Investigation on the carry-over effects of various pre- and post-emergence herbicides applied alone and in combination to cotton on succeeding chickpea crop

ABSTRACT

The carry-over effect of various pre- and post-emergence herbicide treatments used alone or in combination for weed control to cotton on the subsequent chickpea (*Cicer arietinum* L.) crop between 2018-19 and 2019-20 was the subject to a field experiment. Without using any weed control techniques, chickpea was grown on the same field after the cotton crop had been harvested. Three replications of the randomized block design were used to evaluate seven different treatments. The crop was significantly affected by all herbicide applications, with the exception of hand weeding at 30, 60, and 90 DAS. In particular, the application of pyrithiobac sodium 62.5 g/ha as pre-emergence (PE) + quizalopfop ethyl 50 g/ha at 60 DAS yielded de-identified data for all the parameters under study. From the current study, it can be concluded that crops like chickpeas cannot be grown in a safe order after cotton because using pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/ha at 60 DAS as the weed management practice in cotton had a significant impact on growth, yield, and economics.

Keywords: Carry-over effect, Chickpea, Pre- and post-emergence herbicides, Pyrithiobac sodium, Quizalopfop ethyl, Pendimethalin, Paraquat dichloride

INTRODUCTION

Through increasing productivity and the Green Revolution, notably in cereal crops, India has attained self-sufficiency in the production of food grains. India is the world's top producer and consumer of pulses, yet production isn't keeping up with demand. Pulses are the second most significant food group in the diet of developing nations, notably India, where the majority of the population is vegetarian. Because they may easily fit into crop rotations, pulses play a vital part in diversifying the traditional cropping systems.

They can effectively make protein because they can fix atmospheric nitrogen (Havlin et al 2014). The chickpea (*Cicer arietinum* L.), a valuable crop among pulses, offers wholesome food for a growing global population and will be more crucial as a result of climate change (Muehlbauer and Sarker 2017). It is one of the most significant *Rabi* pulse crops in India can come under irrigated and conserved soil moistureconditions (Pandit et al 2017), produced over an area of 9.93 million hectares per year, with a productivity of 960 kg ha^{-1} on average (Anonymous 2012). Additionally, it is gluten-free, low glycaemic, and serves as a functional meal (Rao 2002). Despite high yielding cultivars and modern agronomic techniques, chickpea production remains poor. Weed invasion in chickpea fields is one of the reasons for low production. Due to its modest growth rate and small leaf area at early-stage development, it is a weak weed competitor. Weed-related crop output losses have been estimated to be 54.7% (Poonia and Pithia 2013). One among many crops cultivated in India as a follow-on crop to cotton is chickpea. Following cotton harvest, the chickpea is cultivated in succession depending on the availability of one or two irrigations. However, it is crucial to research, the residual effects of herbicides on subsequent crops in the cycle in order to provide any reasonable and practical herbicidal recommendations for effective weed management in a crop. As the research regarding the carry-over effect of various pre- and post-emergence herbicides on the succeeding crops is limited, the present work was carried out with the objective to assess the residual effect of various pre- and post-emergence herbicides applied alone and in combination to cotton for effective control of mixed weed flora on succeeding chickpea growth, yield, weed metrics and economical parameters. Suitable weed control method or herbicide used in cotton for effective control of mixed weed flora also take care of controlling weed infestation in succeeding chickpea.

MATERIALS AND METHODS

To investigate the residual impact of various pre- and post-emergence herbicides applied alone and in combination to cotton on succeeding chickpea, a field experiment was conducted during the *Kharif* and *Rabi* seasons of 2018-19 and 2019-20 on cotton-chickpea cropping sequence on the fixed plots at the experimental farm of Cotton Research Scheme, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.). It is geographically situated at 19.27^0 North Latitude and 76.78^0 East Longitude and at an altitude of 347 m from sea level. It has a semi-arid and tropical type of climate and comes under assured rainfall zone. The average precipitation of last 30 years (1975-2005) is approximate to 963.1 mm distributed in 47.8 rainy days and mean minimum temperature varies from 11.9^0C to 24.9^0C during winter and summer, respectively. The experimental region owes abundant fertile soil for having being situated in Godavari valley and bedded in horizontally laid deccan lava sheets. The soil of experimental field was clayey in texture and was slightly alkaline in nature, low in organic carbon and medium in available nitrogen, phosphorus and potash. A set of seven treatments comprising application of pendimethalin 0.75 kg/ha as pre emergence (PE) followed by one hand weeding at 60 days after sowing (DAS), pyrithiobac sodium 62.5 g/ha as PE followed by one hand weeding at 60 DAS, pyrithiobac sodium 62.5 g/ha as PE followed by quizalopfop ethyl 50 g/haat 60 DAS, pyrithiobac sodium 62.5 g/ha as Post-emergence (POE) + quizalopfop ethyl 50 g/haat 30 DAS followed by one hand weeding at 60 DAS, paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS followed by one hand weeding at 60 DAS, hand weeding at 30,60 and 90 DAS along with weedy check were laid out in completely randomized block design with three replications. The seeds of Bt-cotton variety Superb (Bayer crop science limited) were dibbled manually at the rate of 2 seeds per hill in second week of June during both the years of experimentation (2018 and 2019), respectively and fertilized with 150, 75 and 75 (N, P_2O_5 and K_2O) kg/ha. Both P and K and 1/2 dose of nitrogen were applied at the time of sowing as basal application, whereas the remaining quantity of N was applied as top- dressing at 30 days after emergence. All the herbicides were applied with the help of knapsack sprayer fitted with flat fan nozzle. The succeeding chickpea crop variety Akash was sown on 29 and 30 November and harvested on 27 and 28 March during both the years of study (2018 and 2019), respectively. As the chickpea crop was leguminous full dose of fertilizers 25 kg N, 50 kg P2O5/ha at were applied as basal dose. All other practices were followed as per recommendations for both cotton and chickpea crops. The unweeded control (weedy check) was kept undisturbed for the entire cropping period of the kharif cotton crop. To see the residual effects of the treatment applied in cotton, the chickpea crop was raised with recommended weed management practices. To investigate the residual effect of various pre- and post-emergence herbicides applied in cotton on chickpea crop, data on various growth, yield, weed parameters were recorded on five plants selected from each net plot randomly using Tippet's random table. Weed control efficiency and weed index among weed parameters were calculated by the formula given by Gautam et al (1975) and Gill and Vijay Kumar (1969) respectively, which was given below:

$$\text{Weed Control Efficiency (\%)} = \frac{\text{Dry weight of weeds in weedy check} - \text{Dry weight of weeds in treated plots}}{\text{Dry weight of weeds in weedy check}} \times 100$$

$$\text{Weed Index (\%)} = \frac{\text{Yield from weed free plot} - \text{Yield from treated plots}}{\text{Yield from weed free plot}} \times 100$$

Economic parameters viz., cost of cultivation under various treatments was estimated on the basis of prevailing rates for inputs in Maharashtra. The input costs included costs of seed, herbicide treatment application, chemical fertilizers, and the hiring charges of human labour and machines for land preparation, irrigation, fertilization, harvesting, and threshing. Gross returns were calculated by multiplying chickpea equivalent yield of the system with Minimum Support Price (MSP) of chickpea in both the years. The net returns were calculated with respect to each treatment by subtracting the total cost of cultivation from gross returns. The benefit: cost ratios were calculated for each treatment applied in the system as the ratios of net returns to cost of cultivation. The data recorded were subjected to analysis of variance (ANOVA) and significant differences among treatments were tested by calculating CD at 5% level of significance by using one-way ANOVA as given by Panse and Sukhatme (1967). Whenever differences were significant, C.D. values were indicated for comparison otherwise only the values of S.E$\pm$ were indicated.

RESULTS AND DISCUSSIONS

Effect on growth parameters: At harvest, the plant height of chickpea was significantly influenced by the residual effects of weed management practices in cotton (Table 1). The treatment of pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/ha at 60 DAS is significantly more effective, followed by the treatment of paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS. Highest plant height at harvest was recorded in the treatment hand weeding at 30,60 and 90 DAS during both the years of study which might be as a result of weeds being manually removed from cotton so that no lasting residual effect is observed. Chickpea leaf area per plant data at harvest (Table 1) showed that residual weed control strategies had a substantial impact on the metric. The treatment of paraquat dichloride (directed spray) 24 % SL 50 g/ha as POE at 30 DAS + hand weeding at 60 DAS during 2018-19 and 2019-20 attained the minimum leaf area per plant (dm^2). This was followed by the treatment of pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/ha at 60 DAS. In contrast, it is discovered that all weed control methods used on cotton were efficient in affecting the dry weight per plant of the chickpea relative to the treatment hand weeding at 30, 60, and 90 DAS at all dates of observation. During 2018–19, the treatment of paraquat dichloride (directed spray) 24 percent SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS recorded the minimum dry weight per plant (g), whereas it was on par with all treatments except hand weeding at 30, 60, and 90 DAS during 2019–20, which recorded the maximum dry weight per plant (19.2 and 18.7) during 2018–19 and 2019-20 respectively. (Table 1). The results of the current experiment are comparable to those of Poonia and Pithia(2013), Kaushik et al (2014), and Singh and Jain (2017) with regard to the carryover impact of the herbicidal weed control practices of cotton on chickpea growth metrics.

Effect on yield parameters:As shown in (Table 2), the leftover effects of cotton's weed control tactics had a considerable impact on the number of pods per plant in chickpea at harvest. In 2018-19 and 2019-20, the treatment of pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 30 DAS + hand weeding at 60 DAS resulted in the highest number of pods per plant ever recorded. At harvest in both research years, the number of seeds per pod (Table 2) was not significant. While it was shown that the lingering effects of weed control techniques had a considerable impact on seed weight per plant at harvest, as described in (Table 2). The treatment hand weeding at 30, 60 and 90 DAS recorded the maximum seed weight per plant in 2018-19, while the treatment pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 30 DAS + hand weeding at 60 DAS recorded the maximum seed weight per plant which was followed by the treatment hand weeding at 30, 60 and 90 DAS which may be attributable to minimal weed competition (low weed density), which increased nutrient uptake from the soil and positively impacted the yield characteristics. These findings are consistent with Singh and Jain (2017), Kaushik et al (2014), Singh et al (2008) and Dubey et al (2018). The residual effects of cotton's weed control strategies seemed to have a substantial impact on the grain yield (kg/ha) of chickpea (Table 2). Hand weeding at 30, 60, and 90 DAS produced the highest grain yield in 2018–19 and 2019–20, closely followed by the treatment pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 30 DAS + hand weeding at 60 DAS. The weedy check had the lowest grain output throughout the course of the two research years. The biological yield of chickpea (kg/ha) and harvest index (%) were significant throughout the course of the two research years. The treatment of pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 30 DAS + hand weeding at 60 DAS in both years produced the highest levels of biological yield, while hand weeding at 30, 60, and 90 DAS in both years produced the highest levels of harvest index. Weed check, however, produced the lowest levels of biological yield and harvest index over the course of the two study years. These findings were supported by similar ones published by Singh and Jain (2017), Chaudhary et al (2005), Kaushik et al (2014), Singh et al (2008), Poonia and Pithia (2013) and Dubey et al (2018).

Effect on weed parameters: Weed control techniques had a considerable impact on the monocot and dicot weed density per sq.m. during harvest, as shown in (Table 3). The treatment hand weeding at 30, 60, and 90 DAS, outperformed the other treatments by recording the lowest monocot and dicot weed density per square metre during both the study years. In contrast, the highest monocot and dicot weed density per square metre was seen using weedy check between 2018-19 and 2019-20. Hand weeding at 30, 60, and 90 DAS was followed by the treatment, pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 30 DAS + hand weeding at 60 DAS resulted in the lowest dry weight of weeds (g) at harvest for both monocot and dicot species. The successful weed control in the early stages by manual weeding and the later stages by the application of herbicides might be the contributing factor for the lower weed population seen under this treatment. Different weed management techniques have a notable impact on the weed index and weed control efficiency (Table 3). When weeds were controlled by hand weeding at 30, 60, and 90 DAS, it was found that this method had the lowest weed index (0 percent in both 2018-19 and 2019-20) and the maximum weed control efficiency (80.02 percent and 78.85 percent, respectively in 2018-19 and 2019-20). This may be the result of manual weeding, which reduced weed population and dry matter generation during the early stages, and the post-emergence application of pyrithiobac sodium + quizalopfop ethyl, which produced a weed-free and hospitable environment for the cotton.

Effect on economic parameters: Any modification to the conventional system of crop-raising procedures is ultimately intended to provide economic gain. To determine the economic feasibility of various weed management measures implemented, gross returns, net returns, and B:C ratios were determined. The findings in (Table 4) demonstrated that the direct and indirect effects of various weed control treatments in cotton on chickpea resulted in significant variation in the net returns and B:C ratio attained in cotton-chickpea cropping systems.The treatment of hand weeding at 30, 60, and 90 DAS generated the highest net returns of Rs. 41760 and Rs. 48190 with B:C ratios of 2.70 and 2.93 in 2018-19 and 2019-20, respectively, and was found to be superior to the other treatments. In contrast, the treatment of weed check generated the lowest returns of Rs. 16980 and Rs. 20107 with B:C ratios of 1.69 and 1.81 in 2018-19 and 2019-20, respectively. Singh et al. (2008), Buttar et al. (2008), Chaudhary et al. (2007), and Dubey et al. (2008) all reported results of a similar kind.

CONCLUSION

Chemical weed management is the finest addition to traditional techniques and is essential to the development of today's crops. The majority of herbicides on the market only offer a limited range of weed control. Additionally, the total active component in herbicide mixes allows for a wider range of weed control. It is advised to use a combination of herbicides on each crop, and in the cropping system, applying herbicides to each crop in turn causes residue to build up in the soil and crop, which has a negative impact on subsequent crops. Depending on the chemical and dosage employed, the majority of herbicides are selective, unique to the crop, and remain in the soil for a few months to a few years. To use herbicides safely and efficiently, one must be aware of their persistence and lasting effects on the soil. In light of the considerable impact on growth, yield, and economics seen while using pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/ha at 60 DAS as the weed control strategy in cotton, it has been determined that crop like chickpea cannot be safely planted in sequence following cotton.

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Table 1: Carry-over effect of various pre- and post-emergence herbicides applied alone and in combination in cotton on succeeding chickpea crop growth parameters

Treatments	Plant height (cm) (At Harvest)		Leaf area per plant (dm^2) (At Harvest)		Dry weight per plant (g) (At Harvest)	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Pendimethalin 0.75 kg/ha PE + hand weeding at 60 DAS	37.3	42.0	9.1	10.3	17.8	18.5
Pyrithiobac sodium 62.5 g/ha PE + hand weeding at 60 DAS	36.3	41.5	8.3	9.5	16.8	18.2
Pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/haat 60 DAS	33.4	39.5	7.2	9.1	16.3	17.7
Pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/haat 30 DAS + hand weeding at 60 DAS	38.6	42.4	9.7	10.9	18.4	18.5
Paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS	34.4	40.2	8.1	9.1	16.6	17.9
Hand weeding at 30,60 and 90 DAS	39.4	43.0	9.2	10.4	19.2	18.7
Weedy check	32.4	39.2	8.9	9.4	16.1	17.4
S.E.(m)+	1.13	0.65	0.32	0.39	0.63	0.57
C.D at 5%	**S**	**S**	**S**	**S**	**S**	**S**

DAS: Days after sowing, PE: Pre emergence, POE: Post emergence, SE: Standard error, CD: Critical difference

Table 2: Carry-over effect of various pre- and post-emergence herbicides applied alone and in combination in cotton on succeeding chickpea crop yield parameters

Treatments	Pods per plant		Seeds per pod		Seed weight per plant		Grain yield (kg/ha)		Biological yield (kg/ha)		Harvest Index (%)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Pendimethalin 0.75 kg/ha PE + hand weeding at 60 DAS	41.6	44.1	1.57	1.66	10.0	10.30	1735	1782	4239	4326	40.92	41.22
Pyrithiobac sodium 62.5 g/ha PE + hand weeding at 60 DAS	41.0	43.9	1.59	1.61	9.60	9.90	1679	1739	4168	4231	40.29	41.11
Pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/haat 60 DAS	38.6	40.1	1.58	1.43	9.10	9.40	1566	1598	4029	3955	38.83	40.32
Pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/haat 30 DAS + hand weeding at 60 DAS	45.6	48.1	1.60	1.83	10.80	12.10	1843	1976	4493	4625	41.02	42.70
Paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS	39.7	41.6	1.43	1.54	9.20	9.60	1603	1636	4070	4007	39.32	40.76
Hand weeding at 30,60 and 90 DAS	46.3	47.9	1.63	1.73	11.90	11.40	18 96	1927	4442	4517	42.72	42.64
Weedy check	38.1	39.5	1.17	1.37	8.90	9.1	1188	1217	3591	3668	33.07	33.10
S.E.(m)+	1.38	0.86	0.04	0.06	0.40	0.24	76.19	97.10	87.55	130.55	1.50	1.68
C.D at 5%	**S**	**S**	**NS**	**NS**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**

DAS: Days after sowing, PE: Pre emergence, POE: Post emergence, SE: Standard error, CD: Critical difference

Table 3: Carry-over effect of various pre- and post-emergence herbicides applied alone and in combination in cotton on succeeding chickpea crop weed parameters

Treatments	Weed density per sq.m				Dry weight of weeds (g)				Weed control efficiency (%)		Weed index (%)	
	Monocot		Dicot		Monocot		Dicot					
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Pendimethalin 0.75 kg/ha PE + hand weeding at 60 DAS	36.7	35.8	28.4	26.8	19.29	18.92	27.54	25.29	74.64	73.88	5.9	9.8
Pyrithiobac sodium 62.5 g/ha PE + hand weeding at 60 DAS	38.3	37.4	31.7	29.8	22.65	23.63	40.81	38.55	65.63	63.27	8.9	11.9
Pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/haat 60 DAS	40.1	38.5	36.1	34.1	25.30	26.88	48.56	47.36	60.00	56.14	15.0	19.0
Pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/haat 30 DAS + hand weeding at 60 DAS	31.5	29.2	25.1	24.7	16.31	17.81	25.21	23.02	77.51	75.88	2.8	2.4
Paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS	39.6	38.1	33.6	32.7	35.35	37.53	43.36	40.25	57.37	54.05	13.0	17.2
Hand weeding at 30,60 and 90 DAS	27.4	25.4	24.2	23.8	15.32	15.58	21.57	20.22	80.02	78.85	0	0
Weedy check	53.3	51.1	42.4	40.5	80.77	74.06	103.88	95.22	0	0	35.5	38.4
S.E.(m)+	1.11	1.01	0.92	1.14	2.58	2.38	2.22	2.05	-	-	-	-
C.D at 5%	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**

DAS: Days after sowing, PE: Pre emergence, POE: Post emergence, SE: Standard error, CD: Critical difference

Table 4: Carry-over effect of various pre- and post-emergence herbicides applied alone and in combination in cotton on succeeding chickpea crop economic parameters

Treatments	Gross monetary returns (Rs./ha)		Net monetary returns (Rs./ha)		B:C Ratio	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Pendimethalin 0.75 kg/ha PE + hand weeding at 60 DAS	60713	65946	36113	41036	2.47	2.65
Pyrithiobac sodium 62.5 g/ha PE + hand weeding at 60 DAS	58765	64343	34165	39433	2.39	2.58
Pyrithiobac sodium 62.5 g/ha as PE + quizalopfop ethyl 50 g/haat 60 DAS	54810	59126	30210	34216	2.23	2.37
Pyrithiobac sodium 62.5 g/ha as POE + quizalopfop ethyl 50 g/haat 30 DAS + hand weeding at 60 DAS	64517	71299	39917	46389	2.62	2.86
Paraquat dichloride (directed spray) 24 % SL 0.5 kg/ha as POE at 30 DAS + hand weeding at 60 DAS	56105	60520	31505	35610	2.28	2.43
Hand weeding at 30,60 and 90 DAS	66360	73100	41760	48190	2.70	2.93
Weedy check	41580	45017	16980	20107	1.69	1.81
S.E.(m)+	2666	3592	2666	3592	-	-
C.D at 5%	**S**	**S**	**S**	**S**	**S**	**S**

DAS: Days after sowing, PE: Pre emergence, POE: Post emergence, SE: Standard error, CD: Critical difference