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Weed Seed Bank Response to Soil Depth, Tillage and Weed Management in the Mid Hill Ecology

Jagat Devi Ranjit[1]*, Rungsit Suwanketnikom[2], Sombat Chinawong[3], Sutevee Suprakarn[4], Isara Sooksathan[2] and Sunanta Juntakool[2]

ABSTRACT

The size and composition of weed seed bank was studied in the glass house based on the study initiated in the field under conventional and minimum tillage with five weed managements in wheat and dry direct seeded rice rotation at various soil depths such as 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm. The experiments were conducted at Agronomy Farm, Khumaltar, Nepal during 2001-2003. The number of weed species was greater in weed seed bank than in the field. Eighty–one weed species belonging to 25 families were retrieved from the soil seed bank samples collected over three seasons. Dicot broadleaves ranked first in terms of number of species followed by grasses, sedges, monocot broadleaves and pteridophytes. *Alopecuros aequalis*, *Digitaria sanguinalis*, *Echinochloa colona*, *Phalaris minor*, *Polypogon fugox, Cyperus difformis*, *C. dilutus*, *C. iria*, *C. sanguinolentus*, *Fimbristyllis littoralis, Chenopodium album, Coronopus didymus, Lindernia procumbens, Rumex crispus, Soliva anthemifolia, Stellaria media, S. aquatica, Commelina diffusa, Murdania* sp. *and Ceratopteri thalictroides* were the common weeds. Vertical distribution of weed seed bank of grasses, sedges, and broadleaves showed in descending order from 5 cm to 20 cm in all season's soil samples and the pressure of most weeds was at 5-10 cm soil depth. The total number of weeds in seed bank per square meter ranged from 6,800 to 9,500 in 0-5 cm depth. Tillage affected on grass weed seed bank but had no consistent effect on sedges and neither on broadleaves over seasons. Sulfosulfuron and fenoxaprop affected on annual grass weed seed bank but not on broadleaf by the later. Bispyribac–sodium and anilophos both suppressed grass and sedge weed seed bank. Weed seed bank was influenced by management as well as soil depths.

Key words: rice, wheat, tillage, weed seed bank, weed management

INTRODUCTION

Tillage, weed management and crop rotation are major variables that affect weed seed banks in the soil. In many parts of the world, the most popular technique for reducing weed seed bank size has been some form of following combined with cultivation. Similarly, in areas relying on chemical weed management, herbicides affect and change the seed bank spectrum and size. For example, atrazine used in maize (*Zea mays*) monoculture reduced the weed seed bank by 90%

1 Agronomy Division, Nepal Agriculture Research Council, GPO Box 404, Kathmandu, Nepal.
2 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
3 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Kamphaeng Sean, Nakhon Pathom 73140, Thailand.
4 Department of Horticulture, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
* Corresponding author, e-mail: nepaljdr@yahoo.com

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after 6 years of application (Cavers and Benoit 1989). However, in many parts of the world, tillage is still the major weed management tool in several cropping systems.

Weed management in the rice (*Oryza sativa*) –wheat (*Triticum aestivum*) cropping systems of the mid hills of Nepal is still heavily reliant on tillage and hand weeding.This rotation is predominant in Nepal and throughout the Indo-Gangetic region. However, with the development of cost effective tillage systems in these rotations, weed management is becoming a major concern because of issues of weed species shifts and alterations in the soil weed seed bank composition. Several studies in temperate regions have shown that changes in tillage regimes cause a change in the weed community composition and seed bank dynamics. It has been cited that, concerns of weed species shift is one of the major constraint to widespread adoption of conservation tillage systems (Derksen *et al*.,1994). Therefore, weed species shift and soil weed seed bank dynamics becomes an important aspect in developing weed management systems and in anticipating future weed problems.

Changes in the tillage system can cause the secondary weed to become a primary problem. For example, there are instances in wheat where the management of broadleaf weeds over time has promoted the prolific growth of grassy weeds (personnel experience). In many areas of the world, rice is direct seeded. Direct seeding of rice is usually achieved with less aggressive tillage and a greater use of herbicides. This method has led to an increase in annual weed problems as well as a shift in the spectrum of annual weeds present. Management of these new weed problems of rice and other tropical weeds in other situations is dependent upon the knowledge of soil seed bank, their size and dynamics (Adkins, 1999).

The past researches on soil seed banks were mainly concentrated on cereals and legumes. Very few studies have looked at the seed bank dynamics in a rice - wheat system. It has been reported that crop rotation in combination with reduced tillage could limit grass and broadleaf weed seed production regardless of the level of weed management input (Kegode *et al*., 1999). However, weed management showed more impact than tillage on weed seed production in a maize-soybean rotation (Perron and Legere, 2000). Reduction of weed seed production has been reported with continuous weed management for six years (Menges, 1987). However, seasonal variations have been found in weed seed production in different habitats (Roberts and Ricketts, 1979). An account of weed seed deposition may help in predicting the effect of weed management and tillage and in anticipating future weed populations. Very little or no attention has been given to this aspect in the rice-wheat cropping systems of Nepal. Further, past researches in other countries have mainly focused on wheat-soybean, maize, pulses and other crops. The present study aims to predict the soil seed bank in a rice-wheat cropping system as influenced by tillage and weed management.

MATERIALS AND METHODS

Three sets of glasshouse experiments were conducted to study the soil seed bank dynamics in a wheat-rice rotation at Agronomy Farm, Khumaltar, Nepal. The experiment was based on samples collected from a field study determining the effect of tillage and weed management in wheat and rice. The field study consisted of two tillage systems, conventional tillage (2 ploughing + 2 harrowing) and minimum tillage (one time 5-7 cm) deep soil scratch made by a Chinese Seed Drill under five weed management regimes (Table 1). Rice was direct seeded in dry soil in both tillage systems and both rice and wheat were row-planted manually. The treatments were replicated four times.

Soil samples were collected from the

Table 1 Weed management regimes in wheat and rice rotation.

Wheat	Rice
Tillage	**Tillage**
Conventional tillage (CT)	Conventional tillage (CT)
Minimum tillage (MT)	Minimum tillage (MT)
Weed management regime	**Weed management regime**
Unweeded control (W1)	Unweeded control (W1)
Handweeding one (W2)	Handweeding two (W2)
Post application sulfosufuron 28 g ai/ha (W3)	Pre-application anilophos @ 0.4 g ai/ha + one handweeding (W3)
Post application fenoxyprop–P-ethyl @ 100 g ai/ha (W4)	Post application bispyribac- sodium 50 g ai/ha (W4)
Straw mulch @ 4 t/ha + sulfosulfuron @ 26 g ai/ha (W5)	Straw mulch @ 4 t/ha + bispyribac-sodium 40 g ai/ha (W5)

field three times during the rotation. The first (1^{st}) sample was collected just prior to wheat planting, the second (2^{nd}) after wheat harvest, and the third (3^{rd}) after rice harvest. The field was divided into forty 4 × 5m plots before land preparation. Soil cores were taken in five spots within each plot at 4 soil depths (0-5, 5-10, 10-15 and 15-20 cm). The cores were taken with a 5-cm diameter soil auger. There were altogether 800 soil cores (5 cores × 4 depths × 2 tillage × 5 weed management × 4 replications). The total area for each depth per plot was 589.04 cm^2. The total soil volume of each core was approximately 491 cm^3. The samples were stored in a dark place at room temperature for 3 weeks and then transferred to plastic trays (5 × 19 × 24 cm). These trays were filled with coarse sand (sterilized at 90°C for 72 hrs in the oven) upto 2 cm and covered with a thin film of cotton gauge. The five soil cores from each plot were combined, crumbled and laid on top of the cotton gauge (Barberi *et al*., 1998). Therefore, altogether there were 160 trays (4 depths × 2 tillage × 5 weed management × 4 replications) for each set of the experiment. The soil was kept moist by watering daily. But watering was suspended for 8-10 days every 4 months. All the soil samples were treated with KNO_3 (potassium nitrate) solution @ 2 gm/1l of water at 32 weeks of the experiment. The date soil cores were taken at the 1^{st}, 2^{nd} and 3^{rd} sampling corresponded to Oct. 2001, May 2002, and Oct. 2002, respectively. The temperature of the glass house ranged from 9.2°C minimum to 21.8°C maximum in December and 22.1°C minimum to 35.9°C maximum in August.

Emerged weed seedlings were pulled out, identified and counted at regular intervals at the 3-5-leaf stage of the weed. Almost all types of weed species were allowed to grow in a separate pot until the flowering stage for identification purposes. Weed identification was done by consulting the Herbarium Division, Department of Forest, Kathmandu, Nepal and other references (e.g. Hirohito, 1997). The identified weeds were categorized into five groups: grass, sedge, broadleaf dicot, broadleaf monocot, and pteridophytes. The weed data were later converted to per square meter.

RESULTS AND DISCUSSION

Weed species composition

Altogether seeds of 81 weed species were retrieved from the soil seed bank samples collected over the three seasons'. Dicot broadleaf, representing 50 species belonging to 18 families, ranked first in terms of number of seedlings emerged. Grasses ranked second with 14 species belonging to a single family. Sedges ranked third with 9 species belonging to 2 families. Further, there were 5 species of monocot broadleaves belonging to 3 families, and 2 pteridophyte species belonging to 2 families (Table 2). A few species were dominant in each broadleaf, grass or sedge category. *Alopecuros aequalis, Digitaria sanguinalis, Echinochloa colona, Phalaris minor* and *Polypogon fugox* were the common species among the grasses. *Cyperus difformis, C. dilutus, C. iria, C. sanguinolentus* and *Fimbristylis littoralis* were the common sedge species whereas, *Chenopodium album, Coronopus didymus, Lindernia procumbens, Rumex crispus, Soliva anthemifolia, Stellaria media* and *S. aquatica* were the most common broadleaf dicots. *Commelina diffusa, Murdania* sp. and *Ceratopteri thalictroides* were the most common monocot broadleaves and pteridophtye, respectively (Table 1).

The number of weed species that emerged from the sampled soil weed seed bank was greater than the number of species that was actually observed in the field. Some species, although not observed growing in the field were recorded in the weed seed bank. This might have been due to allelopathic effect of species in the field or prolonged dormancy of the seed, or lack of ideal conditions for seed germination and seedling emergence. Frequent removal of emerged weed seedlings from the soil cores might have provided an opportunity to several other species of weeds to germinate and emerge from the weed seed bank as opposed to the growing conditions in the field. However, this phenomena needs more attention in future studies.

Response of weeds to soil depths, tillage and weed management

Soil depth

The vertical distribution of total weed seeds in the seed bank showed a declining trend in density as the depth increased from 5 cm to 20 cm in all the soil samples regardless of season (Tables 3, 4 and 5). The total grass weed seeds decreased over the season. But the pressure was in the first 0-5-cm depth (Table 3). The seed bank size of grasses increased from 40%-70% over time. Sedges and broadleaf weed seeds also showed a similar trend but the percent increase was not as high as in grass (Table 3 and 4).

The seeds of *P. minor, A. aequalis,C. difformis, C. iria, C. sanguinolentus, C. album C. thalictroides, C. didymus, E.colona, L. procumbens, M. pumillus, P. fugox, R. crispus, S.anthemifolia, S. media and S. aquatica* were mainly located in the 5-15 cm soil depth (Table 3, 4 and 5). The seed bank density of *C. album* decreased over time in all the depths (Table 5). The seed bank density of broadleaf weeds such *as C. didymus, L.procumbens, R. crispus, S. anthemifolia, S. media* and *S. aquatica* decreased after wheat harvest but increased in the soil samples taken after rice harvest. The density of *S. anthemifolia* increased in 20 cm soil depth after rice harvest than after wheat harvest. Seed bank of *C. thalictroides* decreased in all the depth after rice harvest than before wheat planting and after harvest (Table 5). Seed bank of *A. aequalis, C. album, P. minor* and *S. media* decreased by more than 100% after wheat and rice harvest than before wheat planting or the beginning of the experiment. It might be due to management effect during rice and wheat seasons. But the seed bank of C. *difformis, C. iria, C. sanguinolentus, E. colona, L. procumbens, P. minor, S. anthemifolia* and *S. aquatica* increased after the rice harvest in 5 cm soil depth showing their inconsistency trend (Table 3, 4 and 5). This study showed that the weed seed accumulation of most species was highest in the 5-10-cm soil depth.

Table 2 Occurrence of weed species in the seed bank.

	Weed species	Family	Season[1/]
	Grass		
1	*Alopecuros aequalis* Sobol.	Poaceae	W
2	*Cynodon dactylon* (L.) Pers.	Poaceae	W
3	*Digitaria sanguinalis* (L.) Scop.	Poaceae	S
4	*D.ciliaris* Koel.	Poaceae	S
5	*Echinochloa colona* L. (Link.)	Poaceae	S
6	*E. crusgalli* (L.) Beauv.	Poaceae	S
7	*Eluesine indica* (L) Gaertn.	Poaceae	S
8	*Phalaris minor* Retz.	Poaceae	W
9	*Paspalum distichum* L.	Poaceae	S
10	*Panicum* sp.	Poaceae	S
11	*Poa annua* L.	Poaceae	W
12	*Polypogon fugox* Steud.	Poaceae	W
13	*Setaria* sp.	Poaceae	S
14	Unidentified grass	Poaceae	S
	Sedge		
1	*Cyperus difformis* L (Roxb.)	Cyperaceae	S
2	*C. iria* L.	Cyperaceae	S
3	*C. cuspidatus* Kunth	Cyperaceae	S
4	*C. dilutus* Vahl.	Cyperaceae	S
5	*C. sanguinolentus* Vahl.	Cyperaceae	S
6	*Eleocharis atropurpuria* Kunth.	Eriocaulaceae	S
7	*Eriocaulan sieboldtianum* Siebet.	Eriocaulaceae	S
8	*Fimbristylis littoralis* Gaud.	Cyperaceae	S
9	*Scirpus juncoides* Roxb.	Cyperaceae	S
	Broadleaf Dicot		
1	*Ageratum conyzoides* L.	Asteraceae	S
2	*Aeschenomene indica* L.	Leguminoseae	S
3	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	S
4	*A. sessilis* (L) DC.	Amaranthaceae	S
5	*Ammania baccifera* L.	Lythraceae	S
6	*A. coccinea* Rottb.	Lythraceae	S
7	*Amaranthus retroflexus* L.	Amaranthaceae	S
8	*Bidens pilosa* L.	Asteraceae	W
9	*Bothiospermum* sp.	Boraginaceae	W
10	*Chenopodium album* L.	Chenopodiaceae	W
11	*C. ambrosoides* L	Chenopodiaceae	W
12	*Coronpus didymus* Smith.	Brassicaceae	W
13	*Cardamine pretense* L.	Brassicaceae	
14	*Convulvulus arvensis* L.	Convolvulaceae	W
15	*Cotula* sp.	Asteraceae	W
16	*Dicrocephala* sp.	Asteraceae	W
17	*Dopatrium junceum* Hamilt.	Scrophulariaceae	S

Table 2 (Cont'd)

	Weed species	Family	Season[1/]
18	*Drymaria cordata* (L). Willd.	Cayopyllaceae	W
19	*Elatine* sp.	Elatinaceae	S
20	*Euphorbia hirta* L.	Euphorbiaceae	W
21	*Eclipta prostrata* L.	Asteraceae	S
22	*Fragaria* sp.	Rosaceae	
23	*Gnaphalium affine* D. Don.	Asteraceae	W
24	*Hydrocotyle nepalensis* Hook.	Umbelliferae	S
25	*Ipomea* sp.	Convolvulaceae	S
26	*Lindernia* sp.	Scrophulariaceae	S
27	*L. procumbens* (Krock.)		
28	*L. crustacea* (L.) F. Muell.	Scrophulariaceae	S
29	*Lactuca* sp.	Asteraceae	W
30	*Mazus* sp.	Scrophulariaceae	S
31	*Mazus pumillus* (Burm. f.) Van Steenis.	Scrophulariaceae	S
32	*Oenothera* sp.	Onagraceae	
33	*Oxalis corniculata* L.	Oxalidaceae	W
34	*Polygonum hydropiper* L.	Polygonaceae	W/S
35	*P. plebejum*	Polygonaceae	W
36	*Polygonum* sp.	Polygonaceae	W
37	*P. conspicum* Nakai.	Polygonaceae	S
38	*Rorripa indica*	Brassicaceae	W
39	*Rotala rotundifolia*	Lythraceae	S
40	*Rumex* sp.	Polygonaceae	W
41	*R. crispus* L.	Polygonaceae	W
42	*Ranunculus* sp.	Ranunculaceae	
43	*Senecio vulgaris* L.	Asteraceae	W
44	*Soliva anthemifolia*	Asteraceae	W
45	*Stellaria media* Villars.	Caryophyllaceae	W
46	*S. aquatica* Scop.	Caryophyllaceae	W
47	*S. alsine* Grimm.	Caryophyllaceae	W
48	*Trifolium repens* L.	Leguminoseae	W
49	*Vandellia ungstifolia* Benth.	Scrophulariaceae	S
50	*Vicia hirsuta* S. F. Gray.	Leguminoseae	W
	Broadleaf Mococot		
1	*Commelina diffusa* Burm.f.	Commelinaceae	S
2	*C. benghalensis* L.	Commelinaceae	S
3	*Monochoria vaginalis* Presl.	Pontederaceae	S
4	*Murdania* sp.	Commelinaceae	
5	*Sagittaria guayanensis* H. B. K	Alismaceae	S
	Pteridophytes		
1	*Ceratopteris thalictroides* Brongn.	Parkeriaceae	S
2	*Pteridium* sp.	Pteridaceae	S

[1/] season ; W = winter, S = summer

Table 3 Response of grass weed seed bank density to soil depth, tillage and weed management at before wheat planting (BWP), after wheat harvest (AWH) and after rice harvest (ARH).

Treatments	*P. minor*			*A. aequalis*			*E. colona*			Total grasses		
	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH
	No. of Seedlings/m^2											
Soil depth (A)												
0-5 cm	104^{a} [1/]	154^{a}	352^{a}	1506^{a}	428^{a}	633^{a}	10	43^{a}	76	1887^{a}	1090^{a}	1306^{a}
5-10 cm	115^{a}	8^{b}	0^{b}	1304^{b}	141^{b}	251^{b}	5	34^{ab}	1	1608^{b}	519^{b}	317^{b}
10-15 cm	81^{a}	19^{b}	21^{b}	703^{c}	76^{b}	86^{c}	9	15^{bc}	8	899^{c}	286^{c}	161^{bc}
15-20 cm	17^{b}	20^{b}	4^{b}	145^{d}	84^{b}	20^{c}	40	4^{c}	1	305^{d}	284^{c}	38^{c}
Tillage (B)												
Conventional tillage	78	55	119^{a}	924	197^{a}	283	23	22^{b}	25	1200	566^{a}	518^{a}
Minimum tillage	81	46	70^{b}	905	168^{b}	212	9	26^{a}	18	1149	525^{b}	393
Weed management (C)												
W1 [3/]	90	55	100	870	230^{a}	300	27	15	35	1168	603^{a}	544^{a}
W2	84	48	62	930	215^{a}	232	8	24	11	1186	597^{a}	410^{bc}
W3	71	48	83	924	141^{bc}	187	13	22	19	1159	481^{b}	367^{c}
W4	79	46	98	1003	131^{c}	253	6	40	31	1228	483^{b}	457^{abc}
W5	73	55	130	847	195^{ab}	266	26	20	12	1132	563^{ab}	501^{ab}
A	** [2/]	**	**	**	**	**	NS	*	NS	**	**	**
B	NS	NS	*	NS	**	NS	NS	NS	NS	NS	**	*
A×B	NS	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS
C	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	*	*
A×C	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**
B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

1/ Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

2/ Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

3/ Refer to materials and methods for the details of weed management treatments.

Table 4 Response of sedge weed seed bank density to soil depth, tillage and weed management at before wheat planting (BWP), after wheat harvest (AWH) and after rice harvest (ARH).

	C. difformis			*C. iria*			*C. Sanguinolentus*			Total sedges		
Treatments	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH
	No. of Seedlings/m^2											
Soil depth (A)												
0-5 cm	1220[a] [1/]	861[a]	1534[a]	173[b]	104[b]	1028[a]	1	18[b]	72[a]	1549[a]	1637[a]	3058[a]
5-10 cm	1014[ab]	884[a]	621[b]	255[a]	221[a]	87	6	56[a]	28[b]	1485[a]	1912[a]	888[b]
10-15 cm	758[bc]	541[b]	528[b]	103[c]	113[b]	85[b]	2	45[a]	17[b]	946[b]	998[b]	753[b]
15-20 cm	643[c]	459[b]	268[b]	82[c]	73[b]	55[b]	3	13[b]	3[b]	815[b]	839[b]	406[b]
Tillage (B)												
Conventional tillage	856	723	651[b]	164	135	366	2	33	32	1159	1445[a]	1227
Minimum tillage	962	649	824[a]	142	120	262	4	33	28	1239	1248[b]	1326
Weed management (C)												
W1[3/]	845	677 [ab]	985[a]	177	162	587[a]	5	44	34	1178	1426	1824[a]
W2	927	777[a]	721[bc]	127	126	205[b]	2	31	24	1189	1410	1163[bc]
W3	962	654[ab]	656[bc]	150	111	213[b]	4	29	31	1240	1293	1073[bc]
W4	850	740[a]	775[b]	138	118	300[b]	1	27	36	1113	1327	1299[b]
W5	960	583[b]	550[c]	175	123	263[b]	2	35	25	1275	1276	1025[c]
A	*[2/]	**	**	**	**	**	NS	**	**	*	**	**
B	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	*	NS
A×B	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
C	NS	*	**	NS	NS	**	NS	NS	NS	NS	NS	**
A×C	NS	*	**	NS	NS	**	NS	NS	NS	NS	NS	**
B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

1/ Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

2/ Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

3/ Refer to materials and methods for the details of weed management treatments.

Table 5 Response of broadleaf weed seed bank density to soil depth, tillage and weed management at before wheat planting (BWP), after wheat harvest (AWH) and after rice harvest (ARH).

Treatments	*C album*			*C. didymus*			*C. thalictroides*			*G. affine*			*L. procumbens*			*M. pumillus*		
	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH
	No. of Seedlings/m^2																	
Soil depth (A)																		
0-5 cm	447^{ab}[1/]	231^{ab}	293^{ab}	158^{a}	220^{a}	205^{a}	156^{a}	175	23^{a}	61^{b}	38^{a}	103^{a}	56	58	147^{a}	265^{ab}	166^{ab}	404^{a}
5-10 cm	564^{a}	248^{a}	326^{a}	101^{ab}	110^{b}	228^{a}	84^{ab}	133	2^{b}	103^{a}	29^{a}	83^{ab}	74	101	88^{b}	378^{a}	189^{a}	439^{a}
10-15 cm	339^{b}	156^{b}	176^{bc}	124^{a}	69^{bc}	121^{b}	32^{b}	158	1^{b}	50^{b}	42^{a}	77^{bc}	39	94	51^{c}	150^{bc}	93^{bc}	234^{b}
15-20 cm	94^{c}	46^{c}	74^{c}	53^{b}	37^{c}	81^{b}	24^{b}	91	2^{b}	19^{c}	6^{b}	56^{c}	52	105	30^{c}	74^{a}	40^{c}	131^{b}
Tillage (B)																		
Conventional tillage	394^{a}	179	226	104	122^{a}	157	76	142	5	61	33	81	53	88	75	224	120	286
Minimum tillage	328^{b}	161	208	114	97^{b}	161	72	136	8	55	25	78	57	90	83	210	124	319
Weed management (C)																		
W1[3/]	408	182	191^{b}	142	129	157	77	127^{b}	4	68	27	70	70	103	58^{b}	223	129	332
W2	343	146	213^{b}	108	81	142	53	129^{b}	14	52	28	72	49	91	79^{b}	188	103	273
W3	343	187	212^{b}	82	94	142	91	139^{b}	4	54	38	90	55	82	87^{ab}	221	131	265
W4	304	148	196^{b}	100	130	166	54	106^{b}	2	56	31	71	47	88	62^{b}	239	140	344
W5	408	188	274^{a}	112	113	187	95	195^{a}	10	61	20	95	55	89	110^{a}	213	107	297
A	**[2/]	**	*	*	**	**	*	NS	**	**[2]	*	*	NS	NS	**	**	*	**
B	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
A×C	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	**	NS	NS	NS
B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1/] Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

[2/] Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

[3/] Refer to materials and methods for the details of weed management treatments.

Table 5 (Cont'd).

Treatments	*R. crispus*			*S. aquatica*			*S. media*			*S. anthemifolia*			Total broadleaves		
	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH	BWP	AWH	ARH
	No. of Seedlings/m^2														
Soil depth (A)															
0-5 cm	145 [1/]	50^{a}	53^{a}	196^{a}	48^{a}	173^{a}	491^{ab}	0^{b}	482^{a}	2261^{b}	2303^{a}	2989^{a}	4529^{b}	4072^{a}	5178^{a}
5-10 cm	147	34^{a}	65^{a}	116^{a}	21^{b}	75^{b}	658^{a}	119^{a}	185^{b}	2763^{a}	1748^{a}	2626^{a}	5402^{a}	3335^{a}	4347^{b}
10-15 cm	55	10^{b}	30^{b}	100^{a}	15^{b}	47^{b}	349^{b}	75^{a}	91^{b}	1870^{b}	794^{b}	1466^{b}	3604^{c}	1931^{b}	2687^{c}
15-20 cm	3	2^{b}	7^{c}	16^{b}	1^{b}	5^{c}	67^{c}	20^{b}	25^{b}	581^{c}	155^{c}	456^{c}	1280^{d}	910^{c}	1042^{d}
Tillage (B)															
Conventional tillage	85	26	47^{a}	83	19	83	373	57	236	1805	1181	1759	3638	2547	3239
Minimum tillage	90	22	31^{b}	81	23	67	410	50	156	1932	1319	2010	3769	2577	3388
Weed management (C)															
W1 [3/]	83	20	27^{c}	63	18	73	363	39	196^{b}	1675	1213^{b}	1835	3545	2546^{b}	3228^{abc}
W2	93	26	35^{bc}	91	22	79	433	61	158^{b}	1794	1140^{b}	1807	3589	2355^{b}	3095^{bc}
W3	78	23	20^{c}	84	23	57	434	60	125^{b}	2026	1223^{b}	1724	3853	2559^{b}	2972^{c}
W4	97	27	60^{a}	86	24	89	384	58	340^{a}	2048	1604^{a}	2128	3789	2935^{a}	3703^{a}
W5	87	26	53^{ab}	86	19	77	342	49	161^{b}	1800	1070^{b}	1927	3742	2414^{b}	3570^{ab}
A	NS [2/]	**	**	**2	**	**	**	**	**	**	**	**	**	**	**
B	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
C	NS	NS	**	NS	NS	NS	NS	NS	*	NS	**	NS	NS	*	*
A×C	NS	NS	**NS**	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	*
B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A×B×C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1/] Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

[2/] Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

[3/] Refer to meterials and methods for the details of weed management treatments.

Tillage

The total weed seed bank density of grasses was greatly reduced after wheat and rice harvest in comparison to before wheat planting. The minimum tillage system had fewer grass seeds in the seed bank compared to the conventional tillage system (Table 3). Although seeds of sedges increased in both tillage systems after wheat and rice harvest, the increment was lower in minimum than in conventional tillage after wheat harvest (Table 4). There was no significant impact of tillage systems on the weed seed bank of broadleaves (Table 5).

The seed bank of *A. equals, P. minor* and *R. crispus* was larger in conventional than in minimum tillage. In contrary, the seed bank of *E. colona* and *C. difformis* was larger in minimum than in conventional tillage (Table 3, 4 and 5). It has been reported that tillage systems influence weed seed bank size and composition to a much greater extent than crop rotation (Barberi and Cascio, 2001). Higher concentration of annual dicot weed seed has been reported in 5-15 cm deep in conventional tillage than in minimum tillage or reduced tillage (Vanasse and Leroux, 2000). The effect of tillage systems on winter and summer weed seed bank size was more prominent for grasses because there were fewer grass seeds in minimum tillage in both wheat and rice. However, the total seed bank of sedge was not reduced. This indicated lesser impact of minimum tillage on sedge in rice (Table 4**).** *S. media* does not tolerate deep ploughing but survives with no or moderate soil disturbance (Cardina *et al*., 2002). In the present study *S. media* did not show any significant differences between conventional tillage and minimum tillage (Table 5). It has been reported that zero till reduced the density of *P. minor* and enhanced the wheat yield (Mehla *et al*., 2000). In this present study, some disturbance of soil in the minimum tillage system might have stimulated the germination of *P. minor* seeds over time. This experiment showed that there was a significant effect of tillage systems on grass weeds. However, tillage systems showed no consistent trends for the distribution of sedge weeds in the seed bank. Further, the tillage systems had no impact on the seed bank of broadleaf weeds.

Weed management

The total grass weed seed bank was smaller in both treatments of herbicide application after wheat harvest and treatments hand weeding and both treatments of herbicide application after rice harvest. This indicated the effectiveness of weed management in wheat and rice in suppressing winter and summer grass weeds, respectively. Both sulfosulfuron and fenoxaprop were effective in suppressing grasses associated with the wheat crop. Similarly, anilophos plus hand weeding and bispyribac-sodium was effective on the grass weeds associated with the rice crop (Table 3).

The effect of weed management treatments on weed seed bank of sedge was found after rice harvest. All the treatments, except unweeded control, suppressed the sedge seed bank. The mulch treatment was the most effective as it had the lowest number of sedge seeds in the seed bank (Table 4). The effect of weed management on the broadleaf seed bank was found after wheat and rice harvest. Larger number of broadleaf seeds were found in the seed bank under fenoxaprop and bispyribac-sodium in both after wheat and rice harvest. This showed that herbicides used in this study were not effective in controlling the broadleaf weeds (Table 5).

Significant effect of different weed management treatments was found in the weed seed bank of *A. aequalis, P. fugox,* and *S. anthemifolia* after wheat harvest. Sulfosulfuron and fenoxaprop controlled both *A. aequalis* and *P. fugox* grass weeds in wheat. *P. minor* was not effected by the weed management treatments in this. The seed bank of *S. anthemifolia* was not affected by fenoxaprop.The effects of weed management on the seed bank of *C. album, R. crispus* and *S. media* were only observed in the soil sample taken after rice harvest. *C. Album* was higher in straw mulch + sulfosulfuron whereas *R. crispus* and *S. media* were higher in fenoxaprop application plot (Table 3 and 5).

The seed bank of *C. difformis, C. iria* and *L. procumbens* were significantly reduced after rice harvest. This showed the effect of rice weed management on these weeds as these weeds were associated with the rice crop. Weed management treatments did not show any effect on the seed bank size of *E. colona* (Tables 3, 4 and 5). All the weed management treatments reduced the seed bank of *C. difformis* and *C. iria* when compared to the unweeded control (Table 4). The seed bank size of *C. thalictroides* and *L. procumbens*, however, was larger in the mulch treatment than in the unweeded control. Mulch might have favored the prolific growth of these weeds (Table 5). It needs futher study in the future.

The seed bank of *C. iria, C. didymus, M. pumilus, P. minor* and *S. anthemifolia* increased over time regardless of weed management in the present study. However, the effect of weed management treatments on the seed bank of these species were found within a season (Table 3, 4, and 5). The study showed that the effect of weed management on the seed bank also depended on the type of weed species and their behavior. An earlier study by Yenish *et al*. (1992) showed that seed numbers with no tillage and weed free conditions decreased by 40 % relative to herbicide alone. This study showed that sulfosulfuron and fenoxaprop affected *A. aequalis* and *P. fugox* in the wheat crop. Fenoxaprop did not affect the broadleaf weeds. Bispyribac – sodium and anilophos both suppressed the grass and sedges in the rice crop but the mulch treatment favored the growth of some weeds both in summer and winter.

Interaction effect of soil depth and tillage

The seed bank after wheat harvest showed an interaction of soil depth and tillage for *E. colona* and *S. media* (Table 6). Similarly, the interaction of depth and tillage after rice harvest was evident in the seed bank for *C. album, C. difformis, C. dilutus* and *P. minor* (Table 6). The seed bank size of the above mentioned weeds was smaller in minimum tillage than in conventional tillage. The seed bank size of *C. album, C. difformis, C. dilutus* and *E. colona* increased in conventional tillage in the upper 2 depths (0-5 cm and 5-10 cm) over the season (Table 6**).** These may be due to either the remaining plants of these species escaping from management or the tillage system promoting the germination of buried seeds in the soil. Past studies of Clements *et al.* (1996) and Buhler *et al.* (2001) have shown higher weed pressure in the first 5 cm depth in minimum tillage systems. It has been reported that *C. album* seeds remaining in the soil for 20 years may still have a 23% viability (Harrison, 1990). The seed bank size of *C. album, C. difformis, C. dilutus P. minor* and *S. media* was larger in conventional tillage than in minimum tillage. The lack of much soil disturbance in minimum tillage might have reduced the seed bank of many weeds as compared to conventional tillage.

C. ambrosoides was recorded for the first 2 seasons (before wheat planting and after wheat harvest). The number of this weed was greater in 5-10 cm and 15-20 cm in minimum tillage but disappeared over time. It showed that this weed was more common in minimum tillage than in conventional tillage. This may be a reason why this weed is more common in fallow as well as compost pits than in the crop fields (visual observation).

Interaction effect of soil depth and weed management

Interactions occurred between soil depth and weed management on the seed bank of *C. difformis, Elatin*e sp., *Murdania* sp. and *R. rotundifolia* after wheat harvest (Table 7). Sulfosulfuron was effective in reducing the seed bank of *S. alsine* compared to handweeding. However, the seed bank size of this weed was not suppressed by fenoxaprop.

Table 6 Interaction effect of soil depth and tillage (CT = conventional tillage and MT = minimum tillage) to weed seed bank at before wheat planting (BWP), after wheat harvest (AWH) and after rice harvest (ARH).

Soil depth (A)	*C. album*						*S. media*						*E. colona*					
	1st BWP		2nd AWH		3rd ARH		1st BWP		2nd AWH		3rd ARH		1st BWP		2nd AWH		3rd ARH	
	CT[1/]	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT
	No. of Seedlings/m^2																	
0-5 cm	499[2/]	342	210	169	329[a]	179[c]	471	348	0[c]	87[b]	593	117	14	9	27[bc]	20[bcd]	88	8
5-10 cm	395	336	251	143	253[b]	173[c]	512	350	0[e]	63[c]	372	65	6	8	59[a]	11[cd]	63	9
10-15 cm	634	100	282	56	307[ab]	83[d]	615	57	122[a]	17[d]	207	29	8	61	37[b]	6[d]	1	2
15-20 cm	495	88	215	36	344[a]	59[d]	700	76	115[c]	23[d]	164	21	3	20	31[b]	2[d]	2	0
A × T	NS		NS		*		NS		*		NS		NS		*		NS	

Table 6 (Cont'd).

Soil depth (A)	*P. minor*						*C. difformis*						*C. dilutus*					
	1st BWP		2nd AWH		3rd ARH		1st BWP		2nd AWH		3rd ARH		1st BWP		2nd AWH		3rd ARH	
	CT[1/]	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT	CT	MT
	No. of Seedlings/m^2																	
0-5 cm	89[2/]	87	167	18	447[a]	24[c]	1085	759	878	534	115[b]	485[cde]	15	24	376	105	202[b]	101[c]
5-10 cm	118	75	142	20	258[b]	19[c]	1355	758	845	548	1914[a]	57[c]	12	7	307	88	313[c]	100[c]
10-15 cm	120	16	9	24	0[c]	5[c]	1004	576	947	534	687[c]	279[de]	30	21	340	102	123[c]	85[c]
15-20 cm	111	19	8	17	0[c]	3[c]	1025	710	821	384	555[cd]	256[e]	40	24	202	71	112[c]	59[c]
A × T	NS		NS		*		NS		NS		*		NS		NS		*	

[1/] Refer to materials and methods for the details of tillage (T= tillage, CT = conventional tillage and MT = minimum tillage).

[2/] Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

Table 7 Interaction effect of soil depth and weed management to weed seed bank density after wheat harvest (AWH).

Weed management	*C. difformis*				*Elatine* sp.				*Murdania* sp.				*R. rotundifolia*			
	A1	A2	A3	A4	A1	A2	A3	A4	A 1	A 2	A 3	A 4	A 1	A 2	A 3	A 4
	No. of Seedlings/m^2															
W1[1/]	819^{bcd} [2/]	749^{cde}	602^{d-g}	539^{efg}	81^{a}	32^{cd}	38^{cd}	15^{d}	23^{cd}	55^{b}	21^{d}	49^{bcd}	11^{f}	45^{bcd}	51^{abc}	38^{b-e}
W2	1140^{a}	1036^{ab}	550^{efg}	382^{g}	47^{bc}	23^{cd}	32^{cd}	11^{d}	32^{bcd}	53^{bc}	36^{bcd}	36^{bcd}	40^{bcd}	77^{a}	11^{f}	21^{def}
W3	728^{c-f}	917^{abc}	543^{efg}	427^{g}	30^{cd}	34^{cd}	32^{cd}	30^{cd}	28^{bcd}	51^{bcd}	47^{bcd}	21^{d}	38^{b-e}	64^{ab}	32^{c-f}	26^{c-f}
W4	1061^{ab}	887^{abc}	554^{efg}	459^{g}	34^{cd}	34^{cd}	9^{d}	34^{cd}	21^{d}	28^{bcd}	53^{bc}	30^{bcd}	28^{c-f}	49^{bc}	26^{c-f}	32^{c-f}
W5	558^{efg}	832^{bcd}	454^{g}	488^{fg}	77^{ab}	13^{d}	28^{cd}	30^{cd}	26^{bcd}	91^{a}	23^{cd}	36^{bcd}	34^{c-f}	43^{bcd}	13^{ef}	36^{c-f}
A × W [3/]		*				*				*				*		

[1/] Refer to materials and methods for the details of soil depths (A) and weed management (W).
[2/] Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.
[3/] Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

Weeds like *A. aequalis, C. difformis, C. iria. L. procumbens* and *S. media* showed an interaction between depth and weed management after rice harvest (Table 8). The seed bank size of total grasses, sedges and broadleaved weeds also showed an interaction between depth and weed management. Both sulfosulfuron and fenoxaprop suppressed the seed bank *of A. aequalis* in the 0-5-cm depth. Straw mulch plus sulfosulfuron also suppressed the seed bank size of *A. aequalis* in the 0-5-cm depth but not in the other depths (Table 8). The total grass weed seed bank was less in anilophos + hand weeding in the 0-5-cm depth.

All the weed management treatments decreased the weed seed bank size of *C. difformis, C. iria* and total sedge in the 0-5-cm depth compared to unweeded control. The rice herbicide bispyribac-sodium alone and in combination with straw mulch showed a promising effect on reducing the seed bank size of sedge (Table 8).

Seed bank size of *S. media* was suppressed by sulfosulfuron alone and in combination with mulch but not by fenoxaprop in 0-5-cm depth. *C. thalictroides* was less prevalent in both anilophos and bispyribac-sodium treatments. However, the seed bank size of *L. procombens* was not affected by the anilophos treatment but was affected by the bispyribac-sodium treatment. The seed bank size of these weeds was even less in unweeded control. The reason for the low density of these weeds may be the greater suppression of these species by other weeds in the unweeded control compared to the other treatments. The total seed bank size was larger in bispyribac-sodium application. This might be because the broadleaf weeds were not suppressed by fenoxaprop although the summer broadleaf weed seed bank was less in this treatment (Table 8). This study showed that weed species having an interaction with depth and weed management treatment can be effectively managed in the 1st 0-5-cm layer with the appropriate treatments. It has been reported that weed control

Table 8 Interaction effect of soil depth and weed management on weed seed bank density after rice harvest (ARH).

Weed	*A. aequalis*				*C. difformis*				*C. iria*				*L. procumbens*			
management (W)	A1 [1/]	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
	No. of Seedlings/m^2															
W1[1/]	898^{a} [2/]	225^{e-f}	77^{hij}	2^{j}	2430^{a}	509^{e-h}	654^{def}	348^{fgh}	2037^{a}	119^{d}	128^{d}	64^{d}	77^{c-g}	64^{d-g}	66^{d-g}	26^{fg}
W2	545^{bc}	312de	60^{ef}	13^{j}	1284^{c}	770de	524^{efg}	308^{efg}	588^{c}	98^{d}	53^{d}	81^{d}	119^{cd}	128^{bc}	49^{efg}	21^{g}
W3	414^{cd}	204^{e-i}	98^{g-j}	34^{j}	1256^{c}	660^{def}	446^{e-h}	263^{gh}	681^{c}	57^{d}	74^{d}	40^{d}	181^{b}	70^{c-g}	47^{efg}	51^{efg}
W4	658^{b}	242^{efg}	74^{h-j}	36^{j}	1743^{b}	603^{d-g}	490^{e-h}	265^{gh}	1031^{b}	45^{d}	77^{d}	49^{d}	72^{c-g}	96de	55^{fg}	26^{fg}
W5	651^{b}	274^{def}	123^{f-j}	17^{j}	957^{cd}	562^{efg}	526^{efg}	155^{h}	802^{bc}	115^{d}	94^{d}	40^{d}	289^{a}	85^{c-f}	40^{efg}	28^{fg}
A × W [3/]	*				*				*				*			

Table 8 (Cont'd).

Weed	*S. media*				Total grass				Total broadleaf				Total sedge			
management (W)	A1 [1/]	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
	No. of Seedlings/m^2															
W1[1/]	592^{b} [2/]	134^{cde}	47de	13^{e}	1692^{a}	295de	172^{efg}	15^{g}	5548^{ab}	3906^{e}	2548^{f}	911^{h}	5041^{a}	786^{def}	964de	505^{efg}
W2	342^{c}	196^{cde}	94^{cde}	19de	1093^{c}	405^{d}	117^{efg}	23^{g}	4504^{b-e}	4396^{cde}	2378^{f}	1100^{h}	2394^{c}	1068^{d}	703^{d-g}	486^{efg}
W3	189^{cde}	198^{cde}	104^{cde}	9^{e}	981^{c}	263^{def}	168^{efg}	55^{fg}	4273^{cde}	4377^{cde}	2319^{fg}	920^{h}	2335^{c}	913de	654^{d-g}	389^{fg}
W4	1021^{a}	236^{cde}	77^{cde}	26de	1329^{b}	293de	151^{efg}	55^{fg}	6296^{a}	5054^{bcd}	2476^{f}	985^{h}	3303^{b}	817^{def}	694^{d-g}	380^{fg}
W5	284^{cd}	164^{cde}	136^{cde}	66^{cde}	1435^{b}	329de	198^{d-g}	43^{fg}	5269^{abc}	4002de	3715^{e}	1293^{gh}	2220^{c}	856^{def}	752^{d-g}	272^{g}
A × W	*				*				*				*			

[1/] Refer to materials and methods for the details of soil depths (A) and weed management (W).

[2/] Means within the same column and grouping followed by the same letter are not different according to Fisher's protected test P=0.05.

[3/] Treatment effects and interactions were significant at 5% (*), significant at 1% (**) or nonsignificant (NS).

practices can prevent increased number of weed seed in reduced tillage systems too (Hofman *et al*., 1988).

CONCLUSIONS

The largest number of weed species in this study were recorded in the broadleaf weed groups followed by grasses and sedges. The total number of weed species was 80 falling in 26 families. The important weed species were *A. aequalis, C. difformis, C. iria, C. sanguinolentus, C. didymus, C. thalictroide*s, *C. album, E. colona, L. procumbens, P. minor, R. crispus, S. anthemifolia, S. media* and *S. aquatica*. Seed bank of all these weeds were accumulated in 5-15 cm soil depth. The vertical distribution of total weed seed bank of all 3 categories of weeds showed a descending trend from 5 cm to 20 cm depths in all seasons soil samples. Total grass weed seed bank increased from 40% to 70% in 5 cm in contrast the size decreased from 34-17% in 5-10 cm, 19 - 8% in 10-15 cm and 6 - 2% in 15 - 20 cm depth in all the seasons. Total seed bank size of sedges and broadleaf weeds also showed the same trend but the gap was not as wide as in case of grass weeds among the depths. The total percent increment of sedges was almost doubled after rice harvest than in the beginning of wheat planting. It seems that management practices have to be improved in the future. The total seed bank size of grasses decreased more than 100% after wheat and rice harvest in both conventional and minimum tillage and more than before wheat planting but the size was less in minimum tillage than in conventional tillage. Total sedges increased in both tillage system after wheat and rice harvest but the density was still less in minimum tillage than in conventional tillage. The total broadleaf weed seed bank was not effected by the tillage systems. Weed seed bank of *A. aequalis, P. minor* and *R. crispus* was higher in conventional tillage than in minimum tillage. *E. colona* and *C. difformis* were higher in minimum tillage than in conventional tillage. *P. minor* seed bank size in both tillage system did not show any differences. The little disturbance of soil in minimum tillage might have favored to germinate this weed over time. The seed bank size of *A. aequalis* was affected by sulfosulfuron and fenoxaprop applied in the wheat crop. But fenoxaprop did not effect on broadleaf weeds in wheat crop. Bispyribac-sodium and anilophos both suppressed the weed seed bank of grasses and sedges. Weed seed bank of *C. iria, C. didymus, M. pumillus, P. minor* and *S. anthemifolia* increased over seasons regardless of weed management. Seed bank of *C. album, C. difformis, C. dilutus* and *E. colona* increased in conventional tillage in the upper 2 depths (0-5 cm and 5 - 10 cm) over seasons. The reason might be either the plants escaped from management resulting huge seed shed or tillage system have promoted to germinate the buried seeds from the soil. Straw mulch plus sulfosulfuron suppressed *A. aequalis* in 0-5 cm but not in other depths.

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LITERATURE CITED

Adkins, S. W. 1999. Some aspects of tropical weed seed banks, determination, dynamics and depletion, pp 51-59. *In* **Proc. 17th APWSS Conference.**

Barberi, P. and B. L. Cascio. 2001. Long-term tillage and crop rotation effects on weed seedbank size and composition. **Weed Res.** 41: 325-340.

Barberi, P., M. Macchia and E. Bonari. 1998. Comparison between the seed extraction and seedling emergence methods for weed seed bank evaluation. **Aspects of Appl. Bio.** 51: 9-14.

Buhler, D. D., K. A. Kohler and R. L. Thompson. 2001. Weed seed bank dynamics during a five year crop rotation. **Weed Techno.** 15: 170-176.

Cardina, J., C.P. Herms and D.J. Doohan. 2002. Crop rotation and tillage system effects on weed seed banks. **Weed Sci.** 50: 448-460.

Cavers, P. B. and D. L. Benoit. 1989. Seed banks in arable land, pp 309-328. *In* M. A. Leck, V. T. Parker and R. Simpson (eds) **Ecology of Soil Seed Banks** Academic Press, San Diego, California.

Clements, D. R., D. L. Benoit, S. D. Murphy and C. J. Swanton. 1996. Tillage effects of weed seed return and seedbank composition. **Weed Sci.** 44: 314-322.

Derksen, D. A., G. P. Lafond, A. G. Thomas, H. A. Loeppky and C. J. Swanton. 1994. Impact of agronomic practices on weed communities: tillage systems. **Weed Sci**. 41: 409-417.

Harrison, S. K. 1990. Interference and seed production by common lambsquarter in soybeans (*Glycine max*). **Weed Sci.** 38: 113-118.

Hirohito, M. 1997. **Handbook of Arable Weeds in Japan for Correct and Identification**. Kumiai Chemical Industry Co. Ltd. 128 P.

Hoffman, M. L., M. D. K. Owen and D. D. Buhler. 1988. Effects of crop and management on density and vertical distribution of weed seeds in soil. **Agron. Jour.** 90: 793-799.

Kegode, G. O., F. Forcella and S. Clay. 1999. Influence of crop rotation, tillage. and management inputs on weed seed production. **Weed Sci.** 47: 175-183.

Mehla, R. S., J. K. Verma, R. K. Gupta and P. R. Hobbs. 2000. Stagnation in the productivity of wheat in the Indo-Gangetic plains: zero-till seed- cum fertilizer drill as integrated solution: **Rice- Wheat Consortium Paper Series 8**, New dehli, India 12 P.

Menges, R. M. 1987. Weed seed population dynamics during six years of weed management systems in crop rotations on irrigated soil. **Weed Sci.** 35: 328-332.

Perron, F. and A. Legere. 2000. Effects of crop management practices on *Echinocloa crus-galli* and *Chenopodium album* seed production in a maize/soybean rotation. **Weed Res.** 40: 535-547.

Roberts, H. A. and M. E. Ricketts. 1979. Quantitative relationships between the weed flora after cultivation and the seed poulation in the soil. **Weed Res.** 19: 269-275.

Vanasse, A. and G. D. Leroux. 2000. Floristic diversity, size and vertical distribution of the weed seed bank in ridge and conventional tillage systems. **Weed Sci.** 48: 548-560.

Yenish, J. P., J. D. Doll and D. D. Buhler. 1992. Effects of tillage on vertical distribution and viability of weed seed in soil. **Weed Sci.** 40: 429-433.