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Research Paper

Effect of tillage and tank-mix herbicide application on weed management in chilli (*Capsicum annuum*)

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ABSTRACT

A field experiment was carried out at New Delhi during 2012 and 2013 to investigate the effect of tillage and tank-mix herbicide application on growth, yield, and nutrient uptake of chilli (*Capsicum annuum* L.). Conventional and zero tillage resulted in comparable weed density, dry weight, chilli fruit yield, fruit length and plant height. Tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha was next to weed-free check and superior to all the other weed-control treatments in reducting the weed density. Uptake of N, P and K by chilli plants was comparably higher in weed-free check and tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha. Conversely, N, P and K uptake by weed was significantly higher in weedy check, and the lowest amount of these nutrients after weed-free check was observed in pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha. All the weed-control treatments resulted in significantly higher chilli fruit yield than to weedy check; however, the tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha resulted in 180% higher chilli fruit yield over weedy check. Similarly, chilli fruit yield was increased by 5.2% in zero tillage over conventional tillage and by 18.2% in the second year over the first year.

Key words : Chilli, Nutrients, Tank-mix herbicide, Tillage, Weed management, Yield

In India, chilli is an important commercial crop grown on a wide range of soil at an altitude varying from sea-level to 2,000 m above mean sea-level, both for internal consumption and export. Weeds emerge fast and grow rapidly competing with the crop severely for nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of chilli. Further, wide space provided to the chilli allows fast growth of variety of weed species, causing a considerable reduction in yield by affecting the growth, yield and yield components. The extent of reduction in fruit yield of chilli has been reported 60 to 70%, depending on the intensity and persistence of weed density in standing crop (Patel *et al.*, 2004). Generally, 30 to 60 days after transplanting is the most critical period for weed competition in chilli (Frank *et al*., 1988). The efficacy of post-emergence herbicide application is highly dose-sensitive and time/stage-dependent, and therefore, sometimes may lead to phytotoxic effects on crops. Even selective herbicide poses risk when applied as post-emergence at higher dose. The leaves of crop can be burnt, shriveled or discoloured when herbicides are sprayed. This damage can be extensive, and sometimes over 40% of the leaves of crop plants is damaged. In addition to giving crops a poor cosmetic appearance, plants can be weakened, their growth phases retarded and stunted. In contrast, pre-emergence application is less risky (Das, 2008). Mixing two or more compatible partner herbicides together at lower doses in the spray tank and applying that mixture as pre-emergence may result in better and broad-spectrum weed control, and crop can germinate in weed-free situations (Das, 2008). Therefore, this research was designed to evaluate the effect of herbicides applied pre-emergence, alone or as tank-mix, in different tillage conditions on weed control, yield and nutrient uptake of chilli.

MATERIALS AND METHODS

The field experiment was carried out in 2012 and 2013 at the Indian Agricultural Research Institute, New Delhi. Soil of the experimental field was alluvium (Typic

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Ustochrepts; Order Inceptisol) in origin and sandy loam (62.4% sand, 16.8% silt and 19.2% clay) with 0.54% organic C and pH 7.6. The available P (19.1 kg P/ha) and K (190.8 kg K/ha) were medium, but available N (274.6 kg N/ha) was low.

The experiment, comprising 2 levels of tillage, viz. conventional tillage (CT) and zero-tillage (ZT) in main plots, and 7 weed-management treatments in subplots (Table 1) was laid out in a splitplot design with 3 replications. Pre-emergence applications of herbicide alone or as tank-mix combinations were made 2 days after transplanting and 1 post-emergence herbicide and 1 hand-weeding treatment was given 30 days after transplanting. A knapsack sprayer fitted with a flat-fan nozzle was used with 400 L water/ha for herbicide application. Weed-free check was kept free from weeds all through the growing season by manual weeding. Healthy seedlings (45 days old) of chilli cv. 'Pusa Sadabahar' were transplanted at 45 cm × 60 cm in the first week of August in both the years. Recommended cultural practices except weed-management practices were adopted to raise a healthy crop. Crop was fertilized with 100 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha through urea, diammonium phosphate (DAP) and muriate of potash respectively. Half dose of N and full dose of P_2O_5 and K_2O were applied at the time of transplanting, and remaining N was top-dressed in two equal splits at 45 and 60 days after transplanting.

Weed population and dry weight were recorded at 30 days after transplanting by placing a quadrat of 50 cm × 50 cm randomly in each plot. Chilli dry weight were recorded at 30 and 60 days after transplanting. For determining chilli green fruit yield, 10 plants (excluding the border row plants in every plot) were randomly selected and tagged, and picking of green chillies was done from these plants and weighed. There were 6 pickings of green chillies done in every cropping season. In chilli fruits and stover, and weeds at harvest, N concentration was determined by modified Kjeldahl method; P concentration by vanadomolybdophosphoric acid yellow colour method using spectrophotometer; and K concentration by flame photometer (Prasad *et al*., 2006). Data on weed population and dry weight were transformed through square-root [$\sqrt{(x+0.5)}$] method before analysis of variance (ANOVA). All data on weed and chilli were subjected to ANOVA using the PROC GLM procedure of SAS (SAS Institute, 2003) to evaluate differences among treatments, and interactions between the main and sub-plot treatments. The significance was tested by variance ratio (i.e. F value) at Pd" 0.05 (Gomez and Gomez, 1984). Standard error (SEm±) and critical difference (CD) were worked out for each parameter of weed and chilli studied for comparing the treatment means.

RESULTS AND DISCUSSION

Weed growth, weed control efficiency and weed index

Eleven weed species, 6 monocotyledons (monocots) and 5 dicotyledons (dicots) belonging to eight botanical families were present in chilli. Monocots were more predominant over dicots during both years. The most important monocots were: *Acrachne racemosa* (Heyne ex Roem & Schult.) Ohwi (Poaceae); *Dactyloctenium aegyptium* (L.) P. Beauv. and *Cyperus rotundus* (L.) (Cyperaceae). The most important dicots weeds were: *Trianthema portulacastrum* (L.) (Aizoaceae), *Digera arvensis* (L.) Forsk. (Amaranthaceae) and *Phyllanthus niruri* (L.) (Phyllanthaceae).

Pooled analysis of data on weed population and weed dry weight showed a significant difference between 2012 and 2013, but there was no significant difference between conventional tillage (CT) and zero tillage (ZT) with for pooled data on weed population and dry weight (Table 1). This indicated that both CT and ZT were similar in their effects on weeds in chilli. In contrast, population and dry weight of weeds were significantly affected by the weed-management treatments (Table 1). A significant difference was observed between herbicidal treatments for weed population. The lowest weed density after weed-free check was found in tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha. This herbicide treatment was superior to all the other treatments for weed control during both years. Arnold *et al*. (1993) observed an efficient broad-leaved weed control by imazethapyr applied as pre-plant incorporation or post-emergence. They highlighted that barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] control by imazethapyr ranged from 58 to 96%, and was increased to 98%, when imazethapyr was combined with metolachlor, pendimethalin, trifluralin or EPTC. Weed dry matter reduction due to herbicide treatments in both years (Table 1) followed almost similar trend as the weed population and pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha resulted in the lowest weed dry weight excluding weed-free check. The results confirm the findings of with Monsefi *et al*. (2011) and Younesabadi *et al*. (2013) in soybean. Bhan and Kewat (2002) reported that pendimethalin was the most potent herbicide for effective weed control in soybean at 1.0 kg/ha, but its efficacy against weeds was reduced in heavy soils applied at the same dose. The dose played a role in this experiment, too. The dose of pendimethalin was reduced to 0.75 kg/ha in the tank-mixture compared to 1.0 kg/ha as usually recommended. This affected weed control slightly, but its mixture with imazethapyr 0.075 kg/ha could compensate this

might be due to synergistic action. Weed dry weight was the second highest in pendimethalin 0.75 kg/ha pre-emergence (PE) + hand-weeding (HW). This necessitated the tank-mix application of pendimethalin and imazethapyr for better weed-control in chilli. Shaikh (2005) reported that weed-control efficiency of >80% with hand-weeding, oxyfluorfen at 0.10 kg/ha and pendimethalin at 0.75 kg/ha supplemented with hand-weeding at 45 days. Yadav (2001) opined that oxyfluorfen (0.2 kg/ha) combined with 2 hoeing at 30 and 60 days significantly reduced the dry weight of both grassy and broad-leaved weeds compared to oxyflourfen (0.2 or 0.3 kg/ha) with 1 hoeing. Pendimethalin (1.0 kg/ha) + 1 hoeing controlled grassy weeds as effectively as the oxyflourfen at 0.2 or 0.3 kg/ha with 2 hoeing but oxyflourfen (0.3 kg/ha) + 1 hoeing was more effective on broad-leaf weeds compared to pendimethalin. A significant difference was observed between weed-management treatments with respect to weed-control efficiency WCE and weed index (WI) (Table 1). The lowest WI and highest WCE were observed in the tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha, excluding weed-free check. The WCE and WI of this treatment were 93.4% and 9.6%, respectively, which were significantly higher than that in other herbicide treatments.

Chilli growth and yield

Plant dry weight and plant height of chilli showed a significant difference over the years (Table 2). Dry-matter accumulation varied significantly due to tillage and weed management at 30 and 60 days. The dry weight of chilli was significantly higher in ZT than in CT, and plant height was similar between these 2 treatments. Chilli fruit yield and fruit length were also similar between the tillage treatments during both years (Table 2). This indicated that no-tillage with residue retention was superior to or as good as conventional tillage in producing dry weight, yield attributes and yield of chilli.

Weedy check caused the greatest reduction in plant dry weight and plant height in both years (Table 2). Maximum pooled dry weight of chilli was obtained under weed-free check, which was followed by the tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha at both 30 and 60 days. Similarly,

Table 1. Weed density, weed dry weight, weed-control efficiency (WCE) and weed index (WI) as influenced by tillage and herbicide application (pooled data of 2 years)

Treatment	Weed density (no./m^2) (30 DAT)	Weed dry weight (g/m^2) (30 DAT)	WCE at 60 DAT (%)	WI (%)
Year				
First year (2012)	9.4 (108.1)*	8.64 (97.02)	72.2	26.0
Second year (2013)	6.5 (56.4)	6.45 (58.25)	74.7	26.1
SEm±	0.15 (3.62)	0.20 (3.38)	1.40	0.63
CD (P=0.05)	0.57 (14.21)	0.78 (13.25)	NS	NS
Tillage level (T)				
Conventional tillage (CT)	8.2 (86.9)	7.75 (83.34)	74.0	25.1
Zero tillage (ZT)	7.7 (77.6)	7.34 (71.93)	72.9	27.0
SEm±	0.15 (3.62)	0.199 (3.38)	1.40	0.63
CD (P=0.05)	NS	NS	NS	NS
Weed management (W)				
Pendimethalin 1.0 kg/ha pre-em.	7.5 (60.8)	7.13 (53.08)	86.2	19.6
Pendimethalin 0.75 kg/ha + oxyfluorfen 0.15 kg/ha pre-em tank-mix	7.9 (64.3)	7.56 (57.70)	82.8	18.9
Pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha pre-em tank-mix	5.4 (31.6)	3.97 (20.68)	93.4	9.6
Pendimethalin 0.75 kg/ha pre-em. followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT	9.0 (84.9)	8.67 (78.27)	77.6	32.5
Pendimethalin 0.75 kg/ha pre-em. + hand-weeding (HW) at 30 DAT	9.8 (98.3)	9.09 (86.54)	74.4	35.9
Weedy check (WC)	15.3 (235.8)	15.69 (247.19)	0.0	66.1
Weed-free check (WFC)	0.7 (0.0)	0.71 (0.00)	100.0	0.0
SEm±	0.21 (4.53)	0.218 (4.15)	1.97	0.99
CD (P=0.05)	0.58 (12.89)	0.62 (11.81)	5.61	2.83
Interaction(T×W)	NS	S	NS	S

DAT, Days after transplanting; pre-em., pre-emergence

*Figures in parentheses are original values. Original values were transformed through square-root [$\sqrt{(x + 0.5)}$] method

chilli fruit yield and fruit length were significantly higher in weed-free-check, followed by the tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha in both years (Table 2). Weedy check gave the lowest fruit yield and fruit length and all weed control measures exhibited higher fruit yield and fruit length than that weedy check. Amador-Ramírez *et al*. (2007) reported that internode length, stem diameter and plant height were higher under weed-free conditions compared to weed interference. Internode length, stem diameter and plant height started decreasing after 8 or more weeks of weed interference. At least 4 tonnes weed dry matter/ha was recorded for treatments with increasing periods of weed interference. This was enough to decrease crop yield up to 67%. Adigun (2001) opined that unchecked weed growth throughout crop life cycle resulted in an 81–90% reduction in potential chilli pepper fruit yields. Ved Prakash *et al.* (2003) reported that weed infestation is the major limiting factor in realizing potential yield of chilli, resulting in heavy reduction in the yield as high as 78%. Khokhar *et al*. (2006) reported that compared to weed-free condition, weed-crop competition caused 30.1 and 46.4% reduction in chilli fruit yield in first and second year.

Nutrients uptake by chilli and weeds

Nitrogen, P and K uptake by weed varied significantly due to weed-control management (Table 3). Weeds had lower N, P and K uptake than that of chilli crop (Table 3). Highest N, P and K uptake by weeds was observed in weedy check, and the lowest uptake, excluding weed-free check, in the tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha (Table 3). The results confirm the findings of Kaur *et al*. (2010). Nitrogen, P and K uptake by chilli (Table 3) were not affected by tillage treatments, indicating that ZT with *Sesbania* residue was comparable with conventional tillage. Nitrogen, P and K uptake in chilli was higher in pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha treatment than other weed-control treatments. Monsefi *et al*. (2011) and Younesabadi *et al*. (2013) reported similar results in soybean. This indicates that pendimethalin 0.75

Table 2. Dry matter, plant height of chilli at 30 and 60 DAT, green fruit yield and fruit length as influenced by tillage and herbicide application (pooled data of 2 years)

Treatment	Plant dry-matter (g/m^2)		Plant height (cm)		Yield	Fruit
	30 DAT	60 DAT	30 DAT	60 DAT	(t/ha)	length (cm)
Year						
First year (2012)	5.32	21.59	24.5	42.3	7.24	6.52
Second year (2013)	5.99	29.02	26.3	45.6	8.56	7.07
SEm±	0.09	0.38	0.34	0.68	0.13	0.11
CD (P=0.05)	0.34	1.48	1.32	2.67	0.51	0.44
Tillage level (T)						
Conventional tillage (CT)	5.35	24.33	24.8	43.4	7.70	6.59
Zero tillage (ZT)	5.96	26.28	26.0	44.4	8.10	7.01
SEm±	0.09	0.38	0.34	0.68	0.13	0.112
CD (P=0.05)	0.34	1.48	NS	NS	NS	NS
Weed management (W)						
Pendimethalin 1.0 kg/ha pre-em.	5.79	25.47	26.2	45.1	8.58	6.90
Pendimethalin 0.75 kg/ha + oxyfluorfen 0.15 kg/ha pre-em. tank-mix	5.79	23.59	25.2	44.3	8.62	7.21
Pendimethalin 0.75 kg/ha + imazethapyr 0.075kg/ha pre-em. tank-mix	6.17	34.14	27.3	50.5	10.10	7.55
Pendimethalin 0.75 kg/ha pre-em. followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT	5.38	21.44	24.0	42.8	7.20	6.70
Pendimethalin 0.75 kg/ha pre-em. + hand-weeding (HW) at 30 DAT	5.18	21.07	23.8	43.0	6.86	6.31
Weedy check (WC)	4.90	14.24	23.1	31.1	3.61	5.01
Weed-free check (WFC)	6.38	37.21	28.1	50.7	10.31	7.89
SEm±	0.16	0.59	0.57	1.06	0.18	0.187
CD (P=0.05)	0.45	1.67	1.62	3.03	0.51	0.53
Interaction(T×W)	NS	NS	NS	NS	NS	NS

DAT, Days after transplanting; pre-em., pre-emergence

*Figures in parentheses are original values. Original values were transformed through square-root [method

Table 3. Total N, P and K uptake by weed and crop as influenced by tillage and herbicide application (pooled data of two years)

Treatment	Weed			Chilli crop		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Year						
First year (2012)	63.38	7.11	50.17	104.48	15.47	71.46
Second year (2013)	56.91	6.23	43.92	126.66	17.51	79.90
SEm±	1.12	0.14	0.99	2.37	0.27	1.11
CD (P=0.05)	4.40	0.53	3.90	9.32	1.04	4.35
Tillage level (T)						
Conventional tillage (CT)	69.63	7.34	52.53	111.24	16.22	78.46
Zero tillage (ZT)	50.66	5.99	41.56	119.90	16.77	72.89
SEm±	1.12	0.14	0.99	2.37	0.27	1.11
CD (P=0.05)	4.40	0.53	3.90	NS	NS	4.35
Weed management (W)						
Pendimethalin 1.0 kg/ha pre-em.	55.37	4.25	52.85	118.47	17.84	72.70
Pendimethalin 0.75 kg/ha + oxyfluorfen 0.15 kg/ha pre-em. tank-mix	63.86	5.09	60.46	109.73	17.98	66.40
Pendimethalin 0.75 kg/ha + imazethapyr 0.075kg/ha pre-em. tank-mix	47.76	4.07	24.43	129.81	21.13	116.42
Pendimethalin 0.75 kg/ha pre-em. followed by quizalofop-p-ethyl 0.025 kg/ha at 30 DAT	90.02	12.44	66.45	111.43	17.60	86.39
Pendimethalin 0.75 kg/ha pre-em. + hand- weeding (HW) at 30 DAT	53.14	7.05	36.92	115.89	14.65	64.93
Weedy check (WC)	110.84	13.75	88.20	58.98	8.20	46.58
Weed -free check (WFC)	0.00	0.00	0.00	164.68	18.04	76.32
SEm±	1.84	0.20	1.44	2.91	0.36	1.63
CD (P=0.05)	5.24	0.57	4.10	8.27	1.03	4.64
Interaction(T×W)	S	S	S	S	S	S

DAT, Days after transplanting; pre-em., pre-emergence

*Figures in parentheses are original values. Original values were transformed through square-root [method

kg/ha + imazethapyr 0.075 kg/ha through greater reduction in weed dry weights, reduced N, P and K uptake by weeds, which eventually led to higher uptake of these nutrients by chilli crop. This indirectly shows that this tank-mix herbicide treatment (pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha) was the best in controlling weed.

It is concluded that zero tillage with pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha as tank-mix pre-emergence application may be recommended for better weed management and higher chilli yield.

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