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Research Communication

Effect of tillage and weed-management options on productivity, energy-use efficiency and economics of soybean (*Glycine max*)

MONSEFI ALI[1] AND U.K. BEHERA[2]

Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field experiment was conducted during the rainy season of 2008 at New Delhi, to evaluate the effect of tillage and weed management on productivity, energy relations and economics of soybean [*Glycine max* (L.) Merril]. The maximum grain yield of soybean (2.3 t/ha) was recorded in conventional tillage raised-bed. Among weed-management treatments, the maximum grain yield of 2.2 t/ha was recorded with treatment involving pendimethalin + 1 hand-weeding (HW). Weed-management treatments significantly influenced the energy relations in soybean crop. The highest energy output (99.2×10^3 MJ/ha) was recorded in conventional tillage (CT) - raised bed, which was closely followed by CT flat-bed (97.6×10^3 MJ/ha). The highest energy output of 105.5×10^3 MJ/ha was obtained under weed-free treatment, while the lowest output was obtained in the control (83.6×10^3 MJ/ha). There was 26.2% higher energy output owing to control of weeds. The maximum net returns of ₹30,614 was obtained under conventional tillage raised-bed planting, closely followed by zero tillage raised-bed (₹29,674). Application of pendimethalin + 1 HW was found more remunerative with net returns of ₹28,019/ha, followed by application of only pendimethalin (₹27,840). Energy requirement in conventional tillage was 31.3% higher than the zero tillage flat-bed. Net energy output was the maximum in conventional tillage raised-bed, while maximum energy-use efficiency was obtained on zero tillage raised-bed system of planting.

Key words: Bed and flat planting, Energy, Soybean, Tillage, Weed management

Resource conservation technologies (RCTs) involving zero tillage, bed planting, residues management etc. are recognized as potential tool for enhancing the resource-use efficiency and farm profitability (Sharma and Behera, 2006). Continuous rice and wheat cropping sequence in Indo-Gangetic plains has resulted in development of hard-pan, low input-use efficiency, more pests and environmental pollution. There is need for diversification of rice–wheat sequence for higher sustainability of agriculture. Soybean is a potential rainy-season crop to replace rice with proper drainage. Of late, conservation agriculture systems have gained importance owing to the need of farmers to reduce variable cultivation cost, as major portion of energy (25–30%) is utilized for field preparation and crop establishment. This can be minimized by reducing the intensity of tillage operations. Some of the agronomic practices like zero tillage (ZT) and furrow-irrigated raised bed (FIRB) planting are found to be the potential resource conservation technologies (RCTs), which can play a big role in saving natural resource. Zero-tillage technique is an ecological approach for soil surface management and seed-bed preparation resulting in less energy requirement, less weed problem, better crop-residue management and higher or equal yield (Jain *et al*., 2007), energy efficient and beneficial to environment as compared to conventional practices of sowing (Filipovic *et al*., 2006). Furrow-irrigated raised bed (FIRB) planting systems have number of advantages, i.e. better irrigation management, better crop establishment, better weed management through inter-bed cultivation and less soil compaction (Dhillon *et al.,* 2004). Further, the permanent bed (PB) planting allows the bed to be re-used for succeeding crop and thus has the potential to minimize the cost of cultivation similar to zero tillage. Thus, the study was conducted to study the productivity, energy relations and economics under different tillage and weed management in soybean.

A field experiment was conducted during the rainy season 2008 at the research farm of Indian Agricultural Re-

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[2]**Corresponding author Email:** ukb2008@gmail.com

[1]Ph.D. Student; [2]Principal Scientist, Division of Agronomy, IARI, New Delhi

search Institute, New Delhi. The soil was sandy clay loam (61.7% sand, 11.9% silt and 26.4% clay) in texture having pH (7.6), electrical conductivity (EC) (0.32 dS/m), organic carbon (0.38%), available N (145.1 kg/ ha), available P (9.1 kg/ha) and available K (259.4 kg/ha). The experiment was conducted in split-plot design with 3 replications. The main plot treatments consisted of 4 different tillage practises and crop-establishment techniques to soybean, viz. CT-F (Conventional tillage-flat-bed), CT-B (Conventional tillage-raised-bed), ZT-F (Zero tillage-flat-bed) and ZT-B (Zero tillage - raised-bed); while the subplot treatments included 6 weed-management options, viz. control, weed free, pendimethalin @ 0.75 kg/ha as pre-emergence (PE), chlorimuron ethyl @ 6 g/ha as post-emergence (PoE), pendimethalin @ 0.75 kg/ha as PE + 1 hand-weeding (HW), pendimethalin @ 0.75 kg/ha as PE + chlorimuron ethyl @ 6.0 g/ha as PoE. The gross plot size of the subplot was 16.8 m^2. Soybean variety 'DS 9814' was grown at row spacing of 35 cm. The recommended dose and practice of fertilizers application were followed to raise the crop. The energy output from the economic and by-product yield was estimated. For estimation of energy inputs and outputs (expressed in MJ/ha) for each items of inputs and agronomic practices, energy equivalents were utilized as suggested by Mittal and Dhawan (1988), Baishaya and Sharma (1990) and Singh *et al*. (1997). Energy-use efficiency (EUE) was calculated as per Mittal and Dhawan (1988). Different economic indicators were calculated based on the existing price of the inputs and outputs in the market. Variable cost of cultivation was worked out and the fixed cost was not taken in to account. Gross returns were calculated by taking into account the returns from main product and by-product.

The maximum grain yield of soybean (2.3 t/ha) was recorded in conventional tillage raised-bed. The grain yield obtained under zero tillage raised-bed was similar to that obtained under conventional tillage flat-bed system of planting. There was 34% yield improvement under weed-free treatment compared to the control. Among other weed-management treatments, the maximum grain yield of 2.2 t/ha was recorded with the treatment comprising pendimethalin as PE + 1 HW. This treatment performed similarly with application of only pendimethalin as PE, but was significantly superior to the control, chlorimuron ethyl alone as POE, and pendimethalin as PE and chlorimuron ethyl as POE.

The input energy requirement was maximum 9.15×10^3 MJ/ha for CT-Bed and 8.55×10^3 MJ/ha for CT-Flat (Table 1). Whereas, the minimum input energy requirement was recorded under ZT-flat and ZT-Bed treatments. The input energy requirement for different weed-management options varied from 7,640 MJ/ha in the control treatment to 8,111 MJ/ha weed-free treatment. The highest energy output (99.19×10^3 MJ/ha) was recorded in CT-B, which was closely followed by CT-F (97.6×10^3 MJ/ha). These 2 treatments resulted significantly higher energy output than ZT. Zero tillage raised bed resulted 23.5% higher energy output than ZT-flat. The ZT-B system

Table 1. Energy input, energy output and net energy of soybean cultivation as influenced by tillage and crop establishment and weed-management options

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Energy input ($\times 10^3$ MJ/ha)	Energy output ($\times 10^3$ MJ/ha)	Net energy ($\times 10^3$ MJ/ha)	Energy-use efficiency
Tillage and crop establishment						
Conventional tillage flat-bed	2.171	5.253	8.55	97.57	89.01	11.38
Conventional tillage raised-bed	2.319	5.208	9.15	99.19	90.03	10.83
Zero tillage flat-bed	1.725	3.936	6.51	74.55	68.03	11.41
Zero tillage raised-bed	2.208	4.775	7.11	92.14	85.02	12.93
SEm±	0.056	0.441		5.49	5.49	0.728
CD (P=0.05)	0.200	NS		19.00	18.99	NS
Weed management options						
Control	1.847	4.514	7.64	83.56	75.93	10.97
Weed free	2.477	5.526	8.11	105.47	97.36	13.13
Pendimethalin @ 0.75 kg/ha as PE	2.100	4.753	7.76	90.28	82.52	11.69
Chlorimuron ethyl @ 6 g/ha as PoE	1.977	4.551	7.68	85.93	78.25	11.20
Pendimethalin @ 0.75 kg/ha as PE + 1HW	2.203	5.014	7.99	95.05	87.05	11.94
Pendimethalin @ 0.75 kg/ha as PE + Chlorimuron ethyl @ 6 g/ha as PoE	2.032	4.400	7.80	84.87	77.06	10.93
SEm±	0.051	0.225		2.89	2.89	0.398
CD (P=0.05)	0.148	0.650	8.33	8.33	1.150	

PE, Pre-emergence; PoE, post-emergence; HW, hand-weeding yielded energy output of 74.5 × 10^3 MJ/ha. The energy output was significantly influenced due to weed-management options. The highest output was obtained under weed-free treatment, while the lowest output was obtained in the control. There was 26.2% additional energy output owing to control of weeds.

The energy output in pendimethalin + 1 HW was 95.0 × 10^3 MJ/ha, this was 4,762 MJ additional output than sole application of pendimethalin. The combined application of pendimethalin + chlorimuron ethyl resulted 6% less energy output than the former treatment. Net energy and energy-use efficiency (EUE) were influenced significantly by tillage and crop-establishment practices. The maximum net energy output was obtained under CT-B. This was significantly higher than ZT. The difference in energy output in CT-B and ZT-B was 20.9 × 10^3 MJ, which was 30% higher energy output. Between ZT-F and ZT-B system of planting, there was 25% higher net energy output on latter than the former treatment. The net energy output was significantly influenced due to different weed management options. The maximum net energy output was obtained in weed free, while the lowest net energy output in the weed control. Between pendimethalin and pendimethalin + 1 HW, the latter resulted in 5.5% higher net energy output than the former. Similarly between pendimethalin + 1 HW and pendimethalin + chlorimuron ethyl, the latter yielded 11.5% less energy than the former treatment. The energy-use efficiency (energy output/energy input) was statistically similar due to different tillage and crop-establishment practices. The maximum energy efficiency was obtained under ZT-B and ZT-F system of planting. The energy efficiency was minimum in CT-B system of planting. The EUE was significantly influenced due to different weed-management options. The highest EUE was obtained under weed-free treatment, while the minimum under pendimethalin + chlorimuron ethyl. Between pendimethalin + 1 HW and pendimethalin + chlorimuron ethyl, the former treatment gave 9% higher EUE than the latter.

The cost of cultivation varied for different tillage and crop-establishment practices from ₹16,674 in ZT to ₹18,374 in CT-B (Table 2). Similarly, the cost of production for different weed-management options varied ₹15,977 for control to ₹19,977 under weed-free treatments. The cost of production was 12% higher in pendimethalin + 1 HW treatment than alone application of pendimethalin. Similarly, between pendimethalin + 1 HW and pendimethalin + chlorimuron ethyl, the latter involved 6.5% lower cost of production. The gross returns from grain and straw differed significantly due to different tillage and crop-establishment techniques. The highest gross returns from grain and stover was recorded under CT raised-bed, while it was the lowest in zero tillage. Similarly, the income from grain and stover differed significantly due to weed-management options (Table 2). The highest gross returns were obtained under weed free, while the lowest was obtained in the control. There was 33.4% increase in gross returns owing to full control of weeds.

Table 2. Economics of soybean cultivation as influenced by tillage and crop establishment and weed- management options.

Treatment	Cost of production (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	RUE/rupee invested
Tillage and crop establishment			
Conventional tillage flat-bed	18.09	27.95	2.545
Conventional tillage raised-bed	18.37	30.61	2.666
Zero tillage	16.67	19.79	2.187
Zero tillage raised-bed	16.87	29.67	2.758
SEm±		1.05	0.059
CD (P=0.05)		3.65	0.207
Weed management options			
Control	15.98	23.22	2.453
Weed free	19.98	32.32	2.617
Pendimethalin @ 0.75 kg/ha as PE	16.54	27.84	2.683
Chlorimuron ethyl @ 6 g/ha as PoE	16.65	25.15	2.510
Pendimethalin @ 0.75 kg/ha as PE + 1HW	18.54	28.02	2.511
Pendimethalin @ 0.75 kg/ha as PE + Chlorimuron ethyl @ 6 g/ha as PoE	17.34	25.51	2.471
SEm±		1.02	0.057
CD (P=0.05)		2.94	0.164

PE, Pre-emergence; PoE, post-emergence; HW, hand-weeding; RUE, resource-use efficiency

The net returns were significantly influenced due to tillage and crop-establishment practices. The highest net returns were obtained from conventional tillage raised-bed closely followed by zero tillage raised-bed which remained statistically similar. Conventional tillage raised-bed recorded 9.5% higher net returns than the conventional tillage flat-bed system of planting. Zero tillage resulted in the lowest net returns, being significantly lower than all other treatments. The net returns were significantly influenced due to different weed-management options. The highest net returns were obtained from weed free, while the lowest from the control. The net returns of ₹28,019 were obtained from pendimethalin + 1 HW which was statistically similar to application of only pendimethalin, where the returns were ₹27,840. The net returns from pendimethalin + 1 HW and pendimethalin + chlorimuron ethyl were statistically similar, though the former recorded 9.8% higher net returns than the latter treatment.

It may be concluded that the performance of soybean was better in raised-bed than flat-bed conventional system of planting. Cultivation of soybean was profitable with maximum net returns under conventional tillage raised-bed planting, closely followed by zero tillage raised-bed. Among the weed-management options, pendimethalin + 1 HW was remunerative with net returns of ₹28,019/ha, followed by application of only pendimethalin (₹27,840). Energy requirement in conventional tillage was 31.3% higher than the zero tillage flat-bed.

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