Impact of improved soil and in-situ water conservation practices on productivity in rainfed foothill region of North-west India

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1. Abstract

The foothill region of Northwest India covers about 3 m ha area where maize-wheat rotation is dominant, is seriously suffering from the problem of the soil erosion due to uneven topography, high soil erodibility, low fertility of the soil and high erosivity of the rains. The major part of the tract is rainfed because of more annual evapo-transpiration compared to annual rainfall. The water table is deep to very deep and rainfall is the only scarce source of water in the area. The lack of irrigation facilities and large-scale erosion put main limitations to the agricultural economy resulting in poor socio-economic status of the farmers in the area. On farm studies showed that soil moisture storage increased to the tune of 2.25, 4.01 and 10.77 % at 60 days after sowing (DAS) with shallow tillage, deep tillage and ridge and furrow sowing treatment over the farmers' practice during maize. The application of mulch on the whole plot resulted in 48.4, 61 and 138 % higher soil moisture content at 40, 60 and 80 DAS respectively. Fully covered plots had more than 150 % higher dry matter yield of maize compared to unmulched plots. There was nearly 11 % increase in maize grain yield in ridge and furrow sowing over farmers' practice. Mulch spread on the whole plot increased the grain and straw yield of maize by 58.6 and 35.0 % as compared to unmulched control.

2. Introduction

The rainfed foothill region of North-west India is mostly underfed from the point of view of application of inputs compared to outputs obtained (Hadda et al., 2005). The uneven distribution of rainfall in time and space often causes dry spells of two weeks or more resulting in moisture stress conditions. The studies conducted in the area have shown that there was decline in productivity due to low soil water storage capacity resulting in reduced crop yields (Sur et al., 1992). Thus the major constraint for establishing a crop is the lack of adequate moisture in the seed zone (Hadda et al., 2000; Bhatt et al., 2004). The area therefore, requires adoption of location specific in-situ soil moisture conservation technologies by which the area could be ecologically rehabilitated and its production potential could be realized on a sustained basis. Tillage and mulching are the two most important practices, among various mechanical and agronomic measures, that have been reported to reduce soil erosion and increase in-situ soil moisture storage and improve the productivity of crops (Bhatt et al., 2004). The field experiments were therefore conducted to evaluate important aspects of rainfed maize production techniques namely, tillage and mulching and their role in in-situ moisture conservation and on growth and yield of Maize (*Zea mays*) in the area.

3. Materials and Methods

Two field experiments were conducted during the summer monsoon season 2001 and 2002 on undulating agricultural lands in Hoshiarpur and Nawanshahr districts of Punjab through farmer's participation. Soils of the area remain dry for 4-5 months in a year and qualify for an Ustic soil moisture regime. The soils are sandy loam to loamy sand in texture with low to medium moisture retention capacity and poor in fertility.

3.1 Experimental treatments

In on-farm experiment at Hoshiarpur, the different tillage treatments includes shallow tillage (10-15 cm), deep tillage (20-25 cm) ridge and furrow sowing and farmers' practice (control) where tillage is done at irregular depths and direction. The treatments were replicated thrice in a Randomized Block Design for each of the 5 villages. The recommended doses of fertilizers were applied as basal dose. The total recorded rainfall during the year 2001 was 705 mm considering only those rainstorms that produced ≥10 mm of rainfall in a single rainstorm. Slope steepness on the experimental sites varied in between 2 to 3 per cent.

At Nawanshahr, the treatments included five modes of straw mulch applications i.e. unmulched (control; M_o), fully covered plots (M_f), partial covered (lower 1/3rd covered; M_p) plots, Strip (M_s) and vertical (M_v) mulching. Maize (cv. Parkash) was sown with recommended fertilizer levels. The rice straw mulch was applied @ 6 t ha^{-1} as per treatment. Rainfall was received in 31 rainstorms out of which 12 were erosive (produced runoff). A total of 547 mm rain was received during the monsoon season that was much below the normal rainfall of the area.

3.2 Soil moisture and Yield estimation

To assess the change in soil water status, soil moisture content was measured in soil profiles upto 120 cm. The moisture content of soil layers was measured gravimetrically. Moisture measurements were done every 3-4 weeks interval. Dry matter yield was recorded by taking five plants randomly from each plot and then air-dried followed by oven dry at 65±1°C to a constant weight. The harvested mature crop was separated in grain and straw and yield was recorded. The grain yield was adjusted at 15 % grain moisture content.
The results were analyzed statistically and tested using the F-test to estimate least significant difference at 5% level of significance.

4. Results and Discussion

4.1 Effect of tillage and mulching on soil moisture

On farmers' fields, at 40 and 60 days after sowing (DAS), soil moisture storage increased by 2.46, 3.85 and 5.96 % and 2.25, 4.01 and 10.77 % respectively with shallow tillage, deep tillage and ridge and furrow sowing treatments respectively over the farmers' practice. At 80 DAS, the increase in soil moisture storage was 0.95, 3.81 and 4.76 % under shallow tillage, deep tillage and ridge and furrow sowing treatment over farmers' practice (Fig. 1). It was observed that moisture storage was more in sub-surface layers at 40 DAS in comparison to surface (0-15 cm) layers in all the treatments (Fig. 1). Maximum amount of moisture at lower depths (60-90 cm) was observed in the ridge and furrow sowing treatment. This may be due to more infiltration of excess rainwater impounded in furrows and less evaporation of moisture in the treatment. The increase in soil moisture content may be because of better tilling practices and sowing of maize on ridges (Arora and Hadda, 2003).

Mulch material was found to be quite effective in conserving soil moisture. As compared to control, at 40 DAS, soil moisture was higher to the magnitude of 3.80 and 1.80 % in surface and 4.20 and 2.30 % in sub-surface respectively in whole covered and partial covered plots by straw mulch (Fig. 2). The other two modes of mulch application also helped in conserving the soil moisture but the amount of water conserved was relatively small as compared to that under fully covered treatment. Similarly, at 60 DAS, gravimetric soil moisture was higher to the tune of 4.85, 2.30 and 1.05 % in 0-15 cm and 4.25, 2.75 and 1.80 % in 15-30 cm soil layers in M_f, M_p and M_s modes of mulch application over M_o (Fig. 2). At all the stages of crop growth, moisture storage was greater in sub-surface layers than surface soil layer. The greater the surface area covered by mulch material in a particular mode, the greater is its effectiveness in conserving soil moisture. Thus among different modes of mulch application the area covered varied as 98 % in fully covered followed by 33% in partially covered, 18% in strip mulching, 1.8 % in vertical mulched plots and 0 % in case of unmulched control.

4.2 Effect of tillage and mulching on maize yield

Different tillage treatments affect the crop yield differently. Dry matter yield of plant in shallow tillage, deep tillage and ridge and furrow treatment was higher to the magnitude of 9.48, 15.30 and 26.01 g plant^{-1} over 87.24 g plant^{-1} in farmers' practice at 40 DAS while it was observed to be 129.32 g plant^{-1} in farmers' practice at 80 DAS which increased to 141.44, 148.65 and 162.55 g plant^{-1} with the respective tillage treatments. There was 10.6 per cent increase in maize grain yield in ridge and furrow sowing treatment compared to farmers' practice (Table 1). Straw yield increased significantly in all the tillage treatments with maximum increase of 46.36 % in ridge and furrow sowing treatment over farmers' practice (Table 1).

It was observed that fully mulched plots provided the best growth conditions for maize in Nawanshahr experiment. It was also observed that fully covered plots had 156 % higher dry matter yield of maize as compared to the unmulched plots. The grain yield of maize was significantly higher in whole covered, partial covered and strip mulching plots as compared to the control plots. Mulch spread on the whole plot increased the grain yield by 58.6 % as compared to unmulched control (Table 2). In vertical mulched and control plots (unmulched) grain yield of maize was observed to be almost similar. It was observed that straw yield in whole covered, partial covered and strip application plots was significantly higher by 35.05, 31.39 and 25.3 per cent respectively than the unmulched i.e. controlled plots (Table 2). The vertical mulching though had higher yield than the control plots but it could not reach the level of significance. Similar increase in maize fodder yields with mulch application in rainfed area of Punjab was also observed (Khera and Singh, 1998).

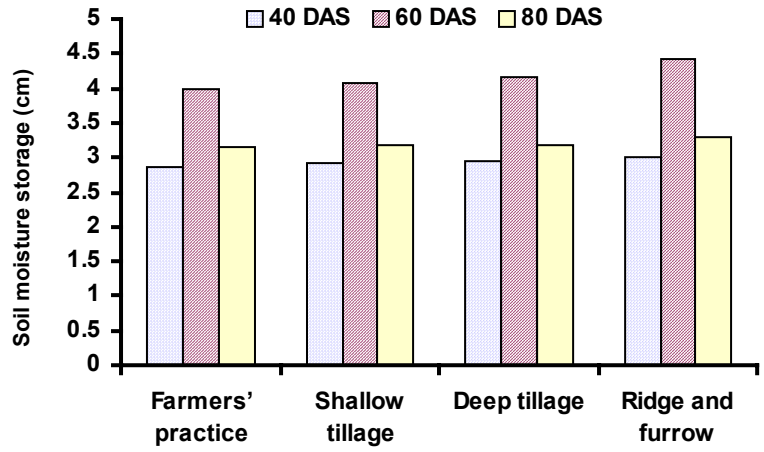

Figure 1 Effect of tillage depth on soil moisture storage

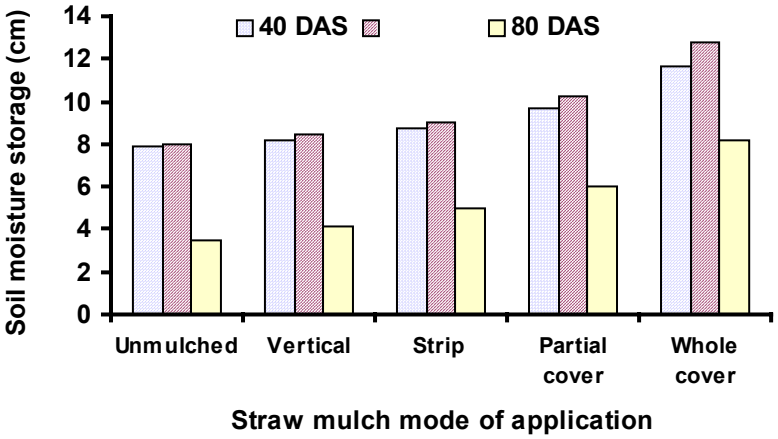

Figure 2 Effect of straw mulching on soil moisture storage

Table 1 Effect of tillage practices on yield of maize

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)
Farmers' practice	2254	4268	34.15
Shallow tillage	2272	4647	32.90
Deep tillage	2315	5422	30.05
Ridge and furrow	2493	6247	28.65
LSD(*P*=0.05)	88	190	NS

DAS : days after sowing; NS : non-significant

Table 2 Effect of modes of mulch application on grain and straw yield of maize

Mode of Mulch Application	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Unmulched (M_o)	2466	4074
Vertical (M_v)	2502	4352
Strip (M_s)	3163	5105
Partial cover (M_p)	3206	5353
Whole cover (M_f)	3912	5502
LSD(*P*=0.05)	104	256

5. References

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