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Effect of live mulching with annual legumes on performance of maize (*Zea mays*) and residual effect on following wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted at Selakui, Dehradun during 2001 to 2004 to study the effect of *in situ* grown live mulching with legumes viz. sunnhemp (*Crotalaria juncea* L.), *dhaincha* (*Sesbania aculeata* Pers.) and cowpea [*Vigna unguiculata* (L.) Walp.], besides weed mulching at 30 and 45 days of maize (*Zea mays* L.) growth on moisture conservation, crop productivity and soil properties in maize–wheat (*Triticum aestivum* L. emend Fiori & Paol.) cropping system. Legume mulching accumulated 1.09–1.17 t/ha dry biomass and added 27.9–31.3 kg N/ha compared with 1.31 t/ha biomass and 10.3 kg N/ha with weed mulching at 30 days; which increased further by 68.5–74.8% when applied at 45 days. Maize productivity was 5.6–8.8% higher with legume mulching at 30 days when compared with no mulching. Soil moisture content (0–15 and 15–30 cm depth) at maize harvest increased by a magnitude of 1.63–2.91% due to live mulching, and the effect of sunnhemp was relatively more pronounced than other materials. Wheat yields increased by 13.3–14.0% due to legume mulching in previous maize following enhanced soil moisture and nutrient conservation. Mulching with weed biomass was inferior to legume mulching in both the crops. Mulching at 45 days adversely affected maize growth and yield but was more beneficial to the following wheat due to addition of greater biomass and N. The yield performance of wheat was lower when mulching with cowpea stover was done at maize harvest or wheat sowing, as well as under minimum tillage compared with conventional tillage conditions. Wheat gave 2.5–3.0 folds more net returns than maize, and the net B : C ratio of the system was >1.0 with live mulching of sunnhemp and *dhaincha*. There was an improvement in organic C and total N, and a decrease in bulk density with a corresponding increase in infiltration rate due to mulching at the end of 3 cropping cycles. It was concluded that live mulching with legumes in maize was beneficial for improving soil moisture conservation, productivity, profitability and soil health in rainfed maize–wheat cropping system under Doon valley conditions.

Key words: Cowpea, Economics, Grain, Moisture content, Mulch, Yield, *Sesbania aculeata*, Soil fertility, Sunnhemp, Tillage

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 largely under rainfed conditions, experiencing moisture deficiency at different stages of growth. Further, nutrient deficiency particularly of N, and unchecked weed infestation inflict considerable reduction in yield. 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*., 2004; Sharma *et al.*, 2010). Application of wild sage (*Lantana camara* L.) mulch in standing maize helps in conservation and carry-over of soil moisture for timely sowing of wheat (Sharma and Acharya, 2000). Despite the beneficial effects of mulching, adoption of this practice is constrained due to non-availability of 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. Live mulching through intercropped sunnhemp (*Crotalaria juncea* L.) with maize has been found beneficial for erosion control and checking weed growth (Narain and Singh, 1997). Further, mulching with weeds lowered the yield of maize marginally but improved the performance of following wheat through enhanced moisture and nutrient conservation (Bhardwaj and Sindwal, 1998). The choice of an appropriate crop and time of its cutting for mulching is very important so that the productivity of maize is not affected adversely. On the

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other hand, conventional or deep tillage was better than zero or minimum tillage in grain production but caused greater soil and nutrient losses through runoff (Sharma *et al*., 1998). However, minimum tillage with mulching resulted in optimum productivity on par with conventional tillage while conserving the resources (Singh *et al*., 2003). Spreading of mulch after harvest of maize or wheat, and sowing with minimum tillage helped in increasing seedling emergence and grain yield (Sandal and Acharya, 1997). There is lack of information on the comparative evaluation of different fast-growing, annual green-manure legumes such as sunnhemp, *dhaincha* (*Sesbania aculeata* Retz.) and cowpea [*Vigna unguiculata* (L.) Walp.], and their time of application as live mulch in maize. Accordingly, this study was undertaken to evaluate and analyze the effects of *in situ* grown legumes and recycling their biomass for developing an integrated moisture and nitrogen management strategy for optimizing productivity in rainfed maize–wheat system.

MATERIALS AND METHODS

A field experiment was conducted during 2001–2004 at the Selakui research farm of the Central Soil and Water Conservation Research and Training Institute, Dehradun, Uttarakhand. The soil of the experimental site was silty loam in texture with bulk density 1.39 g/cc, infiltration rate 7.0 mm/hr, 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 saturation, 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 season (June to October), followed by wheat during winter (October to April). Different legumes, *viz.* cowpea, sunnhemp and *dhaincha* were intercropped with maize, and the legume biomass was cut and applied as mulch at 30 and 45 days of growth. Cowpea was also grown for seed and green pods, and the stover was retained on soil surface after maize harvest. Additional treatments of maize alone (without legumes) were maintained either as clean cultivation (weed-free) or weed mulch was applied at 30 and 45 days. Thus, 11 treatment combinations in maize were arranged in a randomized block design with 4 replications. After the harvest of maize in early October, wheat was sown by October-end either with conventional tillage (CT, one discing followed by two ploughings) or minimum tillage (MT, one discing only) by sub-dividing the plots, each of 26.4 m^2. Thus, there were 22 treatments to wheat (11 treatments to previous maize combined with 2 tillage practices to wheat) arranged in a split-plot design. The crops were grown in a fixed layout over the 3-year period.

Field was ploughed uniformly with a disc plough in May, followed by two cultivations in June to prepare a fine seedbed. Sowing of maize hybrid 'Kanchan' (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. Legume intercrops were sown on the same day as maize. In mulched treatments at 30 and 45 days, sowing of cowpea, sunnhemp and *dhaincha* was done at 20 cm row spacing (2 rows of legumes within maize rows), while in cowpea for seed or green pods, only one row was maintained at 30 cm spacing from maize rows. Seed rate for these crops was reduced to half compared with the recommended rates in sole cropping. The legume biomass was cut along with associated weeds at 30 and 45 days, and spread as mulch in between the maize rows in the respective treatments. A common basal dose of 45–17.5–33.3 kg N–P–K/ha was incorporated at final ploughing. Further, application of 45 kg N/ha was made as top dressing at 30 and 45 days of growth (after mulching). One hand weeding was given at 15–20 days of growth and the weeds along the maize rows (10–15 cm on either side) were removed in the mulched treatments. However in other treatments, weed-free conditions were maintained.

After maize harvest in early October, the field was disc ploughed, incorporating surface-applied mulch biomass for conserving moisture and nutrients for the following wheat. In the plots of CT, two more ploughings were given to prepare a fine seedbed but no further ploughing was done in the plots of MT. Wheat 'PB 2341' was sown by October-end at 20 cm spacing using 100 kg seed/ha. No fertilizer was applied to wheat, and the crop was raised as rainfed on residual soil fertility.

Biomass production of intercrops applied as mulch along with associated weeds or cowpea stover at harvest of maize was assessed. Nitrogen content in grain and straw of crops as well as intercropped legumes was determined to work out N accumulation. Soil moisture content at each maize harvest and residual soil fertility (organic C and total N), and physical parameters (bulk density and infiltration rate) were also determined at the termination of study in May 2004. Economic analysis of the data was done based on the prevailing cost of inputs / operations and price of produce.

RESULTS AND DISCUSSION

Biomass and N addition through mulching

Different intercrops with maize accumulated varying quantities of biomass at the mulching (Table 1). In general, all the legumes accumulated almost equal quantity of biomass at 30 days but at 45 days, *dhaincha* was the best followed by sunnhemp and cowpea. Nitrogen content varied in different crops and decreased with advancement in age. Accordingly, the N addition was similar with *dhaincha* and sunnhemp, and was comparatively more than with cowpea at both the stages, due to relatively higher N content and biomass accumulation in the former crops. Weeds also produced a good amount of biomass but the N addition was less due to their lower N content. The amount and N addition through stover of intercropped cowpea for seed or green pods at harvest of maize was < 1.0 t/ha and 9.5–14.1 kg N/ha, respectively. These differential characteristics of mulches were responsible for variable moisture and nutrient conservation, and thereby influenced growth and productivity of maize and wheat crops.

Growth and yield of maize

The effect of mulching on growth and yield of maize varied depending on legume mulching and time of its application due to different amounts of biomass and N addition (Table 2). In general, intercropping with legumes or allowing the weeds to grow hampered the growth of maize plants initially due to competition for space, light, nutrients etc. The adverse effect was relatively more pronounced when the maize plants suffered competition for 45 days. All the growth and yield attributes were comparatively lower when mulching was done at 45 days than at 30 days, particularly with weed mulching. Maize yield was the lowest when cowpea was grown throughout the season for seed or green pods. Nonetheless, the maize equivalent yield was the highest in maize + cowpea (seed)

Table 1. Biomass production and N addition through legume and weed mulching in maize

Treatment	Dry weight of mulched biomass (t/ha)			N added (kg/ha)		
	2001	2002	2003	2001	2002	2003
Cowpea for seed and stover retained on surface	0.69 (1.50)	0.79 (1.42)	0.91 (1.40)	10.4	11.2	12.7
Cowpea for green pods and stover retained on surface	0.56 (1.69)	0.82 (1.62)	0.88 (1.60)	9.5	13.3	14.1
Cowpea mulching at 30 days	1.16 (2.47)	1.15 (2.50)	1.11 (2.38)	28.7	28.8	26.4
Cowpea mulching at 45 days	1.74 (2.41)	1.48 (2.45)	1.80 (2.32)	41.9	36.3	39.6
Sunnhemp mulching at 30 days	1.21 (2.80)	1.02 (2.88)	1.05 (2.91)	33.9	29.4	30.6
Sunnhemp mulching at 45 days	2.22 (2.75)	1.95 (2.80)	2.11 (2.81)	61.1	54.6	59.3
Dhaincha mulching at 30 days	1.14 (2.70)	1.11 (2.68)	1.25 (2.65)	30.8	29.7	33.1
Dhaincha mulching at 45 days	2.54 (2.61)	2.35 (2.65)	2.15 (2.60)	66.3	62.3	55.9
Weed mulching at 30 days	1.43 (0.80)	1.30 (0.75)	1.20 (0.81)	11.4	9.8	9.7
Weed mulching at 45 days	2.27 (0.73)	1.85 (0.72)	2.18 (0.78)	15.9	13.3	17.0

Values in parentheses indicate N concentration (%)

Table 2. Effect of live mulching with legumes and weeds at different growth stages on growth, yield attributes (mean of 3 years), and productivity of maize (t/ha)

Treatment	Plant height at maturity (cm)	Cobs/ plant	Cob length (cm)	Grains/ cob	1000-grain weight (g)	2001		2002		2003	
						Grain	Stover	Grain	Stover	Grain	Stover
Cowpea for seed and stover retained on surface	206.2	0.90	16.3	297.0	174.2	3.00*	5.30	2.96*	4.38	3.28*	4.54
Cowpea for green pods and stover retained on surface	202.1	0.93	16.5	290.1	176.8	2.78*	5.76	2.89*	4.25	2.99*	4.76
Cowpea mulching at 30 days	210.0	0.99	16.9	316.7	183.7	2.61	7.27	2.56	5.42	2.65	5.42
Cowpea mulching at 45 days	205.5	0.96	16.5	307.2	179.1	2.35	6.06	2.27	5.33	2.55	5.48
Sunnhemp mulching at 30 days	216.4	1.04	18.2	351.5	197.0	2.70	6.92	2.64	5.68	2.72	5.72
Sunnhemp mulching at 45 days	210.7	1.01	17.0	336.8	193.8	2.46	6.17	2.58	5.55	2.62	5.36
Dhaincha mulching at 30 days	216.1	1.02	17.7	343.3	197.5	2.86	7.23	2.62	5.77	2.67	5.62
Dhaincha mulching at 45 days	214.3	1.01	17.0	326.7	187.4	2.48	6.32	2.53	5.68	2.59	5.56
Weed mulching at 30 days	199.2	0.92	16.8	320.4	174.3	2.15	5.71	2.20	5.16	2.52	5.47
Weed mulching at 45 days	189.1	0.85	16.4	287.3	167.4	1.96	5.00	2.06	4.75	2.24	5.09
Clean cultivation	206.7	0.98	17.0	317.4	179.3	2.54	7.41	2.43	5.26	2.52	5.33
SEm±	7.8	0.04	0.6	15.6	4.4	0.09	0.30	0.08	0.21	0.10	0.18
CD (P=0.05)	22.4	0.12	1.7	44.8	12.8	0.26	0.86	0.24	0.61	0.29	0.51

*Maize equivalent yield. The yield of cowpea seed and green pods was 0.36 and 0.71 t, 0.36 and 0.64 t, and 0.42 and 0.81 t/ha in 2001, 2002 and 2003, respectively.

intercropping system, followed by maize + cowpea (green pods). There were no significant differences among the treatments involving live mulching with cowpea, sunnhemp and *dhaincha*. The grain as well as stover yields decreased when the intercrops were allowed to grow for 45 days but these were still on par with mulching at 30 days or clean cultivation. On the other hand, mulching with weeds at both the stages caused significant decrease in yield compared with clean cultivation in 2001 and 2002. A similar adverse effect of weed mulching in maize was reported by Bhardwaj and Sindwal (1998).

Cutting the intercropped legume plants and spreading as mulch after 30 or 45 days helped in suppressing weed growth, and led to enhanced moisture conservation by decreasing runoff, improving infiltration and checking evaporation losses (Narain and Singh, 1997). The benefits due to nutrient conservation and supply were expected to be less in maize as the mulched biomass was only spread on soil surface and not incorporated. Therefore, achieving higher or even the same yield due to live mulching with legumes as with clean cultivation was considered beneficial because this helped in resource conservation and benefited the following crop of wheat.

Residual soil moisture

Soil moisture content at maize harvest varied significantly among different treatments in different years (Table 3). The soil moisture content was much lower in 2001 when compared with 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 and 1,210 mm) when compared with 2002 (841 mm), the monsoons withdrew early in 2001 as the monthly rainfall during September was only 38 mm when compared with 300 mm in 2002 and 208 mm in 2003. Clean cultivation resulted in the lowest soil moisture content in all years, which was on par with cowpea stover mulching at harvest. This was understandable because these treatments did not have any mulch cover on the soil surface, which led to greater moisture loss due to evaporation (Narain and Singh, 1997). On the other hand, use of different legumes as well as weeds as live mulching brought about significant improvement in residual soil moisture, which was evident in both the soil layers. In general, the improvement in soil moisture content was related to the amount and time of biomass applied as mulch. On an average, the maximum amount of soil moisture was conserved with sunnhemp (+3.45%), followed by *dhaincha* (+2.90%), and cowpea (+2.05%) in the surface layer over clean cultivation. A similar trend was observed in 15–30 cm depth. Weed mulching was also equally beneficial as sunnhemp in improving soil moisture conservation. The enhanced moisture conservation was probably due to reduced runoff and greater infiltration as well as reduced evaporation from the surface-applied mulch (Narain and Singh, 1997; Bhardwaj and Sindwal, 1998). Sharma and Acharya (2000) also reported that mulching during standing crop of maize was more effective in conserving rainwater than at maize harvest.

Growth and yield of wheat

Residual effects of mulching applied to maize were significant on growth and yield attributes of wheat (Table 4). In general, the plants were taller and had better yield attributes under different treatments of mulching when compared with clean cultivation. Accordingly, the grain and straw yields of wheat were the lowest under clean cultivation in all the years, whereas the mulched treatments resulted in either the same or significantly higher productivity. The yields were significantly higher when legume

Table 3. Effect of live mulching with legumes and weeds on soil moisture content (%) at two soil depths at maize harvest

Treatment	2001		2002		2003	
	0–15 cm	15–30 cm	0–15 cm	15–30 cm	0–15 cm	15–30 cm
Cowpea for seed and stover retained on surface	6.74	11.48	12.05	15.38	10.30	13.68
Cowpea for green pods and stover retained on surface	5.65	11.16	12.92	16.62	11.15	14.94
Cowpea mulching at 30 days	7.23	12.01	13.67	17.71	12.30	15.75
Cowpea mulching at 45 days	7.03	12.04	15.14	18.18	13.45	16.42
Sunnhemp mulching at 30 days	7.99	11.04	15.41	18.55	13.72	16.92
Sunnhemp mulching at 45 days	8.50	12.71	16.68	19.15	14.95	17.64
Dhaincha mulching at 30 days	7.78	11.00	15.08	18.08	13.22	16.20
Dhaincha mulching at 45 days	7.78	11.47	15.94	19.12	14.10	17.38
Weed mulching at 30 days	8.46	12.24	15.28	18.29	13.55	16.54
Weed mulching at 45 days	10.33	13.56	16.36	19.68	14.62	17.95
Clean cultivation	5.91	9.83	12.10	16.36	10.24	14.72
SEm±	0.39	0.66	0.67	1.24	0.75	1.16
CD (P=0.05)	1.12	1.90	1.94	3.57	2.17	3.33

mulching with cowpea, sunnhemp or *dhaincha* was done at 45 days than at 30 days, and were comparatively superior to weed mulching. This was owing to higher amount of weed biomass applied as mulching at 45 days, which helped in greater moisture and nutrient conservation, and supply to wheat plants. Growing cowpea for seed or green pod and then using the stover as mulch at maize harvest resulted in lower yields due to lower amount of mulched biomass and its delayed application. Further, the stover of mature cowpea contained less N (1.7%) with higher C:N ratio (21:1), which also mineralized slowly during the wheat growing season due to decreasing temperatures. Nonetheless, the system productivity of maize and wheat system was equally good in these treatments as live mulching with other legumes, suggesting thereby that the loss in yield of one crop was compensated with the other. Bhardwaj and Sindwal (1998) reported higher system productivity of maize–wheat due to mulching in maize because the lower yield in maize was more than compensated by the higher yield of wheat. Succulent biomass of legumes was rich in N content (2.4–2.9%) and contained 27.9–61.5 kg N/ha, which contributed to enhanced growth of wheat plants. The practice of mulching to previous maize not only conserved soil moisture for sowing of wheat but also effected conservation in tillage, fertilizer N and higher wheat yield with lower cost of production (Sharma and Acharya, 2000; Sharma *et al.*, 2010)

Interaction between tillage and mulching was not significant on wheat yield. However, the mean effect of tillage was significant, and conventional tillage was superior to minimum tillage in improving the growth and yield performance in all years. The decrease in yield of grain and stover under minimum over conventional tillage was 5.2 and 8.7%, respectively. Conservation tillage systems involving zero or minimum tillage have been found highly beneficial for irrigated wheat grown after rice in the Indo-Gangetic plains of North-Western India (Chauhan *et al.*, 2003; Pandey *et al*., 2003). However, under the present rainfed conditions, the mulched biomass was inadequate and weed infestation was higher, which led to lower wheat productivity.

Nitrogen uptake

There was significant increase in N-uptake of maize due to mulching with intercropped legumes, and the effect was more pronounced when mulching was done at 30 days than at 45 days (Table 5). This was due to the fact that mulching at 45 days caused some adverse effect on maize plants, leading to restricted biomass production despite greater moisture conservation and nutrient addi-

Table 4. Effect of live mulching with legumes and weeds in maize on growth, yield attributes (mean of 3 years), and productivity of following wheat (t/ha)

Treatment	Plant height at maturity (cm)	Spikes/ m row	Spike length (cm)	Grains/ spike	1,000-grain weight (g)	2001-01		2002-03		2003-04	
						Grain	Straw	Grain	Straw	Grain	Straw
Live mulching											
Cowpea for seed and stover retained on surface	68.5	34.7	8.71	35.0	36.4	1.85	3.98	2.17	4.55	2.28	4.50
Cowpea for green pods and stover retained on surface	70.4	36.2	8.81	37.2	37.2	1.89	3.93	2.21	4.53	2.35	4.57
Cowpea mulching at 30 days	69.1	35.0	8.93	36.6	37.7	1.94	4.11	2.25	4.79	2.40	4.68
Cowpea mulching at 45 days	69.3	35.8	9.06	38.8	38.3	1.99	4.33	2.30	4.60	2.48	4.85
Sunnhemp mulching at 30 days	69.4	36.0	9.41	38.8	38.9	2.08	4.41	2.40	4.82	2.54	5.14
Sunnhemp mulching at 45 days	70.6	37.2	9.44	41.8	39.8	2.22	4.81	2.53	5.14	2.67	5.06
Dhaincha mulching at 30 days	67.1	35.1	9.32	38.1	37.7	2.05	4.30	2.37	5.02	2.49	4.96
Dhaincha mulching at 45 days	67.6	36.3	9.30	40.0	38.1	2.13	4.37	2.45	5.04	2.59	5.09
Weed mulching at 30 days	65.8	36.6	9.27	38.3	37.6	1.96	4.21	2.28	4.66	2.41	4.74
Weed mulching at 45 days	64.0	33.3	9.05	38.3	38.4	2.04	4.25	2.36	4.90	2.49	4.91
Clean cultivation	65.2	33.8	8.58	35.5	36.0	1.72	3.65	2.04	4.48	2.36	4.43
SEm±	1.5	1.1	0.20	1.3	0.7	0.04	0.12	0.06	0.16	0.07	0.15
CD (P=0.05)	4.4	3.1	0.59	3.6	2.0	0.12	0.35	0.17	0.47	0.20	0.42
Tillage to wheat											
Conventional	70.3	37.2	9.32	39.6	38.5	2.17	4.59	2.42	4.92	2.55	4.92
Minimum	65.5	33.6	8.84	36.5	37.2	1.80	3.84	2.19	4.63	2.33	4.70
SEm±	0.4	0.3	0.07	0.4	0.2	0.01	0.04	0.02	0.05	0.02	0.04
CD (P=0.05)	1.1	0.8	0.19	1.2	0.7	0.04	0.12	0.05	0.16	0.07	0.12

tion. The effect of weed mulching and stover of matured cowpea was almost similar as clean cultivation. On the other hand, the N uptake of wheat was significantly more when live mulching of legumes in maize was done at 45 days than at 30 days, and the clean cultivation was significantly inferior to all other treatments. In fact, there was not much change in N concentration in grain or straw of maize and wheat due to mulching. However, the enhanced moisture conservation and N addition from the mulched biomass might have improved nutrient supply, and thus resulted in better growth and dry matter production. The maximum beneficial effect was due to sunnhemp, followed by *dhaincha*, cowpea and weed mulch, while the effect of cowpea stover and weed mulch was equal but still better than clean cultivation. These results suggest that the direct effects of live mulching on maize might be less pronounced but the residual effects on the following wheat crop were large due to enhanced moisture and nutrient supply. Evidently, the mean N uptake of wheat was 11.3% lower under minimum tillage than conventional tillage due to lower yield under the former condition.

Soil physico-chemical properties

There was a definite improvement in soil organic C and total N content with mulching over clean cultivation, and the beneficial effect was related to the amount of biomass added (Table 5). The improvement in these parameters was comparatively more pronounced when mulching was done at 45 days than at 30 days, presumably due to greater addition of legume biomass. Build-up of soil organic C through *Lantana* mulching or incorporation was reported by Sandal and Acharya (1997). Compared with the initial content, there was no change in organic C and total N under clean cultivation, and also a smaller increase was noticed under cowpea stover application. On the other hand, soil bulk density decreased and infiltration rate increased due to mulching when compared with clean cultivation. These beneficial effects were understandable due to the addition of total mulched biomass amount of 3.3–6.3, 3.5–7.1, 3.4–5.0 and 3.9–6.3 t/ha through sunnhemp, *dhaincha*, cowpea and weed mulching, respectively over the 3-year period. Soil structure remains in friable condition due to increased organic C under mulched condition (Sandal and Acharya, 1997). This suggested that mulching every year improved physico-chemical properties of soil due to its favourable effect on soil and moisture conservation, C enrichment and nutrient addition. Apparently, there was no perceptible change in soil physico-chemical properties under minimum tillage compared with conventional tillage.

Economics

Total system productivity in terms of maize-equivalent yield was the highest with sunnhemp mulching, closely followed by *dhaincha* and cowpea grown for seed or green pods (Table 6). Clean cultivation and weed mulch-

Table 5. Effect of live mulching with legumes and weeds on N uptake of maize and following wheat, and physico-chemical properties of soil at the termination of study (mean of 3 cropping cycles)

Treatment	N uptake (kg/ha)		Organic C (%)	Total N (%)	Bulk density (g/cc)	Infiltration rate (mm/hr)
	Maize	Wheat				
Live mulching						
Cowpea for seed and stover retained on surface	67.2	65.5	0.61	0.060	1.41	6.89
Cowpea for green pods and stover retained on surface	60.9	68.4	0.65	0.060	1.40	7.38
Cowpea mulching at 30 days	60.3	69.2	0.70	0.067	1.39	7.91
Cowpea mulching at 45 days	63.6	72.0	0.72	0.069	1.35	7.50
Sunnhemp mulching at 30 days	64.7	77.5	0.68	0.065	1.34	7.98
Sunnhemp mulching at 45 days	73.6	85.2	0.72	0.072	1.31	8.20
Dhaincha mulching at 30 days	76.6	71.9	0.71	0.068	1.32	7.75
Dhaincha mulching at 45 days	70.9	78.9	0.74	0.071	1.31	7.82
Weed mulching at 30 days	59.1	64.2	0.65	0.065	1.38	7.36
Weed mulching at 45 days	55.4	67.6	0.69	0.068	1.36	7.73
Clean cultivation	59.2	59.8	0.61	0.060	1.42	7.08
SEm±	2.4	2.4				
CD (P=0.05)	6.9	6.8				
Tillage to wheat						
Conventional		75.2	0.66	0.064	1.35	7.88
Minimum		66.7	0.70	0.067	1.37	7.32
SEm±		0.7				
CD (P=0.05)		1.9				

Table 6. System productivity and economic analysis as influenced by live mulching (mean of 3 cropping cycles)

Treatment	Mean productivity (t/ha)			Cost of cultivation (x 10^3 Rs/ha)		Net returns (x 10^3 Rs/ha)			Net benefit : cost ratio		
	Maize	Wheat	Total maize equivalent	Maize	Wheat	Maize	Wheat	System	Maize	Wheat	System
Live mulching											
Cowpea for seed and stover retained on surface	3.08	2.10	6.44	12.5	10.8	7.64	14.68	22.32	0.611	1.359	0.958
Cowpea for green pods and stover retained on surface	2.89	2.15	6.33	12.5	10.8	6.87	15.08	21.95	0.550	1.396	0.942
Cowpea mulching at 30 days	2.64	2.20	6.16	12.5	10.8	6.74	15.86	22.60	0.539	1.469	0.970
Cowpea mulching at 45 days	2.39	2.26	6.01	12.5	10.8	5.07	16.46	21.53	0.406	1.524	0.924
Sunnhemp mulching at 30 days	2.69	2.34	6.43	12.5	10.8	7.06	17.50	24.56	0.565	1.620	1.054
Sunnhemp mulching at 45 days	2.55	2.47	6.50	12.5	10.8	5.94	18.96	24.90	0.475	1.756	1.069
Dhaincha mulching at 30 days	2.72	2.30	6.40	12.5	10.8	7.31	17.12	24.43	0.585	1.585	1.048
Dhaincha mulching at 45 days	2.53	2.39	6.35	12.5	10.8	6.00	17.98	23.98	0.480	1.665	1.029
Weed mulching at 30 days	2.29	2.22	5.84	11.5	10.8	5.40	16.04	21.44	0.470	1.485	0.961
Weed mulching at 45 days	2.09	2.30	5.77	11.5	10.8	3.90	16.98	20.88	0.339	1.572	0.936
Clean cultivation	2.50	2.04	5.76	12.0	10.8	6.50	13.90	20.40	0.542	1.287	0.895
Tillage to wheat											
Conventional		2.38			11.1		17.56			1.582	
Minimum		2.11			10.5		15.16			1.444	

Common cost of cultivation involving land preparation, seed, sowing, fertilization, weeding, harvesting, threshing and rental value of land was Rs 11,000/ha for maize and Rs 10,800/ha for wheat. The cost of legume mulching was Rs 1,500/ha.
Price of produce (Rs/t); maize grain, 5,000; maize stover, 1,000; wheat grain, 8,000; wheat stover, 2,000; cowpea seed, 20,000 and cowpea green pods, 8,000.

ing resulted in the lowest productivity. Total cost of cultivation was the same under live mulching with all legumes, while it was comparatively lower with weed mulching and clean cultivation because these treatments did not involve the cost of legume seed. Similarly, wheat cultivation incurred equal cost under all the mulching treatments as it was grown solely on residual fertility. Net returns from maize were the highest when it was intercropped with cowpea for seed, followed by *dhaincha* and sunnhemp mulching at 30 days. Wheat gave 2.5–3.0 folds more net returns than maize, and the beneficial effect was more pronounced under live mulching with legumes than clean cultivation. Interestingly, delayed application of live mulch at 45 days gave lower net returns in maize but was more economical for wheat than at 30 days due to greater residual effect and improved productivity. Accordingly, total net returns and B : C ratio of the system were the highest under sunnhemp, followed by *dhaincha* and cowpea. Maize cultivation was less economical than wheat, as the latter gave net B : C ratio >1.0 under all treatments compared with <1.0 in the former. Clean cultivation in maize resulted in almost the same B : C ratio as live mulching with legumes, but it was poorest in wheat, leading to the lowest net B : C ratio of the system. Presumably, MT in wheat involved less cost of cultivation but also resulted in lower net returns and B : C ratio than CT.

It was concluded that live mulching with intercropped annual legumes in maize was beneficial for improving system productivity and profitability in rainfed maize–wheat cropping system. Mulching with sunnhemp, *dhaincha* and cowpea at 30 days may be adopted for enhanced moisture conservation, nutrient supply and soil health under Doon valley conditions.

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