct seeding	2.43(1.25)[a]	3.56(2.06)[a]
Conventional mouldboard ploughing	4.55(0.06)[b]	5.67(1.37)[a]

Means in the same column with common superscripts are not significantly different at P = 0.05
SD stands for standard deviation.

of direct seeding to mouldboard ploughing. Rainfall data in Table 1 shows that the January mid-season dry spell is a common feature in most seasons was virtually non-existent with all the first and last decades exceeding 70 mm of rainfall and the seasonal total (1227.9 mm) exceeded the mean (SD) 791 (204 mm) for the seasons 2000/2001 to 2008/2009. Spacing of plants might also have had a bearing on the differences in grain yield obtained between the two tillage methods. According to Strieder et al. (2008), the photosynthetically active solar radiation intercepted (PAR_{int}) by the canopy Is one of the main requirements to obtain high yields in the absence of water shortage. Plant arrangement, therefore has influence on crop yields (Strieder et al., 2008).

In the current study, although, the plant population in the two plots was the same (74,074 plants/ ha), the interaction of plants in direct seeded plots with a spacing of 0.90 × 0.15 m (one seed per hill) was different to that in conventionally ploughed plots spaced at 0. 90 × 0.30 m (two seeds per hill). The differences in grain yield between conventional mouldboard ploughing and direct seeding may have been due to the difference of PAR_{int} caused by the different plant arrangements. However, there is not enough evidence that interactions affected the portioning of metabolites between the grain and the stover because the harvest indices are similar in value. Ripping equalled conventional mouldboard ploughing in grain yield because like conventional mouldboard ploughing, ripping also loosens the soil in the root zone allowing easy root growth. In this study, ripping is accompanied by hoeing planting stations, thus, further loosening the root zone.The results support findings by Pabin et al. (2006) who states that reduced and no-tillage in combination with straw retaining can be used without any significant decrease in grain yield of maize grown to medium and coarse textured soils. However, the system is suitable for row crops like maize only (Fenger, 2006). Mouldboard ploughs mostly used by smallholder farmers have been identified as the primary cause of soil erosion although all tillage implements contribute to this problem.

Lobb et al. (1995) estimates soil loss from tillage sequence of mouldboard ploughing and cultivating to be 54 t/ha/year and that a risk of accelerating erosion existed on cultivated land from the moment natural and surface litter is removed. When weighed against these negative impacts of mouldboard ploughing, ripping may be preferred for sustainable agriculture in communal areas. In addition, the adoption of reduced tillage practices may also be able to increase or at least stabilize the carbon content in the previously ploughed soil, thus, reducing respiratory carbon dioxide emissions to the atmosphere. According to McClymont and Winkfield (1984), better yields are unlikely to be experienced under conservation tillage until at least in third and fourth year. Therefore, the early relatively good performance of ripping in this experiment is quite encouraging. Results from this study therefore, imply that farmers can achieve yields similar to those of conventional tillage using ripping. In view of the overwhelming evidence of ecological sustainability of conservation tillage, farmers should be encouraged to adopt it as a viable alternative to conventional tillage in the study area. The lack of significant difference on the maize stover yield produced among the three tillage methods implies that for purposes of fodder production any one of the tillage methods may be used.

Conclusions

Conventional tillage out yielded direct seeding in grain yield but it was equalled in performance by ripping. There was no variation in stover yield among the three tillage treatments. Further studies are needed in order to establish effects on yield of the different planting arrangements used in this study. We recommend monitoring of the performance of treatments in the medium to long-term in order to establish inter-seasonal performance of the treatments. Multi-season monitoring is important because conservation tillage benefits usually accrue with time as soil quality improves. In view of the comparative advantages of conservation tillage in terms of carbon sequestration and the subsequent soil quality improvement, mitigation of greenhouse gas emissions, and reduced soil erosion, we recommend adoption of conservation tillage.

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