



Tillage and mulching effects on performance of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system under varying land slopes

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Received: 28 August 2009; Revised accepted: 7 February 2011

ABSTRACT

A field experiment was conducted at Selakui, Dehradun during 2001–04 to study the effect of tillage (conventional and minimum) and mulching practices (no mulching and live mulching) under artificially created varying land slopes (0.5, 2.5, 4.5 and 9.5%) on soil-moisture conservation, productivity and nutrient uptake in maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend Fiori & Paol.) cropping system. Sunnhemp (*Crotalaria juncea* L.) intercropped with maize gave 0.87–1.09 tonnes biomass (dry weight) and accumulated 24.8–31.4 kg N/ha at 30 days of growth when it was mulched. Biomass and N accumulation generally decreased with increasing land slope and under minimum tillage. Maize performed better on moderate slopes (2.5–4.5%) than on the relatively flat (0.5%) and highly sloping land (9.5%). However, the yield of wheat decreased linearly and significantly with increasing slope due to less conservation of soil moisture on sloping lands during the previous rainy season. Conventional tillage gave significantly higher productivity of both maize and wheat than the minimum tillage. Intercropping of maize with sunnhemp and spreading the cut biomass as mulch at 30 days (live mulching) improved soil moisture conservation at maize harvest (+1.63 to 1.94%), and yield of maize (12.0%) as well as of following wheat (13.8%) compared with the no mulching.

Key words: Land slopes, Live mulching, Maize, Minimum tillage, Moisture conservation

Maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend Fiori & Paol.) is the dominant cropping system in the sub-mountainous western Himalayan region of India. These crops are grown on terraced or sloping lands, largely under rainfed conditions, and experience deficit moisture stress at different stages of crop growth. Further, nutrient deficiency, particularly of N, and unchecked weed growth inflict considerable reduction in grain yield. Erosion due to runoff on sloping lands causes loss of soil, water and nutrients, leading to low productivity (Bhardwaj and Sindwal 1998). Further, intensive ploughing due to elaborate tillage operations exposes the soil to increased erosion losses (Dogra *et al.* 2002). Maize is a widely spaced crop and its canopy closes in within about a month, during which time, erosion losses on sloping lands are quite high. Mulching is a useful

practice in rainfed areas for controlling erosion, weed growth and conserving moisture as well as nutrients in the soil profile (Sharma *et al.* 2000 and 2005). Despite the beneficial effects of mulching, adoption of this practice is constrained due to non-availability of vegetative mulch material. There is a possibility of biomass production and nutrient cycling through live mulching of *in situ*-grown annual legumes along with field crops (Narain and Singh 1997). Live mulching with intercropped sunnhemp, cowpea and *dhaincha* improved maize productivity by 6–9%, residual soil moisture at harvest by 1.6–2.9% and yield of following wheat by 13–15% under Doon valley conditions (Sharma *et al.* 2010). Sunnhemp is fast growing green manure crop, develops canopy cover quickly and helps in checking erosion and reducing weed growth, besides producing ample quantity of N-rich biomass. There is also the possibility of reducing tillage operations for checking erosion losses (Bhardwaj and Sindwal, 1998), and equally good yields can be obtained as with conventional tillage (Pramanik and Bandyopadhyay 1998). Minimum tillage was more effective in conserving soil moisture and resulted in the same yield of maize as conventional tillage (Bhatt *et al.* 2004). Conservation agriculture systems based on no-till and residue management are considered alternative to ensure double cropping, improved farm income and

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livelihood in north-eastern India (Ghosh *et al.* 2010). The effects of intercropped grain legumes with maize have been widely investigated but the role of green manure legumes for live mulching under varying tillage conditions has not been adequately studied. Therefore, an experiment was conducted to study the effect of varying tillage and live mulching with sunnhemp on moisture conservation and crop productivity under different land slopes in maize–wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during 2001–04 at the Selakui experimental farm of Central Soil and Water Conservation Research and Training Institute, Dehradun. The soil was silty loam in texture with pH 5.4, organic C 0.57%, total N 0.064%, available P 35 kg/ha and available K 160 kg/ha. The soil moisture content at maximum water-holding capacity, field capacity and permanent wilting point was 35.5, 24.8 and 11.2% respectively. The climate of the area is sub-humid, and the rainfall during maize and wheat growing seasons was 1 203 and 245 mm, 841 and 186 mm, and 1 210 and 131 mm in 2001–02, 2002–03 and 2003–04, respectively.

Maize was grown during rainy (June to October) season in four large plots (60 cm×15 m) having artificially created varying land slopes, viz 0.5, 2.5, 4.5 and 9.5%. Each main plot was divided into four sub-plots along the length of slope to accommodate four treatment combinations of each of two tillage practices, viz conventional and minimum; and mulching, viz control and *in situ*-grown sunnhemp. While making the plots and demarcating plots on various slopes, suitable drains for disposal of runoff were provided so that the rainwater from one plot does not enter into other plot. The runoff from each plot was diverted into drainage channels on the sides of the plots and finally disposed off at the lowest end of the field. After the harvest of maize, wheat was grown with conventional or minimum tillage in the respective plots, and residual effect of mulching applied to maize. Thus 16 treatment combinations were arranged in a split-plot design with four replications, keeping land slopes in main plot and tillage×mulching combinations in subplots (12 m×2 m). Randomization of main plot treatments was restricted due to the typical nature of this experiment. All crops were grown in fixed plots without changing the layout over three cropping cycles.

Conventional tillage for maize involved ploughing of field with a disc plough in May, followed by two cultivations in June to prepare a fine seedbed. However, in case of minimum tillage, paraquat was sprayed 0.5 kg/ha to kill the previously growing weeds and only one ploughing was given with a cultivator before sowing in June. Sowing of ‘Kanchan’ maize hybrid (90 days) was done in the third week of June with a seed drill at a row spacing of 60 cm, and 20–25 cm spacing between plants was maintained after thinning. Sunnhemp

was sown on the same day using 60 kg seed/ha in between the rows of maize (two rows at 20 cm spacing), thus leaving a 40 cm spacing for maize rows. Herbicide alachlor was sprayed uniformly 2 kg/ha within 2–3 days of sowing. The biomass of sunnhemp along with the associated weeds was cut at 30 days of growth and spread as mulch in between the inter-row spaces. A common basal dose of 45 kg N + 17.5 kg P + 33.3 kg K/ha was applied at sowing. Further, 45 kg N/ha was top-dressed at knee-high stage (30 days after sowing, i e after mulching).

After maize harvest, the field was ploughed within a week, incorporating surface applied mulch biomass for conserving moisture and nutrients for the following wheat. Further, two cultivation operations were performed under conventional tillage and none under minimum tillage before sowing with a seed drill. Wheat was sown by October-end at 20 cm spacing, using 100 kg seed/ha and a common basal dose of 40 kg N + 17.5 kg P + 33.3 kg K/ha. Top-dressing of 40 kg N/ha was done after 1–2 months, depending on occurrence of rainfall.

Observations were recorded on growth and yield performance of maize and wheat crops. Biomass production of *in situ*-grown sunnhemp was assessed. Nitrogen content in grain and straw of crops as well as sunnhemp was determined to work out N accumulation. Soil moisture content was also determined at each maize harvest. Statistical analysis of the data was done as per the standard analysis of variance technique, and the treatment means were compared at $P=0.05$ level of significance.

RESULTS AND DISCUSSION

Biomass and N accumulation through sunnhemp

There was no significant difference in biomass accumulation and N addition through sunnhemp due to different land slopes in 2001 (Table 1). However, in 2002 and 2003, biomass production and N addition were maximum at 0.5% slope, and decreased significantly with increasing land slopes. This was due to more evenly distributed rainfall in early stages in 2001 which resulted in equal biomass production across all land slopes. In other years, scanty rainfall resulted in relatively poor growth of plants at higher land slopes presumably due to quick runoff and less opportunity time for rainwater infiltration into the soil profile. On the other hand, conventional tillage resulted in significantly more biomass accumulation and N addition than minimum tillage in all years, although the differences were less pronounced in 2001.

Growth and yield of maize

Maize showed variable performance under varying land slopes in different years (Table 2). In 2001, the grain and stover yields of maize were the highest at 2.5% slope, followed closely by that at 4.5% slope. The yields were significantly lower at 0.5 and 9.5% slopes than at 2.5 and 4.5% slopes. In

Table 1 Effect of varying land slopes and tillage on biomass production and N addition through sunnhemp mulching

Treatment	Biomass accumulation (tonnes/ha)				N addition (kg/ha)			
	2001	2002	2003	Mean	2001	2002	2003	Mean
<i>Land slopes (%)</i>								
0.5	1.13	1.11	1.05	1.09	31.6	31.9	30.6	31.4
2.5	1.04	0.84	0.95	0.94	29.1	24.2	27.6	26.9
4.5	1.07	0.75	0.80	0.87	29.9	21.6	23.3	24.9
9.5	1.16	0.70	0.75	0.87	32.5	20.2	21.8	24.8
SEm±	0.048	0.043	0.035		1.36	1.25	1.03	
CD (P=0.05)	NS	0.138	0.112		NS	3.98	3.28	
<i>Tillage</i>								
Conventional	1.14	0.95	0.98	1.02	31.9	27.4	28.5	29.3
Minimum	1.06	0.75	0.80	0.87	29.7	21.6	23.2	24.8
SEm±	0.020	0.018	0.020		0.58	0.51	0.60	
CD (P=0.05)	0.062	0.054	0.062		1.78	1.57	1.84	

2002, the yields decreased significantly with increasing slopes. In 2003, the grain yields were the same at 0.5–4.5% slopes, and the decrease at 9.5% slope was significant only when compared with that at 2.5% slope. Further, the stover yield was not affected significantly under varying slopes. These differences in yield performance of maize under varying slopes were primarily due to varying rainfall pattern in different years. Ram and Khola (2000) reported that grain yield of maize was similar at 0.5–4.5% slope but decreased by 16% at 9.5% slope under the same conditions. Maize is a crop susceptible to waterlogging as well as sensitive to deficit moisture stress. In 2001, the rainfall was more and well distributed throughout the season. Therefore, the yield was highest at the relatively moderate slopes of 2.5–4.5%, but at 0.5% slope, there was waterlogging for short periods, and at 9.5% slope there was deficit moisture stress, leading to poor yields. In other years, when rainfall was less and not so well distributed, maize yields were better at lower slopes due to higher availability of moisture in the soil profile. These results suggest that mild degree of slope is beneficial for higher productivity of maize in high rainfall situations.

Reducing the tillage operations resulted in lower yield of maize in all years. The mean decrease under minimum tillage was 6.8–12.1% in grain yield, and 5.9–17.1% in stover yield compared with conventional tillage. Dogra *et al.* (2002) also reported that reducing tillage operations in maize checked erosion losses but caused more weed growth, thereby leading to decreased productivity and profitability. This decrease in yield was apparently due to more weed infestation in minimum tillage plots. Although a non-selective herbicide (paraquat) was used to kill the previously-growing weeds before sowing and a selective pre-emergence herbicide (alachlor) was applied after sowing, weed growth was not adequately checked because these appeared in several flushes during the season. Nonetheless, minimum tillage along with live mulching with sunnhemp was better than without as it controlled the later flushes emerging after 30 days of growth.

Live mulching with sunnhemp gave significantly higher yield of grain as well as stover, and the magnitude of beneficial effect was more pronounced at higher slopes and under minimum tillage. Intercropping with sunnhemp ensured early canopy cover, checked erosion losses and weed growth, and after spreading as mulch at 30 days, conserved more moisture, which ultimately led to 10.7–13.3% increase in grain yield, and 8.8–14.3% in stover yield compared with unmulched conditions. Similar observations were made by Narain and Singh (1997) and Sharma *et al.* (2010). However, minimum tillage along with mulching was found more effective in conserving soil moisture and achieving almost same yield of maize as the conventionally-tilled plots in the sub-mountainous rainfed region of Punjab (Bhatt *et al.* 2004).

Residual soil moisture

Moisture availability in the soil profile varied in the surface and sub-surface layers in different years due to varying rainfall pattern, particularly in the later part of the monsoon season. The soil moisture content was much lower in 2001 than in 2002 and 2003, and was considerably more in 15–30 cm than in 0–15 cm depth. Although the total rainfall during maize-growing season was almost same in 2001 and 2003 (1 203–1 210 mm) compared with 2002 (841 mm), the monsoons withdrew early in 2001 as the monthly rainfall during September was only 38 mm compared with 300 mm in 2002 and 208 mm in 2003 (Table 3). There was a decreasing trend in soil moisture content with varying slopes in all years at both the soil depths. A similar observation was made by Ram and Khola (2000). This was understandable because there was less opportunity time for the rainwater to infiltrate into the soil profile at higher land slopes. *In situ* conservation of rainwater was more efficient in flat lands due to short-term ponding and less runoff, which was beneficial for sowing of *rabi* crops.

Conventional tillage resulted in more conservation of soil

Table 2 Effect of varying land slopes, tillage and mulching on yield performance of maize and wheat (tonnes/ha)

Treatment	2001–02		2002–03		2003–04		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
<i>Maize</i>								
<i>Land slopes (%)</i>								
0.5	2.68	6.05	1.99	4.46	2.38	5.23	2.35	5.25
2.5	3.63	7.30	1.77	3.92	2.51	5.40	2.64	5.54
4.5	3.61	7.12	1.67	3.70	2.41	5.23	2.56	5.35
9.5	3.12	5.88	1.55	3.46	2.34	5.03	2.34	4.79
SEm±	0.066	0.168	0.041	0.107	0.045	0.153		
CD (<i>P</i> =0.05)	0.211	0.537	0.131	0.342	0.144	NS		
<i>Tillage</i>								
Conventional	3.47	7.20	1.82	4.03	2.49	5.38	2.59	5.54
Minimum	3.05	5.97	1.67	3.74	2.32	5.06	2.35	4.92
SEm±	0.035	0.128	0.018	0.058	0.026	0.079		
CD (<i>P</i> =0.05)	0.101	0.368	0.052	0.167	0.075	0.227		
<i>Mulching</i>								
Control	3.09	6.15	1.64	3.65	2.26	5.00	2.33	4.93
Sunnhemp	3.42	7.03	1.85	4.12	2.56	5.44	2.61	5.53
SEm±	0.035	0.128	0.018	0.058	0.026	0.079		
CD (<i>P</i> =0.05)	0.101	0.368	0.052	0.167	0.075	0.227		
<i>Wheat</i>								
<i>Land slopes (%)</i>								
0.5	2.08	4.34	2.20	4.65	2.35	4.83	2.21	4.61
2.5	1.84	4.04	1.95	4.34	2.10	4.50	1.96	4.29
4.5	1.74	3.79	1.83	4.06	2.01	4.17	1.86	4.01
9.5	1.60	3.44	1.70	3.80	1.78	3.68	1.69	3.64
SEm±	0.038	0.096	0.034	0.089	0.039	0.091		
CD (<i>P</i> =0.05)	0.121	0.307	0.109	0.284	0.125	0.291		
<i>Tillage</i>								
Conventional	1.89	4.06	2.00	4.36	2.12	4.48	2.00	4.30
Minimum	1.73	3.75	1.84	4.07	2.00	4.12	1.86	3.98
SEm±	0.019	0.043	0.014	0.048	0.024	0.038		
CD (<i>P</i> =0.05)	0.055	0.123	0.040	0.138	0.069	0.109		
<i>Mulching</i>								
Control	1.70	3.69	1.81	4.07	1.91	4.06	1.81	3.94
Sunnhemp	1.93	4.12	2.03	4.36	2.21	4.54	2.06	4.34
SEm±	0.019	0.043	0.014	0.048	0.024	0.038		
CD (<i>P</i> =0.05)	0.055	0.123	0.040	0.138	0.069	0.109		

moisture at both the depths than minimum tillage. This was also related to more infiltration of rainwater due to better permeability of soil under conventional tillage, although it might have also led to more soil erosion. Mulching with sunnhemp ensured greater moisture availability than unmulched condition, and the magnitude of increase was even more pronounced than of conventional over minimum tillage. For example, the conventional tillage improved the soil moisture content in absolute terms over minimum tillage by +1.07% at 0–15 cm, and +1.08% at 15–30 cm; while sunnhemp mulching showed an increase of +1.63% and +1.94% at the respective depths over no mulching. Thus, tillage and mulching are the two most important moisture conservation practices in rainfed areas, and an appropriate combination of both is beneficial for reducing erosion losses,

improving soil moisture availability and crop productivity (Ghosh *et al.* 2010, Sharma *et al.* 2010).

Growth and yield of wheat

Wheat yields were relatively lower than that of maize, and decreased more conspicuously with increasing land slopes in all years (Table 2). In fact, there was linear decrease in yield of grain and stover of wheat uniformly as the land slope increased from 0.5 to 9.5%. The highest yield was obtained at 0.5% slope due to maximum soil moisture availability. The yield of grain and stover at 9.5% slope was 23.5 and 21.0% lower than at 0.5% slope. Ram and Khola (2000) reported that wheat yield decreased progressively with increasing land slopes under similar conditions due to reduced availability of soil moisture at different stages of

Table 3 Effect of varying land slopes, tillage and mulching on soil moisture content (%) at varying depth at maize harvest

Treatment	2001		2002		2003		Mean	
	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
<i>Land slopes (%)</i>								
0.5	9.32	10.96	13.77	15.78	12.09	15.17	11.73	13.97
2.5	8.47	10.77	13.51	15.40	11.75	14.72	11.24	13.63
4.5	7.18	9.66	12.13	13.92	10.43	13.60	9.91	12.39
9.5	5.96	8.63	11.89	13.58	10.03	13.23	9.29	11.81
SEm±	0.273	0.330	0.498	0.469	0.319	0.447		
CD (P=0.05)	0.872	1.055	1.591	1.499	1.019	1.428		
<i>Tillage</i>								
Conventional	8.25	10.57	13.36	15.20	11.64	14.69	11.08	13.49
Minimum	7.22	9.43	12.29	14.13	10.51	13.67	10.01	12.41
SEm±	0.149	0.166	0.256	0.218	0.192	0.268		
CD (P=0.05)	0.428	0.477	0.735	0.626	0.551	0.769		
<i>Mulching</i>								
Control	6.89	9.19	12.04	13.89	10.25	12.85	9.73	11.98
Sunnhemp	8.58	10.81	13.61	15.45	11.89	15.50	11.36	13.92
SEm±	0.149	0.166	0.256	0.218	0.192	0.268		
CD (P=0.05)	0.428	0.477	0.735	0.626	0.551	0.769		

growth. This indicates that wheat is a more slope-sensitive crop compared with maize, which was more stable and productive across different land slopes. Wheat experienced more acute and frequent moisture stress than maize because the winter rains were less and more unpredictable. Due to these reasons, wheat cultivation is considered more risky, while maize gives stable yields at moderate slopes under Doon valley conditions.

The yield performance of wheat under varying tillage practices was similar to that of maize as the grain and stover yields were significantly lower with minimum tillage than conventional tillage. The mean decrease in wheat yield was 7.0–7.4%, while it was 9.3–11.2% in maize yield. Maize was adversely affected under minimum tillage due to higher weed growth, while wheat growth was affected due to lower moisture availability following less conservation of moisture under minimum tillage conditions. Live mulching with sunnhemp in maize improved productivity of following wheat significantly. This was due to enhanced moisture conservation and nutrient supply from the decomposing biomass. The increase in grain and stover yield of wheat was 13.8 and 10.2% respectively over no mulching, which was more or less similar to that of maize (12.0 and 12.2%). Sharma and Acharya (2000) also reported increased yields of wheat when *Lantana* mulching was done in standing maize due to enhanced moisture and nutrient conservation. Live mulching with annual legumes in maize at 30 days of growth increased wheat yield by 13–14% due to their effect on controlling weeds, improving soil moisture conservation and N addition (Sharma *et al.* 2010). Growing mustard on residual soil moisture following rainfed maize was possible under conservation tillage (no-till with residue of crops including weeds) in the north-eastern hills region (Ghosh *et al.* 2010).

Nutrient uptake

The absolute values of uptake of N and P were the same for maize and wheat, while the uptake of K was more in wheat than in maize (Table 4). There was a variable trend in the uptake of N, P and K by maize and wheat under varying land slopes. In fact these variations in nutrient uptake were related to the yields of grain and stover of the respective crops as the differences in nutrient content across varying slopes were marginal. Higher moisture and nutrient availability at the lower slopes led to more uptake of nutrients,

Table 4 Effect of varying land slopes, tillage and mulching on N uptake of maize and wheat (kg/ha) (mean of three cropping cycles)

Treatment	N uptake		P uptake		K uptake	
	Maize	Wheat	Maize	Wheat	Maize	Wheat
<i>Land slopes (%)</i>						
0.5	60.0	70.6	13.0	13.1	77.6	72.8
2.5	67.7	62.1	13.4	11.8	83.3	64.3
4.5	59.8	60.7	12.6	10.8	79.6	57.8
9.5	60.5	51.3	12.2	8.7	75.4	50.1
SEm±	1.27	1.15	0.39	0.29	2.03	1.50
CD (P=0.05)	4.06	3.67	1.25	0.93	6.49	4.79
<i>Tillage</i>						
Conventional	65.1	64.1	13.1	11.7	81.7	63.7
Minimum	58.5	58.2	12.5	10.5	76.3	58.8
SEm±	0.70	0.63	0.21	0.14	1.06	0.65
CD (P=0.05)	2.01	1.80	0.59	0.41	3.05	1.86
<i>Mulching</i>						
Control	59.4	54.7	11.8	9.6	75.2	55.3
Sunnhemp	64.2	67.7	13.7	12.6	82.8	67.2
SEm±	0.70	0.63	0.21	0.14	1.06	0.65
CD (P=0.05)	2.01	1.80	0.59	0.41	3.05	1.86

while the loss of nutrients due to runoff at higher slopes resulted in poor growth of plants, and hence lower nutrient uptake (Ram and Khola 2000).

Conventional tillage recorded significantly higher nutrient uptake than minimum tillage due to higher crop productivity. The magnitude of decrease in the uptake of all nutrients was more or less similar in maize and wheat crops. On the other hand, sunnhemp mulching was vastly superior to no mulching, and the increase in uptake of N, P and K was 8.1, 16.1 and 10.1% in maize, and 23.8, 31.3 and 21.5% in wheat. This showed that the increase in nutrient uptake of wheat due to mulching was more pronounced than of maize. Mulched biomass of sunnhemp was spread in maize, while its incorporation at wheat sowing caused increased nutrient availability due to mineralization, which benefited wheat more in terms of yield and nutrient uptake (Sharma *et al.* 2010).

It is concluded that maize performed better under moderately sloping lands (2.5–4.5% slope) of high rainfall areas of Doon valley but the following wheat gave higher productivity on relatively flat lands (0.5% slope) due to enhanced soil moisture conservation. Growing maize with *in situ*-grown sunnhemp mulching, followed by wheat under conventional tillage conditions was beneficial for enhanced moisture conservation, productivity and nutrient uptake.

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