Influence of tillage systems and seedbed types on sorghum yields and economics in northern Ghana

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Abstract

Inappropriate tillage practices and seedbed types have often been identified as major constraints to cereal crop production in the Savanna agro-ecological zone of northern Ghana. In an effort to increase crop production and conserve the soil from degradation, through mechanical manipulation of the soil, field experiments were conducted from 1992 to 1995 to study the effects of tillage systems and seedbed types on performance of sorghum (Sorghum bicolor (L.) Moench), weed infestation, and tillage economics. The tillage methods evaluated were: manual, bullock, and tractor and the seedbeds studied were: flat and ridge. The highest sorghum grain yield was recorded in 1994 for tractor ridge with manual flat recording the least in 1995. Tractor and bullock tillage systems recorded a mean increase in sorghum grain yield of about 42% over manual tillage. Mean increases in grain yield recorded by ridge seedbeds over their flat counterparts for different tillage systems for the 4 years were: manual, 176%; bullock, 57%; tractor, 54%. Bullock ridging gave the highest straw yield in 1992 with manual flat recording the least in 1995. Ridges for all tillage systems recorded significantly higher straw yields compared to their flat counterparts. Weed infestation was significantly (p<0.05) higher for manual tillage and the least for tractor tillage under both seedbeds. Mean weed populations recorded for the tillage systems were: manual, 508 weeds m⁻²; bullock, 358 weeds m⁻²; tractor, 242 weeds m⁻². Bullock ridging resulted in the highest gross margin with the least obtained for manual ploughing.

Keywords: Gross margin; Infiltration; Seedbed; Sorghum; Tillage

1. Introduction

Results of tillage work carried out under the semi-arid environment in West Africa often recommended the need for some degree of tillage. However, when comparing results, it is important to take into consideration the soil type and rainfall pattern (Nicou, 1979). Chopart (1981) and Chopart et al. (1981), summarising results from extensive work carried out in Senegal, Togo and Ivory Coast, concluded that mechanical tillage has beneficial effects on structurally inactive soils. These soils are quite extensive in the semi-arid areas in West and East Africa. Consequently, generalisation of tillage for large areas with-
out due consideration of the soil type is bound to result in many errors and disappointments. Tillage is location and crop specific.

The use of animal or tractor power for deep tillage in the dry lands of West Africa has several advantages in terms of timeliness of operation, water infiltration, weed control and deeper root growth (Malek et al., 1973). Charreau (1974) estimated the land area that could be cultivated by hand hoe, one horse, a pair of oxen, and a tractor as 1, 6, 10 and 25 ha per day, respectively. Charreau (1977) concluded that deep tillage is particularly important for ferruginous tropical soils, which are prone to severe weed infestation and have a high content of fine sand. Under these conditions, ploughing proved to be the most efficient tillage practice. Comparing untied ridges and flat bed configurations in a mixed cropping system in the Guinea Savanna zone, Kumar et al. (1987) concluded that overall system productivity was marginally higher in the ridge system, but that the yield differences were not significant.

The use of machinery for ploughing has increased in recent times; however, without basic information on soil suitability, there are many constraints associated with the introduction of these machines for land preparation. As a result, soil degradation and erosion have increased in some areas in Africa (Ofori, 1995). In northern Ghana, particularly in the Upper-East Region, about 65% of the farm families own or hire draft animals. The use of animal traction is intensive and has a long history in the region dating back to the 1930s. Considering the importance of tillage and seedbed in any cropping system, research is needed to evaluate the various tillage systems and seedbed types in northern Ghana. The objective of this study is to evaluate the existing tillage systems and seedbed types, and assess their agronomic and economic advantages for increased and stable sorghum production.

2. Materials and methods

2.1. Experimental site

The experiments were conducted during the cropping seasons of 1992–1995 on the research plots of Manga Agricultural Research Station near Bawku in the Upper-East Region of Ghana, located on latitude 11°01’N and longitude 00°64’–00°16’W, with an altitude of 249 m above sea level. The soils of the experimental area are shallow, and located on gently sloping terrain of gradient 1–2%. The soils are sandy to sand loam by texture within the 0–30 cm depth and thus well to moderately well drained. They are classified as Plinthic Lixisols according to the FAO–UNESCO classification (Boateng and Ayamga, 1992). The gravel fraction is 10 g kg\(^{-1}\) with inherently low fertility status (N 0.02–0.008 g kg\(^{-1}\), organic carbon 0.28 g kg\(^{-1}\), available phosphorus 1.6–5.2 g kg\(^{-1}\)). The pH of the soils (CaCl\(_2\)) ranges from 5.0 to 5.8. The soils have been developed from parent material derived from biotite granite with intrusions of biotite gneiss. The mean annual rainfall from 1981 to 1992 is 960 mm, mostly distributed from May to September, with March and October recording 24–30 mm of rainfall. Mean annual temperature is 28.5°C. Average maximum temperatures are highest in March or April (40–45°C), while absolute minimum temperature ranges from 15 to 18°C, occurring in December and rarely in January. Climatic data during the experimental period are presented in Table 1.

2.2. Tillage and cropping experiments

The field experiment was a 3\(\times\)2 factorial, laid out in a split-plot design with four replications. The main-plot factor was tillage systems and the sub-plot factor was seedbed types. The tillage systems evaluated were: manual, bullock and tractor, and the seedbed types studied were: ridge and flat. The trial was planted in the third week of June of each cropping season. The test crop was a local sorghum cultivar “Bawku-Red” which has a maturity period of four months and is the most extensively grown sorghum in the area.

For the tractor tillage system, land was prepared using a tandem disc harrow for the main-plot, half of which was later ridged using a ridger, leaving the remaining half flat. For manual tillage system, the hand hoe was used for preparing the main plot, half of which was later ridged using the hoe. For the bullock tillage system, a bullock plough was used in preparing the main-plot, half of which was later ridged using a bullock ridger. In making ridges for the ridge seed-
beds, each implement was adjusted to a spacing of 0.75 m, as this is the standard practice. The manual ridge was like a pyramid in shape, tapering at the top, while the bullock and tractor ridges were similar in shape like a trapezium. The manual ridge was 53 cm wide at the base, 27 cm wide at the top, and 21 cm in height. The bullock ridge was 59 cm wide at the base, 30 cm wide at the top, and 19 cm in height. The tractor ridge was 76 cm wide at the base, 44 cm wide at the top, and 19 cm in height.

Sorghum seeds were sown at a rate of 4–6 seeds per stand, and later thinned to two plants per hill, two weeks after emergence. Compound fertiliser in the form of 15–15–15 at the rate of 30 kg N ha\(^{-1}\), 30 kg P ha\(^{-1}\) and 30 kg K ha\(^{-1}\), was applied exactly two weeks after sowing. Sulphate of ammonia was applied as a side-dress at the rate of 10 kg N ha\(^{-1}\) at exactly six weeks after sowing as recommended locally for sorghum. The spacing between rows in both the types of seedbeds was 0.75 m and spacing between plants was 0.30 m. Each treatment consisted of six ridges/rows with data taken from the middle four ridges or rows for planting on the flat one, leaving out the outer two ridges or rows. Weeding was done before applying the fertilisers.

2.3. Plant and weed measurements

Post-harvest data were taken on fresh and dry head weights, plant count at harvest, fresh straw weight, and head length. Plants from the middle four ridges or rows were harvested for post-harvest analysis. Weed samples were taken from a 1 m\(^2\) area using a measuring tape at three random sites within the net plot area and the average number of weeds taken. This was done prior to each weeding and the mean taken for analysis. Plant measurements were statistically analysed using ANOVA techniques, and mean separation using least significant difference (LSD).

2.4. Economic analysis

For economic analysis, data were collected on labour input for the various operations under each tillage, cost of land preparation, and other operations for each tillage system. Cost of labour as well as the prices of sorghum and dry straw were also utilised. The total labour input was calculated in mandays (Md) as the sum for labour involved in all the operations for each tillage system. Costs were also taken to embody the total cost involved in land preparation and labour for all the other operations for each tillage system. In arriving at the gross margins, the straw was also taken into account since it is sold as fuel wood. This together with the value of the grain constituted the gross income.

3. Results and discussion

3.1. Weed infestation

There was a significant (p<0.05) tillage effect on weed infestation in sorghum for all the years when the experiment was conducted (Table 2). In 1992, the highest weed infestation was recorded for manual flat with tractor ridge recording the least. Manual flat and ridge recorded a significantly (p<0.05) higher weed.
infestation compared to their bullock and tractor counterparts. Similarly, bullock flat and ridge recorded a significantly higher weed infestation compared to their tractor counterparts. In 1993, manual flat supported the highest weed infestation and tractor ridge the least. Tractor ridge recorded a significantly ($p<0.05$) lower weed infestation compared to the other seedbeds for all tillage systems. Tractor flat supported a significantly ($p<0.05$) lower weed infestation compared to manual and bullock seedbeds. Bullock seedbeds also recorded a significantly ($p<0.05$) lower weed pressure than their manual counterparts. In 1994 and 1995, trends were the same as for the previous years.

The higher weed infestation recorded for manual tillage system compared to bullock and tractor tillage systems might be attributed to the rather superficial effect of the hoe resulting in poor weed control during land preparation. It is often argued that the main effect of the hoe on the soil is superficial (Ofori, 1995).

Unger (1984), and Nitant and Singh (1995) reported that deeper ploughing allows maximum absorption of rainwater and reduces weed populations at the initial stage of crop growth, which ultimately increased crop yields.

### 3.2. Sorghum grain yield

There was a significant ($p<0.05$) year effect on sorghum grain yield (Table 3). The highest sorghum grain yield was obtained in 1994, while the lowest was recorded in 1995. This is probably due to the higher rainfall and its more optimum distribution throughout the growing period (Table 1). Lower grain yields in 1995 was attributed to an outbreak of sorghum shoot fly, which resulted in many chuffy sorghum heads at harvest in 1995.

Tillage effect on grain and straw yields of sorghum was significant ($p<0.05$) according to the analysis of variance table. Mean grain yield (kg ha$^{-1}$) recorded under the different tillage systems from 1992 to 1995 are: manual, 459; bullock, 701; tractor, 708. Bullock and tractor tillage systems consistently recorded higher grain yields compared to their manual counterparts for the experimental period.

Sowing sorghum on ridges for all tillage systems resulted in superior grain yields compared to sowing on the flat (Table 3). Mean increase in grain yield recorded by ridges over flat seedbeds from 1992 to 1995 are: manual, 175%; bullock, 54%; tractor, 54%.

The superior sorghum grain and straw yields obtained for bullock and tractor tillage systems might

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<td>Flat</td>
<td>Ridge</td>
<td>Flat</td>
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<tr>
<td>Manual</td>
<td>193</td>
<td>333</td>
<td>130</td>
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<tr>
<td>Bullock</td>
<td>211</td>
<td>466</td>
<td>241</td>
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<td>Tractor</td>
<td>272</td>
<td>350</td>
<td>296</td>
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<td>LSD (0.05)</td>
<td>87</td>
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probably be attributed to the better weed control achieved by these tillage systems compared to manual tillage. Bullock and tractor tillage systems work the soil deeper than manual, thereby resulting in a better weed control as reflected in the lower weed populations obtained for these tillage systems. Olufayo et al. (1994) reported a yield increase of 40% of sorghum grain due to ploughing compared to hand hoeing.

The volume of soil accumulated under ridges is relatively larger, thereby concentrating plant nutrients for better plant growth and development as indicated by the results obtained in this study. The results reported here also confirm previous works carried out by Nicou et al. (1990).

Kumar et al. (1987) concluded that overall system productivity was marginal in the ridge system, but that the yield differences were not significant. The use of animal or tractor power for deep tillage in the dry lands has several advantages in terms of timeliness of operations, water infiltration, weed control and deeper crop root growth (Malek et al., 1973).

3.3. Sorghum straw yield

The highest sorghum straw yield for the experimental period was recorded in 1993 for bullock ridging and the lowest for manual flat in 1995 (Table 4). In 1992, bullock ridges recorded the highest straw yield with manual flat recording the lowest.

Mean straw yields (Mg ha\(^{-1}\)), recorded by the tillage systems over the experimental period were: manual, 9.2; bullock, 12.2; tractor, 10.7. The highest straw yield was recorded in 1993, while the lowest was obtained in 1995.

Mean increase in straw yields recorded by ridges over flat seedbed for the tillage system were: manual, 119%; bullock, 69%; tractor, 52%.

The superior straw yields obtained for bullock and tractor tillage systems over manual tillage and ridge seedbeds over flat ones could similarly be attributed to the earlier explanations given above for sorghum grain yields.

3.4. Economic analysis

3.4.1. Labour input

The highest labour input resulted from manual ridging and the least from tractor ploughing (Table 5). The labour input for bullock ploughing and bullock ridging was similar. In comparison, the labour input for manual ploughing and ridging was higher than the other tillage systems. This is due to the drudgery associated with manual operations, which are time and energy consuming. Ridging also resulted in higher labour input than flat.

3.4.2. Costs

Tractor ridging resulted in the highest cost, while bullock ploughing resulted in the least (Table 5). In tractor ridging, the field has to be ploughed before ridging and this coupled with the high rates charged for tractor services resulted in the highest cost. Tractor ploughing also gave a higher cost than manual and bullock tillage systems as a result of the high costs for tractor services. The results also indicate that ridge tillage systems resulted in higher costs than ploughed tillage methods. This is due to the higher labour input involved in ridge tillage methods.

3.4.3. Gross margin

The benefits are the gross margins resulting from the different tillage systems. Bullock ridging was found to have the highest gross margin with the least

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<td></td>
<td>Flat</td>
<td>Ridge</td>
<td>Flat</td>
<td>Ridge</td>
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coming from manual ploughing. In all the three tillage systems, ridge seedbeds gave higher gross margins than flat seedbeds. Although the gross income for tractor ridging was the highest, bullock ridging still resulted in the highest gross margin. This is due to the high rates charged for tractor services and the fact that in the case of tractor, the land has to be prepared before being ridged. For the small-scale farmer, bullock ridging looks more promising since it is more affordable than the tractor operations and the drudgery associated with it is also lesser than that of manual ploughing.

4. Conclusions

In this study, bullock tillage system and ridge seedbeds gave the highest grain and straw yields, and gave the highest economic returns. These results indicate that sowing on ridges is superior to sowing on the flat. Bullock tillage system gave best returns compared to tractor and manual tillage systems for all the years when the experiment was conducted from both agronomic and economic considerations.

Bullock tillage also attracts less operational charges as compared to tractor tillage and involves less drudgery compared to manual tillage operations. Considering the fact that the Upper-East Region of Ghana has about 20% of the country’s livestock population, bullock tillage system and ridge seedbeds can easily be adopted for increased, stable and economic crop production.

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