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Effect of different weed control methods on productivity of Bt cotton (*Gossypium hirsutum* L.) - chickpea (*Cicer arietinum* L.) cropping sequence

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Abstract
A field experiment was conducted during 2018–19 and 2019–20 at Parbhani, Maharashtra to evaluate the efficacy of different weed control methods in a Bt cotton–chickpea cropping sequence. Seven weed management treatments were assessed, including pre-emergence, post-emergence herbicides, hand weeding, and a weed-free control. Results revealed that the weed-free treatment and post-emergence application of pyrithiobac sodium + quizalofop-ethyl followed by hand weeding achieved the highest weed control efficiency, seed cotton yield, gross and net monetary returns, and B:C ratio. The weedy check consistently resulted in the lowest values for all economic and agronomic parameters. The study concludes that integrated weed management using herbicides with hand weeding is a viable approach to maximize productivity and profitability in Bt cotton–chickpea systems.

Keywords: Bt cotton, chickpea, weed control, herbicides

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the chief fibre crop and plays a crucial role in agriculture, industrial development, employment generation and economic development of India. Cotton, widely known as “King of fibre” and “White gold” is the most important fibre and commercial crop of India.

India ranks first in global scenario occupying about 33% of the world cotton area but with regard to production it ranks second, next to China. It plays important role in the Indian economy involving about 60 million people in cotton cultivation, fabric industries and trade.

Yield in cotton depends on the climatic conditions, rainfall pattern, weed competition and incidence of pests and diseases. Weeds consume 5 to 6 times of Nitrogen, 5 to 12 times of Phosphorous and 2 to 5 times of Potassium more than cotton crop and thus reduces the cotton yield from 54 to 85%. Initial slow growth, wide row spacing, high dose of chemical fertilizers combined with prostate nature of its growth permit early and severe crop-weed competition resulting in loss of yield to the tune of 45 to 85%. At present, manual weeding has become costly due to insufficiency of labourers and hence, it become enormously difficult to keep the crop weed free. Effective and economical weed control in irrigated cotton is possible through integrating pre- and post-emergence herbicides along with hand weeding and inter-culturing.

After harvesting cotton, on availability of one or two irrigations the chickpea is grown in sequence. Chickpea is the integral part of the cropping system because this crop fit well in the crop sequence and is most suited diversifying crops in cropping systems.

Chickpea (*Cicer arietinum* L.) is important pulse crop occupying third place among pulses. It is a rich source of protein (18-22 per cent), carbohydrate (62 per cent), B-group vitamins and certain minerals *viz*., Ca, Fe etc. and vitamin C in green stage. The productivity of chickpea is low in spite of high yielding varieties and new agronomic practices. One of the causes of poor productivity is infestation of weeds in the field of chickpea. It is a poor competitor of weeds because of slow growth rate and limited leaf area development at early stages. Crop yield losses due to weeds have been estimated to range from 54.7 per cent.

Materials and Methods

A field experiment entitled "Effect of weed control methods on productivity of Bt cotton (*Gossypium hirsutum* L.) – chickpea (*Cicer arietinum* L.) cropping sequence" was conducted during 2018-19 and 2019-20 at experimental farm of Cotton Research Scheme, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.).

Weed control Treatments for Bt cotton

T1	PE pendimethalin @ 0.75 kg ai/ha followed by one hand weeding at 60 DAS
T2	PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS
T3	PE pyrithiobac sodium @ 62.5 g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS
T4	POE pyrithiobac sodium @ 62.5 g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS
T5	POE paraquat dichloride (directed spray) 24% SL @ 0.5 kg ai/ha at 30 DAS followed by one hand weeding at 60 DAS
T6	Weed free (hand weeding at 30,60 and 90 DAS)
T7	Weedy check

Crop	Cotton	Chickpea
Variety	Superb	Akash
Spacing	150 cm x 30 cm	45 cm x 15 cm
Plot size		
Gross	7.5 m x 6.0 m	7.5 m x 6.0 m
Net	6.0 m x 5.1 m	6.0 m x 5.1 m
Design	Randomized Block Design	
Replications	3	

Weed control efficiency (%)

The data pertaining to weed control efficiency is depicted in Table 1.

At 30 DAS, weed free treatment (T6) recorded highest weed control efficiency (66% and 65%) followed by (T3) PE Pyrithiobac sodium @ 62.5g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS, (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and(T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS during 2018-19 and 2019-20 respectively.

At 60 DAS, weed free treatment (T6) recorded maximum weed control efficiency of (90.6% and 90.2%) in 2018-19 and 2019-20 respectively followed by (T5) POE paraquat dichloride (directed spray) 24% SL @ 0.5 Kg ai/ha at 30 DAS followed by one hand weeding at 60 DAS in 2018-19 and (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS in 2019-20 followed by (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and (T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS during 2018-19 and 2019-20.

At harvest, weed free treatment (T6) recorded maximum weed control efficiency of (83.4%) followed by(T4) POE pyrithiobac sodium@ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one Hand weeding at 60 DAS, (T3) PE pyrithiobac sodium @ 62.5g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS, (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and (T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS in 2018-19 where in 2019-20 (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS recorded the maximum weed control efficiency (82.6%) followed by (T6) weed free treatment,(T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS and (T3) PE pyrithiobac sodium @ 62.5g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS and (T5) POE paraquat dichloride (directed spray) 24% SL @ 0.5 Kg ai/ha at 30 DAS followed by one hand weeding at 60 DAS.

Weed index (%)

The data regarding weed index is portrayed in Table 4.12. Weed index was less in 2019-20 as compared to 2018-19.

Lowest weed index was recorded with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS (3.92% and 1.96%) followed by (T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS, (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS, (T5) POE paraquat dichloride (directed spray) 24% SL @ 0.5 Kg ai/ha at 30 DAS followed by one hand weeding at 60 DAS and (T3) PE pyrithiobac sodium @ 62.5 g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS during 2018-19 and 2019-20 respectively.

Table 1: Effect of weed management practices on weed control efficiency (%) & weed index (%) at various growth stages of Bt- cotton during 2018-19 and 2019-20.

Treatment	Weed control efficiency (%)						Weed Index (%)	
	2018-19			2019-20			2018-19	2019-20
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest	At Harvest	
T_1	35.0	66.4	67.2	33.6	64.2	75.7	12.99	10.20
T_2	39.2	72.8	70.8	36.4	71.8	69.3	16.95	12.61
T_3	39.4	60.9	71.9	34.2	59.4	71.1	29.94	27.18
T_4	-	84.5	83.3	-	85.6	82.6	3.92	1.96
T_5	-	85.8	63.0	-	84.2	72.8	22.83	22.33
T_6	66.6	90.6	83.4	65.0	90.2%	82.5	-	-
T_7	-	-	-	-	-	-	42.89	45.05

Treatment (T7) weedy check recorded highest weed index of 42.89 and 45.05% during 2018-19 and 2019-20 respectively.

Seed cotton yield (kg ha^{-1})

The data pertaining to seed cotton yield (kg ha^{-1}) depicted in Table 4.13. Highest seed cotton yield (kg ha^{-1}) of 2348 and 2244 was attained with weed free treatment (T6) which was at par with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS during 2018-19 and 2019-20. (T1) PE pendimethalin @ 0.75 Kg ai/ha followed by one hand weeding at 60 DAS was on par during 2019-20 and significantly higher as compared to all other weed control treatments.

The lowest seed cotton yield (1341 and 1233 kg ha^{-1}) was

obtained with weedy check (T7) during 2018-19 and 2019-20 correspondingly.
In pooled analysis, highest seed cotton yield (kg ha^{-1}) was attained with weed free treatment (T6) which was at par with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS and significantly higher as compared to all other weed control treatments.
Lowest seed cotton yield (1287 kg ha^{-1}) was obtained with (T7) weedy check.

Effect of weed management practices on economics of Bt cotton

Gross monetary returns (Rs. ha^{-1})

The gross monetary returns (Rs. ha^{-1}) significantly influenced by weed management practices and depicted in Table 2. Maximum gross monetary returns (Rs. ha^{-1}) of Rs. 129122 and Rs. 114444 was attained with weed free treatment (T6) which was at par with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS (Rs.124080 and 112200) in 2018-19 and on par with (T1) PE pendimethalin @ 0.75 kg ai/ha followed by one hand weeding at 60 DAS and (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS in 2019-20 and significantly higher as compared to all other weed management practices during 2018-19 and 2019-20 respectively.

Table 2: Effect of weed management practices on seed cotton yield (kg ha^{-1}) at various growth stages of Bt- cotton during 2018-19 & 2019-20 and pooled.

Treatment	Seed cotton yield (kg ha^{-1})		
	2018-19	2019-20	Pooled Mean
T_1	2043	2015	2029
T_2	1950	1961	1956
T_3	1645	1634	1640
T_4	2256	2200	2228
T_5	1812	1743	1778
T_6	2348	2244	2296
T_7	1341	1233	1287
S.E.(m)+	81	110	64
C.D. at 5%	250	341	200
General Mean	1914	1861	1887

In pooled analysis, weed free treatment (T6) recorded the maximum gross monetary returns (Rs. 121783) which was at par with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS (118140), (T1) PE pendimethalin @ 0.75 kg ai/ha followed by one hand weeding at 60 DAS and (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and significantly higher as compare to all other weed management practices.
Weedy check (T7) recorded the lowest gross monetary return (Rs. 68327).

Net monetary returns (Rs. ha^{-1})

The net monetary returns (Rs. ha^{-1}) significantly influenced by weed management practices and depicted in Table 4.14. Maximum net monetary returns (Rs. ha^{-1}) of 77182 and 64250 was attained with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS which was at par with (T6) Weed free treatment, (T1) PE pendimethalin @ 0.75 kg ai/ha followed by one hand weeding at 60 DAS and (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and significantly higher as compare to all other weed management practices during 2018-19 and 2019-20 respectively.
In pooled analysis, (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS recorded the highest net monetary return (Rs. ha^{-1} 71216) which was at par with (T6) weed free treatment, (T1) PE pendimethalin @ 0.75 kg ai/ha followed by one Hand weeding at 60 DAS and (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS and significantly higher as compare to all other weed management practices.
Weedy check (T7) recorded the lowest net monetary returns of Rs. 36944.

B:C

The B:C ratio as influenced by weed management practices is depicted in Table 4.15. Maximum benefit cost ratio of (2.69, 2.34 and 2.53) was attained with (T4) POE pyrithiobac sodium @ 62.5g ai/ha + quizalofopethyl @ 50 g ai/ha at 30 DAS followed by one hand weeding at 60 DAS followed by (T1) PE pendimethalin @ 0.75 kg ai/ha followed by one hand weeding at 60 DAS, (T2) PE pyrithiobac sodium @ 62.5 g ai/ha followed by one hand weeding at 60 DAS, (T3) PE pyrithiobac sodium @ 62.5g ai/ha followed by quizalofopethyl @ 50 g ai/ha at 60 DAS during 2018-19, 2019-20 and pooled respectively.
Weedy check (T7) recorded the lowest B:C ratio during 2018-19, 2019-20 and in pooled correspondingly.

Table 3: Effect of weed management practices on gross monetary returns (Rs. ha^{-1}) and net monetary returns (Rs. ha^{-1}) of Bt- cotton during 2018-19, 2019-20 and pooled

Treatment	Gross monetary returns (Rs. ha^{-1})			Net monetary returns (Rs. ha^{-1})		
	2018-19	2019-20	Pooled Mean	2018-19	2019-20	Pooled Mean
T_1	112347	102772	107560	69655	58286	63971
T_2	107268	100000	103634	65066	55753	60410
T_3	90475	83333	86904	54165	45477	49821
T_4	124080	112200	118140	78182	64250	71216
T_5	99678	88889	94284	58630	46653	52642
T_6	129122	114444	121783	74790	58698	66744
T_7	73737	62900	68327	42461	31250	36856
S.E.(m)+	4465	5657	6301	4465	5657	6301
C.D. at 5%	13740	17407	19417	13740	17404	19417
General Mean	105240	94934	100090	63278	51481	57379

Table 4: Effect of weed management practices on B:C ratio of Bt-cotton during 2018-19 and 2019-20and pooled.

Treatment	B:C		
	2018-19	2019-20	Pooled Mean
T_1	2.63	2.31	2.47
T_2	2.54	2.26	2.40
T_3	2.49	2.18	2.34
T_4	2.69	2.34	2.52
T_5	2.43	2.10	2.27
T_6	2.38	2.05	2.22
T_7	2.36	1.9	2.13
S.E.(m)+	-	-	-
C.D. at 5%	-	-	-
General Mean	2.50	2.16	2.33

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