Indian Journal of Agronomy **54**(1): 29–35 (March 2009)

Weed dynamics and productivity of soybean (*Glycine max*) - based cropping systems as influenced by tillage and weed management

J.S. MISHRA[1] AND V.P. SINGH

National Research Centre for Weed Science, Maharajpur, Adhartal, Jabalpur, Madhya Pradesh 482 004

Received: July 2008

ABSTRACT

A field experiment was conducted during 2001-02 to 2004-05 at Jabalpur to find out the effect of 4 tillage sequences [zero-till planting of both the crops (ZT-ZT), conventional planting in both the crops (CT-CT), and two rotational tillage sequences that altered between zero-till and conventional tillage (ZT-CT and CT-ZT)] and three weed control treatments (weedy check, herbicide alone, and herbicide + 1 hand weeding at 30 days after sowing) on weeds and productivity of soybean (*Glycine max* L. Merr.)-based cropping systems, comprising soybean during the rainy (*kharif*) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and linseed (*Linum usitatissimum* L.) during the winter (*rabi*). Weeds in weedy check caused 86, 18 and 15.8 % reduction in seed yields of soybean, linseed and grain yield of wheat, respectively. Soybean-wheat cropping system produced higher soybean equivalent yield (3.01 t/ha), net returns (Rs 24,318/ha) and B: C ratio (2.17) than soybean-linseed system (1.78 t/ha; Rs 8,709/ha and 1.48, respectively). Zero tillage in both the seasons and effective weed control increased the system productivity as well as profitability. Nearly 50% of the total weed seeds were located in 0-5 cm soil layer. Soybean-linseed cropping system significantly reduced the seed bank of *Echinochloa colona* but increased the seed bank of *Vicia sativa* and *Chenopodium album*. Rotational tillage systems significantly reduced the seed density of *E. colona* as compared to continuous zero or conventional tillage systems. Weed seed number decreased considerably in plots receiving effective weed control (herbicide + 1 hand weeding). Zero tillage with effective weed control was found more remunerative in soybean-wheat system.

Key words: Cropping systems, Economics, Soybeans, Tillage, Weeds, Weed control

The introduction of soybean (*Glycine max* L. Merr.) in vertisols (swell-shrink) led to a shift in cropping system from a fallow (rainy season)-monocrop (post-rainy wheat or chickpea) system to soybean-wheat/chickpea/linseed/mustard system. Soybean-wheat for irrigated and soybean-linseed/chickpea/safflower cropping systems for rainfed conditions have been found most remunerative (Chauhan, 2007). Weeds are a major problem in most cropping systems and their control is essential for successful crop production. Tillage and/or herbicides are used for weed control, but the degree of control achieved may vary widely depending on weed species present, soil type, climatic condition, crop grown, tillage method and cropping system (Unger *et al.*, 1999). Altering tillage practices changes weed seed depth in soil, which plays a role in weed species shifts and affects efficacy of control practices (Buhler *et al.*, 1997). Because tillage systems affect soil disturbance, weed management, and weed seed production, a change in tillage systems will influence the species composition and vertical distribution of weed seeds in agricultural soils (Buhler, 1995) and reduction in population of troublesome species (Edward *et al.*, 2006). The tillage sequence with in a crop rotation is often unrecognized as a rotational component, but like crop rotations, the sequence may reduce weeds and other pests in annual cropping systems if managed properly (Carter, 1994). Less effort has been made to manage weed populations by imposing divers and designed tillage sequences within crop rotations. Hence, the present investigation was undertaken to find out the effect of tillage sequences and weed management on weed dynamics and productivity of soybean-based cropping systems.

MATERIALS AND METHODS

A field experiment was conducted at Jabalpur (latitude 23^0 90' N, longitude 79^0 58' E, and altitude 412 m above mean sea level) during 2001-02 to 2004-05. The soil was clay loam (Typic chromusterts), low in available N (240

[1]**Corresponding author** (E-mail: jsmishra31@gmail.com)

Present Address: Project Directorate of Sorghum Research, Rajendranagar, Hyderabad Andhra Pradesh 500 030

kg/ha), medium in organic C (0.58 %) and available P (18 kg/ha), and high in available K (304 kg/ha), with neutral pH (6.8) and EC (0.36 dS/m). The experimental design was a split-split plot with 3 replications. Main plot treatments were the two cropping systems (soybean-wheat and soybean-linseed), sub-plot treatments were 4 tillage sequences (zero tillage in both the crops (ZT-ZT), conventional tillage in both the crops (CT-CT), and two rotational tillage sequences of zero-till and conventional tillage (ZT-CT and CT-ZT) and sub-sub plot treatments were the three weed control methods (weedy check, recommended herbicide and herbicide + 1 hand weeding (HW) at 30 days after sowing). Crops were either direct-seeded without tillage (zero tillage) or conventionally planted after the tillage (conventional tillage). Conventional tillage consisted of tillage twice with a field cultivator, disked once with disc harrow and 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 at 1.0 kg/ha was applied a week before seeding in all the zero-till plots to kill the existing vegetation. Metribuzin at 0.50 kg/ha in soybean, isoproturon at 1.0 kg/ha in wheat and pendimethalin at 1.0 kg/ha in linseed were applied as pre-emergence (a day after sowing) with 500 litre/ha of water with the help of knapsack sprayer, fitted with flat-fan nozzle. Soybean 'JS 335' was grown from July to October, and wheat 'C 306' and linseed 'JL 23' were grown from November to March in each treatment with recommended package of practices. The experiment was conducted under irrigated conditions. Weed density was recorded at 30 days after sowing (DAS) and weed dry matter was collected at 90 DAS (before crop harvesting) from 1m^2 area by placing a quadrate of 50 cm x 50 cm randomly at four places in each plot.

The cost of cultivation was calculated by taking into account the prevailing prices of inputs. The returns were calculated by using the minimum support price of soybean (Rs 9.30/kg) and wheat (Rs 6.30/kg) and prevailing market price of linseed (Rs. 14.00/kg) for 2003-04. Different crop sequences were compared by converting the yield of all crops into soybean-equivalent on price basis. Soybean, wheat and linseed yields and soybean-equivalent yield were analysed on yearly basis and combined over the years for comparison of treatments.

Sampling of weed seedbank was done in early May 2004 after harvest of *rabi* crops (at the end of the 3-year rotation). In each plot, 5 areas were sampled using a 4 cm dia metal core. For each area, the core was used to carefully excavate soil from the 0 - 5, 5 - 10 and 10 - 20 cm soil depths. All samples for a given depth were bulked to give a composite soil sample per plot. Bulked soil samples were partially air-dried and then any clods were broken by hand. The soil seedbank was estimated by the seedling emergence method as described by Ter Heerdt *et al.* (1996). This method can underestimate the absolute weed seedbank size, but provides a relative comparison to assess tillage effects. Three 500 g soil samples for each depth/plot were prepared. They were spread in a plastic containers (16 cm dia and 3 cm depth) and placed in a greenhouse and watered daily. The emerged weed seedlings were identified, counted, and removed until emergence was nil. Soil was then dried, rewatered, and stirred to initiate further emergence. This cycle was repeated approximately monthly through July to December. Estimation of the vertical distribution of the weed seeds was made from the number of seedlings that emerged from the soil cores of different depths.

RESULTS AND DISCUSSION

Effect on weeds

Major weeds observed at 30 DAS were *Echinochloa colona*, *Commelina communis*, *Phyllanthus niruri* and *Cyperus iria* during rainy season and *Chenopodium album*, *Vicia sativa*, *Medicago hispida*, *Convolvulus arvensis*, *Euphorbia geniculata*, *Asphodelus tenuifoius* and *Cichorium intybus* during winter. Cropping system had variable effects on population of different weed species. During rainy season, soybean-linseed cropping system significantly reduced the population of *Phyllanthus niruri* as compared to soybean-wheat system (Table 1); however, the population of other weed species showed variable effects in different years. The total weed population did not vary significantly due to change in cropping system. Total weed dry matter was reduced in soybean-linseed system as compared to soybean-wheat system. This might be due allelopathic potential of linseed crop residues resulting in lower weed dry matter production in succeeding soybean crop. Different tillage systems did not influence the population of *E. colona* and *P. niruri* significantly. However, tillage in *kharif* significantly reduced the population of *C. communis* as compared to ZT. CT in both the seasons (CT-CT) significantly increased the population of *Cyperus iria* as compared to continuous ZT. Total population and dry matter of weeds were, however, not affected significantly due to variation in tillage systems. Pre-emergence application of metribuzin 0.50 kg/ha significantly reduced the population of all the weed species as compared to weedy check. Total weed dry matter was significantly lower with pre-emergence application of metribuzin + 1 HW at 30 DAS.

During winter, soybean-wheat system significantly reduced the population of most of the weeds (except *C.*

Table 1. Effect of cropping system, tillage and weed control methods on population at DAS and dry matter of weeds (g/m^2) at 90 DAS in soybean

Treatment	*E. colona*		*C. communis*		*P. niruri*		*C. iria*		Total		Weed dry weight	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Cropping system												
Soybean-wheat	6.3 (39.2)	13.4 (190)	4.1 (11.8)	6.6 (43.1)	5.0 (24.5)	4.8 (22.5)	1.7 (2.4)	5.5 (29.8)	9.5 (90)	17.0 (289)	13.9 (193)	22.8 (519)
Soybean-linseed	6.6 (43.1)	12.6 (158)	4.6 (21.2)	6.2 (37.9)	4.2 (17.1)	3.8 (13.9)	1.6 (2.1)	4.8 (22.5)	9.5 (90)	15.9 (252)	12.9 (166)	20.2 (408)
SEm ±	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.7	0.2	1.5
CD (P=0.05)	NS	0.7	NS	0.4	0.6	0.4	NS	0.3	NS	NS	0.6	NS
Tillage												
ZT-ZT	6.3 (39.2)	13.1 (171)	5.7 (32.0)	6.9 (47.1)	4.2 (17.1)	4.0 (15.5)	1.4 (1.5)	4.7 (21.6)	9.8 (96)	16.3 (265)	13.3 (176)	22.1 (488)
ZT-CT	5.4 (28.7)	12.4 (153)	5.7 (32.0)	7.9 (61.9)	3.6 (12.5)	4.6 (20.7)	1.1 (0.7)	5.3 (27.6)	8.9 (79)	16.8 (282)	13.5 (182)	21.8 (475)
CT-ZT	8.1 (65.6)	13.7 (187)	3.3 (10.4)	5.5 (29.8)	5.2 (26.5)	4.0 (15.5)	1.8 (2.7)	4.8 (22.5)	10.5 (110)	16.6 (275)	13.0 (169)	21.8 (475)
CT-CT	5.9 (34.3)	12.9 (166)	3.6 (12.5)	5.4 (28.7)	5.6 (30.9)	4.6 (20.7)	2.2 (4.3)	5.6 (30.9)	9.1 (82)	16.1 (259)	13.9 (193)	20.4 (416)
SEm ±	0.9	0.3	0.5	0.2	0.9	0.2	0.2	0.2	0.6	0.4	0.5	1.2
CD (P=0.05)	2.7	1.0	1.6	0.6	2.4	0.5	0.7	0.5	NS	NS	NS	NS
Weed control												
Herbicide	5.6 (30.9)	7.7 (58.8)	3.5 (11.8)	4.5 (19.8)	4.4 (18.9)	2.0 (3.5)	1.5 (1.8)	1.8 (2.7)	8.5 (72)	9.3 (86)	13.6 (184)	23.8 (566)
Herbicide + 1 HW	5.2 (26.5)	7.3 (52.8)	4.2 (17.1)	4.1 (16.3)	3.4 (11.1)	1.8 (2.7)	1.4 (1.5)	1.7 (2.4)	7.9 (62)	9.2 (84)	7.4 (54)	14.0 (196)
Weedy check	8.4 (70.1)	24.1 (595)	5.4 (28.7)	10.6 (112)	5.9 (34.3)	9.1 (82.3)	2.0 (3.5)	11.8 (139)	12.2 (148)	30.7 (942)	19.2 (368)	28.2 (795)
SEm ±	0.4	0.2	0.2	0.2	0.3	0.1	0.1 0.2	0.3	0.6	0.2	1.4	
CD (P=0.05)	1.2	0.7	0.6	0.5	0.8	0.4	0.4 0.5	1.0	1.7	0.7	3.9	

Data subjected to square root transformation. Values in parentheses are original *arvensis* and *E. geniculata*, which were at par) as compared to soybean-linseed system due to smothering effect of wheat crop on weeds as compared to linseed (Table 2). No definite trend on the effect of tillage systems on population of *C. album* and *Medicago hispida* over the years was observed. Continuous ZT significantly reduced the population of *V. sativa* and *C. intybus* as compared to continuous CT. Rotational tillage systems significantly increased the population of *C. arvensis* as compared to either continuous ZT or CT. Application of herbicides (isoproturon in wheat and pendimethalin in linseed) significantly reduced the population of *C. album* only but integration of herbicide with HW significantly reduced the population of most of the weed species as compared to weedy check.

Table 2. Effect of cropping system, tillage and weed control methods on population (no./m^2) of winter season weeds at 30 DAS

Treatment	*C. album*		*V. sativa*		*M. hispida*		*C. arvensis*		*E. geniculata*		*A. tenuifolius*		*C. intybus*	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Cropping system														
Soybean-wheat	1.4 (1.5)	1.2 (0.9)	1.2 (0.9)	1.9 (3.1)	2.1 (3.9)	2.3 (4.8)	1.5 (1.8)	1.9 (3.1)	1.4 (1.5)	3.5 (11.8)	1.0 (0.5)	1.1 (0.7)	1.2 (0.9)	1.4 (1.5)
Soybean-linseed	1.5 (1.8)	1.9 (3.1)	1.9 (3.1)	3.3 (10.4)	2.4 (5.3)	5.4 (29)	1.5 (1.8)	2.2 (4.3)	1.5 (1.8)	3.8 (13.9)	1.7 (2.4)	1.9 (3.1)	1.8 (2.7)	2.3 (4.8)
SEm±	0.1	0.1	0.04	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.04	0.08
CD (P=0.05)	NS	0.2	0.1	0.2	0.2	0.5	NS	0.3	NS	NS	0.2	0.2	0.1	0.2
Tillage														
ZT-ZT	1.3 (1.2)	1.6 (2.1)	1.3 (1.2)	1.9 (3.1)	1.7 (2.4)	4.8 (23)	1.1 (0.7)	1.5 (1.8)	2.1 (3.9)	4.5 (19.8)	1.3 (1.2)	1.6 (2.1)	1.2 (0.9)	1.8 (2.7)
ZT-CT	1.6 (2.1)	2.1 (3.9)	1.4 (1.5)	2.4 (5.3)	2.5 (5.8)	5.3 (28)	1.5 (1.8)	2.2 (4.3)	1.4 (1.5)	3.9 (14.7)	1.2 (0.9)	1.2 (0.9)	1.4 (1.5)	1.5 (1.8)
CT-ZT	1.3 (1.2)	1.0 (0.5)	1.5 (1.8)	3.0 (8.5)	2.5 (5.8)	2.7 (6.8)	2.2 (4.3)	3.0 (8.5)	1.2 (0.9)	3.5 (11.8)	1.3 (1.2)	1.5 (1.8)	1.3 (1.2)	1.8 (2.7)
CT-CT	1.6 (2.1)	1.6 (2.1)	2.0 (3.5)	3.2 (9.7)	2.3 (4.8)	2.5 (5.8)	1.1 (0.7)	1.5 (1.8)	1.1 (0.7)	2.6 (6.3)	1.6 (2.1)	1.7 (2.4)	1.9 (3.1)	2.4 (5.3)
SEm±	0.15	0.1	0.05	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.2	0.1	0.03	0.1
CD (P=0.05)	0.4	0.2	0.1	0.2	0.3	0.8	0.2	0.4	0.3	0.6	NS	0.3	0.1	0.3
Weed control														
Herbicide	1.1 (0.7)	1.6 (2.1)	1.6 (2.1)	2.8 (7.3)	2.6 (6.3)	4.1 (16)	1.7 (2.4)	2.4 (5.3)	1.4 (1.5)	4.3 (18.0)	1.3 (1.2)	1.5 (1.8)	1.5 (1.8)	1.7 (2.4)
Herbicide + 1 HW	1.1 (0.7)	0.9 (0.3)	1.3 (1.2)	2.1 (3.9)	1.9 (3.1)	3.2 (9.7)	1.4 (1.5)	2.2 (4.3)	1.2 (0.9)	1.5 (1.8)	1.2 (0.9)	1.5 (1.8)	1.2 (0.9)	1.8 (2.7)
Weedy check	2.2 (4.3)	2.2 (4.3)	1.8 (2.7)	2.9 (7.9)	2.6 (6.3)	4.3 (18)	1.3 (1.2)	1.6 (2.1)	1.8 (2.8)	5.1 (25.5)	1.3 (1.2)	1.4 (1.5)	1.7 (2.4)	2.1 (3.9)
SEm±	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.1	0.3	0.1	0.1	0.1	0.1	0.1
CD (P=0.05)	0.3	0.2	0.2	0.2	0.2	0.3	0.1	0.2	NS	0.3	NS	NS	0.2	0.3

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

Effect on yield

Soybean

In general the seed yield of soybean in 2002 was low due to excessive rains and severe infection of yellow mosaic virus. Different cropping systems and tillage did not influence the seed yield of soybean significantly; however, soybean after linseed and ZT in both the seasons gave the highest seed yield (Table 3). Infestation of weeds caused 86% reduction in seed yield of soybean. Pre-emergence application of herbicide followed by HW at 30 DAS significantly increased the seed yield of soybean as compared to herbicide alone and weedy check due to effective control of weeds.

Wheat

Variation in tillage systems did not influence the grain yield of wheat significantly except in 2002-03, where continuous ZT yielded significantly higher (5.13 t/ha) as compared to CT rotated with ZT (4.28 t/ha). On an average, infestation of weeds caused 15.8 % reduction in seed yield of wheat. Integration of herbicide with HW produced significantly higher grain yield as compared to herbicide alone during 2002-03 and 2003-04. No significant interaction was observed between tillage systems and weed control.

Linseed

In 2001-02, the seed yield of linseed under continuous ZT was at par with that of continuous CT and ZT rotated with CT, however, in subsequent years, continuous ZT produced significantly higher seed yields than other tillage treatments. On an

Table 3. Effect of cropping system, tillage and weed control on seed yield (t/ha) of soybean, wheat and linseed

Treatment	Soybean		Wheat			Linseed		
	2002	2003	2001-02	2002-03	2003-04	2001-02	2002-03	2003-04
Cropping system								
Soybean-wheat	0.23	0.93	3.72	4.74	3.73			
Soybean-linseed	0.19	0.98				0.96	1.10	1.52
SEm±	0.02	0.03						
CD (P=0.05)	NS	NS						
Tillage sequences								
ZT-ZT	0.27	1.02	3.69	5.13	3.49	1.02	1.31	1.71
ZT-CT	0.17	0.91	4.01	4.86	3.47	0.92	0.98	1.46
CT-ZT	0.12	0.97	3.51	4.28	3.68	0.73	1.07	1.38
CT-CT	0.27	0.92	3.66	4.65	4.28	1.16	1.04	1.54
SEm±	0.02	0.04	0.22	0.21	0.34	0.13	0.08	0.04
CD (P=0.05)	0.06	NS	NS	0.58	NS	0.36	0.22	0.11
Weed control methods								
Herbicide alone	0.24	1.22	3.69	4.65	3.67	0.98	1.11	1.43
Herbicide+1 HW	0.31	1.55	3.88	5.12	4.35	1.00	1.19	1.85
Weedy check	0.07	0.10	3.58	4.46	3.18	0.90	1.01	1.29
SEm±	0.01	0.04	0.13	0.16	0.15	0.04	0.05	0.07
CD (P=0.05)	0.03	0.12	NS	0.45	0.46	NS	0.15	0.22

average, infestation of weeds caused 18 % reduction in seed yield of linseed. Application of herbicide (pendimethalin) alone did not provide significant increase in the seed yield of linseed as compared to weedy check due to poor control of weeds viz., *V. sativa, M. hispida, C. arvensis* and *E. geniculata;* however, its integration with HW significantly increased the seed yield. The interaction between tillage systems and weed control was not significant.

Soybean equivalent yield (SEY) and economics

Soybean-wheat system produced higher soybean equivalent yield (3.01 t/ha) than soybean-linseed system (1.78 t/ha), Table 4. SEY in soybean-wheat system under continuous zero (3.11 t/ha)/conventional (3.12 t/ha) tillage system was almost the same. However, in soybean-linseed system, continuous zero tillage gave higher SEY, (2.0 t/ha), than continuous CT (1.84 t/ha). Rotational tillage in both cropping systems produced lower SEY than continuous tillage systems. Irrespective of the system, maximum SEY was recorded in herbicide + HW treatment followed by herbicide alone and weedy check.

Soybean-wheat system generated higher net returns (Rs 24,318/ha) and benefit: cost ratio (2.17) than soybean-linseed system (Rs 8,709/ha and 1.48). Higher SEY under soybean-wheat cropping system was due to higher yields of wheat that caused a variation in net returns and B:C ratio. Continuous ZT (ZT-ZT) generated higher net returns (Rs 28,085 and Rs 14,225) and B:C ratio (2.50 and 1.89) in both the cropping systems due to lower cost of cultivation and higher SEY (Table 4). Among weed control treatments, higher net returns were obtained from herbicide + HW. However, the B:C ratio was higher in herbicide alone plots due to lower cost of cultivation.

Weed seed bank

The entire 11 weed species identified from the above ground weed flora of the field experiment (Tables 1 and 2) were present in the seed bank. Irrespective of the treatments, major portion (71%) of weed seed bank was comprised of *E. colona* (Table 5). The other species observed in the seed bank in relatively higher proportion were *V. sativa* (10%), *C. album* (9%) and *C. communis* (6%). Nearly 50% of the total weed seeds were located in 0-5 cm soil layer. Seed numbers decreased as depth increased in all the treatments. Soybean-linseed cropping system significantly reduced the seed bank of *E. colona* but increased the seed bank of *V. sativa* and *C. album* as compared to soybean-wheat system. Continuous zero tillage system contained significantly higher proportion of total viable seed of *E. colona* in 0-5 cm soil depth as compared to continuous conventional tillage and rotational tillage systems. Higher weed seed densities in no-tillage systems may be the result of reduced herbicides availability because of adsorption to near surface organic matter (Isensee and Sadeghi, 1994). Rotational tillage systems significantly reduced the seed density as compared to continuous zero or CT systems. Edward *et al.* (2006) also observed that rotational tillage reduced seed density of hairy nightshade (*Solanum sarrachoides* Sendtner) and powell amaranth (*Amaranthus powellii* S. Wats) as compared to continuous conventional tillage. Continuous zero tillage sys-

Table 4. Soybean-equivalent yield, (SEY, t/ha)cost of cultivation (CC) net returns (NR, x 10^3 Rs/ha) and benefit cost ratio as affected by tillage systems and weed control (average of 2 years)

Treatment	Herbicide alone				Herbicide + 1 Hand weeding				Weedy check				Mean			
	SEY (t/ha)	CC	NR	B:C ratio	SEY	CC	NR	B:C ratio	SEY	CC	NR	B:C ratio	SEY	CC	NR	B:C ratio
Soybean-wheat system																
ZT-ZT	3.26	17.60	31.23	2.77	3.71	22.60	33.10	2.46	2.37	15.60	19.94	2.28	3.11	18.60	28.09	2.50
ZT-CT	3.07	20.00	26.05	2.30	3.59	25.00	28.81	2.15	2.26	18.00	15.87	1.88	2.97	21.00	23.58	2.11
CT-ZT	2.81	20.00	22.12	2.11	3.43	25.00	26.39	2.06	2.28	18.00	16.19	1.90	2.84	21.00	21.57	2.02
CT-CT	3.38	21.80	28.89	2.33	3.57	26.80	26.77	2.00	2.42	19.80	16.49	1.83	3.12	22.80	24.05	2.05
Mean	3.13	19.85	27.07	2.38	3.57	24.85	28.76	2.17	2.33	17.85	17.12	1.97	3.01	20.85	24.32	2.17
Soybean-linseed system																
ZT-ZT	2.18	15.20	17.43	2.15	2.48	19.70	17.46	1.89	1.33	12.20	7.80	1.64	2.00	15.70	14.23	1.89
ZT-CT	1.74	17.60	8.56	1.49	2.17	22.10	10.39	1.47	1.09	14.60	1.68	1.11	1.67	18.10	6.88	1.36
CT-ZT	1.72	17.60	8.20	1.47	2.00	22.10	7.87	1.36	1.10	14.60	1.89	1.13	1.61	18.10	5.99	1.32
CT-CT	1.96	19.40	9.93	1.51	2.48	23.90	13.30	1.56	1.10	16.40	0.03	1.00	1.84	19.90	7.75	1.36
Mean	1.90	17.45	11.12	1.66	2.28	21.95	12.35	1.57	1.15	14.45	2.85	1.22	1.78	17.95	8.71	1.48

Table 5. Distribution of major weed species (seeds/500g soil) in top 20 cm of soil as affected by cropping systems, tillage sequences and weed management

Treatment	*Echinochloa colona*			*Commelina communis*			*Vicia sativa*			*Chenopodium album*		
	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm	0-5 cm	5-10 cm	10-20 cm
Cropping system												
Soybean-wheat	40.10	20.39	11.08	2.19	0.86	0.86	1.42	1.14	0.66	0.31	0.31	0.47
Soybean-linseed	26.70	16.33	8.78	2.06	1.33	0.75	9.47	6.25	2.87	3.39	3.22	3.06
SEm±	3.12	1.63	0.45	0.08	0.07	0.04	0.22	0.27	0.06	0.12	0.14	0.07
CD (P=0.05)	9.20	NS	1.36	NS	0.21	NS	0.62	0.84	0.18	0.35	0.41	0.21
Tillage												
ZT-ZT	44.40	21.56	10.89	2.50	1.50	0.94	1.94	3.00	1.89	1.61	0.83	0.89
ZT-CT	28.70	18.67	8.17	1.83	1.17	0.83	5.17	3.44	1.83	4.44	3.06	3.33
CT-ZT	26.30	12.50	10.06	1.72	0.39	0.72	3.56	3.78	2.73	0.22	0.50	0.83
CT-CT	34.30	20.72	9.61	2.44	1.33	0.72	11.11	4.56	4.06	1.11	2.67	2.00
SEm±	1.50	0.55	0.40	0.07	0.04	0.04	0.17	0.18	0.09	0.07	0.07	0.18
CD (P=0.05)	4.40	1.58	1.15	0.22	0.13	0.12	0.53	0.54	0.26	0.22	0.23	0.53
Weed control												
Herbicide	41.00	22.92	11.33	1.33	1.00	0.71	7.50	5.96	3.63	0.58	0.53	0.92
Herbicide+1 HW	12.30	5.50	3.67	0.54	0.17	0.29	2.96	1.25	1.04	1.46	0.58	0.46
Weedy check	46.90	26.67	14.79	4.50	2.12	1.42	5.88	3.88	3.21	3.50	3.65	3.92
SEm±	0.95	0.25	0.28	0.08	0.04	0.04	0.18	0.12	0.11	0.08	0.07	0.10
CD (P=0.05)	2.70	0.74	0.84	0.23	0.12	0.11	0.50	0.33	0.31	0.23	0.21	0.29

tem significantly reduced the seed bank of *V. sativa* as compared to continuous conventional tillage and rotational tillage systems. Weed management significantly influenced the weed seed number in soil. Weed seed number decreased considerably in plots receiving effective weed control (herbicide + 1 hand weeding). Similar finding was also reported by Burnside *et al.* (1986).

Consequently soybean-wheat, which is the predominant crop sequence in irrigated areas of Madhya Pradesh, could be made more remunerative by adopting conservation tillage and effective weed control without affecting the system productivity. Rotational tillage systems have been found more effective in reducing soil weed seedbank.

REFERENCES

Buhler, D.D. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean production in central USA. *Crop Science* **35**: 1247 -1257.

Buhler, D.D., Hartzler, R.G., and Forcella, F. 1997. Implications of weed seed bank dynamics to weed management. *Weed Science* **45**: 329-336.

Burnside, O.C., Moomaw, R.S., Roeth, F.W., Wicks, G.A. and Wilson, R.G. 1986. Weed seed demice in soil in weed-free corn (*Zea mays*) production across Nebraska. *Weed Science* **34**: 248-251.

Carter, M.R. 1994. Strategies to overcome impediments of adoption of conservation tillage. (In): Conservation tillage in Temperate Agroecosystems. pp. 3-19. Carter, M.R. (Ed.), Boca Raton, FL:Lewis.

Chauhan G. S. 2007. Soybean research-trends and developments. (In): National Symposium on 'Legumes for Ecological Sustainability: Emerging Challenges and Opportunities', held from 3-5 November 2007 at Indian Institute of Pulses Research, Kanpur, pp 18-23.

Isensee, A.R., and Sadeghi, A.M., 1994. Effect of tillage on atrazine residue level in soil. *Weed Science* **42**: 461-467.

Peachey, B.E., William, R.D., and Mallory-Smith, C., 2006. Effect of spring tillage sequence on summer annual weeds in vegetable row crop rotations. *Weed Technology* **20**: 204-214.

Ter Heerdt, G. N. J., Verwey, G. L., Bekker, R. M. and Bakker, J. P. 1996. An improved method for seed-bank analysis: seedling emergence after removing the soil sieving. *Functional Ecology* **10**: 144-151.

Unger, P.W., Miller, S.D. and Jones, O.R. 1999. Weed seeds in long-term dryland tillage and cropping system plots. *Weed Research* **39**: 213-223.