Indian Journal of Weed Science **45**(2): 99–105, 2013

Nutrient removal by weeds and crops as affected by herbicide combinations in soybean-wheat cropping system

Navell Chander, Suresh Kumar*, Ramesh and Surinder Singh Rana

Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176 062

Received: 25 February 2013; Revised: 11 May 2013

ABSTRACT

Eight weed control treatments in soybean and three in wheat were evaluated in soybean-wheat cropping system during 2009-10 and 2010-11 at Palampur. *Commelina benghalensis* followed by *Echinochloa colona* were the most competitive weeds in soybean. In wheat, *Phalaris minor* and *Avena ludoviciana* were the most predominant weeds. Pendimethalin *fb* chlorimuron reduced dry weight of *Aeschynomene, Ageratum, Cyperus, Echinochloa* and *Panicum* significantly over the unweeded check. Isoproturon 1000 g/ha + 2, 4-D 500 g/ha reduced dry weight of *Phalaris minor* over the weedy check. In soybean, application of pendimethalin *fb* chlorimuron-ethyl allowed weeds to remove 89.2, 89.1 and 88.9% less N, P and K, respectively as compared to the unweeded check. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha reduced N, P and K depletion by weeds by more than 24% over the unweeded check. Application of pendimethalin *fb* chlorimuron-ethyl resulted in 187.5% higher N and 166.3% higher K uptake by soybean over weedy check. Unchecked weed growth reduced P uptake by 62.4% as compared to pendimethalin *fb* chlorimuron ethyl. Isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly higher N, P and K uptake by wheat over unweeded check. Weedy check reduced soybean equivalent yield by 37.4 and 28.8% during 2009 and 2010, respectively. Imazethapyr *fb* imazethapyr produced higher soybean equivalent yield (3.34 t/ha) during 2009, whereas, pendimethalin *fb* chlorimuron (3.16 t/ha) was better during 2010. Isoproturon 1000 g/ha + 2,4-D 500 g/ha (₹ 1,17,736) and isoproturon 750 g/ha + 2,4-D 500 g/ha (₹ 1,16,861) resulted in higher net returns and net per ₹ invested as compared to weedy check.

Key words: Chlorimuron, Herbicide, Imazethapyr, Nutrient removal, Pendimethalin, Quizalofop, Soybean

Soybean-wheat cropping system has a great potential in northern plains of India. With many problems in the traditional rice-wheat (Verma and Sharma 2007) or maize-wheat cropping systems, the soybean-wheat has emerged as a good alternative both for crop diversification as well as for maintaining the sustainable soil health. In fact, soil nutrient supply is improved when crops with relatively high nutrient demands are rotated with crops leaving relatively high amount of residues containing substantial amount of nutrients. Soybean is one crop, which builds up the soil fertility by atmospheric nitrogen fixation through the root nodules and also through leaves falling on the ground at maturity. Besides residual effect on soil fertility, soybean has great potential as an exceptionally nutritive and very rich protein food. Being long duration crop, wheat also exhausts the soil to maximum potential. Infestation of weeds removes nutrients from the soil thus, adversely affects the production of both the crops. Weeds increase cost of cultivation and deplete the resource base (Buriro *et al.* 2003 and Upadhyay *et al.* 2012). In order to achieve enhanced crop production and higher benefits from applied inputs, weeds must be kept under check by any of the safe and effective mean. Herbicide combinations are more effective weapons in tackling weed menace and thereby nutrient depletion by them than a single herbicide approach (Pisal and Sagarka 2013 and Upadhyay *et al.* 2013). Therefore, present study works out nutrient removal by weeds and crops and impact on system productivity as influenced by herbicide combinations in soybean-wheat cropping system.

***Corresponding author:** skg_63@yahoo.com

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2009-10 and 2010-11 at Palampur (32º 62 N Latitude, 76º 32 E longitude, 1280 m above msl). The soil of experimental site was silty clay loam in texture, acidic in reaction (5.6), low in available nitrogen (204.6 kg/ha), medium in available phosphorus (18.1 kg/ha) and high in

available potassium (308.2 kg/ha). Eight weed control treatments, *viz.* pendimethalin 1.5 kg/ha (pre), imazethepyr 200 g/ha (pre), quizalofop-ethyl 60 g/ha (early post), imazethapyr 75 g/ha (pre) *fb* imazethapyr 75 g/ha (early post), quizalofop-ethyl 50 g/ha + chlorimuron-ethyl 4 g/ha (early post), pendimethalin 1.5 kg/ha (pre) *fb* chlorimuron-ethyl 4 g/ha (early post), hand weeding (twice) and weedy check in soybean as main plot factors and weedy check, isoproturon 1.0 kg/ha + 2,4-D 0.50 kg/ha and isoproturon 0.75 kg/ha + 2,4-D 0.50 kg/ha (post emergence) in wheat as sub-plot factors were tested in split plot design with three replications. The seeds of soybean variety '*Harit Soya'* were sown in rows 45 cm apart on June 18, 2009 and June 5, 2010 using 75 kg seed/ha. The crop was fertilized with 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha as basal dose. Wheat variety '*HPW-155'* was sown on November 11, 2009 and November 3, 2010 using 100 kg seed/ha. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha. In each crop, required amount of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. Herbicides were applied with the help of Maruyama power sprayer using flat fan nozzle. Rest of the management practices were in accordance with the recommended package of practices for individual crop. Weed dry weight was recorded by placing 50 x 50 cm quadrates at two random places in each plot and after drying them in hot air oven (72^0C for 72 hours). Yields were harvested from net plot.

RESULTS AND DISCUSSION

Effect on weeds

Soybean: The experimental field was infested with *Commelina benghalensis* (43.36 and 57.87% during 2009 and 2010, respectively), *Echinochloa colona* (18.04 and 15.02%), *Aeschynomene indica* (3.78 and 2.73%), *Ageratum conyzoides* (3.68 and 4.91%), *Panicum dichotomiflorum* (11.53 and 5.12%), *Digitaria sanguinalis* (4.25 and 3.69%), *Eleusine indica* (3.54 and 3.48%) and *Cyperus* sp. (9.21 and 5.12%). *Commelina benghalensis* was the most dominant weed in soybean (Singh *et al.* 1992, Rajput and Kushwah 2004 and Kumar *et al.* 2008).

Weeds accumulated maximum dry matter by 60 DAS. On dry weight basis *Commelina* was most competitive weed in soybean and assumed alarming growth particularly in 2009. All the three combinations of herbicides were comparable to hand weeding twice in influemcing its growth. Imazethapyr and quizalofop-ethyl also could bring down its dry weight during 2009 and were as good as the above treatments in reducing its dry weight. However, pendimethalin was not effective against *Commelina* during both the years. Application of imazethapyr, pendimethalin, pendimethalin *fb* chlorimuron-ethyl and hand weeding (twice) significantly reduced the dry weight of *Aeschynomene* over the unweeded check during 2009. Pendimethalin *fb* chlorimuron-ethyl remaining at par with pendimethalin alone and hand weeding (twice) resulted in significantly lower dry weight of *Ageratum* during 2010. All treatments were significantly superior to unweeded check in controlling *Cyperus* during both the years and *Digitaria* during 2010. Application of quizalofop-ethyl, imazethapyr *fb* imazethapyr, quizalofop-ethyl + chlorimuron-ethyl and pendimethalin *fb* chlorimuron-ethyl remaining at par with each other resulted in significant lower dry weight of *Echinochloa* during both the years. Dry weight of *Panicum dichotomiflorum* was significantly affected during 2009. All treatments except imazethapyr *fb* imazethapyr significantly reduced dry weight of *Panicum dichotomiflorum* over weedy check. However, weed control treatments could not significantly reduced the dry weight of *Polygonum alatum* and *Eleusine indica*. All treatments except pendimethalin during 2009 significantly decreased total weed dry weight over the untreated check. Pendimethalin *fb* chlorimuron resulted in significantly lower total weed dry weight. However other herbicidal mixtures during both the years and imazethapyr, quizalofop-ethyl and hand weeding during 2009 were compareable to pendimethalin *fb* chlorimuron. Herbicide combinations had an edge over the individual application of herbicides in reducing total weed dry weight. Superiority of herbicide combinations has been documented (Singh *et al.*, 2006a Upadhyay *et al*., 2013 and Jadhav and Gadade 2012). The residual effects of treatments in wheat were not significant on weeds in soybean.

Wheat: *Phalaris minor* and *Avena ludoviciana* were the most predominant weeds constituting 66.5 and 27.65% of the total weed flora. The other weeds found growing in association with wheat crop were *Lolium temulentum* (2.0%), *Vicia sativa* (3.0%) and *Coronopus didymus* (0.6%).

The application of herbicides in soybean did not cause any residual activity in influencing the dry weight of weeds in wheat as dry weight of different weeds in wheat was not significantly affected under weed control treatments in soybean. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaved statistically alike to isoproturon 750 g/ha+ 2,4-D 500 g/ ha resulted in significantly lower dry weight of *Phalaris minor* and *Avena ludoviciana* at 90 DAS as compared to weedy check. Weed control treatments in wheat did not significantly influence the dry weight of *Lolium temulentum*. Application of isoproturon

Table 1. Effect of treatments on dry weight (g/m²) of weeds at 60 DAS in soybean

Treatment	Rate (g/ha)	Time	*Commelina*		*Aeschynomene*		*Ageratum*		*Cyperus*		*Echinochloa*		*Panicum*		*Digitaria*		Total	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Soybean																		
T_1- Pendimethalin	1500	Pre	18.6	12.1	2.9	2.0	3.3	7.4	2.2	2.5	7.1	5.2	1.7	2.5	1.0	2.5	21.5	15.3
			(403)	(148)	(10)	(7)	(16)	(61)	(7)	(10)	(68)	(30)	(3)	(9)	(0)	(10)	(497)	(238)
T_2- Imazethapyr	200	Pre	3.7	12.3	1.2	3.0	3.3	4.9	2.2	4.4	7.0	7.2	2.8	3.3	3.9	3.1	10.0	17.1
			(15)	(167)	(0)	(12)	(20)	(32)	(5)	(22)	(65)	(60)	(9)	(17)	(41)	(15)	(107)	(307)
T_3- Quizalofop-ethyl	60	EP	10.4	11.5	4.0	2.8	2.5	4.4	1.9	3.5	1.3	2.4	1.2	2.2	2.8	4.2	12.0	13.9
			(145)	(157)	(20)	(10)	(8)	(26)	(3)	(17)	(2)	(7)	(1)	(7)	(18)	(24)	(179)	(216)
T_4- Imazethapyr *fb* imazethapyr	75 *fb* 75	Pre *fb* EP	4.3	6.9	3.6	2.0	1.8	4.8	1.3	1.1	1.0	3.1	4.8	3.8	4.3	2.7	9.0	10.3
			(32)	(48)	(18)	(5)	(3)	(33)	(1)	(0)	(0)	(11)	(31)	(24)	(28)	(9)	(96)	(110)
T_5- Quizalofop-ethyl + chlorimuron-ethyl	50 + 4	EP	10.3	6.6	4.7	2.8	1.1	3.1	1.1	2.4	1.5	2.6	1.0	2.4	1.5	2.0	11.7	9.5
			(127)	(45)	(29)	(11)	(0)	(13)	(0)	(8)	(2)	(11)	(0)	(8)	(3)	(5)	(160)	(94)
T_6- Pendimethalin *fb* chlorimuron-ethyl	1500 *fb* 4	Pre *fb* EP	4.9	6.7	1.3	2.6	1.3	2.5	1.2	1.0	3.2	3.2	1.8	1.9	1.9	1.7	6.7	8.9
			(30)	(45)	(1)	(10)	(1)	(10)	(0)	(0)	(12)	(12)	(3)	(4)	(4)	(3)	(49)	(82)
T_7- Hand weeding	twice	25&40 DAS	3.6	8.6	1.3	2.6	2.3	7.9	2.1	3.8	8.4	7.1	2.1	3.5	1.7	3.3	10.6	14.7
			(18)	(75)	(1)	(12)	(6)	(69)	(4)	(19)	(76)	(59)	(4)	(15)	(6)	(15)	(116)	(221)
T_8- Weedy check			21.1	15.5	4.8	3.3	4.0	8.1	4.3	4.9	9.0	8.3	6.2	4.8	5.2	7.4	26.7	21.6
			(535)	(243)	(36)	(15)	(19)	(71)	(21)	(29)	(81)	(73)	(44)	(30)	(63)	(62)	(817)	(475)
LSD (P=0.05)			7.1	4.3	2.73	NS	NS	3.1	1.4	2.0	4.9	3.3	1.6	NS	NS	2.6	7.9	4.9
Wheat																		
S_1- Weedy check			9.4	9.6	3.04	2.9	1.1	2.7	2.0	3.4	5.3	4.8	3.2	3.7	1.6	2.4	14.2	14.2
			(156)	(100)	(15)	(12)	(0)	(14)	(5)	(17)	(49)	(35)	(18)	(19)	(3)	(10)	(258)	(219)
S_2- Isoproturon + 2,4-D	1000 + 500	Post	10.9	10.1	3.14	2.3	1.2	2.2	2.3	2.9	4.8	5.5	2.5	2.8	2.0	2.6	15.1	14.1
			(200)	(119)	(17)	(8)	(1)	(7)	(8)	(13)	(41)	(40)	(10)	(11)	(8)	(10)	(294)	(221)
S_3- Isoproturon + 2,4-D	750 + 500	Post	8.5	10.4	2.72	2.8	1.4	2.1	1.8	2.6	4.4	4.3	2.3	2.6	2.0	2.7	12.6	13.7
			(133)	(128)	(11)	(11)	(3)	(7)	(4)	(9)	(33)	(26)	(8)	(12)	(6)	(10)	(206)	(214)
LSD (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Values given in parentheses are the means of original values

Table 2. Effect of treatments on dry weight (g/m²) of weeds at 60 DAS in wheat

Treatment	*Phalaris*		*Avena*		*Lolium*		*Vicia*		Total	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Soybean										
T_1	2.8 (8)	3.6 (14)	3.4 (11)	3.5 (13)	1.2 (0)	1.1 (0)	1.2 (1)	1.0 (0)	4.5 (20)	5.2 (28)
T_2	3.3 (14)	3.3 (11)	4.1 (17)	3.3 (11)	1.1 (0)	1.1 (0)	1.0 (0)	1.3 (1)	5.3 (31)	4.8 (23)
T_3	4.3 (23)	4.2 (18)	3.1 (9)	3.0 (8)	1.0 (0)	1.4 (1)	1.2 (1)	1.1 (0)	5.4 (32)	5.3 (28)
T_4	4.1 (17)	3.7 (14)	3.8 (18)	3.5 (14)	1.1 (0)	1.1 (0)	1.2 (1)	1.4 (1)	5.9 (36)	5.3 (29)
T_5	3.4 (11)	3.3 (11)	3.0 (8)	3.4 (12)	1.2 (1)	1.2 (1)	1.6 (2)	1.4 (1)	4.7 (22)	4.9 (24)
T_6	9.6 (188)	2.6 (7)	4.0 (19)	3.5 (16)	1.1 (0)	1.0 (0)	1.4 (1)	1.2 (1)	11.4 (208)	4.5 (23)
T_7	2.6 (6)	4.1 (18)	4.6 (29)	3.7 (15)	1.0 (0)	1.4 (1)	1.0 (0)	1.5 (1)	5.3 (35)	5.8 (35)
T_8	2.4 (6)	4.8 (28)	4.9 (24)	4.6 (23)	1.1 (0)	1.1 (0)	1.2 (1)	1.1 (0)	5.5 (31)	6.8 (51)
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wheat										
S_1	4.8 (49)	4.1 (20)	4.3 (22)	4.2 (20)	1.2 (0)	1.2 (1)	1.5 (2)	1.2 (1)	7.1 (72)	6.1 (41)
S_2	3.5 (26)	3.1 (10)	3.4 (12)	3.1 (10)	1.0 (0)	1.2 (0)	1.1 (0)	1.3 (1)	5.2 (38)	4.6 (21)
S_3	3.9 (28)	3.8 (15)	3.8 (17)	3.4 (12)	1.1 (0)	1.1 (0)	1.2 (0)	1.3 (1)	5.8 (46)	5.3 (29)
LSD (P=0.05)	0.7	0.8	0.7	0.8	NS	NS	0.2	NS	0.8	0.8

Values given in parentheses are the means of original values

1000 g/ha + 2,4-D 500 g/ha behaving statistically alike with isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower dry matter accumulation of *Vicia sativa*. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaving statistically similar to isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower dry matter accumulation of *Coronopus didymus* at 90 DAS during 2010. Owing to species-wise reduction in dry weight, applica-

tion of isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower total weed dry weight over weedy check. Similar results have been reported by Das and Yaduraju (1999) and Punia *et al.* (2004).

Nutrient removal by weeds

***Soybean*:** There was tremendous reduction in the nutrient depletion under different weed control treatments. However, due to wide variation in nutrient content in weeds, nutrient removal by them was significantly influenced during 2010 only. All weed control treatments were significantly superior to weedy check in decreasing N and P removal by weeds. Among weed control treatments applied in soybean, pendimethalin *fb* chlorimuron-ethyl being at par to quizalofop-ethyl + chlorimuron-ethyl resulted in significantly lower nitrogen removal by weeds. Weeds removed 89.2% less nitrogen and 89.1% less phosphorus than unweeded check. Rests of the treatments being at par were comparable to hand weeding twice in depleting the soil for available nitrogen and phosphorus. Application of pendimethalin *fb* chlorimuron-ethyl resulted in significantly lowest potassium depletion by weeds. This treatment reduced potassium depletion by weeds by 88.9% due to effective weed control as compared to the unweeded check. Rests of the treatments were comparable to hand weeding twice in influencing potassium depletion by weeds. Weeds have considerably depleted the soil for N, P and K in weedy check mainly because of higher dry weight of weeds in these plots. Similar results have been reported by Kumar and Das (2008), Singh *et al.* (2006a) and Pasal and Sagarka (2013). Treatments in wheat could not significantly influence nutrient depletion by weeds in soybean.

***Wheat*:** Similar to weed dry weight, treatments in soybean did not significantly influence nutrient uptake by weeds in wheat. Inspite of having significant reduction in weed dry weight, N, P and K uptake by weeds in wheat was not significantly influenced due to weed control treatments in wheat. This clearly indicated vide variation in the content of nutrients in weeds. The application of isoproturon 1000 g/ha + 2,4-D 500 g/ha reduced N, P and K depletion by 24.2 and 24.8 and 21.1 and 24.1% over the unweeded check during 2009 and 2010, respectively.

Soybean + wheat system: Mean nutrient depletion by weeds under soybean – wheat cropping system was significantly affected due to treatments in soybean. Weeds in unweeded check removed 71.5 kg of N, 6.9 kg of P and 97.4 kg of K, thus depriving crops for that much amount of available nutrients. Out of this total removal by weeds more than 65% depletion of NPK (*i.e.* 66.7% N, 72.2% P and 65.4% K in soybean) occurred during *Kharif*. Application of pendimethalin *fb* chlorimuron could save 48.1 kg N, 9.9 kg P and 66 kg K/ha from being depleted by weeds under soybean – wheat cropping system. Treatments in wheat also brought about significant variation in total NPK depletion by weeds in soybean – wheat cropping system. Isoproturon 0.7-1.00 kg/ha + 2,4-D 0.50 kg/ha significantly reduced total N, P and K depletion by weeds in soybean – wheat cropping system.

Nutrient uptake by crops

***Soybean*:** Weed control treatments significantly increased the nitrogen uptake by soybean crop over unweeded check. In general, all the herbicide combinations were superior to alone application of herbicides in improving the nitrogen uptake by crop. Because of higher seed and straw yield, pendimethalin *fb* chlorimuron-ethyl resulted in significantly higher nitrogen uptake by crop during 2009. However, this treatment remained statistically similar with imazethapyr *fb* imazethapyr and quizalofop-ethyl + chlorimuron-ethyl during 2010. Application of pendimethalin *fb* chlorimuron-ethyl resulted in 187.5 and 52.7% higher nitrogen uptake over weedy check during 2009 and 2010, respectively. P and K content showed variation and therefore their uptake by soybean crop was not significantly affected under weed control treatments in soybean during 2010. Pendimethalin *fb* chlorimuron-ethyl remaining at par with imazethapyr *fb* imazehapyr and handweeding twice resulted in significantly higher P uptake by soybean over other treatments. Herbicides alone were alike to hand weeding twice in influencing P uptake by soybean crop. Unchecked weed growth reduced phosphorus uptake in soybean by 62.4% as compared to pendimethalin *fb* chlorimuron-ethyl.

Similar trend as that of P uptake was observed with respect to K uptake in soybean during 2009. Pendimethalin *fb* chlorimuron-ethyl recorded 166.3% higher potassium uptake by soybean than unweeded check. However, this treatment behaved statistically alike to imazethapyr *fb* imazethapyr and hand weeding (twice). Higher dry matter accumulation by soybean with application of pendimethalin *fb* chlorimuron-ethyl may be attributed to better root spread and penetration in soil due to weed free environment. Also, lower N, P and K removal by weeds allowed soybean to grow more vigorously and accumulated more biomass, which consequently led to higher uptake of these nutrients (Kumar and Dass 2008 and Singh *et al.* 2006). Treatments in wheat did not significantly influence nutrients uptake by soybean during both the years.

Table 3. Effect of treatments on nutrient uptake (kg/ha) by weeds

Treatment	Soybean						Wheat						Total*		
	N		P		K		N		P		K				
	2009	2010	2009	2010	2009	2010	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	N	P	K
Soybean															
T_1	27.2	27.8	6.0	5.0	44.4	36.0	24.3	22.0	3.6	3.3	31.3	29.7	50.7	9.0	70.7
T_2	19.8	28.2	4.7	5.2	30.9	33.1	21.9	17.7	3.7	2.6	29.4	23.2	43.8	8.1	58.3
T_3	31.5	25.0	5.7	4.7	39.1	32.2	17.2	20.1	2.7	3.2	23.2	27.2	46.9	8.2	60.9
T_4	17.0	20.1	3.5	3.9	25.4	25.3	19.9	21.1	3.0	3.3	25.7	29.0	39.1	6.9	52.7
T_5	21.5	14.1	4.5	2.7	34.0	19.2	18.8	18.8	2.9	2.8	24.5	24.3	36.6	6.5	51.0
T_6	5.2	5.8	1.3	1.1	7.2	7.9	18.1	17.6	2.7	2.8	23.5	24.2	23.4	4.0	31.4
T_7	9.0	20.6	1.6	4.0	11.6	27.4	30.1	21.6	4.8	3.4	41.2	28.7	40.7	6.9	54.5
T_8	41.8	53.5	9.8	10.2	61.8	71.4	27.2	20.4	4.5	3.2	35.0	26.5	71.5	13.9	97.4
LSD (P=0.05)	NS	9.1	NS	1.8	NS	10.3	NS	NS	NS	NS	NS	NS	8.6	2.9	10.2
Wheat															
S_1	25.1	24.6	5.5	4.6	37.0	31.6	25.6	23.1	4.1	3.5	33.8	30.8	49.2	8.9	66.6
S_2	20.8	24.1	4.5	4.6	29.9	30.8	19.4	17.4	3.1	2.8	26.2	23.4	40.9	7.5	55.2
S_3	19.0	24.5	3.9	4.6	28.6	32.3	21.6	19.2	3.3	3.0	27.7	25.5	42.2	7.4	57.1
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.5	0.9	3.5

*Mean of two years

Table 4. Effect of treatments on nutrient uptake (kg/ha) by crops

Treatment	Soybean						Wheat						Total*		
	N		P		K		N		P		K				
	2009	2010	2009	2010	2009	2010	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	N	P	K
Soybean															
T_1	110.3	116.8	12.9	14.0	125.8	138.9	134.5	125.8	24.9	25.5	149.2	155.7	243.7	38.7	284.8
T_2	106.4	123.9	13.0	14.7	126.6	150.1	123.5	122.8	23.4	23.8	139.2	144.3	238.3	37.5	280.1
T_3	110.0	124.2	12.6	14.3	122.6	141.5	124.0	120.7	22.1	22.8	135.1	148.6	239.5	35.9	273.9
T_4	142.4	140.3	16.6	16.8	151.5	151.6	144.3	130.6	27.2	27.8	163.7	165.4	278.8	44.2	316.1
T_5	133.6	138.8	14.6	16.0	140.8	155.5	128.8	117.5	24.5	24.6	144.4	150.0	259.4	39.9	295.4
T_6	170.2	148.7	20.5	15.4	192.8	148.6	134.3	133.0	25.9	25.4	147.1	170.4	293.1	43.6	329.5
T_7	136.0	129.4	16.2	14.7	150.3	138.9	143.1	122.0	25.3	23.1	156.7	137.2	265.3	39.7	291.6
T_8	59.2	97.4	7.7	12.3	72.4	130.8	122.6	108.3	22.7	21.4	129.8	131.4	193.8	32.1	232.2
LSD (P=0.05)	36.45	12.10	4.95	NS	50.09	NS	NS	NS	NS	NS	NS	NS	27.3	5.5	40.0
Wheat															
S_1	118.3	126.3	13.9	14.6	131.1	144.1	117.2	109.4	21.2	21.4	131.4	136.2	235.6	35.6	271.4
S_2	120.5	128.7	14.2	15.0	138.2	144.1	143.9	130.5	26.5	26.1	157.4	156.7	261.8	40.9	298.2
S_3	124.3	127.3	14.7	14.8	136.8	145.3	134.6	127.8	25.8	25.4	148.1	157.8	257.0	40.4	294.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	11.36	8.44	2.20	1.72	12.88	12.97	7.9	1.5	12.9

*Mean of two years

***Wheat*:** Weed control treatments in soybean did not bring about significant variation in uptake of N, P and K by wheat. Weed control treatments in wheat resulted in significant variation in NPK uptake by wheat. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaving statistically alike with isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly higher N, P and K uptake over unweeded check. The higher nutrient uptake can be ascribed to more grain and straw yield under isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha. Similar results have been reported by Pandey *et al.* (2007) and Bharat and Kachroo (2007). Higher dry matter accumulation by wheat under herbicidal treatments might have increased the nutrient uptake (Brar and Walia 2009 and Pandey *et al.* 2001).

Table 5. Effect of treatments on soybean seed yield (t/ha), soybean equivalent yield (t/ha), net returns (₹/ha) and net returns per rupee invested in soybean-wheat cropping system

Treatment	Soybean seed yield (t/ha)		Soybean equivalent yield		Net return (x10^3 ₹/ha)		Net returns/ ₹ invested	
	2009	2009	2009	2010	2009	2010	2009	2010
Soybean								
T_1	1.33	1.33	2.80	2.72	65.52	68.13	1.45	1.51
T_2	1.34	1.34	2.69	2.79	61.56	69.49	1.37	1.55
T_3	1.38	1.38	2.69	2.76	61.52	68.28	1.38	1.53
T_4	1.79	1.79	3.34	3.15	83.60	82.61	1.87	1.85
T_5	1.67	1.67	3.10	2.89	75.23	75.73	1.69	1.70
T_6	1.87	1.87	3.30	3.16	85.09	85.16	1.88	1.88
T_7	1.63	1.63	3.11	2.94	73.67	64.80	1.49	1.32
T_8	0.75	0.75	2.09	2.25	40.43	45.49	0.91	1.02
LSD (P=0.05)	0.43	0.43	0.59	0.35	22.10	14.57	0.49	0.31
Wheat								
S_1	1.45	1.45	2.72	2.69	61.41	64.11	1.36	1.42
S_2	1.43	1.43	2.96	2.97	72.18	73.85	1.58	1.62
S_3	1.53	1.53	2.99	2.84	71.39	71.92	1.57	1.58
LSD (P=0.05)	NS	NS	0.17	0.11	6.22	4.10	0.14	0.09

***Soybean + wheat*:** Treatments in soybean significantly affected total NPK uptake in soybean – wheat cropping system. Under weedy check, crop uptake was only 193.8 kg N, 32.1 kg P and 232.2 kg K which increased to 293.1 kg N, 43.6 kg P and 329.5 kg K under the best treatment *i.e.* pendimethalin *fb* chlorimuron-ethyl. However, uptake of nutrients by the cropping system was tremendously higher than the recommend application rate even in the weedy check. The upake by weeds was extra. The all other treatments were also superior to weedy check in increasing N and K uptake by soybean – wheat cropping system. Treatments in wheat significantly influenced total N, P and K uptake by soybean – wheat system. Application of 0.75-1.00 kg/ha + 2,4-D 0.50 kg/ha significantly increased total NPK uptake by soybean – wheat cropping system.

System productivity

Application of pendimethalin *fb* chlorimuron-ethyl remaining statistically at par to imazethapyr *fb* imazethapyr, quizalofop-ethyl + chlorimuron-ethyl and hand weeding (twice) resulted in significantly higher soybean seed yield. Weeds in weedy check reduced the seed yield of soybean by 59.9 and 41.0% during 2009 and 2010, respectively as compared to pendimethalin *fb* chlorimuron ethyl. Mishra and Singh (2009) have reported 86% reduction in seed yield of soybean due to weeds. There were no residual effects of treatments applied in wheat on seed yield of soybean as the treatments were not significantly different. Herbicide combinations and hand weeding twice were better than herbicides alone in influencing soybean equivalent yield (Table 5). During 2009, pendimethalin alone was also at par with herbicide combinations. Application of imazethapyr *fb* imazethapyr produced higher soybean equivalent yield (3.34 t/ha) during 2009, whereas during 2010, application of pendimethalin *fb* chlorimuron (3.16 t/ha) was better. Weedy check reduced soybean equivalent yield by 37.4 and 28.8% during 2009 and 2010, respectively. Among treatments in wheat, application of isoproturon 0.75 kg/ha + 2,4-D 0.50 kg/ha and isoproturon 1000 g/ha+ 2,4-D 500 g/ha was statistically similar in influencing soybean equivalent yield over weedy check during 2009. During 2010, application of isoproturon 1000 g/ha + 2,4-D 500 g/ha produced highest soybean equivalent yield (2.97 t/ha).

Profitability

Pendimethalin *fb* chlorimuron remaining at par with pendimethalin, imazethapyre *fb* imazethapyre, quizalofop + chlorimuron and hand weeding twice during 2009 and imazethapyre *fb* imazethapyre and quizalofop + chlorimuron during 2010 resulted significantly higher net returns (₹ 85,096, 85,165) and net returns per rupee invested (1.88 and 1.88). Among treatments in wheat, isoproturon 1000 g/ha + 2,4-D 500 g/ha (₹ 1,17,736 and 1.60) and isoproturon 750 g/ha + 2,4-D 500 g/ha (₹ 1,16,861 and 1.58) remaining statistically at par resulted in higher net returns and net return per rupee invested as compared to weedy check.

REFERENCES

Bharat R and Kachroo D. 2007. Bio-efficacy of various herbicides and their mixtures on weeds and yield of wheat (*Triticum aestivum*) under sub-tropical agro-ecosystem. *Indian Journal of Agronomy* **52**(1): 53-59.

Brar AS and Walia US. 2009. Weed dynamics and wheat (*Triticum aestivum*) productivity techniques and weed control practices. *Indian Journal of Weed Science* **41**(3&4): 161-166.

Buriro UA, Oad FC, Agha SK and Solangi GS. 2003. Post emergence weed control in wheat. *Journal of Applied Sciences* **3**(6): 424-427.

Das TK and Yaduraju NT. 1999. Effect of weed competition on growth, nutrient uptake and yield of wheat as affected by irrigation and fertilizers. *Journal of Agricultural Science, Cambridge* **133**(1): 45-51.

Jadhav AS and Gadade GD. 2012. Evaluation of post-emergence herbicides in soybean. *Indian Journal of Weed Sci*ence **44**(4): 259-260.

Kumar M and Das TK. 2008. Integrated weed management for system productivity and economics in soybean (*Glycine max*)-wheat (*Triticum aestivum*) systems. *Indian Journal of Agronomy* **53**(3): 189-194.

Kumar S, Angiras NN, Rana SS and Kumar AK. 2008. Evaluation of doses of some herbicides to manage weeds in soybean (*Glycine max* L.). *Indian Journal Weed Sci*ence **40**(1&2): 56-61.

Mishra JS and Singh VP. 2009. Weed dynamics and productivity of soybean (*Glycine max*)–based cropping systems as influenced by tillage and weed management. *Indian Journal of Agronomy* **53**(1): 29-35.

Pandey IB, Sharma SL, Tiwari S and Bharati V. 2001. Effect of tillage and weed management on grain yield and nutrient removal by wheat (*Triticum aestivum*) and weeds. *Indian Journal of Weed Science* **33**(3&4): 107-111.

Pandey KA, Joshi OP and Billore SD. 2007. Effect of herbicidal weed control on weed dynamics and yield of soybean [*Glycine max* (L.) Merrill]. *Soybean Research* **5**: 26-32.

Pisal RR and Sagarka BK. 2013. Integrated weed management in wheat with new molecules. *Indian Journal of Weed Sci*ence **45**(1): 25-28.

Punia SS, Malik RK and Shoeren P. 2004. Bioefficacy of tank mix combinations of fenoxaprop and clodinafop with broad-leaved herbicides for broad spectrum weed control in wheat (*Triticum aestivum*). *Indian Journal of Ecology* **31**: 128-132.

Rajput RL and Kushwah SS. 2004. Integrated weed management in soybean on farmers filed. *Indian Journal of Weed Science* **36**(3&4): 210-212.

Singh P, Nepalia V and Tomar SS. 2006a. Effect of weed control and nutrient management on soybean (*Glycine max*) productivity. *Indian Journal of Agronomy* **51**(4): 314-317.

Singh R, Kalia BD and Negi PS. 1992. Integrated weed management in soybean. *Indian Journal of Weed Science* **24** (1&2): 93-95.

Singh R, Tomar SS and Kumar A. 2006. Integrated weed management in wheat. *Crop Research* **32**(3): 289-293.

Upadhyay VB, Bharti V and Anay Rawat. 2012. Bioefficacy of post-emergence herbicides in soybean. *Indian Journal of Weed Sci*ence **44**(4): 261-263.

Upadhyay VB, Singh A and Anay Rawat. 2013. Efficacy of early post-emergence herbicides against associated weeds in soybean. *Indian Journal of Weed Sci*ence **45**(1): 73-75.

Verma S and Sharma PK. 2007. Effect of long-term manuring and fertilizers on carbon pools, soil structure and sustainability under different cropping systems in wet-temperate zone of north-west Himalayas. *Biology and Fertility of Soils* **44**(1): 235-240.