*Indian Journal of Agricultural Sciences* **81** (2): 129–33, February 2011

# Effect of tillage and weed control on weed dynamics, crop productivity and energy-use efficiency in rice (*Oryza sativa*)-based cropping systems in Vertisols

J S MISHRA[1] and V P SINGH

*Directorate of Weed Science Research, Jabalpur, Madhya Pradesh 482 004*

Received: 6 November 2009; Revised accepted: 8 December 2010

ABSTRACT

Field experiments were conducted during winters of 2004–06 on a Typic Chromusterts soils at Jabalpur to study the effect of tillage and weed control on weed dynamics, productivity and energy-use efficiency of various oilseeds and pulses grown in rice (*Oryza sativa* L.)-based systems. Results revealed that zero tillage significantly increased the population of common vetch (*Vicia sativa* L.) but reduced the problem of common lambsquarters (*Chenopodium album* L.) compared with the conventional tillage. The suppressing effect of crops on total weed dry matter was in order of pea (*Pisum sativum* L.) > linseed (*Linum usitatissimum* L.) > mustard (*Brassica juncea* Czernj & Cosson) > chickpea (*Cicer arietinum* L.) > lentil (*Lens culinaris* Medik.). Pre-emergence application of pendimethalin 1.0 kg/ha significantly reduced the dry biomass of all weeds except common vetch (*Vicia sativa* L.). Higher yields of mustard, lentil and chickpea were recorded under conventional tillage and that of field pea under zero tillage. Field pea proved most economical under zero tillage with net returns of ₹ 23 199/ha and benefit:cost ratio of 2.87. However, the Indian mustard was more economical under conventional tillage (₹ 21 039 and 2.31). The maximum energy productivity was obtained under zero tillage in all the crops. The highest output energy (50 675 MJ/ha) and energy output : input ratio (5.02) were obtained from mustard in conventional tillage with pendimethalin.

**Key words**: Cropping system, Economics, Energy, Tillage, Weed dynamics, Yield

In rice (*Oryza sativa* L.)-based cropping systems, the productivity of succeeding winter crops is considerably influenced by crop establishment methods across the country. Late harvesting of high-yielding transplanted rice varieties, particularly in northern and eastern parts of the country delays the sowing of succeeding oilseeds and pulses resulting in lower crop yields and input-use efficiency. In India, zero tillage in wheat after rice has become a reality and is being followed on nearly 2.1 million ha area in Indo-Gangetic plains (Yadav *et al.* 2009). In medium and heavy-textured soils (Vertisols) of Madhya Pradesh, the tillage operations are difficult. Moisture stress in these soils results in deep (>50 cm) and wide (1–5 cm) cracks and higher moisture content makes the soil sticky and plastic and thus difficult to till. With increased combine harvest of rice, large quantities of crop residues are left on soil surface and poses problem in tillage operations resulting delayed sowing. Energy is one of the most important indicators of crop performance (Singh *et al*. 2008). The net energy and monetary returns of a cropping system can be quantified for sound planning of sustainable systems (Chaudhary *et al*. 2006). In view of the success of zero tillage technology in wheat under rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol) system and continued energy crisis and ever increasing prices of oilseeds and pulses, the present investigation was undertaken to study the effect of tillage and weed control on weed dynamics, productivity and energy-use efficiency of various oilseeds and pulses grown in rice-based systems in vertisols.

[1]Principal Scientist (e mail: jsmishra31@gmail.com), Directorate of Sorghum Research, Rajendranagar, Hyderabad 500 030; [2]Principal Scientist (e mail: vpsinghnrcws@gmail.com)

## MATERIALS AND METHODS

Field experiments were conducted during 2004–06 at the Directorate of Weed Science Research, Jabalpur (23° 90' N, 79° 58' E, 412 m above mean sea level). The soil was clay loam (Typic chromusterts), low in available nitrogen (238 kg/ha), medium in available phosphorus (18 kg P/ha), and high in available potassium (304 kg/ha), with organic carbon 0.54% and *p*H 6.8. The experiment was laid out in a split-split plot design, comprising two tillage systems (zero and conventional) in main plots, five crops, viz 'JG 315' chickpea (*Cicer arietinum* L.), 'JP 885' pea (*Pisum sativum* L.), 'JL 40–70' lentil (*Lens culinaris* Medik.), 'JL 23' linseed (*Linum usitatissimum* L.) and 'Pusa Bold' Indian mustard (*Brassica juncea* Czernj & Cosson) in sub-plots and two weed management practices (weedy check and pendimethalin at 1.0 kg/ha) in sub-subplots replicated thrice. Conventional tillage consisted of disc ploughing once, tillage twice with a field cultivator (5 cm wide shovels), rototilled once with a vertical tine tiller to prepare a fine seedbed before planting

the crops. Zero-till crops were planted by direct seeding into dead residue of the previous crop without field preparation using zero till ferti-seed drill having inverted T-type furrow openers. Glyphosate [N-(phosphonomethyl) glycine] at 1 000g/ha was applied 1 week before seeding in all the zero-till plots to kill the existing vegetation. All the winter crops were sown on 4 November in both the tillage systems during both the years. Field was irrigated through sprinkler immediately after sowing to ensure proper seed germination. Pendimethalin was applied as pre-emergence (1 day after sowing) with 500 litre/ha of water with help of knapsack sprayer, fitted with flat-fan nozzle. The crops were raised under irrigated conditions with recommended package of practices except weed control. Weed density at 30 days after sowing and weed dry matter at 90 days after sowing (before crop harvesting) were recorded from $1m^2$ area by placing a quadrat of 50 cm by 50 cm randomly at four places in each plot.

The cost of cultivation was calculated by taking into account the prevailing market prices of inputs. The returns were calculated by using minimum support price of mustard (₹ 18.30/kg), chickpea (₹ 17.30/kg) and lentil (₹ 18) and prevailing market price of linseed (₹ 17) and pea (₹ 16) for 2008–09. To calculate the input energy, all inputs in the form of labour, machinery, fuel, fertilizer, seed, pesticide and irrigation were taken into consideration with use of energy conversion factors. The farm produce (grain yield + straw yield) was also converted into energy in terms of energy output (MJ) (Singh *et al*. 2008, Devasenapathy *et al*. 2009).

All the data were subjected to analysis of variance (ANOVA) by using a split-split plot design and main effects and interactions were tested for significance. Weed density and weed dry matter values as affected by tillage sequence and weed control method were square root transformed [$\sqrt{(x + 0.5)}$] to normalize data distribution. Treatment means obtained by ANOVA were compared using least significant difference (LSD) procedures at $P$=0.05 level of significance.

## RESULTS AND DISCUSSION

*Effect on weeds*

The experimental field was dominated with broad-leaved weeds (95.4%), viz burclover (*Medicago hispida* Gaertn.) (50 %), common vetch (*Vicia sativa* L.) (22.6 %), common lambsquarters (*Chenopodium album* L.) (7.3 %), and others including field bindweed *Convolvulus arvensis* L.), *V. hirsuta* L., sweet clover (*Melilitus indica* All.) and *M. alba* L. (15.5 %). The grassy weeds, viz littleseed canary grass (*Phalaris minor* Retz.) (3.1%) and wild oats (*Avena sterilis* ssp *luduviciana* Dur. Nym.)(1.5 %) were of minor importance.

Zero tillage significantly increased the population of *V. sativa* but reduced the problem of *C. album* as compared to conventional tillage (Table 1). The population of *M. hispida*, *A. luduviciana, P. minor* and total weeds did not vary significantly due to change in tillage systems. Winter season crops significantly influenced the population of specific weeds. The lowest population of *V. sativa* (14.3/$m^2$), *M. hispida* (71/$m^2$) and total weeds (124/$m^2$) was recorded in field pea. Mustard was more effective in reducing the population of *C. album*. The magnitude of reduction in total weed population due to field pea was by 50–52% over the chickpea and mustard. The response of various crops in reducing total weed population was in order of pea > lentil > linseed > chickpea > mustard. Application of pendimethalin at 1.0 kg/ha as pre-emergence significantly reduced the population of *V. sativa* and *C. album* and the total weeds over weedy check. The magnitude of reduction was 20.5, 71.8 and

Table 1 Effect of treatments on weed population (mean data of two years)

| Treatment | Weed population (No/$m^2$) at 60 DAS | | | | | |
|---|---|---|---|---|---|---|
| | *V. sativa* | *M. hispida* | *C. album* | *P. minor* | *A. luduviciana* | Total |
| *Tillage* | | | | | | |
| Zero | 8.6 (73) | 10.9 (117) | 2.1 (3.9) | 2.5 (6.3) | 2.0 (3.5) | 14.9 (220) |
| Conventional | 5.5 (29) | 10.6 (111) | 4.4 (19) | 2.8 (7.3) | 1.9 (3.1) | 13.9 (191) |
| LSD ($P$=0.05) | 0.50 | NS | 0.9 | NS | NS | NS |
| *Crops* | | | | | | |
| Mustard | 5.1 (26) | 13.6 (184) | 2.1 (3.7) | 2.8 (7.1) | 2.2 (4.3) | 16.0 (256) |
| Linseed | 8.2 (67) | 10.9 (117) | 3.2 (9.7) | 2.2 (4.3) | 1.3 (1.2) | 14.6 (213) |
| Lentil | 9.3 (85) | 8.9 (78) | 3.2 (9.4) | 2.4 (5.0) | 3.1 (8.8) | 14.3 (204) |
| Pea | 3.9 (14.3) | 8.5 (71) | 4.1 (16.3) | 2.6 (6.3) | 1.7 (2.2) | 11.2 (124) |
| Chickpea | 8.4 (69) | 11.2 (125) | 3.9 (14.3) | 3.3 (10.4) | 1.4 (1.3) | 15.7 (246) |
| LSD ($P$=0.05) | 0.9 | 0.5 | 0.7 | 0.6 | 0.5 | 1.0 |
| *Weed control* | | | | | | |
| Pendimethalin 1.0 kg/ha | 6.7 (44) | 10.1 (102) | 2.3 (4.8) | 2.5 (5.8) | 1.8 (2.7) | 13.4 (178) |
| Weedy check | 7.3 (53) | 10.9 (117) | 4.2 (17) | 2.8 (7.3) | 2.0 (3.5) | 15.30 (234) |
| LSD ($P$=0.05) | 0.2 | NS | 0.4 | NS | NS | 1.00 |

Data subjected to square root transformation. Values in parentheses are original

23.9 %, respectively, over weedy check. Pendimethalin, however, did not reduce the population of *M. hispida*, *P. minor* and *A. luduviciana* significantly.

Zero tillage significantly reduced the dry matter of *M. hispida* and *C. album* as by 20.3 and 58% as compared to conventional tillage, however, the dry matter of *A. luduviciana* and *V. sativa* increased (Table 2). Among different crops, field pea as compared to other crops was the most effective in suppressing almost all the weeds resulting in the lowest weed dry matter accumulation. The suppressing effect of different crops on total weed dry matter was in order of pea > linseed > mustard > chickpea > lentil. Pre-emergence application of pendimethalin significantly reduced the dry biomass of all weeds except *V. sativa*. *C. album* was most susceptible weed species to pendimethalin.

*Effect on seed yield*

Tillage practices had variable effect on seed yield of different crops (Table 3). Higher yields of mustard, lentil and chickpea were recorded under conventional tillage and that of field pea under zero tillage. The yield of linseed was, however, not affected. Irrespective of the tillage, application of pendimethalin improved the seed yield of all the crops over weedy check. However, reduction in seed yields due to weeds varied in different crops under different tillage systems. Weeds caused higher reduction in yields in conventional tillage in mustard, lentil and pea as compared to zero tillage. Reduction in yield in conventional tillage was 17.12, 57.51 and 37.41%, respectively, in mustard, lentil and pea. The corresponding values in zero tillage were 8.92, 43.39 and 32.28%. Similarly, higher losses due to weeds were observed in chickpea (69.59%) and linseed (39.83%) under zero tillage. The corresponding values in conventional tillage were 40.93 and 20.06%.

*Economics*

Overall, mustard was more remunerative followed by pea and linseed in rice-based cropping system. Chickpea and lentil were not economical. Linseed and pea were more economical under zero tillage with net returns of ₹ 8 227/ha and 23 199/ha and B: C ratio of 1.76 and 2.87 due to higher yields. The corresponding values for conventional

Table 2 Effect of winter crops, tillage and herbicide on weed dry matter (mean data two years)

| Treatment | Weed dry weight (g/m$^2$) at 90 DAS | | | | | |
|---|---|---|---|---|---|---|
| | *V. sativa* | *M. hispida* | *C. album* | *P. minor* | *A. luduviciana* | Total |
| *Tillage* | | | | | | |
| Zero | 5.0 (24) | 7.5 (55) | 2.3 (5) | 4.4 (19) | 3.6 (12) | 10.2 (103) |
| Conventional | 4.1 (18) | 8.3 (69) | 4.4 (19) | 4.2 (17) | 2.8 (7) | 10.5 (111) |
| LSD (*P*=0.05) | 0.4 | 0.6 | 0.3 | 0.3 | 0.2 | NS |
| *Crop* | | | | | | |
| Mustard | 2.8 (7) | 9.5 (91) | 2.0 (4) | 3.1 (9) | 2.7 (7) | 10.1 (102) |
| Linseed | 4.1 (17) | 7.5 (56) | 3.3 (13) | 3.8 (11) | 2.2 (4) | 9.8 (95) |
| Lentil | 8.3 (68) | 8.3 (68) | 4.2 (17) | 5.6 (31) | 7.0 (48) | 14.8 (217) |
| Pea | 2.3 (5) | 6.0 (35) | 3.6 (12) | 3.2 (10) | 1.9 (3) | 7.2 (52) |
| Chickpea | 5.2 (27) | 8.1 (66) | 3.7 (13) | 5.8 (33) | 2.2 (4) | 11.4 (129) |
| LSD (*P*=0.05) | 1.1 | 1.0 | 0.47 | 0.7 | 0.7 | 1.2 |
| *Weed control* | | | | | | |
| Pendimethalin1.0 kg/ha | 4.2 (17) | 7.2 (52) | 1.6 (2) | 3.6 (12) | 2.7 (7) | 9.2 (84) |
| Weedy check | 4.9 (23) | 8.6 (73) | 5.1 (25) | 5.0 (24) | 3.7 (13) | 11.9 (142) |
| LSD (*P*=0.05) | 0.9 | 1.3 | 0.4 | 0.3 | 0.7 | |

Data subjected to square root transformation. Values in parentheses are original

Table 3 Seed yield (kg/ha) of different crops as influenced by tillage and weed control (mean data of two years)

| Crop | Zero tillage (ZT) | | | Conventional tillage (CT) | | |
|---|---|---|---|---|---|---|
| | Pendimethalin 1.0 kg/ha | Weedy check | Mean | Pendimethalin 1.0 kg/ha | Weedy check | Mean |
| Mustard | 1 592 | 1 450 | 1521 (8.92) | 2 027 | 1 680 | 1854 (17.12) |
| Linseed | 1 087 | 654 | 871 (39.83) | 982 | 785 | 884 (20.06) |
| Lentil | 304 | 166 | 235 (45.39) | 466 | 198 | 332 (57.51) |
| Pea | 2 227 | 1 508 | 1 867 (32.28) | 2 010 | 1 258 | 1634 (37.41) |
| Chickpea | 582 | 177 | 369 (69.59) | 513 | 303 | 413 (40.93) |

Values in parentheses are per cent reduction in yield due to weeds

Table 4 Economics of various treatments

| Crop | Cost of cultivation (₹/ha) | | Net returns (₹/ha) | | Benefit: cost ratio | |
|---|---|---|---|---|---|---|
| | ZT | CT | ZT | CT | ZT | CT |
| Mustard (pendimethalin) | 12 702 | 16 055 | 16 432 | 21 039 | 2.29 | 2.31 |
| Mustard (weedy check) | 11 006 | 14 359 | 15 529 | 16 385 | 2.41 | 2.14 |
| Mean | 11 854 | 15 207 | 15 981 | 18 712 | 2.35 | 2.23 |
| Linseed (pendimethalin) | 10 795 | 14 148 | 8 227 | 3 037 | 1.76 | 1.21 |
| Linseed (weedy check) | 9 099 | 12 452 | 2 346 | 1 286 | 1.26 | 1.10 |
| Mean | 9 947 | 13 300 | 5 287 | 2 162 | 1.53 | 1.16 |
| Lentil (pendimethalin) | 12 333 | 15 685 | –6 648 | –6 971 | 0.46 | 0.56 |
| Lentil (weedy check) | 10 636 | 13 989 | –7 532 | –10 286 | 0.29 | 0.26 |
| Mean | 11 485 | 14 837 | –7 090 | –8 628 | 0.38 | 0.42 |
| Pea (pendimethalin) | 12 433 | 16 085 | 23 199 | 16 075 | 2.87 | 2.00 |
| Pea (weedy check) | 11 036 | 14 389 | 13 092 | 5 739 | 2.19 | 1.40 |
| Mean | 11 735 | 15 462 | 18 145 | 10 682 | 2.55 | 1.69 |
| Chickpea (pendimethalin) | 13 833 | 17 485 | –3 764 | –8 610 | 0.73 | 0.51 |
| Chickpea (weedy check) | 12 436 | 15 789 | –9 374 | –9 547 | 0.25 | 0.33 |
| Mean | 13 135 | 16 637 | –6 569 | –9 578 | 0.50 | 0.42 |

Table 5 Input energy, output energy and output : input energy ratio of different crops as influenced by tillage and weed control (mean data of two years)

| Crop | Input energy (MJ/ha) | | Output energy (MJ/ha) | | Energy output : input ratio | |
|---|---|---|---|---|---|---|
| | ZT | CT | ZT | CT | ZT | CT |
| Mustard (pendimethalin) | 8 128.5 | 10 086.8 | 39 800 | 50 675 | 4.90 | 5.02 |
| Mustard (weedy check) | 7 690.1 | 9 648.4 | 36 250 | 42 000 | 4.71 | 4.35 |
| Mean | 7 909.3 | 9 867.6 | 38 025 | 46 337.5 | 4.81 | 4.69 |
| Linseed (pendimethalin) | 6 930.5 | 8 888.7 | 27 175 | 24 550 | 3.92 | 2.76 |
| Linseed (weedy check) | 6 492.1 | 8 450.4 | 16 350 | 19 625 | 2.52 | 2.32 |
| Mean | 6 711.3 | 8 669.6 | 21 762.5 | 22 087.5 | 3.22 | 2.54 |
| Pea (pendimethalin) | 5 180.9 | 7 139.2 | 32 736.9 | 29 547 | 6.32 | 4.14 |
| Pea (weedy check) | 4 742.5 | 6 700.8 | 22 167.6 | 18 492.6 | 4.67 | 2.76 |
| Mean | 4 961.8 | 6 920.0 | 27 452.25 | 24 019.8 | 5.50 | 3.45 |
| Chickpea (pendimethalin) | 5 477.6 | 7 435.9 | 8 555.4 | 7 541.1 | 1.56 | 1.01 |
| Chickpea (weedy check) | 5 039.3 | 6 997.5 | 2 601.9 | 4 454.1 | 0.52 | 0.64 |
| Mean | 5 258.5 | 7 216.7 | 5 578.65 | 5 997.6 | 1.04 | 0.83 |
| Lentil (pendimethalin) | 4 592.9 | 6 551.2 | 4 468.8 | 6 850.2 | 0.97 | 1.05 |
| Lentil (weedy check) | 4 154.5 | 6 112.8 | 2 440.2 | 2 910.6 | 0.59 | 0.48 |
| Mean | 4 373.7 | 6 332.0 | 3 454.5 | 4 880.4 | 0.78 | 0.77 |

tillage were ₹ 3 037/ha and ₹ 16 075/ha and 1.21 and 2.0. The mustard was more economical under conventional tillage (₹ 21 039 and 2.31) as compared to zero tillage (₹ 16 432/ha and 2.29). Use of pendimethalin for weed control improved the B: C ratio in all the crops and tillage systems except under zero-till mustard (Table 4). The maximum net returns (₹ 23 199/ha) and B: C ratio (2.87) were obtained from zero-till pea with pendimethalin.

*Energy*

Irrespective of the crops, the total operational energy input was higher in conventional tillage than zero tillage due to consumption of higher energy in field preparation (Table 5). Among different crops, mustard required higher energy (10086.8 MJ/ha) due to more fertilizer requirements as compared to other crops. The maximum energy productivity was obtained under zero tillage in all the crops due to energy saving in field preparation. Except in pea, output energy was higher in conventional tillage as compared to zero tillage in all the crops. Use of pendimethalin for weed control enhanced the output energy in all the crops. The highest output energy (50675 MJ/ha) and energy output : input ratio (5.02) were obtained from mustard in conventional tillage with pendimethalin.

The study suggested that field pea under zero tillage is a better option after transplanted rice for realizing maximum benefits in Vertisols.

## REFERENCES

Chaudhary V P, Gangwar B and Pandey D K. 2006. Auditing of energy use and out put of different cropping systems in India. *Agricultural Engineering International*: *The CIGR Journal of Scientific Research and Development* VIII (June).

Devasenapathy P, Senthilkumar G and Shanmugam P M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54** (1): 80–90.

Singh K P, Prakash Ved, Srinivas K and Srivastva A K. 2008. Effect of tillage management on energy-use efficiency and economics of soybean (*Glycine max*) based cropping systems under the rainfed conditions in North-West Himalayan Region. *Soil & Tillage Research* **100**: 78–82.

Yadav Ashok, Malik R K, Malik R S, Kadian V S, Kumar V, Phogat V K, Kukreja K, Dabur K R, Kumar Ramesh and Mehta Anil. 2009. Productivity and sustainability of long-term zero tillage in non-rice-wheat cropping systems in Haryana, India. (*in*) *Proceedings (Abstracts) of 4th World Congress on Conservation Agriculture,* pp 121–2, held during 4–7 February 2009 at New Delhi.