EFFECT OF TILLAGE ON PERFORMANCE OF WINTER MAIZE IN NORTHERN INDIA

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Abstract

The performance of five maize genotypes grown using resource conserving technologies (no till (NT) on the flat and on permanent beds) was compared with conventional tillage (CT) in terms of economic yield, irrigation water productivity, profitability and soil properties during winter 2004-05 on a sandy loam soil in northern India. Yields of the highest yielding varieties were similar on NT permanent beds and CT. There was an average 4% increase in grain yield and a 20% increase in profitability with NT permanent beds compared with CT, and 16 and 24% increases in yield and profitability on NT permanent beds compared with NT on the flat. Irrigation water productivity (kg grain m⁻³ water) in permanent beds was 42 and 35% higher than in CT and NT on the flat, respectively. Among the genotypes, the performance, in terms of economic yield (t/ha), water productivity (kg grain m⁻³ water) and profitability (US$/ha), of Bio-9681 was best (9.4, 2.3 and 814) followed by ST-2324 (9.3, 2.3 and 804) and HQPM-1 (8.8, 2.1 and 748), respectively. The soil physical properties (bulk density, aggregate size distribution and cone resistance) after one year of experimentation were improved in the NT systems compared to CT.

Introduction

Maize (Zea mays L.) is one of the major cereal crops with wide adaptability to diverse agro-climatic conditions around the world. It is the third most important crop in India and occupies 6.6 million hectares with an average productivity of about 2.2 Mg ha⁻¹ (t/ha) compared to the world average of 4.4 Mg ha⁻¹. Traditionally, maize is grown either in rows or by random broadcasting, after tillage to a suitable tilth. The traditional practice of broadcasting the seed has limitations such as inconvenient input management, improper plant geometry, and uneven plant population resulting in inefficient utilization of space and plant competition leading to low productivity and input efficiency.

Tillage practices contribute greatly to the labour cost in any crop production system resulting in lower economic returns (Labios et al. 1999, Jat et al. 2005a). Farmers in Indo-Gangetic Plains (IGP) of India are yet to grow maize under a double no-till system either on the flat or raised beds, although these are common practices in many western countries (Gupta et al. 2002). Reduced or conservation tillage is gaining more attention in recent years with increasing concerns about natural resource degradation. Intensive tillage systems result in increased soil compaction and decreased soil organic matter (Gangwar et al. 2005) and biodiversity (Biamah et al. 2000). Sub-soil compaction due to repeated tillage leads to reduced water and nutrient use efficiency (Ishaq et al. 2001). Hence, conservation tillage practices, such as zero and minimum tillage, may be introduced to offset the production cost and other constraints associated with environment and socio-economic conditions. Raised bed planting of maize helps achieve good plant establishment, increases input efficiency, increases yields, and opens up avenues for a double no-till system.

Adoption of no-till helps in timeliness of seeding each crop in the rotation, and hence leads to increase in productivity. Paliwal (2003) demonstrated how a successful zero-till maize crop could be grown using various best management practices. Various on-farm participatory trials revealed little or no difference in the yield of zero-till maize when compared to the best managed conventional crops (Gupta et al. 2002). They further reported that despite similar yields, the economic advantage with zero-till maize to the farmers was USD 50 ha⁻¹ due to saving in the costs of tillage and the first irrigation. Similarly, Srivastava et al. (2005) reported that the performance of QPM hybrids on a sandy loam soil was better under FIRB and NT planting compared to CT with respect to yield, water productivity and profitability. The objective of the work reported here was to compare the performance of winter maize with NT on permanent beds and flat layouts with CT maize.
Materials and methods

Experimental site

The experimental site was located at the Project Directorate of Cropping Systems Research, Modipuram (29° 42' N latitude, 77° 46' E longitude and at an elevation of 237 m above mean sea level), India. A site comparing no till flat and permanent bed layouts with conventionally tilled flats was developed in collaboration with CIMMYT-India and the Rice-Wheat Consortium of the IGP. The experimental site has a semi-arid sub-tropical climate with average annual rainfall of 863 mm. The soil is a sandy loam (*Typic Ustochrept*) with slight alkaline reaction (pH 8.1), low in organic carbon (0.40%), available N (135 kg ha⁻¹) and medium in available P (13 kg ha⁻¹) and K (165 kg ha⁻¹). Wheat was sown in winter 2003-04, followed by monsoon maize in 2004, and winter maize in 2004-05. This paper reports on the performance of the winter maize crop.

Several soil physical properties were determined before establishment of the monsoon maize crop. The values of the bulk density (BD) in the 0-15 and 15-30 cm soil layers were 1.51 and 1.70 Mg m⁻³, 64.7% of the soil aggregates were larger than >0.25 mm, and the mean weight diameter (MWD) of aggregates in the 0-15 cm soil layer was 2.50 mm.

The total rainfall received during the winter maize season was 63 mm with 8 effective rainy days distributed over 5 weeks (Figure 1).

![Figure 1. Weather conditions during the experimental period](image)

Experimental techniques

Treatments and seeding techniques

The experimental design was a split-plot with three tillage/crop establishment methods, referred to as "tillage" treatments, as the main plots in three replicates. The tillage treatments were: no-till on the flat (NT), no-till permanent raised bed (FIRB) and conventional tillage on the flat (CT) in main plots. The beds were 15 cm high, with flat tops about 30 cm wide, and with a spacing (mid-furrow to mid-furrow) of 67 cm. There were five genotypes (HQPM-1, Shaktiman-4, Bio-9681, ST-2324, and HM-5) in sub-plots. The sub-plot size was 50 m². The NT and CT treatments were planted using the zero till drill, while the raised beds were planting using a bed planter. Row spacing in all tillage treatments was 67 cm, with the row in the centre of the beds. A seed rate of 12 kg ha⁻¹ was used.
Input application

The crop was maintained with the same nutrient inputs in all the treatments. The recommended level of nutrients (120, 26, 40 kg ha\(^{-1}\) N, P and K, respectively) and irrigation scheduling (as per the critical growth stage scheduling criteria) were applied to all treatments. The quantity of water applied at each irrigation to each subplot was measured using a Parshall flume, and the grain productivity per unit of irrigation water was expressed as irrigation water productivity (kg grain m\(^{-3}\) water).

Sampling techniques

The soil was sampled before sowing of the monsoon maize crop and after harvest of the winter maize crop to determine bulk density (Mg m\(^{-3}\)), aggregate size distribution and mean weight diameter (MWD) of aggregates (mm), and cone resistance (MPa). For bulk density, soil samples were taken from each main-plot at 0-15 and 15-30 cm soil depths using a core sampler and were placed in moisture boxes and oven dried at 105 °C for 48 hours. The oven-dried weights of the samples were recorded using an electronic top pan balance and bulk density was computed and expressed as Mg m\(^{-3}\). A cone penetrometer (steady system) was used to determine soil strength (cone resistance) under each of the main-plots at 5-cm intervals from 0 to 45 cm soil depth. For measurements on soil aggregates, large clods were taken from the 0-15 cm soil layer and sun dried. The clods were gently broken by hand into small pieces and passed through the 8 mm mesh sieve in a Yoder type wet sieve shaker (Van Bavel, 1953). The mean weight diameter (MWD) was determined as per the method of Van Bavel (1949).

Grain yield was determined from the net plot area after removing the border rows in each sub-plot. The plots were harvested manually and the cobs were detached from the plants, shelled and grain yield was determined after sun drying and converted to kg ha\(^{-1}\).

Statistical analysis

The data were analyzed statistically by Fishers’ analysis of variance technique and the LSD (least significant difference) test was used to compare the treatment means (Cochran and Cox, 1957). The LSD was computed as: \[ \text{LSD} = (\bar{O}^{2}V_{e}^{-1}) \times t_{\alpha/2} \] where \( V_{e} \) is the error variance, \( r \) is the number of replications of the factor for which LSD is being calculated, \( t_{\alpha/2} \) the table value of ‘t’ at 5% level of significance for the error degrees of freedom.

Results and discussion

Crop productivity

There was a consistent trend for highest yield on the beds and lowest yield on the NT flats for all varieties, and for highest yields with Bio-9681 and ST-2324 and lowest yield with HM-5 (Table 1). There was a significant interaction between tillage treatment and variety. Yields of all the hybrids were significantly higher on beds and CT flats compared to NT flats, except for similar yields of HM-5 in CT and NT. Yields of the highest yielding varieties (ST-2324, Bio-9681 and HQPM-1) were similar on the beds and CT flats for respective varieties. On the beds and CT flats, ST-2324 outyielded all other varieties, followed by Bio-9681, whereas Bio-9681 had the highest yield on the NT flats, followed by HQPM-1. Yield of the poorest yielding variety, HM-5, was significantly higher on the beds than on the CT and NT flats, but the differences were small.

Table 1. Grain yield of maize genotypes under double no-till practices

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>No-till flat (NT)</th>
<th>Conventional till (CT)</th>
<th>Permanent beds (FIRB)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQPM-1</td>
<td></td>
<td>8022</td>
<td>9145</td>
<td>9330</td>
<td>8832</td>
</tr>
<tr>
<td>Shaktiman-4</td>
<td></td>
<td>7039</td>
<td>7434</td>
<td>8390</td>
<td>7621</td>
</tr>
<tr>
<td>HM-5</td>
<td></td>
<td>5733</td>
<td>5886</td>
<td>6122</td>
<td>5914</td>
</tr>
<tr>
<td>ST-2324</td>
<td></td>
<td>7831</td>
<td>9953</td>
<td>10068</td>
<td>9284</td>
</tr>
<tr>
<td>Bio-9681</td>
<td></td>
<td>8983</td>
<td>9500</td>
<td>9629</td>
<td>9371</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>7522</td>
<td>8384</td>
<td>8708</td>
<td></td>
</tr>
</tbody>
</table>

LSD (P=0.05) Tillage (T) = 110, Genotypes (G) = 106, Interaction (T*G) = 211
Irrigation water productivity

The beds had significantly higher irrigation water productivity compared to CT due to lower irrigation application, and than NT due to both higher yield and lower irrigation water application (Jat et al. 2005b). Mean irrigation water productivity (IWP) of maize was 2.7 kg grain m\(^{-3}\) (t/ML) followed by NT (2.0 kg grain m\(^{-3}\)) and CT (1.9 kg grain m\(^{-3}\)) (Table 2). Mean IWP of Bio-9681 and ST-2324 (2.3) was significantly higher than other Shaktiman-4 and ST-2324. Further, the (non-significant) G X T interaction with respect to IWP suggested that Bio-9681 was better (2.4) under NT but that ST-2324 performed best both under FIRB (3.1) and CT (2.2).

Table 2. Irrigation water productivity of maize genotypes under double no-till practices

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>No-till flat (NT)</th>
<th>Conventional till (CT)</th>
<th>Permanent beds (FIRB)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQPM-1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Shaktiman-4</td>
<td>1.9</td>
<td>1.7</td>
<td>2.6</td>
<td>1.8</td>
</tr>
<tr>
<td>HM-5</td>
<td>1.5</td>
<td>1.3</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>ST-2324</td>
<td>2.1</td>
<td>2.2</td>
<td>3.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Bio-9681</td>
<td>2.4</td>
<td>2.1</td>
<td>3.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Mean</td>
<td>2.0</td>
<td>1.9</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>

LSD (P=0.05) Tillage (T) = 0.2, Genotypes (G) = 0.2,

Profitability

Tillage had a significant effect on the profitability of maize for all genotypes. The NT permanent beds had significantly higher profitability (US$ 762 ha\(^{-1}\)) than the flat NT (US$ 617 ha\(^{-1}\)) and CT plantings (US$ 634 ha\(^{-1}\)). The higher profitability with permanent beds was mainly due to reduced fuel, water, and labour costs compared to CT, while maintaining the same or higher yield levels, consistent with the findings of Limon et al. (2000). The various genotypes responded differently to the different tillage techniques. Under NT on the flat, the profitability of Bio-9681 was highest, but with permanent beds and CT, ST-2324 performed best. The most profitable cultivars were Bio-9681 (US$ 814 ha\(^{-1}\)) and ST-2324 (US$ 804 ha\(^{-1}\)), due to higher yields (Table 3). In CT flats and FIRB, the profitability of ST-2324 was significantly higher compared to other varieties but under NT flats, Bio-9681 performed significantly better to Shaktiman-4 and HM-5.
Table 3. Profitability of maize genotypes under double no-till practices

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>No-till flat (NT)</th>
<th>Conventional till (CT)</th>
<th>Permanent beds (FIRB)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQPM-1</td>
<td>678</td>
<td>728</td>
<td>839</td>
<td>748</td>
</tr>
<tr>
<td>Shaktiman-4</td>
<td>559</td>
<td>518</td>
<td>724</td>
<td>600</td>
</tr>
<tr>
<td>HM-5</td>
<td>396</td>
<td>327</td>
<td>444</td>
<td>389</td>
</tr>
<tr>
<td>ST-2324</td>
<td>655</td>
<td>827</td>
<td>929</td>
<td>804</td>
</tr>
<tr>
<td>Bio-9681</td>
<td>796</td>
<td>771</td>
<td>875</td>
<td>814</td>
</tr>
<tr>
<td>Mean</td>
<td>617</td>
<td>634</td>
<td>762</td>
<td>671</td>
</tr>
</tbody>
</table>

LSD (P=0.05) Tillage (T) = 26, Genotypes (G) = 29, Interaction (T*G) = 48

Soil physical properties

The bulk density of the upper 15 cm soil was significantly lower in the permanent beds compared to CT and NT (Figure 3). At 15-30 cm depth, bulk density of CT and FIRB was similar but significantly higher than in NT (Figure 4). Cone resistance increased with depth up to 20-25 cm and below this it again decreased. The penetration resistance was least in upper layers of the permanent beds, consistent with the bulk density results. Soil aggregation was improved in the NT treatments on beds and flats, more so on the flat. The proportion of soil aggregates > 0.25 mm was highest (78.5%) in NT (Figure 5) followed by the permanent beds (70.5%). Mean weight diameter of aggregates was similar in NT and FIRB (3.25 and 3.27 mm, respectively) but significantly lower in CT (Figure 6).

The raised bed planting with double no-till system was superior to other tillage methods when taking into account yield, irrigation water productivity, profitability and soil physical conditions in a sandy loam soil.
Figure 4. Effect of tillage and crop establishment methods on cone resistance

Figure 5. Effect of tillage and crop establishment methods on soil aggregates >0.25 mm (%)

Figure 6. Effect of tillage and crop establishment methods on mean weight diameter (MWD) of soil aggregates (mm)
References


Cochran WG, Cox GM (1957) Experimental Designs, Wiley NY, USA


