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Assessment of Clethodim for Bio-efficacy and Phytotoxicity to Control Weeds in Soybean and its Carry Over Effect in Succeeding Wheat

Pratap Singh[1], Chaman K. Jadon[2], Uditi Dhakad[3] and S. N. Meena[4]

Agricultural Research Station, Directorate of Research[1,2,4], Ph.D.Scholar[3],Dept.of Agronomy, College of Agriculture, Ummedganj, Kota, Agriculture University, Kota, Rajasthan, India-324001
Corresponding author Email – psd427@rediffmail.com

Abstract: A field experiment was conducted during *kharif* seasons of 2018 and 2019 at Agricultural Research Station, Kota to evaluate the bio-efficacy and phytotoxicity of clethodim 12 % (w/v) EC against weeds flora of soybean and residual effect on succeeding wheat crop. Experimental field was mainly dominated by grassy weeds. Results revealed that post-emergence application of clethodim 12% (w/v) EC at 120 g *a.i.*/ha and 144 g *a.i.*/ha were found more effective in controlling grassy weeds than other treatments pertaining to lower weed density and significantly higher weed control efficiency without any phytotoxicity to the soybean. Seed yield of soybean under different treatments was found to be significantly higher than weedy check.Clethodim 12% (w/v) EC at 120 g *a.i.*/ha and 144 g *a.i.*/ha resulted in higher soybean seed yield (1561 kg/ha and 1985and 2024kg/ha during 2018 and 2019, respectively) being at par with each other and were significantly superior to other treatments and weedy check. The residual effect of the test herbicides clethodim 12% (w/v) EC applied in soybean, was not observed in succeeding wheat crop as growth parameters, yield attributes and yield of wheat varied non-significantly.

Keywords: Clethodim, bio-efficacy, soybean, carryover, wheat

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) has emerged as a premier pulse and oil seed crop in India. It provides the cheapest as well as the largest source of edible vegetable protein than any other pulse crop accounting 40 to 43 per cent protein content and 20 per cent oil content. Being a *kharif* season crop weed infestation in soybean is one of the major problems, which limits its productivity to a greater extent. Weeds like *Echinochloa crusgalli, Echinochloa colona, Commelina benghalensis, Panicum dichotomiflorum, Polygonum spp., Aeschynomene indica and Digitaria sanguinalis, Eleusine aegyptium and Cyperus spp.* are predominantly associated with soybean. It is estimated that the extent of reduction in yield ranges from 30-80% due to weed competition (Gupta *et al*., 2006). The continuous use of pre-emergence herbicides has led to the changes in the emergence patterns of weeds in different crop ecosystems (Sridhara *et al*., 2010). This has led to the need of post emergence herbicides. Apart from this, the composition of weed flora occurring in different crop ecosystems is also changing from dicots to more of grasses and sedges. Therefore, evaluation of the efficacy of grass killers in different soybean crop ecosystem is also needed. To find out the dynamic assessment of bio-efficacy of newer herbicides in terms of their effect on weed flora, phytotoxicity to the main crop as well as residual effect on the succeeding crops is also of great concern in soybean based cropping system.

MATERIALS AND METHODS

The experiment was carried out at Agricultural Research Station, Ummedganj, Kota situated in Agro-climatic zone V (South-Eastern humid

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plain zone) of Rajasthan and located between $25^0$13′ North latitude and 75^0 25′ East longitudes, at altitude of 258 m above mean sea level. The rainfall received during the experimental years was 529.8 mm and 1372.1 mm, during *kharif* 2018 and *kharif* 2019, respectively. The experiment was laid out in randomized block desing (RBD) with 8 treatments *viz.* Clethodim 12% EC at 96, 120 and 144 g *a.i.*/ha as PoE, Propaquizafop 10% EC at 75 g *a.i.*/ha(PoE), Quizalofop-ethyl 5% EC at 50 g *a.i.*/ha(PoE), two hand weeding at 20 & 40 DAS, untreated control were tested in three replications. The experimental field was prepared by adopting standard agronomical practices as per requirement of soybean crop. Soybean (RKS 45) was sown in row to row spacing of 30 cm. Di-ammonium phosphate and murate of potash were used as source of nitrogen, phosphorus and potash in soybean crop, and were applied before sowing with recommended dose of nutrient (40 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha). All the herbicidal treatments were sprayed at 20 DAS (2018) and 21 DAS (2019) using knapsack sprayer with flat fan nozzle at 500 liters per hectare. The wheat crop (Raj 4037) was sown as succeeding crop after harvest of soybean on the same experimental site without disturbing the layout during rabi seasons. Weed density was observed with the help of quadrate from 0.25 m^2 area from five randomly selected locations in each plot and were taken at 15, 30 and 45 DAT (days after treatments) and its dry weight was weighed. All the data were subjected to statistical analysis. Weed control efficiency (WCE) was calculated at 15, 30 and 45 DAS using the following formula;

$$WCE = \frac{\text{WDM in UTC} - \text{WDM in treated X100}}{\text{WDM in UTC}}$$

where, WDM = Weed Dry Matter and UTC = Untreated control

The phytotoxicity symptoms were observed visually using rating scale of 0-10. The controlled plot was used as reference. Observation on toxicity on the soybean crop stand and growth were taken at 0, 1, 3, 7 and 14 days after treatment application. Residual effect of Clethodim 12% EC applied in preceding soybean was evaluated on succeeding wheat crop and was observed for phytotoxicity symptoms at 7, 10, 15, 20 and 30 days after germination. Growth,yield parameters and yields were recorded for all the treatments.

Table 1: Population dynamics of grasses, sedges and dicots weeds (No./ 0.25 m^{-2}) as influenced by weed control treatments in soybean

Treatments	*Grasses*				*Sedges*				*Dicots*			
	2018		*2019*		*2018*		*2019*		*2018*		*2019*	
	30 DAT	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*
Clethodim 12 % EC @ 96 g a.i./ha	2.12 * (4.07)	2.92 (8.13)	2.07 (3.87)	2.84 (7.67)	2.64 (6.47)	2.64 (6.47)	2.72 (6.93)	2.68 (6.73)	3.07 (9.02)	3.48 (11.71)	3.25 (10.18)	3.59 (12.53)
Clethodim 12 % EC @ 120 g a.i./ha	1.36 (1.40)	2.20 (4.25)	1.34 (1.40)	1.99 (3.60)	2.16 (4.2)	2.27 (4.80)	2.35 (5.07)	2.48 (5.67)	2.99 (8.85)	3.36 (10.89)	3.16 (9.60)	3.48 (11.80)
Clethodim 12 % EC @ 144 g a.i./ha	1.21 (1.07)	2.04 (3.80)	1.20 (1.07)	1.84 (3.07)	2.01 (3.53)	2.15 (4.13)	2.13 (4.2)	2.45 (5.6)	2.90 (8.22)	3.26 (10.25)	3.06 (8.93)	3.39 (11.04)
Propaquizafop 10 % EC @ 75 g a.i./ha	2.15 (4.20)	3.22 (9.93)	2.13 (4.20)	3.10 (9.20)	2.64 (6.53)	2.74 (7.13)	2.67 (6.67)	2.78 (7.27)	3.14 (9.47)	3.55 (12.27)	3.32 (10.69)	3.66 (13.09)
Quizalofop-ethyl 5% EC @ 50 g a.i./ha	1.90 (3.25)	2.94 (8.27)	1.87 (3.13)	2.83 (7.67)	2.58 (6.2)	2.70 (6.80)	2.48 (5.73)	2.6 (6.33)	3.22 (9.98)	3.65 (12.91)	3.33 (10.76)	3.66 (12.98)
Hand weeding at 20 and 40 DAS	1.07 (0.73)	1.76 (2.67)	1.00 (0.60)	1.66 (2.33)	1.16 (0.87)	1.85 (2.93)	1.37 (1.40)	1.93 (3.27)	1.27 (1.15)	2.12 (4.16)	1.35 (1.36)	2.10 (4.05)
Untreated control	4.29 (18.53)	5.05 (25.53)	4.60 (21.47)	5.14 (26.73)	3.76 (13.67)	3.92 (14.87)	4.27 (17.8)	4.13 (16.6)	3.50 (11.85)	3.91 (14.87)	3.67 (13.07)	4.09 (16.11)
S.Em. ±	0.14	0.12	0.13	0.15	0.11	0.15	0.17	0.16	0.21	0.22	0.22	0.24
C.D. (P=0.05)	0.42	0.37	0.41	0.45	0.35	0.48	0.53	0.49	0.64	0.69	0.67	0.73

* values are $\sqrt{x+0}$ transformed and actual values are in parentheses

3. RESULTS AND DISCUSSION

3.1. Weed flora

During the course of study the major weed flora were invaded in the field. The weed flora was dominated by the grassy weeds namely, *Echinochloa* spp. (*Echinochloa crusgalli, Echinochloa colonum*), *Cynodon dactylon, Elusine indica, Dinebra arabica* and *Dactyloctenium aegyptium* and *Cyperus spp.* (sedges) during both the years. Among the broad leaved weeds, *Digera arvensis, Celosia argentea, Trianthema* spp *and Commelina benghalensis* were the predominant.

3.2. Effect on weed density, weed dry matter and weed control efficiency

The two season study have indicated that weed management practices like, hand weeding and herbicide application has significantly reduced the weed population in soybean crop up to 45 days as compared to untreated control plot. Overall results indicated that, hand weeding at 20 & 40 DAS was found best in controlling the weed density up to 45 days. However, among the herbicidal treatments Clethodim 12% EC at 144 g *a.i.*/ha was found superior in reducing the weed population and was at par with Clethodim 12% EC at 120 g *a.i.*/ha during both the seasons, followed by treatments Quizalofop-ethyl 5% EC at 50 g *a.i.*/ha, Propaquizafop 10% EC at 75 g *a.i.*/ha and lower dose treatment of Clethodim 12% EC at 96 g *a.i.*/ha. Among all the treatments untreated control registered maximum weed density and weed dry weight at all the intervals of observation during both the seasons (Table1). Hand weeding twice significantly reduced the dry weight of grassy weeds and resulted in higher weed control efficiency. Among herbicides post-emergence Clethodim 12% EC at 144 g *a.i.*/ha and 120 g *a.i.*/ha were found effective in reducing the weed dry weight of grassy weeds especially and were statistically at par with each other at all the intervals of observations. By reducing highest weed dry weight Clethodim 12% EC at 144 g *a.i.*/ha and Clethodim 12% EC at 120 g *a.i.*/ha recorded higher weed control efficiency followed by quizalofop-ethyl 5% EC at 50 g *a.i.*/ha, propaquizafop 10% EC at 75 g *a.i.*/ha and clethodim 12% EC at 96 g *a.i.*/ha (Table 3) which recorded moderate weed control efficiency over untreated control during both the seasons. All herbicidal treatments were found non-significant for controlling broad leaved weeds in terms of their weed counts and dry weight during the study period. Similar results were also reported by Kumar *et al.,* (2008).

Table 2: Dry matter of grasses, sedges and dicots weeds (No./ 0.25 m^{-2}) as influenced by weed control treatments in soybean

Treatments	*Grasses*				*Sedges*				*Dicots*			
	2018		*2019*		*2018*		*2019*		*2018*		*2019*	
	30 DAT	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*	*30 DAT*	*45 DAT*
Clethodim 12 % EC @ 96 g a.i./ha	1.79 * (2.77)	3.08 (9.09)	1.75 (2.60)	2.99 (8.58)	1.91 (3.14)	2.06 (3.75)	1.97 (3.4)	1.78 (2.7)	2.43 (5.48)	2.86 (7.79)	2.57 (6.21)	2.90 (8.05)
Clethodim 12 % EC @ 120 g a.i./ha	1.20 (0.95)	2.33 (4.98)	1.17 (0.92)	2.16 (4.23)	1.62 (2.14)	1.79 (2.78)	1.72 (2.48)	1.61 (2.12)	2.37 (5.23)	2.77 (7.27)	2.50 (5.86)	2.82 (7.59)
Clethodim 12 % EC @ 144 g a.i./ha	1.08 (0.72)	2.16 (4.23)	1.08 (0.74)	2.02 (3.65)	1.52 (1.8)	1.7 (2.4)	1.57 (2.06)	1.59 (2.08)	2.30 (4.85)	2.69 (6.84)	2.43 (5.47)	2.75 (7.16)
Propaquizafop 10 % EC @ 75 g a.i./ha	1.81 (2.82)	3.39 (11.08)	1.81 (2.81)	3.27 (10.28)	1.95 (3.33)	2.14 (4.14)	1.94 (3.27)	1.86 (3.00)	2.48 (5.75)	2.92 (8.17)	2.63 (6.55)	2.96 (8.45)
Quizalofop-ethyl 5% EC @ 50 g a.i./ ha	1.62 (2.22)	3.11 (9.18)	1.61 (2.12)	3.00 (8.57)	1.91 (3.16)	2.11 (3.94)	1.81 (2.81)	1.72 (2.48)	2.55 (6.06)	3.00 (8.60)	2.63 (6.56)	2.95 (8.36)
Hand weeding at 20 and 40 DAS	0.94 (0.43)	1.87 (3.12)	0.90 (0.36)	1.77 (2.69)	0.97 (0.44)	1.48 (1.71)	1.08 (0.69)	1.51 (1.82)	1.06 (0.65)	1.72 (2.62)	1.13 (0.80)	1.70 (2.49)
Untreated control	3.38 (11.66)	5.26 (27.73)	3.38 (11.67)	5.26 (27.74)	2.73 (6.97)	2.93 (8.12)	3.03 (8.72)	2.69 (6.80)	2.73 (7.08)	3.20 (9.84)	2.87 (7.82)	3.27 (10.38)
S.Em. ±	0.10	0.09	0.08	0.10	0.08	0.11	0.12	0.13	0.16	0.18	0.16	0.18
C.D. (P=0.05)	0.29	0.27	0.24	0.31	0.24	0.35	0.35	0.41	0.49	0.54	0.51	0.56

* values are $\sqrt{x+0.5}$ transformed and actual values are in parentheses

Table 3: Weed control efficiency (%) as influenced by weed control treatments in soybean

Treatments	Grasses				Sedges				Dicots			
	2018		2019		2018		2019		2018		2019	
	30 DAT	45 DAT	30 DAT	45 DAT	30 DAT	45 DAT	30 DAT	45 DAT	30 DAT	45 DAT	30 DAT	45 DAT
Clethodim 12 % EC @ 96 g a.i./ha	71.84	66.16	73.29	68.31	54.74	53.37	61.15	60.6	30.61	28.86	30.82	31.74
Clethodim 12 % EC @ 120 g a.i./ha	90.95	81.69	91.41	84.26	69.16	65.74	70.88	67.26	36.94	36.17	36.76	37.00
Clethodim 12 % EC @ 144 g a.i./ha	93.35	84.15	93.71	86.45	74	70.32	77.13	70.16	42.06	40.43	42.20	41.25
Propaquizafop 10 % EC @ 75 g a.i./ha	71.43	58.48	72.67	61.42	50.9	47.66	62.56	55.42	26.82	24.77	28.23	28.00
Quizalofop-ethyl 5% EC @ 50 g a.i./ha	75.48	64.80	79.29	67.51	54.4	51.19	66.86	61.18	24.36	22.54	29.14	29.93
Hand weeding at 20 and 40 DAS	96.42	88.60	97.68	89.66	93.68	78.93	95.67	82.56	91.33	75.47	91.13	77.90
Untreated control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.3. Effect on soybean crop

The better growth and development of the crop under weed free environment with effective weed control treatments reflected its influence on the yield attributing characters and resulted in higher productivity of soybean. Seed yield of soybean was significantly affected due to different treatments. The highest yield of 1649 & 2075 kg/ha was recorded under two hand weed treatment during 1st and 2nd season respectively, whereas seed yield ranged under various clethodim 12 % EC doses *i.e.* 96 g *a.i.*/ha (1305 & 1607 kg/ha), 120g *a.i.*/ha (1561 & 1985 kg/ha) and 144 g *a.i.*/ha (1631 & 2024 kg/ha) were found significantly superior over weedy check, during the year 2018 & 2019, respectively (Table 4).

Among the herbicidal treatments, the mean yield of soybean under test herbicide was recorded highest under clethodim 12 % EC 144 g *a.i.*/ha followed by clethodim 12 % EC 120 g *a.i.*/ha. Straw yield, pods per plant and seeds per pod represented similar trend as per seed yield and whereas 100 seed weight was found non-significant among all the treatments (Table 4). Kothawade *et al.*,(2007) reported that post emergent herbicides gave significantly higher

Table 4: Effect of weed control measures on growth and yield attributes and yield of soybean

Treatments	Plant height (cm)		Dry matter / plant (g)		Pods / Plant		Seeds / pod		100 Seed Weight (g)		Seed Yield (Kg/ha)		Straw yield (Kg/ha)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Clethodim 12 % EC @ 96 g a.i./ha	78.4	82.3	62.3	74.6	40.1	47.1	2.4	2.6	9.51	9.44	1305	1607	2059	2499
Clethodim 12 % EC @ 120 g a.i./ha	80.2	82.9	65.6	82.9	46.3	54.5	2.5	2.6	9.46	9.53	1561	1985	2396	3021
Clethodim 12 % EC @ 144 g a.i./ha	80.5	82.9	67.7	82.8	49.0	56.6	2.7	2.6	9.58	9.61	1631	2024	2558	3131
Propaquizafop 10 % EC @ 75 g a.i./ha	78.4	81.5	63.5	78.2	39.4	48.5	2.4	2.5	9.41	9.58	1293	1595	2042	2552
Quizalofop-ethyl 5% EC @ 50 g a.i./ha	80.7	82.1	64.8	81.5	46.2	51.3	2.4	2.6	9.53	9.44	1342	1625	2180	2787
Hand weeding at 20 and 40 DAS	82.7	83.8	72.2	90.5	53.0	60.6	2.6	2.8	9.65	9.73	1649	2075	2586	3203
Untreated control	72.3	89.7	53.1	55.5	22.0	25.6	2.0	2.2	9.62	9.92	951	1184	1510	1852
S.Em. ±	2.2	1.1	2.6	2.7	2.1	2.2	0.1	0.1	0.16	0.13	93.15	123	141	196
C.D. (P=0.05)	6.8	4.1	7.2	7.6	6.6	6.8	0.4	0.3	NS	NS	286	379	436	606

yield and yield parameters like weight of pods per plant (20.6 g), weight of seeds per plant (14.6 g), 1000 seed weight (141.0 g) and seed yield (30.1 and 30.3 q ha^{-1}).Similar results were also reorted by Deore *et al.,* (2008) and Yadav *et al*., (2009).

3.4. Phytotoxicity studies on soybean crop

Frequent observations on toxicity to the soybean crop were made during both years. The herbicidal treatments did not show any phytotoxicity symptom (leaf tip/surface injury, witling, stunting, yellowing, necrosis, chlorosis, epinasty, hyponasty) on soybean crop during both the years of the study (Table 5). The test herbicide was found selective to the soybean crop.

3.5. Carryover effect on succeeding wheat

Under field conditions none of the treatment showed adverse effect on succeeding wheat crop. The data on germination, plant stand, effective tillers, grains/ear, 1000 seed weight and seed yield was found non-significant in all the treatments (Table 6). Since the half life of clethodim was only 30 - 38 days (EPAPEST, 2001) and it had completely degraded in the soil by the time wheat crop was sown. Post emergence application of Clethodim 12% EC at 120 and 240 g a.i./ha applied in preceding soybean did not observe adverse effect (visual) on the succeeding wheat crop (Table 5 & 6). The results are in conformity with the findings of Arora *et al*., (2005) and Shudhkara *et al.* (2014).

CONCLUSION

Based on the two years (2018 and 2019) experimentation, it can be inferred that post emergence Clethodim 12% (w/v) EC at 120 g *a.i./* ha to 144 g *a.i./*ha had been found effective and selective in controlling grassy weeds in soybean crop as compared to 96 g *a.i.*/ha. Clethodim 12% (w/v) EC without phytotoxic effect on

Table 5 : Phytotoxicity in soybean and carryover effect on succeeding wheat crop due to clethodim application in soybean

Treatments	*Yellowing, Chlorosis , Stunting & Wilting,Necrosis, Hyponasty & Epinasty, Leaf tip/surface injury (0-10 scale)*									
	2018	*2019*	*2018*	*2019*	*2018*	*2019*	*2018*	*2019*	*2018*	*2019*
Clethodim 12 % EC @ 96 g a.i./ha	0	0	0	0	0	0	0	0	0	0
Clethodim 12 % EC @ 120 g a.i./ha	0	0	0	0	0	0	0	0	0	0
Clethodim 12 % EC @ 144 g a.i./ha	0	0	0	0	0	0	0	0	0	0
Propaquizafop 10 % EC @ 75 g a.i./ha	0	0	0	0	0	0	0	0	0	0
Quizalofop-ethyl 5% EC @ 50 g a.i./ha	0	0	0	0	0	0	0	0	0	0
Hand weeding at 20 and 40 DAS	0	0	0	0	0	0	0	0	0	0
Untreated control	0	0	0	0	0	0	0	0	0	0

Table 6: Residual effect of weed control measures on growth, yield attributes and yield of succeeding wheat

Treatments	*Germination (%)*		*Plant Stand /m (no.)*		*Plant height (cm) at harvest*		*Plant dry matter (g/m^2) at harvest*		*Tiller / m. (no.)*		*Spike length (cm)*		*1000 seed/ wt. (g)*		*Seed yield (Kg/ha)*		*Straw yield **(Kg/ha)***	
	2018 -19	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*	*2018 -19*	*2019 -20*
Clethodim 12% EC @ 96 g a.i./ha	93	92	32	32	94.6	100.0	1112	1135	118	121	12.7	13.	42.5	42.5	4940	5094	6683	6857
Clethodim 12% EC @ 120 g a.i./ha	92	93	32	33	96.3	99.0	1124	1142	122	132	13.0	13.3	42.9	42.6	5122	5238	6925	7042
Clethodim 12% EC @ 144 g a.i./ha	95	94	34	33	99.6	99.7	1129	1149	125	133	13.1	13.3	43.2	43.9	5131	5249	6933	7045
Propaquizafop 10% EC @ 75 g a.i./ha	93	93	33	33	99.7	101.6	1111	1148	120	125	13.0	13.0	42.6	43.6	5004	5113	6778	6883
Quizalofop-ethyl 5% EC @ 50 g a.i./ha	93	93	33	33	100.3	96.6	1118	1138	121	125	12.9	13.1	42.7	42.6	5073	5189	6868	6982
Hand weeding at 20 and 40 DAS	92	92	33	33	95.6	97.6	1136	1157	128	132	13.2	13.6	43.4	43.1	5153	5229	6940	6995
Untreated control	93	93	32	33	96.3	98.3	1105	1125	123	122	13.1	12.9	42.3	42.0	4901	5057	6669	6807
S.Em. ±	3.0	3.3	1.2	1.3	3.8	4.1	38.6	44.3	4.9	4.6	0.6	0.5	0.48	0.72	240	295	369	378
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

the soybean crop. Application of Clethodim 12% (w/v) EC at 120 g *a.i.*/ha and 144 g *a.i.*/ha resulted higher soybean yield being at par with each other but were significantly superior to other treatments and weedy check. The residual effect of the test herbicides (96 to 240 g *a.i.*/ha) applied in soybean was not observed on the succeeding wheat crop.

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