Maize Response to Different Ploughing Systems

Asim Osman Elzubeir

ABSTRACT

A field experiment to investigate the effect of some ploughing systems on maize (Zea mays L.) growth and yield was carried out during two summer seasons, 2006 and 2007, at Dongola area, Northern State (Sudan). The study investigated ploughing practices were disc ploughing (20 cm depth) followed by disc harrowing and levelling, chisel ploughing (30 cm depth) followed by disc harrowing and levelling, and no-ploughing. Before the application of the treatments, the land was freed from weeds and crop residues using hand hoe and axe except the no-ploughing plots in which resulted a high number of weeds. Ploughing practices had significant effect (P ≤ 0.05) on plant height 30 and 45 days after sowing, plant population, number of seeds/cob and stover yield. Ploughing practices had also significant effects (P ≤ 0.01) on leaf area index, cob length, grain yield, and field water use efficiency. Disc ploughing treatment gave the highest values of all mentioned parameters in both seasons.

Keywords: Zea mays L., Ploughing practices, Land preparation systems, Northern State, Sudan.

INTRODUCTION

Soil ploughing is one of the fundamental agrotechnical operations in agriculture because of its influence on soil properties, environment and crop production in general. It is a major factor in determining the success or failure of crop production.

A wide range of ploughing implements, which suit various soils, climates and socio-economic conditions, is available under a wide range of conditions. Each of which has specific features.

According to Hussein and Munir (1986) disc plough is the most widely used primary implement because it converts the soil and bury weeds at a depth ranging 30-46 cm.

Chisel plough is a plough with maximum loosening effect on soil, but with minimum pulverizing, mixing and inverting effects. It has a workable depth of 46-76 cm, and generally suits all types of soils, especially the light ones that are free of stones and similar obstructing objects.

Disc harrows are the most popular harrow groups. They are very effective clod crushers and surface smoothing implements. Yusuf and Asota (1998) reported that workable depth range of 10-15 cm. Plain discs are generally used, while notched discs are preferred when more cutting action is required.

In Sudan disc implements are more popular where as chisel implements are rarely used as stated by Ahmed (2000). In rain-fed sector the wide level disc is the main ploughing tool. In the irrigated sector, disc ploughs and disc harrows are also the main ploughing tools used for all crops. Offset disc harrow is the most commonly used among harrows in both irrigated and rain-fed agriculture.

The research results from any one soil and climate situation cannot be generalized to areas that differ in soil and/or climate, and special attention should be paid to...
the specific, crop, soil and climate in ploughing research.

Recently, there has been an increasing interest in developing maize (*Zea mays* L.) production in Sudan. But still, maize has no defined standard ploughing system especially in the Northern State -Sudan. Therefore, this study was conducted at Dongola area-Northern State to determine the most appropriate ploughing practice for maize production in the area. The sustainability of ploughing practices were evaluated in terms of their effect on crop growth and yield.

**MATERIALS AND METHODS**

The experiment was carried out during two summer seasons; 2006 and 2007, at Dongola town, Northern State- Sudan (latitude 19°10' N, longitude 30°29' E and altitude 228 m). The climate of the locality is desert (Adam, 2002); with extremely hot summer in which temperature ranges between 25° C and 42° C, high bright sunshine duration for more than 10 hours and low relative humidity of less than 20% (Sudan Meteorological Authority, 2006). The textural class of the soil is a loamy with 315 g sand, 465 g silt and 220 g clay per kg of soil.

The experiment design was split-split-plot with three replications. The treatments were part of other experiments; the main plots were allotted for the irrigation water amount treatments were 100% (*W*₁), 75% (*W*₂) and 50% (*W*₃) of crop evapotranspiration as determined by FAO Penman-Monteith equation, the strip-plots for ploughing treatments, and whereas the irrigation interval treatments were 10 (*I*_₁), 15 (*I*_₂) and 20 (*I*_₃) days intervals distributed randomly in the subplots of each strip-plot. Three meters wide areas were left between blocks as buffer zones. The area of each subplot (experimental unit) was 24 m² (4 × 6 m). The experimental units were 1.5 m apart from each other, with a total number of 27 experimental units. Figure 1 shows the layout of the experimental field for the first replicate. The experimental site had previously been used for producing wheat and broad bean for several winter seasons.

Three different ploughing treatments were used as shown in Table 1. The depth of ploughing was measured and checked for each treatment during the operations. The implements used for ploughing operations were standard disc plough (with three bottoms, 60 cm width), mounted chisel plough (with seven shovel-double point blades) and offset disc harrow (with 55 cm blade width). The land after the site had been selected and before the application of the treatments, was freed from weeds and crop residues using hand hoe and axe except the no-ploughing plots.

The standard cultural practices recommended by the Agricultural Research and Technology Corporation in Sudan; other than treatments, were followed throughout the growing seasons. Seeds of an open pollinated Egyptian yellow cultivar of maize Mugtama-45 were used in the study.

A seed rate of 17.9 kg ha⁻¹ was used. Three seeds per hole were sown by hand on the row using hand hoe on the 22nd of May for the two seasons. Row-to-row and plant-to-plant spacing were kept at 80 and 30 cm, respectively. The inner three rows in each subplot were used to assess the yield and its components, while the outer two rows were used for destructive sampling.

Urea (46% N) at a rate of 86 kg N ha⁻¹ per season was broadcasted in two equal doses; the first dose was applied after thinning and before the second irrigation and the second dose was applied with the third irrigation. Also, triple super phosphate (48% P₂O₅) was used at a rate of 43 kg P₂O₅ ha⁻¹ per season at sowing.

The plants were thinned to one plant per hole 20 days from sowing after attaining good establishment. The first weeding was carried out using hand hoe three weeks after sowing whereas the second weeding was done two weeks
later. No herbicide and insecticides were used in the experiments.

The first two irrigations were applied according to the field capacity of the soil to fill the root zone and, thereafter, the application of irrigation water amounts and intervals treatments was started at the third irrigation. There was no rainfall during the growing season for the two seasons. The method of irrigation used was the basin irrigation and the source of water supply for farm irrigation system was River Nile.

Harvest started when signs of maturity as mentioned by Abakora (1997) were observed (development of black layer on the grain as an indication of physiological maturity, brown husk, complete yellowing of leaves and ears and partial shedding of leaves). The crop was harvested on August 25th for both seasons.

Dry bulk density of the soil was determined before ploughing operations in both seasons using the clod method, as described by Black et al. (1965). Also, the determination of water content of soil (% w.b.) before ploughing operations was done in both seasons. No chemical analysis of the soil was done in the given experiment.

Dry matter accumulation was taken after 30 days of sowing. Three plants per plot were taken, roots were detached, and then the shoots were dried in an oven at 55°C for 96 hours until the sample maintained a constant weight. Then the samples were weighted to determine dry matter (g/plant).

Ten random plants per plot from the inner three rows were selected and tagged to measure their height (cm) after 30, 45, 60 and 75 days of sowing, each season. Leaf area index (LAI) after 75 days of sowing was determined using the formula as follows (Babiker, 1999):

\[
LAI = \text{max length} \times \text{max width} \times \frac{\text{no. of leaves per plant} \times 0.75 \times \text{no. of plants per m}^2}{\text{no. of plants per linear m}}
\]

The selected ten plants were used. The maximum length and maximum width of the fourth leaf (from the top) of each plant was measured and the leaf area index was calculated relatively for each treatment.

Plant population (no. of plants/ha) was determined for both seasons from each plot at harvest time. The following formula was used (Mohamed, 2004):

\[
\text{no. of plants} / m^2 = \frac{\text{no. of plants per linear m}}{0.80}
\]

For both seasons at harvest time, a quadrate of one square meter was tossed (three times) at the inner three rows on each plot. The plants inside the quadrant were cut at the ground level, tied in bundles and brought to a store and left to dry. Some yield and yield component parameters were determined; those included: cob length, number of rows/cob, number of seeds/cob, and 100-seed weight and grain yield per unit area.

After harvesting of cobs, stover was left to dry in the field for two weeks and its weight was measured using a spring balance. Then the weight of stover in tons ha\(^{-1}\) was determined.

Harvest index (HI) was obtained using the following equation (Babiker, 1999):

\[
\text{Harvest index} = \frac{\text{grain yield (economic yield)}}{\text{biological yield}}
\]

Also, field water use efficiency (kg m\(^{-3}\)) was determined as follows (Michael, 2001):

\[
FWUE = \frac{Y}{WR}
\]

where:

\begin{align*}
FWUE & = \text{field water use efficiency, kg m}^3. \\
Y & = \text{grain yield, kg ha}^{-1}. \\
WR & = \text{total water applied to the field in the season, m}^3 \text{ ha}^{-1}.
\end{align*}
The results for the experiment were means of the ploughing practice treatments for each individual season. Analysis of variance appropriate for the split-split plot design was applied (Gomez and Gomez, 1984). Mean separation was done using Duncan's Multiple Range Test (DMRT) for different treatments.

RESULTS AND DISCUSSION

Table 2 shows the results of water content of soil (\% w.b.) and soil dry bulk density (g cm\(^{-3}\)) of the experimental site before ploughing for increments of 25 cm down the soil profile for both seasons. In both seasons the value of water content of soil (\% w.b.) at different soil depths followed the same trend; it was noticed that the soil water content decreased with soil depth. Also, the results of soil dry bulk density agreed with the results obtained by Chi et al. (1993) confirming that the soil dry bulk density of the experimental site was within the limits for agricultural soils (0.9-1.8 g cm\(^{-3}\)).

Table 3 presents plant dry mass (g/plant) after 30 days of sowing, plant height after 30, 45, 60 and 75 days of sowing and leaf area index after 75 days of sowing for both seasons in the three treatments.

The results showed that there were no significant differences (P ≤ 0.05) due to ploughing between treatments when plant dry mass was checked early in the season. This could be attributed to the fact that the effect of ploughing practices on plant attributes needs more time to be observed. These results were in the same line with the findings of Ahmed (2000) and Elnazif (2000). The plant dry mass values in the first season were greater than those of the second season. The variation in temperature resulted in different emergence times, which may have led to variation in plant dry mass between the two seasons. Disc ploughing treatment resulted in the highest plant dry mass of 7.9 and 6.4 g/plant in the first and the second seasons, respectively.

Ploughing treatments showed significant differences (P ≤ 0.05) after 30 days of sowing in plant height in both seasons. The ploughing treatments recorded the tallest plant heights than no-ploughing treatment in both seasons. These results were similar to the findings of Elnazif (2000). On the other hand, ploughing had a high significant effect (P ≤ 0.01) on plant height in the two seasons, except after 60 and 75 days of sowing in the first season where the effect was not significant (P ≤ 0.05). The disc ploughing treatment resulted in consistently the tallest plants throughout the different stages of growth as compared to the other ploughing treatments. Also, it was observed that the no-ploughing treatment recorded the shortest plants in both seasons. The greatest plant height values of 201 and 205 cm were recorded under disc ploughing treatment after 75 days of sowing for the first and the second seasons, respectively.

Leaf area index was significantly (P ≤ 0.01) affected by ploughing in both seasons. The results observed that the ploughing treatments gave higher values of leaf area index than no-ploughing treatment in both seasons. The disc ploughing treatment recorded the highest values of leaf area index than the other two ploughing treatments in both seasons.

Table 4 shows the mean effect of ploughing practices on plant population and yield and some yield components at harvest on both seasons.

There was a significant effect (P ≤ 0.05) on plant population due to ploughing practices. It is evident that no-ploughing treatment was inferior to two ploughing practices in both seasons. The plants in ploughing treatments were capable to survive water stress relative to their rooting ability to explore the soil i.e. those in ploughing treated soil are better than those grown in no-ploughing.

The mean cob length in both seasons was significantly (P ≤ 0.01) affected by ploughing treatments; this was in the same line with the findings of Elnazif (2000). The disc ploughing treatment produced more cob length than the other
ploughing treatment in both seasons.

Ploughing treatments showed significant differences \((P \leq 0.05)\) when number of rows/cob was checked in the second season, while they failed to show any significant differences in the first season.

The number of seeds/cob at harvest in both seasons had significant effect \((P \leq 0.05)\) among ploughing treatments. The disc ploughing treatment produced greater number of seeds/cob than the mean of the other two treatments in both seasons.

The results showed no significant differences \((P \leq 0.05)\) on 100-seed weight due to ploughing treatments in both seasons. These results agreed with the findings of Mohamed (1993) and Ahmed (2000).

The analysis of variance for both seasons showed significant differences on grain yield \((P \leq 0.01)\) and stover yield \((P \leq 0.05)\) due to ploughing treatments. As reported by NATESC (2003) ploughing depth of 20-25 cm is necessary for the high-yield maize. The greater grain yield and stover yield were obtained under disc ploughing treatment in both seasons.

It is evident that no-ploughing was inferior to all other ploughing treatments on the tested parameters in both seasons. This because no-ploughing produces undesirable surface condition characterized by high bulk density, high number of weeds due to not controlling of weeds before sowing, and low water infiltration as mentioned by Lindstorm and Onstad (1984).

Ploughing practices had highly significant effect \((P \leq 0.01)\) on harvest index in one out of the two seasons. The disc ploughing treatment obtained the higher values of harvest index in both seasons than the other ploughing treatments.

It was evident that field water use efficiency was significantly affected \((P \leq 0.01)\) by ploughing practices in both seasons. It was recorded that the highest values of field water use efficiency of 0.601 and 0.883 kg m\(^{-3}\) were obtained under disc ploughing treatment, whereas the lowest values of 0.371 and 0.491 kg m\(^{-3}\) were recorded under no-ploughing treatment in the first and the second seasons, respectively. This may be due to the high weed infestation and poor soil structure prevailed under no-ploughing which did not encourage the soil to hold moisture and hence compacted soil was not suitable for plant growth to produce more grains.

CONCLUSIONS

The results of the study indicate that the disc ploughing treatment is more effective for maize production under Dongola area conditions in Sudan, since it could improve weed control and the vegetative and yield components.

ACKNOWLEDGEMENTS

An immense debt of gratitude is owned to Dr. Abdelmoniem Elamin Mohamed (Faculty of Agriculture, University of Khartoum, Khartoum North, Sudan) for his unlimited help and advice throughout the progress of my research.
Table 1. Ploughing treatments and operations.

<table>
<thead>
<tr>
<th>Ploughing treatments</th>
<th>Ploughing operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>Disc ploughing (20 cm)</td>
</tr>
<tr>
<td></td>
<td>Disc harrowing</td>
</tr>
<tr>
<td></td>
<td>Levelling</td>
</tr>
<tr>
<td>T₂</td>
<td>Chisel ploughing (30 cm)</td>
</tr>
<tr>
<td></td>
<td>Disc harrowing</td>
</tr>
<tr>
<td></td>
<td>Levelling</td>
</tr>
<tr>
<td>T₃*</td>
<td>No-ploughing</td>
</tr>
</tbody>
</table>

* No-ploughing: the seeds were sown directly into the soil that was left after harvest of the previous crop without soil disturbance.

Table 2. Water content of soil (% w.b.) and dry bulk density (g cm⁻³) at different soil depths (cm) of the experimental site before ploughing for both seasons.

<table>
<thead>
<tr>
<th>Soil depths (cm)</th>
<th>Water content of soil (% w.b.)</th>
<th>Soil dry bulk density (g cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>0-25</td>
<td>20.0</td>
<td>20.3</td>
</tr>
<tr>
<td>25-50</td>
<td>18.7</td>
<td>19.3</td>
</tr>
<tr>
<td>Means</td>
<td>19.4</td>
<td>19.8</td>
</tr>
</tbody>
</table>

Table 3. The mean effect of ploughing practices on plant dry mass, plant height and leaf area index for both seasons.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Season 2006</th>
<th>Season 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant dry mass (g/plant) after 30 days of sowing</td>
<td>T₁ 7.9a; T₂ 6.7a; T₃ 5.3a</td>
<td>T₁ 6.4a; T₂ 5.5a; T₃ 2.9a</td>
</tr>
<tr>
<td>Plant height (cm) after 30 days of sowing</td>
<td>T₁ 65a; T₂ 63a; T₃ 54b</td>
<td>T₁ 64a; T₂ 58a; T₃ 39b</td>
</tr>
<tr>
<td>Plant height (cm) after 45 days of sowing</td>
<td>T₁ 159a; T₂ 136b; T₃ 119c</td>
<td>T₁ 138a; T₂ 125b; T₃ 123b</td>
</tr>
<tr>
<td>Plant height (cm) after 60 days of sowing</td>
<td>T₁ 187a; T₂ 171b; T₃ 160b</td>
<td>T₁ 191a; T₂ 179b; T₃ 164c</td>
</tr>
<tr>
<td>Plant height (cm) after 75 days of sowing</td>
<td>T₁ 201a; T₂ 187b; T₃ 172c</td>
<td>T₁ 205a; T₂ 190b; T₃ 180c</td>
</tr>
<tr>
<td>Leaf area index after 75 days of sowing</td>
<td>T₁ 2.90a; T₂ 2.60b; T₃ 2.28c</td>
<td>T₁ 2.24a; T₂ 1.89b; T₃ 1.54c</td>
</tr>
</tbody>
</table>

Means followed by the same letter(s) in a row are not significantly different at P ≤ 0.05.

Abbreviations of ploughing treatments as explained in Table 1.
Table 4. The mean effect of ploughing practices on maize yield and yield components for both seasons.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Season 2006</th>
<th>Season 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing treatments</td>
<td>T₁</td>
<td>T₂</td>
</tr>
<tr>
<td>Plant population (no. of plants/ha)</td>
<td>38 920*</td>
<td>38 812a</td>
</tr>
<tr>
<td>Cob length (cm)</td>
<td>17**</td>
<td>16a</td>
</tr>
<tr>
<td>Number of rows/cob</td>
<td>14**</td>
<td>14a</td>
</tr>
<tr>
<td>Number of seeds/cob</td>
<td>288**</td>
<td>249a,b</td>
</tr>
<tr>
<td>100- seed weight (g)</td>
<td>21**</td>
<td>21a</td>
</tr>
<tr>
<td>Grain yield (kg ha⁻¹)</td>
<td>4 728**</td>
<td>3 934a</td>
</tr>
<tr>
<td>Stover yield (tons ha⁻¹)</td>
<td>4.7**</td>
<td>4.3a,b</td>
</tr>
<tr>
<td>Harvest index</td>
<td>0.32**</td>
<td>0.29a</td>
</tr>
<tr>
<td>Field water use efficiency (kg m⁻³)</td>
<td>0.60**</td>
<td>0.50a</td>
</tr>
</tbody>
</table>

Mean followed by the same letter(s) in a row are not significantly different at P ≤ 0.05.

*, ** Means are significantly different at P ≤ 0.05 and P ≤ 0.01, respectively.

Abbreviations of ploughing treatments as explained in Table 1.
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الاستجابة محصول الذرة الشامية لتنظيم حرارة مختلفة

عاصم عثمان الزبير

ملخص

أجريت تجربة حقلية بغرض دراسة تأثير بعض نماذج الحرارة على نمو وإنتاج محصول الذرة الشامية (Zea mays L.) في مواسمين صيفيين (2006 و2007) بمنطقة دنقلا-الولاية الشمالية (السودان). طرق الحرارة التي تم تطبيقها هي الحرارة القرصية (عمق 20 سم) ثم التبعد بالمشط القرصي والتسطيح، الحرارة الحفرية (عمق 30 سم) ثم التتبع بالمشط القرصي والتسطيح، ومعاملة عدم الحرارة. قبل تطبيق المعاملات تم تجهيز الأرض من الحشائش وفراش المحاصيل باستخدام الطورية والقفس بعد أحيان استخدام عن طريق الطرق المقترحة.之后 أجريت معاملات الحرارة تأثيراً معيكاً (0.05 ≤ P < 0.01) على طول النبات في 30 و40 يوماً بعد الزراعة. تأثيرات مشابهة تأثير الحرارة على الكثافة الزيتية، عدد البذور بالكوز، وإنتاجية الطف. كما أن معاملات الحرارة تأثيراً معيكاً (0.01 ≤ P < 0.05) على طول الكوز، إنتاجية الحبوب، وكفاءة الاستخدام المائي الحالي. سيجلب استخدام الحرارة على القيم العامل المذكور في كل المواسم.

الكلمات الدالة: الكالما الذين الدالة: ملاحظة Cargo L. تجربة استخدام الحرارة، نظم تجهيز الأرض، الولاية الشمالية/السودان.