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Effect of weedicides on weeds and yield of Bt cotton (*Gossypium hirsutum* L.)

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Abstract
A field trial was conducted at Cotton Research Station, Nanded (M.S., India) to evaluate effect of pre and post emergence weedicides in Bt cotton during 2012-13 to 2014-15 under rainfed condition for three years in *kharif* season. The experiment was conducted with eight treatments laid out randomized block design in three replications. Weedicides *viz.,* PE (Pendimethalin), PoE (Quizalofop ethyl, Pyrithiobac sodium and Glyphosate) were evaluated alone or in combination along with weed free check and un weeded control. The research results revealed that the seed cotton yield was reduced by 60.07 per cent due to weeds when were not controlled. The non-selective weedicide Glyphosate 41 SL @ 1.0 kg *a.i.* ha^{-1} as directed spray at 45 DAS recorded lowest weed density and weed dry weight at 9 WAS and at harvest. Among the selective weedicides, tank mix application of Pyrithiobac sodium 10 EC @ 62.5 g *a.i.* ha^{-1} + Quizalofop ethyl 5 EC @ 50 g *a.i.* ha^{-1} fb one hoeing at 45 DAS treatment was found to lower weed density and dry weight of grassy as well as broadleaf weeds. The seed cotton yield from treatments Glyphosate (1572 Kg ha^{-1}) and tank mix Pyrithiobac sodium + Quizalofop ethyl fb one hoeing (1570 Kg ha^{-1}) were on par with weed free check (1698 Kg ha^{-1}).

Keywords: Effect**,** weedicides, weeds and yield, Bt cotton (*Gossypium hirsutum* L.)

Introduction
Cotton (*Gossypium hirsutum* L.) exercises profound influence on economics and social affairs of dryland farmers in India. It is cultivated on 122lakh ha area with productivity of 523kg lint ha^{-1}. Although area in India is around 36 per cent of world area, the Indian productivity is low as compared to that of world. Major reasons for low yields in crops are infestation of weeds, pest, diseases and abiotic stresses. Weeds had highest loss potential (32%) with animal pests and pathogens being less important (18% and 15%, respectively) over the globe (Oerke and Dehne, 2004) [6]. Cotton is long durational and wide spaced crop andhavingslower growth during early stage of crop, it suffers heavy weed infestation. Weeds consume 5 to 6 times of N, 5 to 12 times of P and 2 to 5 times of K more than cotton crop (Jain *et al*., 1981) [2]. Weed infestation in cotton is a major biotic constraint which reduce cotton yield by 40 to 85% (Nalayini and Kandasamy, 2013) [4].
The critical period of crop weed competition is 15 to 60 days in cotton (Sharma, 2008) [8]. Two hand weeding and intercultural operations followed by farmers are found to difficult due to unremitting rains in *kharif* season. Cotton is labour intensive crop especially for picking, weed management and plant protection. Due to increasing problem of labour availability and costly wages, cotton growers are attracted towards use of weedicides for weed management. Farmers need pre or post emergence weedicides in single application or in combination for long term weed management considering longer duration of the crop. Many pre-emergence weedicides are available for the crop which cover good weed control for initial period but it is necessary to do hand weeding and interculture in later stages. Post emergence weedicides has greater potential for effective weed management under this situation. Therefore, farmers need selective post emergence weedicides alone or in mixture which can cover broad spectrum of weeds. Considering above factors, the present study was conducted with weedicides alone or in sequence or in combination for effective and timely weed control.

Materials and methods
A field experiment was conducted at Cotton Research Station, Nanded (M.S., India) in year 2012-13 to 2014-15 for three years to evaluate effect of pre and post emergence weedicides in Bt cotton under rainfed condition. Bt Cotton hybrid was sown after receipt of monsoon in 25 MW, 29 MW and 25 MW during the period of experimentation, respectively. The first year had average, second was deficit and third year had surplus rains over average rainfall of the location. The experimental field was vertisol with low available N content (111.24 kg ha^{-1}),

medium (10.37 kg ha^{-1}) phosphorus and high (492 kg ha^{-1}) potassium content with pH value of 7.46.

Eight treatments were evaluated in randomized block design with three replications. Treatments consisted of Pre emergence (PE) Pendimethalin 30 EC @ 1.0 kg *a.i.* ha^{-1}followed by (fb) one hoeing at 45 DAS (T_1), Quizalofop ethyl 5 EC @ 50 g *a.i.*ha^{-1} as post emergence (PoE) fb one hoeing (T_2), Pendimethalin 30 EC @ 1.0 kg *a.i.* ha^{-1} followed by (fb) Quizalofop ethyl 5 EC @ 50 g *a.i.* ha^{-1}fb one hoeing (T_3), Pyrithiobac sodium 10 EC @ 62.5 g *a.i.* ha^{-1}as post emergence fb one hoeing at 45 DAS (T_4), Pyrithiobac sodium 10 EC @ 62.5 g *a.i.* ha^{-1} + Quizalofop ethyl 5 EC @ 50 g *a.i.* ha^{-1} fb one hoeing at 45 DAS (T_5), Glyphosate 41 SL @ 1.0 kg *a.i.* ha^{-1} as directed spray at 45 DAS (T_6), Weed free check (T_7) and Weedy control (T_8).

Pre-emergence application of weedicide was done 1 DAS whereas post emergence weedicides were sprayed at 2-4 weed leaf stage which was coincided around 18-21 DAS. Observations on weed density and dry weight of monocot and dicot weeds were recorded separately from 1 m^2quadrat of each treated plot at 3 weeks after sowing (WAS), 9 WAS and at harvest. This data was subjected to square root transformation of $\sqrt{x+0.5}$ prior to analysis. As the trend of results with regard to weed management was similar in all the three years, the pooled data of three years are presented and used for discussion.

Results and discussion

The dominant weed flora in the experimental plots were consisted *Cynadondactylon*, *Amischopoacelouscucculata*, *Cyperusrotundus*, *Digera arvensis*, *Phyllanthus niruri*, *Merremiaemerginata*, *Acalyphaindica*, *Abitulonindicum*, *Corchorus actangulus*, *Cassia tora* and *Xanthium strumarium.*

Weed density

The weed management treatments showed significant variations in the pooled mean weed density at various stages (Table 1). Weedy control recorded highest number of weeds and weed dry matter at 9 WAS and at harvest. Weed free check recorded lowest density of monocot and dicot weeds. This was followed by Glyphosate (T_6) directed spray effecting lower monocot and dicot weed density at 9 WAS as well as at harvest. However, Glyphosate is non-selective weedicide and can't be recommended for use in cotton crop.

At 3 WAS, weed density of monocot weeds was effectively reduced by PE Pendimethalin application (T_1 and T_3) as weed free check (T_7). The dicot as well as monocot weed density was significantly reduced at 3 WAS due to Pendimethalin over Weedy control (T_8).Nalini *et al* [5]. (2011) also reported lesser weed density and higher weed control efficiency confirming effectiveness of Pendimethalin in initial period.

Among selective weedicides, Pyrithiobac sodium PoE + Quizalofop ethyl PoE (T_5) fb one hoeing was the most effective treatment to lower mean monocot as well as dicot weed population at 9 WAS and at harvest. Weedy control was found to count significantly highest weed density at 9 WAS and at harvest during all the years and pooled mean. Among PoE weedicides, treatments receiving Quizalofop-ethyl PoE spray was found to lower monocot weed density. Similarly, Patil (2007) [7]. has also observed effective control of grassy weeds by application of Quizalofop-ethyl at 35 DAS.

Weed dry weight (g m^{-2})

The weed dry weight at various stages on pooled mean basis was significantly differed due to different weed management treatments (Table 2). Dicot weed dry weight at 3 WAS was comparably reduced as weed free check in Pendimethalin PE application treatments (T_1 and T_3). However, the pooled mean weed dry weight in Pendimethalin treatment was found to increased gradually over weed free check at 9 WAS and at harvest. This clears that PE Pendimethalin need effective supplementary weed management practice after 3 WAS. Madavi *et al.* (2017) also reported good weed control up to 30 DAS by application of Pendimethalin fb hand weeding. The Quizalofop ethyl PoE (T_3) has reduced monocot weed dry weight significantly over un weeded control. However, dicot weed dry weight was higher in this treatment. This shows that Quizalofop ethyl (PoE) was not effective against some of the dicot weeds. The weed control trend was about similar at harvest as it was recorded at 9 WAS. The weedicide Pyrithiobac sodium (PoE) alone (T_4) has reduced dicot weed dry weight significantly over PoE Quizalofop ethyl alone (T_2). Hargilas *et al.* (2015) also reported that Quizalofop ethyl weedicide is effective against monocot weeds and Pyrithiobac sodium against dicot weeds. However, independent use of PE or PoE weedicides alone was not sufficient to reduce weed density and dry weight as compared to its combined spray. The weedicide Glyphosate directed spray had controlled all types of weeds comparably with weed free check. However, as it is a non-selective systemic weedicide, it is needed to spray with great caution. Among selective weedicides, the combination of Pyrithioback sodium PoE + Quizalofop ethyl PoE (T_5) fb one hoeing was effective to record lowest weed dry weight of monocot as well as dicot weeds over weedy control. This combination of PoE weedicide (T_5) was significant to lower monocot dry weight over PE Pendimethalin, Quizalofop ethyl PoE and Pyrithiobac sodium PoE alone. Similarly Pyrithiobac sodium + Quizalofop ethyl PoE spray had reduced the dicot weed dry matter over PE Pendimethalin, Quizalofop ethyl PoE and Pendimethalin + Quizalofop ethyl. Significant reduction in weed dry weight in these treatments were might be due to reduced weed density resulting due to combination of two PoE weedicides effective against different groups of weeds. Madavi *et al.* (2017) also reported reduction in weed dry weight by sequential application of Pendimethalin fb PoE Pyrithiobac sodium + Quizalofop ethyl was might be due to better weed control by tank mix combination of these PoE weedicides. The grassy weedicide (Quizalofop ethyl) has controlled monocot weeds whereas broad leaf weedicide (Pyrithiobac sodium) has controlled flush of dicot weeds when sprayed at 18-21 DAS (2-4 weed leaf stage). Whereas the weeds those were germinated after a month were controlled by intercultural operation.

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

Different weed management treatments exhibited significant variation in yield on pooled mean basis (Table 2). Application of weedicides at different stages as sole or in combinations increased seed cotton yield over un weeded control. The weed free check was found to have highest values of seed cotton yield (1646 kg ha^{-1}) whereas weedy control was the lowest for seed cotton yield (678 kg Kg ha^{-1}). There was 60.07 per cent yield reduction due to non-adoption of weed management practices. Venugopalan *et al.* (2012) reported that cotton yield was directly related to increasing weed density and duration of weed interference. Pyrithoiobacsodium PoE + Quizalofop

ethyl PoE fb hoeing (T_5- 1570 kg ha^{-1}) and Glyphosate PoE directed spray (T_6-1572 kg ha^{-1}) were found on par with Weed free check (1698 kg ha^{-1}). As Glyphosate is non-selective and systemic weedicide, it can't be used safely by common farmer. Veeraputhiran and Srinivasan (2015) and Madavi *et al.* (2017) also reported higher yield among selective weedicides by combination of Pyrithoioback sodium and Quizalofop ethyl as PoE. This might be due to effective weed control, greater weed control efficiency and lower weed index.

Conclusion

Among the weedicide treatments, lowest weed density and dry weight at 9 WAS and at harvest was recorded in directed spray of Glyphosate @ 1.0 Kg *a.i.* ha^{-1} at 45 DAS. However, Glyphosate is non-selective and doesn't have label claim for cotton crop. Among selective weedicides, Pyrithiobac sodium 10 EC PoE@ 62.5 g *a.i.* ha^{-1} + Quizalofop ethyl 5 EC PoE @ 50 g *a.i.* ha^{-1}(tank mix) fb one hoeing at 45 DAS reduced number of weeds per unit area and weed dry weight of grassy as well as broadleaf weeds. The tank mix application of Pyrithiobac sodium + Quizalofop ethyl was on par seed cotton yield with weed free check.

Table 1: Pooled mean weed density (no. m^{-2}) as influenced by different weed control treatments

Treatments	Monocot weed count (m^{-2})			Dicot weed count (m^{-2})		
	3 WAS	9 WAS	At harvest	3 WAS	9 WAS	At harvest
T_1: Pendimethalin @ 1.0 kg *a.i.* PE fb one hoeing	12.72 (3.34)	13.11 (3.66)	13.39 (3.64)	10.39 (3.25)	14.50 (3.83)	11.83 (3.47)
T_2: Quizalofop ethyl @ 50 g *a.i.* PoE fb hoeing	31.61 (5.11)	20.11 (4.32)	13.61 (3.49)	34.78 (5.43)	40.89 (6.13)	29.17 (5.12)
T_3: Pendimethalin @ 1.0 kg *a.i.* as PE + Quizalofop ethyl @ 50 g *a.i.* PoE fb hoeing	11.89 (3.22)	13.06 (3.63)	9.67 (3.10)	11.94 (3.24)	25.22 (4.69)	17.83 (3.96)
T_4: Pyrithioback Sodium @ 62.5 g *a.i.* PoE fb hoeing	54.33 (7.40)	10.17 (3.26)	7.00(2.73)	26.33 (4.88)	11.83 (3.47)	7.33 (2.72)
T_5: Pyrithioback Sodium @ 62.5 g *a.i.* PoE + Quizalofop ethyl @ 50 g *a.i.* 2-4 PoE + hoeing	34.33 (5.89)	7.17 (2.75)	3.00(1.85)	23.50 (4.54)	11.22 (3.39)	7.94 (2.78)
T_6: Glyphosate @ 1.0 kg *a.i.* as directed spray at 45 DAS	52.83 (7.30)	6.17 (2.57)	3.00(1.85)	32.78 (5.25)	4.83 (2.24)	5.00 (2.26)
T_7: Weed free check	17.50 (4.24)	4.33 (2.18)	1.33(1.34)	6.72 (2.53)	4.17 (2.08)	3.28 (1.80)
T_8: Weedy control	43.67 (6.63)	76.00 (8.74)	48.67(7.01)	37.17 (5.68)	56.67 (7.12)	56.00 (7.17)
SE±	0.13	0.14	0.16	0.13	0.13	0.11
CD at 5%	0.42	0.43	0.51	0.43	0.43	0.36

* Figures in parenthesis are √x+0.5 transformed values

Table 2: Weed dry weight (g m^{-2}) and seed cotton yield (Kg ha^{-2}) as influenced by different weed control treatments (pooled mean)

Treatments	Monocot weed dry weight (g m^{-2})			Diocot weed dry weight (g m^{-2})			Seed cotton yield (Kg ha^{-1})
	3 WAS	9 WAS	At harvest	3 WAS	9 WAS	At harvest	
T_1: Pendimethalin @ 1.0 kg *a.i.* PE fb one hoeing	3.00 (1.85)	13.17 (3.62)	11.34 (3.40)	2.58 (1.70)	18.78 (4.35)	13.28(3.69)	1440
T_2: Quizalofop ethyl @ 50 g *a.i.* PoE fb hoeing	4.22 (2.14)	14.00 (3.76)	11.58 (3.32)	8.86 (2.91)	28.86 (5.37)	20.19 (4.47)	1190
T_3: Pendimethalin @ 1.0 kg *a.i.* as PE + Quizalofop ethyl @ 50 g *a.i.* PoE fb hoeing	2.28 (1.64)	10.14 (3.22)	8.89 (2.97)	3.56 (1.93)	16.64 (4.11)	10.19 (3.19)	1469
T_4: Pyrithioback Sodium @ 62.5 g *a.i.* PoE fb hoeing	5.97 (2.52)	13.83 (3.71)	10.50 (3.30)	10.06 (3.17)	10.03 (3.21)	6.28 (2.54)	1519
T_5: Pyrithioback Sodium @ 62.5 g *a.i.* PoE + Quizalofop ethyl @ 50 g *a.i.* 2-4 PoE + hoeing	4.67 (2.25)	8.67 (2.99)	6.17 (2.48)	11.08 (3.37)	8.95 (3.05)	5.36 (2.32)	1570
T_6: Glyphosate @ 1.0 kg *a.i.* as directed spray at 45 DAS	5.47 (2.42)	3.61 (2.00)	2.44 (1.67)	9.67 (3.10)	4.53 (2.21)	3.47 (1.94)	1572
T_7: Weed free check	1.75 (1.48)	2.97 (1.83)	1.86 (1.49)	3.53 (1.99)	4.53 (2.13)	2.17 (1.56)	1698
T_8: Weedy control	5.47 (2.42)	26.75 (5.20)	29.75 (5.47)	12.64 (3.54)	46.39 (6.78)	51.28 (7.13)	678
SE±	0.07	0.10	0.08	0.07	0.13	0.11	47.33
CD at 5%	0.23	0.33	0.26	0.23	0.43	0.36	158.30

* Figures in parenthesis are √x+0.5 transformed values

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