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INFLUENCE OF WEED CONTROL PRACTICES ON WEED DENSITY AND PERFORMANCE OF *BT* COTTON GROWN UNDER NORTH GUJARAT AGROCLIMATIC CONDITIONS

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ABSTRACT

Weeds offer competition and suppress the growth of cotton especially during the initial growth stage because of its slow growing habit. The critical period of crop-weed competition in cotton prevails up to 60 to 90 DAS and during this period the crop needs weed free environment for realizing good yield potential. Therefore, a field experiment was conducted at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *kharif* 2022 to study the influence of weed control practices on weed density and performance of *Bt* cotton grown under North Gujarat agroclimatic conditions on loamy sand soil. The experiment was conducted in randomized block design with three replications and ten treatments. The *Bt* cotton variety GTHH 49 was sown manually at a distance of 120 cm between row to row and 45 cm between plant to plant.

Total ten different type of weeds were found in the experimental field, out of that three were monocots and 7 were dicots. Weed free plot had resulted significantly higher plant height, monopodial and sympodial branches/plants, yield per plant and seed cotton yield followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS which remained at par with weed free treatment. These two treatments had resulted the lowest monocot, dicot and density of total weeds at 25, 50 and 75 DAS as compared to all other treatments. The shortest plants, minimum monopodial and sympodial branches/ plants, yield per plant and seed cotton yield were observed under weedy check plot which were significantly lower than all the weed control treatments. Weedy check plot had resulted maximum monocot, dicot and density of total weeds at 25, 50 and 75 DAS. The maximum gross return (` 186735/ha) was obtained under weed free plot, whereas, net returns and B:C ratio *i.e.*, ` 112391/ha and 2.62, respectively was recorded maximum under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS. Results revelated that the application of pyrithiobac sodium + quizalofop 100 (60+40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS controlled weeds effectively in *Bt* cotton and gave higher seed cotton yield and net return under North Gujarat conditions.

Key words : Cotton, Weed control practices, Weed density, Yield, Economics.

Introduction

Cotton (*Gossypium hirsutum* L.) is most important fibre crop grown in India, which plays a pivotal role in boosting the agricultural growth and textile industry. In India, 4 million farmers and 60 million people directly or indirectly depend on cotton production sector and textile industry for their livelihood. Cotton is designated as white gold and plays an important role in the economic development of India. India contributes more than 23 % to the world's cotton production and occupies second place after China. During 2022-23, India grown cotton on 13.05 million ha land and produced 33.72 million bales

Abbreviations : PE: Pre-emergence, PoE: Post-emergence, DAS: Days after sowing, GTHH: Gujarat Talod Hirsutum Hybrid, IC: Interculturing, *fb*: Followed by, HW: Hand weeding, WI: Weed index of cotton with an average productivity of 439 kg lint per ha (Anonymous, 2023). Gujarat is the largest cotton producing state in India. It is hub for textile industries because of huge cotton production. Cotton area, production and productivity in Gujarat during 2021-22 was 2.26 million ha, 8.10 million bales and 610 kg lint per ha, respectively (Anonymous, 2022). Other cotton producing states in India are Maharashtra, Telangana, Rajasthan, Karnataka, Andhra Pradesh, Haryana, Madhya Pradesh and Punjab. Major products of the cotton cultivation are lint, oil, seed meal, hulls and linter.

There are many constraints in the in successful cultivation of cotton, but weeds are major one. Due to slow growing habit of cotton, it is highly vulnerable to weed competition especially in the initial stage of growth. Weeds offer competition and suppress the growth of cotton, since they compete with the crop not only for nutrients and water but also for space and sunlight. As a result of that, growth and development of cotton is affected negatively. Proper weed control measures enhance the availability of nutrients and moisture for the benefit of crop (Jalis and Shah, 1982). Weeds cause 50 to 85 per cent yield loss in cotton depending upon the nature and intensity of weeds (Prabhu *et al.*, 2012). The critical period of crop-weed competition in cotton prevails up to 60 to 90 DAS and during this period the crop requires weed free environment for better performance (Thind *et al.*, 1995).

Hand weeding is a time consuming, expensive and tedious practice. Scarcity of agrarian labour and unfavourable weather conditions during kharif season especially frequent and heavy rains force the farmers to think beyond manual weed control methods. Weeds in cotton field can be effectively controlled with the application of suitable herbicides or herbicide mixtures. Herbicides are capable of giving the crop a relatively better weed free situation in the early stage of crop. Pre-emergence application of herbicides will control the weeds during early crop growth stages and minimizes the crop-weed competition. Weeds emerged in the later period of crop growth need to be controlled efficiently for minimizing crop-weed competition and obtaining optimum yield. Hence, the combination of chemical and cultural methods of weed control become necessary for effective weed control which ultimately result in higher yields. Keeping in mind these facts, this experiment was planned and conducted.

Materials and Methods

Experimental site description

A field experiment was conducted at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat) to study the influence of weed control practices on weed density and performance of *Bt* cotton grown under North Gujarat agroclimatic conditions during *kharif* season of the year 2022. Geographically, Sardarkrushinagar is situated at 24°19' North latitude and 72°19' East longitude with an elevation of 154.52 m above the mean sea level in the North Gujarat Agro-climatic region (AES IV) of Gujarat.

Climate and weather conditions

This region is characterized by semi-arid climate with extreme cold winter and hot and dry summer. Generally, monsoon commences by the third week of June and retreats from the middle of September, but there is an uncertain and uneven distribution of rainfall during the monsoon. The partial failure of rain once in three or four years is very common. Most of the precipitation is received from South-West monsoon, concentrating in the months of July and August.

The winter season is fairly cold and dry start from the end of October and continues till the end of February. The minimum temperature of the year is reached in the months of December and January. The summer season (March-June) is generally hot and dry. The wind velocity is very high during summer. The temperature starts rising from February and reaches the maximum in the months of April or May. The standard week-wise meteorological data for the period of this investigation recorded at the Meteorological Observatory, Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha are graphically depicted through Fig. 1.

Experimental details

The soil samples of the experimental field were taken randomly from different spots to a depth of 0-15 cm before layout of experiment and composite soil sample was prepared. The soil sample was analysed to know physical as well as chemical properties of the soil. The soil of the experimental field was loamy sand in texture having 7.8 pH, analysed through international pipette method (Piper, 1966) and potentiometric method (Jackson, 1973), respectively. The soil was low in organic carbon (0.38%) and available nitrogen (162.8 kg/ha), medium in available phosphorus (39.2 kg/ha) and potassium (254.3 kg/ha) content analysed through Modified Walkley and Black method (Walkley and Black, 1934), Alkaline $KMnO_4$ method (Subbiah and Asija, 1956), Olsen's method (Olsen

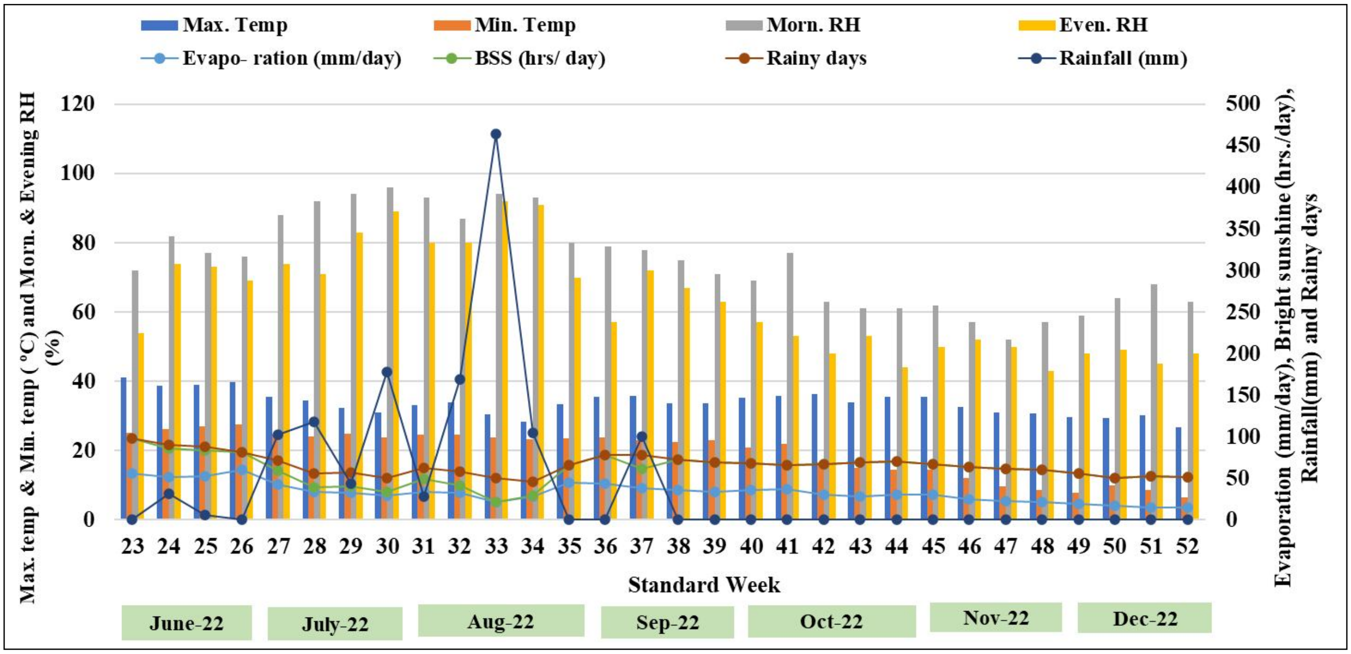

Fig. 1 : Mean weekly meteorological data recorded during the period of experimentation.

Table 1 : Treatment details.

S. no.	Treatment number	Details
1	T_1	Pendimethalin 1000 g/ha as PE
2	T_2	Quizalofop ethyl 50 g/ha as PoE at 25 DAS
3	T_3	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS
4	T_4	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS
5	T_5	Pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS
6	T_6	Quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS
7	T_7	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS
8	T_8	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS
9	T_9	Weed free
10	T_{10}	Weedy check

In T_4, T_5 and T_8: Pyrithiobac sodium + quizalofop ethyl is a ready-mix herbicide formulation

et al., 1954) and Neutral N NH_4OAc Flame photometric method (Jackson, 1973) methods, respectively. The experiment was conducted in randomized block design having three replications. The cotton variety GTHH 49 was sown manually at a depth of 4 to 5 cm in previously opened furrows at 120 cm and 45 cm, row to row and plant to plant spacing, respectively on 17th June, 2022 using recommended seed rate of 2.5 kg/ha. There were ten treatments details of which are given in Table 1.

The 1/3 of the recommended dose (320:00:120 kg N: P_2O_5: K_2O/ha) of nitrogen and full dose of potassium in the form of urea and MOP, respectively was commonly applied in all treatments just before sowing of seeds in the furrow. Remaining dose of nitrogen was top dressed in four equal splits. Irrigations were given as per the requirement of crop. Interculture in T_6, T_7 & T_8 was done by using manually operated cycle weeder followed by hand weeding at 50 DAS to remove the weeds. In weed free plot, hand weedings were done to maintain weed free situation during the whole crop period. No any weed management practices were done in T_{10} *i.e.*, weedy check plot. In the herbicidal treatments (T_1 to T_8), the required quantity of herbicides spayed as per the treatments using knapsack sprayer with flat fan nozzle. The required quantity of formulation of each herbicide for gross plots was calculated using the following formula.

$$Rh = \frac{Ai}{Ci} \times 100$$

where,

Rh = Required quantity of formulation of herbicide per hectare (kg)

Ai = Quantity of active ingredient to be applied (kg)

Ci = Concentration of active ingredient in the trade formulation

Observations

Five plants were randomly selected and labeled from each net plot. These plants were used for recording different observations. Plant population at 30 DAS and at harvest was recorded by counting the number of plants per net plot. The average values were worked out and recorded separately for each treatment. The plant height (cm) was measured from ground levels to tip of the terminal bud with the help of metric scale. Monopodial (nonfruiting) and sympodial (fruiting) branches were counted from five tagged plants at harvest in each net plot. Mean of five plants was expressed as a monopodial and sympodial branches/plants. Seed cotton was harvested from five tagged plant and weighted during each picking. Mean seed cotton yield/plant was calculated and expressed as grams/plant. Seed cotton was picked from each net plot and its weight was recorded picking wise. Thereafter, it was converted into kilogram/hectare and presented as seed cotton yield (kg/ha). After the last picking, the stalks of the plant from each net plot area were uprooted and dried in the field under the sun. Thereafter, the weight of dry stalks recorded separately for each net plot and converted into kilogram/hectare which was expressed as stalk yield (kg/ha).

The monocot and dicot weeds densities (No./m^2) were recorded randomly at 25, 50 and 75 DAS from each plot using 50 cm × 50 cm quadrate (0.25 m^2/plot). The weed index was calculated by using the following formula (Gill and Kumar, 1969).

$$WI\ (\%) = \frac{X - Y}{X} \times 100$$

where,

X = Seed cotton yield from the weed free plot

Y = Seed cotton yield from the treated plot for which WI is to be worked out.

To know the most effective treatment, economics of each treatment calculated out using gross returns, net returns and benefit: cost ratio (BCR). Gross returns in term of rupees per hectare was worked out from the income received from seed cotton yield and stalk yield of each treatment separately, considering the recent market price of seed cotton and stalk. The cost of cultivation was calculated based on the cost incurred for all the operations from the preparation of land to the harvesting of the crop and the cost of all the other inputs involved. The net returns were calculated by subtracting the total cost of cultivation from the gross returns per hectare for each treatment and recorded accordingly. The BCR was calculated on the basis of formula given below.

$$\text{Benefit: cost ratio (BCR)} = \frac{\text{Gross returns (`/ha)}}{\text{Total cost of cultivation (`/ha)}} \times 100$$

Statistical analysis

Since the data on related to weeds were not normally distributed, therefore, the data were transformed using the $\sqrt{x+0.5}$ transformation as suggested by Gomez and Gomez (1984). The transformed data were analysed statistically. The statistical analysis of the data collected for different parameters were carried out following the procedures as described by Panse and Sukhatme (1967) using computer system at the Computer Centre, Department of Agricultural Statistics, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar. The values of calculated 'F' are taken at 5 percent level of significance.

Results and Discussion

Weeds density

The weed flora in the experimental plot were *Cyperus rotundus* L., *Digitaria sanguinalis* L. and *Dactyloctenium aegyptium* L. among monocot weed and *Portulaca oleracea* L., *Boerhavia erecta* L., *Tribulus terrestris* L, *Leucas aspera*., *Digeria arvensis* L., *Commelina benghalensis* L. and *Amaranthus viridis* among dicot weed. The emergence of different weed species was attributed to major weed flora of that region, soil weed seed bank, soil type, tillage intensity, previous crops/cropping system, weather parameters and congeniality of soil environment. Data pertaining to the weed's density (No./m^2) in *Bt* cotton at 25, 50 and 75 DAS are presented in Table 2. Perusal of data revealed that the different weed control treatments significantly affected the monocot, dicot and total weed density across the crop growth stages.

The weed free plot significantly reduced the monocot weeds density compared to all other treatments at 25, 50 as well as 75 DAS. After weed free plot, the minimum monocot weeds density at 25 DAS was observed under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS

Table 2 : Influence of different weed control practices on weeds density in *Bt* cotton.

Treatment		Monocot weeds density (No./m²)			Dicot weeds density (No./m²)			Total weed density (No./m²)		
		25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
T_1	Pendimethalin 1000 g/ha as PE	3.50(12.00)	5.21(26.67)	5.69(32.00)	3.84(14.67)	5.67(32.00)	5.90(34.67)	5.21(26.67)	7.67(58.67)	8.17(66.67)
T_2	Quizalofop ethyl 50 g/ha as PoE at 25 DAS	5.03(25.33)	4.26(18.67)	5.30(28.00)	5.44(29.33)	5.06(25.33)	5.55(30.67)	7.39(54.67)	6.61(44.00)	7.66(58.67)
T_3	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS	4.94(24.00)	4.49(20.00)	5.42(29.33)	5.33(28.33)	4.36(18.67)	5.28(28.00)	7.23(52.00)	6.25(38.67)	7.54(57.33)
T_4	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	4.78(22.67)	3.89(14.67)	4.18(17.33)	5.81(33.33)	3.87(14.67)	4.64(21.33)	7.51(56.00)	5.44(29.33)	6.25(38.67)
T_5	Pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	3.33(10.67)	3.12(9.33)	4.04(16.00)	3.66(13.33)	3.03(9.33)	4.37(18.67)	4.90(24.00)	4.31(18.67)	5.91(34.67)
T_6	Quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	4.99(24.67)	4.18(17.33)	3.87(14.67)	5.93(34.67)	5.33(28.00)	4.01(16.00)	7.72(59.33)	6.75(45.33)	5.52(30.67)
T_7	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	5.21(26.67)	4.67(21.33)	3.71(13.33)	5.69(32.00)	4.53(20.00)	3.66(13.33)	7.69(58.67)	6.47(41.33)	5.19(26.67)
T_8	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	5.30(28.00)	3.50(12.00)	2.65(6.67)	6.04(36.00)	3.71(13.33)	2.39(5.33)	8.01(64.00)	5.06(25.33)	3.50(12.00)
T_9	Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
T_{10}	Weedy check	5.46(29.33)	6.73(45.33)	7.32(53.33)	6.11(37.33)	7.39(54.67)	7.86(61.33)	8.19(66.67)	9.97(100.00)	10.72(114.67)
S.Em. ±		0.32	0.33	0.31	0.31	0.34	0.34	0.34	0.40	0.38
C.D. at 5%		0.96	0.97	0.92	0.92	1.01	1.00	1.01	1.19	1.14
C.V. %		12.93	13.94	12.45	11.08	13.54	13.11	9.08	11.75	10.82

Note: Square root transformation ($\sqrt{x+0.5}$) was applied to the original value which are given in the parenthesis.

i.e., T_5 (3.33) followed by pendimethalin 1000 g/ha as PE *i.e.*, T_1 (3.50). These two treatments adjudged at par with each other and reduced the monocot weeds density significantly than all other weed control treatments except weed free plot. The minimum weeds density in T_5 and T_1 is due to pre-emergence application of herbicides in these treatments. At 50 DAS, the monocot weeds density after weed free plot was found minimum under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_5 (3.12) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (3.50) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_4 (3.89). These three treatments remained at par with respect to monocot weeds density at 50 DAS. The maximum monocot weeds density was observed under weedy check plot *i.e.*, T_{10} (6.73), which was significantly higher over all other weed control treatments. After weed free plot, the monocot weeds density at 75 DAS was found minimum under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (2.65), which had significantly reduced the monocot weeds density compared to all other treatments except weed free plot. Treatments 7, 6, 5 and 4 remained at par with each other in reducing the monocot weed density at 75 DAS. The maximum monocot weeds density at 75 DAS was observed under weedy check plot (7.32), which was significantly higher than all other weed control treatments.

The weed free plot reduced the dicot weeds density significantly compared to other treatments at 25, 50 as well as 75 DAS. After weed free plot, the minimum dicot weeds density at 25 DAS was observed under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_5 (3.66) followed by pendimethalin 1000 g/ha as PE *i.e.*, T_1 (3.84), which adjudged at par with T_5. These two treatments had reduced the dicot weeds density significantly than all other weed control treatments except weed free plot. After weed free plot, The dicot weeds density at 50 DAS was found minimum under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_5 (3.03) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (3.71) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_4 (3.87). These three treatments remained at par with respect to dicot weeds density at 50 DAS. The maximum dicot weeds density was at 50 das was observed under weedy check plot *i.e.*, T_{10} (7.39), which was significantly higher over all other weed control treatments. At 75 DAS, the dicot weeds density after weed free plot was found minimum under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (2.39) which had reduced the dicot weeds density significantly compared all other treatments except weed free plot. Treatments 7, 6, 5 and 4 remained at par with each other in reducing the dicot weed density at 75 DAS. The maximum dicot weeds density at 75 DAS was observed under weedy check plot (7.86), which was significantly higher than all other weed control treatments.

The weed free plot significantly reduced the total weeds density compared to all other treatments at 25, 50 as well as 75 DAS. After weed free plot, the minimum total weeds density at 25 DAS was observed under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_5 (4.90) followed by Pendimethalin 1000 g/ha as PE *i.e.*, T_1 (5.21). These two treatments adjudged at par with each other and reduced the total weeds density significantly than all other weed control treatments except weed free plot. The minimum total weeds density in T_5 and T_1 is due to pre-emergence application of herbicides in these treatments. At 50 DAS, the total weeds density after weed free plot was observed minimum under pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_5 (4.31) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (5.06) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS *i.e.*, T_4 (5.44). These three treatments remained at par with respect to total weeds density at 50 DAS. The maximum total weeds density was observed under weedy check plot *i.e.*, T_{10} (9.97), which was significantly higher over all other weed control treatments. After weed free plot, the total weeds density at 75 DAS was found minimum under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, T_8 (3.50) which had significantly reduced the total weeds density compared to all other treatments except weed free plot. Treatments 7, 6, 5 and 4 remained at par with each other in reducing the total weed density at 75 DAS. The maximum total weeds density at 75 DAS was observed under weedy check plot (10.72), which was significantly higher than all other weed control treatments. The present finding was accordance with Prabhu *et al*. (2011), Madhu *et al*. (2014) and Malarkodi *et al*. (2017).

Plant population

The yield of any crop is depending on establishment of optimum plant population, which ultimately serves a potential factor for realising optimum productivity of crop. The data exhibited in Table 3 revealed that different weed control treatments did not influence initial plant population as well as plant population at harvest significantly. Though the plant population did not influence by different weed control treatments significantly at harvest, the maximum plant population per net plot was remained under weed free plot closely followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS, whereas, the least plant population was recorded under weedy check plot.

Plant height

The data pertaining to plant height (cm) of *Bt* cotton recorded periodically at 25, 50, 75 DAS and harvest are presented in Table 3 revealed that different weed control treatments did not affect the plant height at 25 DAS, whereas, at 50, 75 DAS and at harvest the plant height was significantly affected by the different weed control treatments. Significantly taller plants were observed under weed free plot *i.e.*, 71.3, 101.2 and 132.3 cm at 50, 75 DAS and at harvest, respectively, followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_8), pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_7), quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_6) and pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS (T_5). All these treatments adjudged at par with weed free plot with respect to the plant height at 50, 75 DAS and at harvest. Significantly the lowest plant height *i.e.*, 45.8, 65.9 and 92.8 cm was recorded under weedy check plot at 50, 75 DAS and at harvest, respectively, which remained significantly lower than rest of the weed control treatments. Effective control of weeds through manual weeding in weed free plot and combination of post-emergence herbicide with manual weeding resulted into less weed-crop competition throughout the growth stage of crop and created

Table 3 : Influence of different weed control practices on plant population and plant height of *Bt* cotton.

Treatment		Plant population (per net plot)		Plant height (cm)			
		At 30 DAS	At harvest	25 DAS	50 DAS	75 DAS	Harvest
T_1	Pendimethalin 1000 g/ha as PE	26.00	24.67	25.3	56.8	81.4	110.7
T_2	Quizalofop ethyl 50 g/ha as PoE at 25 DAS	27.33	25.33	22.7	57.1	82.5	112.1
T_3	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS	29.33	26.00	23.4	58.5	84.5	113.1
T_4	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	27.00	26.67	24.9	60.0	85.4	114.6
T_5	Pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	31.33	27.00	25.6	62.5	90.6	116.4
T_6	Quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	29.00	27.33	22.9	62.9	91.9	118.0
T_7	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	28.00	27.67	23.8	65.3	95.9	120.2
T_8	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	28.67	28.33	24.8	68.5	99.1	125.5
T_9	Weed free	29.33	28.67	26.9	71.3	101.2	132.3
T_{10}	Weedy check	28.00	24.00	21.7	45.8	65.9	92.8
S.Em. ±		1.83	1.60	1.58	3.63	5.14	5.85
C.D. at 5%		NS	NS	NS	10.78	15.27	17.38
C.V. %		11.16	10.45	11.33	10.32	10.13	8.76

Table 4 : Influence of different weed control practices on branches and yield of *Bt* cotton.

Treatment		Monopodial branches (No./plant)	Sympodial branches (No./plant)	Seed cotton yield (kg/ha)	Stalk yield (kg/ha)	WI (%)
T_1	Pendimethalin 1000 g/ha as PE	2.27	16.53	2005	3923	34.5
T_2	Quizalofop ethyl 50 g/ha as PoE at 25 DAS	2.33	17.23	2107	3994	31.2
T_3	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS	2.40	17.93	2207	4043	28.0
T_4	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	2.47	19.67	2392	4609	21.9
T_5	Pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	2.53	20.20	2448	4641	20.1
T_6	Quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	2.67	20.80	2508	4688	18.1
T_7	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	2.73	21.13	2592	4719	15.4
T_8	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	2.80	24.40	2981	5451	2.7
T_9	Weed free	3.20	25.53	3066	5549	0.00
T_{10}	Weedy check	2.00	13.33	1608	3156	47.5
S.Em. ±		0.21	1.04	129.23	215.03	
C.D. at 5%		NS	3.08	383.96	638.89	
C.V. %		14.53	9.14	9.36	8.32	

favourable environment for plant growth. Thus, enhance availability of nutrients, water, light and space, which might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates leading to increase in growth characters. These results were in accordance with the findings of Sadangi and Barik (2007), Sangle *et al.* (2007) and Veeramani *et al.* (2009)

Monopodial and sympodial branches per plant

The data pertaining to the monopodial and sympodial branches per plant was recorded at first picking are furnished in Table 4.

Data indicated that the different weed control treatments did not influence the number of monopodial branches per plant significantly. Though the number of monopodial branches per plant did not influence by different weed control treatments significantly, the maximum and minimum number of monopodial branches per plant was obtained under weed free and weedy check plot, respectively. Sympodial branches per plant were significantly affected by different weed control treatments. Weed free plot had resulted significantly higher number of sympodial branches per plant (25.53) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (24.40). These two treatments adjudged at par with respect to the number of sympodial branches per plant. The least number of sympodial branches per *i.e.*, plant was found under weedy check plots (13.33), which were found significantly lower than all other weed control treatment. This is might be due to severe weed competition. Similar results were reported by Sandangi and Barik (2007) and Mounica *et al.* (2021).

Seed cotton yield

Data related to the seed cotton yield are presented in Table 4 revelated that different weed control treatments significantly affected the seed cotton yield. Maximum seed cotton *i.e.*, 3066 kg/ha was obtained under weed free plot (T_9) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_8) which had resulted 2981 kg/ha seed cotton yield and remained at par with weed free plot with regard to seed cotton yield. These two treatments

Table 5 : Influence of different weed control practices on economics of *Bt* cotton.

Treatment		Total cost of cultivation (`/ha)	Gross realization (`/ha)	Netrealization (`/ha)	B:C ratio
T_1	Pendimethalin 1000 g/ha as PE	53089	122262	69172	2.30
T_2	Quizalofop ethyl 50 g/ha as PoE at 25 DAS	55096	128417	73321	2.33
T_3	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS	56404	134442	78038	2.38
T_4	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	59369	145825	86455	2.46
T_5	Pendimethalin 1000 g/ha as PE + pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS	62080	149201	87120	2.40
T_6	Quizalofop ethyl 50 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	63521	152824	89303	2.41
T_7	Pyrithiobac sodium 62.5 g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	64451	157880	93428	2.45
T_8	Pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS	69304	181695	112391	2.62
T_9	Weed free	82457	186735	104277	2.26
T_{10}	Weedy check	47737	98058	50321	2.05

had produced significantly higher seed cotton yield over rest of the weed control treatments. The T_7, T_6, T_5 and T_4 found at par with each other. The lowest seed cotton yield was recorded under weedy check plot (T_{10}) *i.e.*, 1608 kg/ha which was significantly lower than all other weed control treatments. The seed cotton yield was reduced by 47.5 per cent in weedy check plot as compared to weed free. The maximum seed cotton yield in weed free plot is due to improved yield attributes *viz.*, number of bolls per plant, boll weight and seed cotton yield, this in turn was because of improvement in plant height, leaf area index and number of sympodial branches. The increased seed cotton yield in this treatment could also be attributed to the efficient utilization of growth resources and other environment factors. This was the outcome of reduced crop-weed competition due to good control of weeds. Analogous findings have been reported by Singh and Kakate (2010), Bharathi *et al*. (2011). Prabhu *et al*. (2011), Ali *et al*. (2013), Chinnusamy *et al*. (2013), Pawar *et al*. (2015) and Rani *et al*. (2016).

Stalk yield

Result revealed that, similar to seed cotton yield, different weed control treatments also affected the stalk yield of *Bt* cotton significantly (Table 4). Maximum stalk yield *i.e.*, 5549 kg/ha was obtained under weed free plot (T_9) followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_8), which had resulted 5451 kg/ha stalk yield and found at par with weed free plot with respect to stalk yield of cotton. These two treatments had produced significantly higher stalk yield of cotton over rest of the weed control treatments. The T_7, T_6, T_5 and T_4 remained at par with each other. The lowest stalk yield of cotton was recorded under weedy check plot (T_{10}) *i.e.*, 3156 kg/ha which was significantly lower than all other weed control treatments. The maximum stalk yield of cotton in weed free plot is due to improvement in plant height, leaf area index and number of sympodial branches. This was the result of reduced crop-weed competition due to good control of weeds.

Weed index (%)

WI is a measure of the crop yield loss occurred due to weeds in comparison to weed free plot. Different weed control treatments profoundly influenced the WI in *Bt* cotton as presented in Table 4. The data indicated that after weed free plot, lowest weed index *i.e.*, 2.7 % was calculated under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS. The highest value of weed index was observed under weedy check (T_{10}) *i.e.*, 47.5%. Highest weed

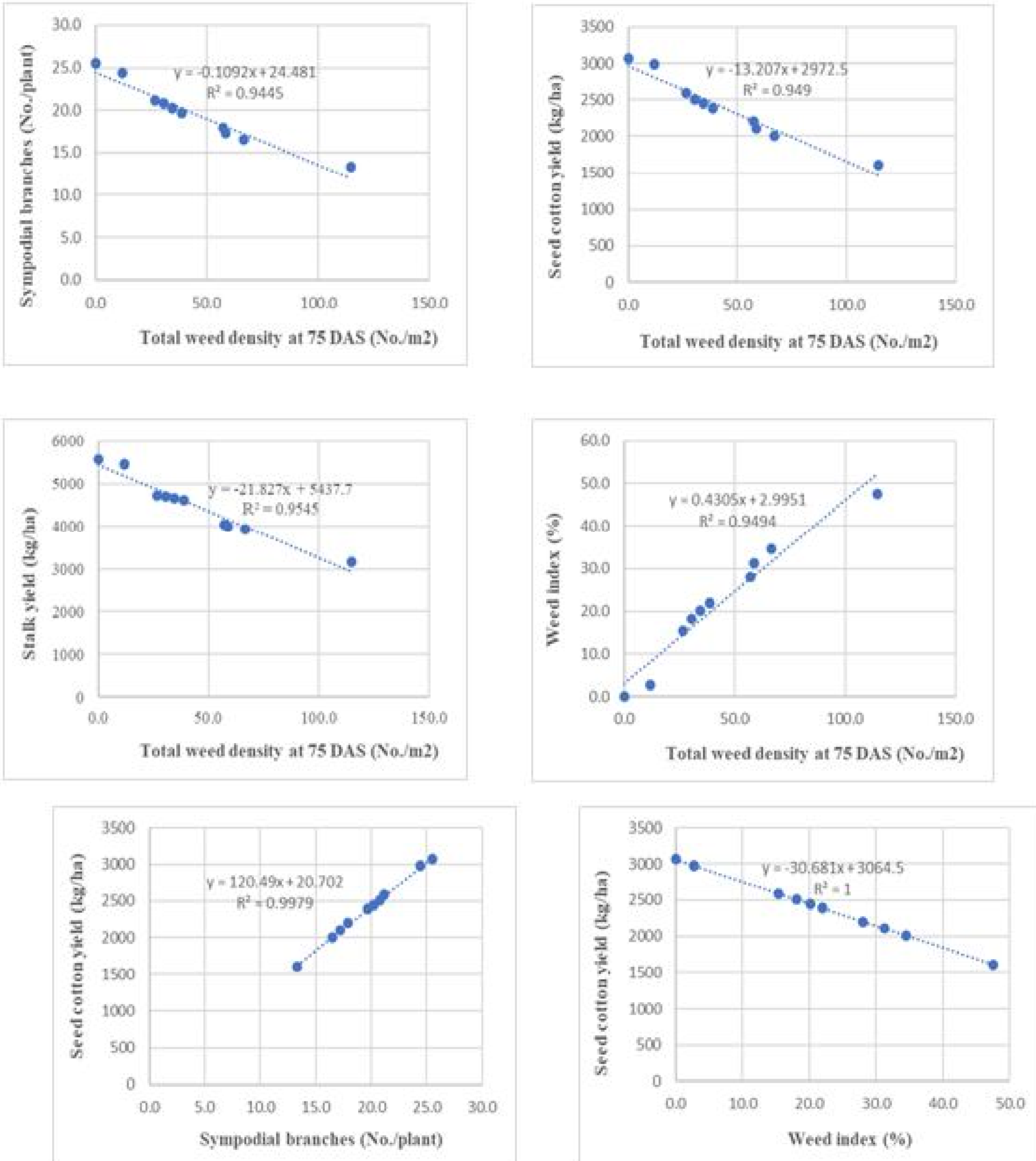

Fig. 2 : Correlation study of different parameters in *Bt* cotton.

index in weedy check was due to lowest seed cotton yield which interns was because of significantly higher weed density, weed dry weight, maximum crop-weed competition and poor utilization of the resources by the crop in this plot. The similar findings were reported by Giri *et al*. (2006), Thorat *et al*. (2007), Rathod (2023) and Shelke *et al*. (2013).

Economics

The ultimate aim of any agricultural technology/ practice is to obtain maximum returns per rupee invested. Any farming technology to be adopted under farmer situations should have a sound economic viability in terms of higher net returns or benefit: cost ratio. The data pertaining to the economics of different weed control treatments are given in Table 5. Maximum gross return (` 186735/ha) were accrued under treatment weed free ($T_9$), which was closely followed by pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS *i.e.*, $T_8$ (` 181895/ha), whereas, maximum net returns and B:C ratio *i.e.*, ` 112391/ha and 2.62, respectively was recorded under pyrithiobac sodium + quizalofop ethyl 100 (60 + 40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS (T_8). The maximum benefit under this treatment might be due to effective control of weeds and lower cost of cultivation as compared to weed free plot. The higher cost of cultivation of weed free plot mainly due to highest labour cost incurred for weeding operations. Lowest, gross returns, net returns and B:C ratio *i.e.*, ` 98058/ha, 50321/ha and 2.05, respectively, was observed under weedy check (T_{10}).

Correlation study

The correlation study of different parameters is presented through Fig. 2, revealed that the relationship of weed density with the growth and yield of cotton was perfectly negative one. Regression equation indicated that increase in total weed density (No./m^2) by one at 75 DAS reduced the number of sympodial branches, seed cotton yield and stalk yield by 0.109/plant, 13.207 kg/ha and 21.827 kg/ha, respectively. On the other hand, the relationship of number of sympodial branches per plant and seed cotton yield was found positive. Increase in the number of sympodial branches by one increased the seed cotton by 120.49 kg/ha.

Conclusion

Results revelated that the application of pyrithiobac sodium + quizalofop 100 (60+40) g/ha as PoE at 25 DAS + IC *fb* HW at 50 DAS controlled weeds effectively in *Bt* cotton and gave higher seed cotton yield and net return under North Gujarat conditions.

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Competing interests

The authors declare that they have no competing interests.

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