“EFFECT OF HIGH DENSITY PLANTING AND WEED MANAGEMENT PRACTICES ON WEED DRY MATTER, WEED INDICES AND SEED COTTON YIELD OF *Bt.* COTTON”

BY

RATHOD NITIN SUBHASH

B.Sc. (Agriculture)

MASTER OF SCIENCE

(Agriculture)

IN

AGRONOMY

DEPARTMENT OF AGRONOMY,

COLLEGE OF AGRICULTURE, PARBHANI

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH,

PARBHANI- 431 402 (M.S.) INDIA

2022

"EFFECT OF HIGH DENSITY PLANTING AND WEED MANAGEMENT PRACTICES ON WEED DRY MATTER, WEED INDICES AND SEED COTTON YIELD OF *Bt.* COTTON"

BY

RATHOD NITIN SUBHASH

B.Sc. (Agriculture)

Submitted to

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

in partial fulfillment of the requirement for the Degree of

MASTER OF SCIENCE

(Agriculture)

IN

AGRONOMY

DEPARTMENT OF AGRONOMY,

COLLEGE OF AGRICULTURE, PARBHANI

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH,

PARBHANI- 431 402 (M.S.) INDIA

2022

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled, **"Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton"** submitted by me is based on the actual work carried out by me under the guidance and supervision of **Dr. V. K. Khargakharate**. The extent of information derived from the existing literature have been duly cited and referenced. The existing research work or its any part is not submitted anywhere else for the award of any degree or diploma.

I also declare that no sentence, equation, diagram, table, paragraph or section has been copied verbatim from previous work unless it is cited and duly referenced. There is no plagiarism; the work presented is original and own work of the researcher. No ideas, process, results or words of another have been presented as researcher's own work.

Place : Parbhani

Date : 28 /11 /2022

(RATHOD NITIN SUBHASH)

Reg. No: - 2020A/10M

CERTIFICATE - I

This to certify that the thesis/dissertation entitled, "**Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton**" submitted by **RATHOD NITIN SUBHASH, Reg. No: 2020A/10M** in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY** submitted to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani is a record of bonafide research work carried out by him under my guidance and supervision. The thesis or its any part has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Parbhani

Date :28 /11 /2022

(V. K. Khargakharate)

CERTIFICATE - II

This is to certify that the thesis entitled, "**Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton**" submitted by **RATHOD NITIN SUBHASH, Reg. No: 2020A/10M** in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani has been approved by the student's Advisory Committee after viva voce examination of the student in collaboration with the External Examiner.

External examiner

(V. K. Khargakharate)
Research guide & Chairman,
Advisory committee

(B. V. Asewar)
Member

(V. B. Awasarmal)
Member

(P. H. Gourkhede)
Member

Associate Dean (PG)

PLAGIARISM CLEARANCE CERTIFICATE

This is to certify that the thesis entitled "**Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton**" submitted by **RATHOD NITIN SUBHASH, Reg. No: 2020A/10M** has been properly examined by Ouriginal: Anti plagiarism software. The percentage of similarities found in the thesis is 08%.

No sentence, equation, diagram, table, paragraph or section has been copied verbatim from previous work unless it is duly cited and referenced. The work presented is original and own work of the researcher (i.e. there is no plagiarism). No ideas, process result or words of other have been presented as researcher's own work.

The thesis has been checked using Ouriginal anti plagiarism software.

(V. K. Khargakharate)

Ouriginal

Document Information

Analyzed document	final thesis I-VI.doc (D151189127)
Submitted	11/28/2022 6:08:00 AM
Submitted by	Dr. V.K. Khargakharate
Submitter email	vilaskhargakharate@gmail.com
Similarity	8%
Analysis address	vilaskhargakharate.vnmkv@analysis.urkund.com

Sources included in the report

W	URL: http://www.aelsindia.com/rjcesjune2017/11.pdf Fetched: 7/22/2021 9:19:35 AM	2
W	URL: http://www.crdaindia.com/fileserve.php?FID=318 Fetched: 7/5/2022 6:08:22 PM	4
SA	**VNM Krishi Vidyapeeth / Sunil Bhimrao Pawar.pdf** Document Sunil Bhimrao Pawar.pdf (D123742948) Submitted by: anandkarle@rediffmail.com Receiver: anandkarle.vnmkv@analysis.urkund.com	24
SA	**VNM Krishi Vidyapeeth / THESIS_ 15 _FEB 2021.doc** Document THESIS_ 15 _FEB 2021.doc (D95574229) Submitted by: asjadhav31@rediffmail.com Receiver: asjadhav31.vnmkv@analysis.urkund.com	8
SA	**Pratik Panchal .pdf** Document Pratik Panchal .pdf (D142426435)	23
SA	**SEQUENTIAL APPLICATION OF HERBICIDES ON WEED DYNAMICS, YIELD AND QUALITY OF COTTON (Gossypium hirsutum L.).docx** Document SEQUENTIAL APPLICATION OF HERBICIDES ON WEED DYNAMICS, YIELD AND QUALITY OF COTTON (Gossypium hirsutum L.).docx (D83634950)	2
W	URL: https://www.ijcmas.com/special/7/K.%20R.%20Siddagangamma%20and%20A.%20S.%20Channabasavanna.pdf Fetched: 5/3/2020 3:20:05 PM	9
SA	**M B POOJA PGS20AGR8543.doc** Document M B POOJA PGS20AGR8543.doc (D147192969)	14
W	URL: https://www.imedpub.com/articles/improving-the-productivity-of-cotton-based-intercropping-syst... Fetched: 7/24/2022 12:14:16 PM	2
J	**08_chapter_2.pdf** URL: d69d1d5c-cf35-4399-ba12-fdd2e7325772 Fetched: 8/21/2022 8:03:11 PM	5
SA	**Pramod kumar.pdf** Document Pramod kumar.pdf (D108075083)	3

CONTENTS

Acknowledgement

I bow my head with great reverence to him who is omnipresent, omnipotent & omniscient and cause behind every effort. I owe my deep sense to almighty "God" for giving me strength.

It is my proud privilege to express heart-felt indebtedness and deepest sense of gratitude to ***my research guide Dr. V. K. Khargakharate****, Cotton Agronomist, Officer In charge Central Farm, V.N.M.K.V., Parbhani for his inspiring guidance, keen interest, his activeness and sharpness. I take this opportunity to express my deep and sincere feeling of gratitude to him for suggesting research topic, valuable guidance, constant inspiration, constructive criticism talented versatile advice and untiring efforts in preparation of the manuscript of this dissertation.*

I express my sincere thanks to ***Dr. Indra Mani Mishra****, Vice Chancellor, VNMKV, Parbhani,* ***Dr. D. N. Gokhale****, Director of Instruction and Dean, Faculty of Agriculture,* ***Dr. Syed Ismail*** *Associate Dean and Principal, College of Agriculture, Parbhani and* ***Dr. W. N. Narkhade****, Head Department of Agronomy, Parbhani, for their kind co-operation and providing facilities and resources during my post graduate programme.*

I take opportunity to express a heartfelt thanks to the member of Advisory committee, ***Dr. B.V. Asewar****, Associate Dean and Principal, College of Agriculture, Golegaon.,* ***Dr. V. B. Awasarmal****, Associate professor, Department of Agronomy, College of Agriculture, Parbhani.,* ***Dr. P. H. Gaurkhede****, Assistant Professor, Department of SSAC, College of Agriculture, Parbhani.*

My cordial thanks are to ***Dr. V.B. Awasarmal, Dr. I.A.B. Mirza, Dr. M.P. Jagtap, S.U. Pawar,*** *all staff members of Department of Agronomy, VNMKV, Parbhani may be regarded as the light hours for the ocean liners who have been kindly navigate my ship of academic pursuit and I would like to mention my gratitude to them.*

There are no words to express the great sacrifice, devotion, every time encouragement, inspiration, support of my respected and adorable father ***Mr. Subhash Haridas Rathod*** *and my mother* ***Mrs. Sangitabai Subhash Rathod*** *which increase the level of principles of right, wrong and morale during the whole educational life. It is beyond my capacity to express in words, their untiring pain taking, dedicated help, affection, silent wishes and blessings only made me what am today. I also express my whole hearted senseof gratitude, towards my lovely Sister's* ***Priyanka*** *and my brother* ***Ajay.***

It is great pleasure to acknowledge the unfailing help rendered from my friends and my ***Star Agronomist Family, Sachin, Bhagwat, Raju, Sambhaji, Kalpana, Megha, Swapnali, Chaitanya, Dhanashree., Sneha, Supriya, Srija, Shireen*** *and* ***especially heartiest thanks to Gangsters, Sidhant, Shivam, Amar, Bhagwat, Sachin, Ankush and Vaibhav*** *deserve special thanks for their great support and inspiring words which gave me strength to keep on move with all my potentials and lastly, and sincere heartfelt gratitude to my senior Sangram Bainade, Santosh Thombare, Sachin Dahle, Nilesh, Sudhir Mane, Sharad Jadhav, Mahesh Darule, Vikas Pisore, Avdhut Pawar, Atul Chalak, Bhagwat Bhosale and Santosh Mundhe and special thanks to Rushi, Prakash, Ganesh, Sidhart, and Ms. Rutuja, Asha & Apeksha. I would like to express my sincere appreciation to my classmates, seniors and Juniors for their support during research work.*

I sincerely apologize to all those who have extended their good will and moral support during the tenure of my experiments whose names have not been mentioned those will always be cherished.

Inadvertently I might have forgotten to mention the names of invisible hands for their help I am thankful to them as well.

Last but not last my warm acknowledgements to farmers, soldiers, scientists COVID-19 soldiers and social workers, who have devoted their whole life for the country.

Place: *Parbhani*

Date: 28/11/*2022* ***(Rathod Nitin Subhash)***

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

/	:	Per
%	:	Per cent
^{0}C	:	Degree Celsius
@	:	At the rate of
AGR	:	Absolute Growth Rate
a.i.		Active Ingredient
B:C ratio	:	Benefit cost ratio
BSS	:	Bright Sunshine
CD at 5%	:	Critical difference at 5 per cent
Cm	:	Centimeter (s)
DAP	:	Di ammonium phosphate
DAS	:	Days after sowing
dS m^{-1}	:	Deci Siemens per meter
dm^2	:	Decimeter squares (s)
et al.	:	*et al* (and others)
ES	:	Elemental sulphur
EVP	:	Evaporation
Fig.	:	Figure
FYM	:	Farm yard manure
G	:	Gram (s)
G.M.	:	General Mean
Ha	:	Hectare
ha^{-1}	:	Per Hectare
hrs.	:	Hours
i.e.	:	id est. (that is)
K or K_2O	:	Potassium
Kg	:	Kilogram (s)
LAI	:	Leaf Area Index
M	:	Meter
MOP	:	Muriate of potash

M.W.	:	Meteorological Week
Max	:	Maximum
Min	:	Minimum
MT	:	Million tones
N	:	Nitrogen
N.S.	:	Non-significant
No.	:	Number
PE	:	Pre Emergence
PoE		Post Emergence
P or P_2O_5	:	Phosphorus
pH	:	Puissance de hydrogen
$Plant^{-1}$	:	Per Plant
RDF	:	Recommended dose of fertilizer
Rs Or □	:	Rupees
RF	:	Rainfall
R/R	:	Row to Row
RGR	:	Relative Growth Rate
S.E.	:	Standard error
Spp.	:	Species
T	:	Tonne (s)
viz.	:	Videlicet *i.e.* namely
WG	:	Wettable Granule
WP	:	Wettable Powder
W.V.	:	Wind velocity
WCI	:	Weed Control Efficiency
WI	:	Weed Index

THESIS ABSTRACT

THESIS ABSTRACT

1.	Title of the Thesis	:	**“ Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton ”**
2.	Name of student	:	Rathod Nitin Subhash
3.	Name of Research Guide	:	Dr. V. K. Khargakharate
4.	Department	:	Agronomy
5.	College/University	:	College of Agriculture,VNMKV, Parbhani
6.	Degree to be awarded	:	M.Sc. (Agri.) Agronomy

ABSTRACT

The field investigation entitled “Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt*. cotton” was carried out on black soil during the *Kharif* season of 2021-22 at the experimental Central Farm Balsa, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.). The experimental field was leveled and well drained. The soil was clayed in texture, low in nitrogen, medium in phosphorous and high in potassium and alkaline in reaction. The environmental condition prevailed during experimental period was favorable for normal growth and maturity of *Bt.* cotton hybrid.

The field investigation entitled “Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt*. cotton” was carried out on black soil during the *Kharif* season of 2021-22 at the experimental Central Farm Balsa, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.). The experimental field was leveled and well drained. The soil was clayed in texture, low in nitrogen, medium in phosphorous and high in potassium and alkaline in reaction. The environmental condition prevailed during experimental period was favorable for normal growth and maturity of *Bt.* cotton hybrid.

The topography of the experimental plot was well uniform and levelled.

The soil was black in colour, deep and fairly well drained. The experiment was laid out in Split Plot Design with 3 replications and 12 treatments combination. The main plot consisted of three plant density D_1-90 cm x 45 cm (24,691 plant ha^{-1}), D_2-90 cm x 30 cm (37,037 plant ha^{-1}), and D_3-90 cm x 20 cm (55,555 plant ha^{-1}) and sub plot consisted of four weed management treatments W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing, W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS. W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding and W_4: Weedy check. Sowing was done on 8th July 2021 by dibbling the seeds. The recommended cultural practices and plant protection majors where undertaken. The crop was uprooted on 18th November 2021.

The plant density of D_1-90 cm x 45 cm (24,691 plant ha^{-1}) recorded significantly higher number of functional leaves $plant^{-1}$, leaf area $plant^{-1}$, monopodial and sympodial branches $plant^{-1}$, dry matter $plant^{-1}$, picked bolls and seed cotton yield $plant^{-1}$ as compare to plant density of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) and D_2-90 cm x 30 cm (37,037 plant ha^{-1}). The maximum plant height was observed with plant density of D_3-90 cm x 20 cm (55,555 plant ha^{-1}). The seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}), gross monetary returns (Rs ha^{-1}), net monetary returns (Rs ha^{-1}) and B:C ratio where recorded significantly higher with plant density of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) and D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and as compare to D_1-90 cm x 45 cm (24,691 plant ha^{-1}).

The observed weed species from monocot and broad leaved were *Cynodon dactylon*, *Commelina benghalensis* L., *Parthenium hysterophorus* L., *Phyllanthus niruri* L., *Digera arvensis* L., *Euphorbia hirta* L., *Alternanthera triandra* L., *Celosia argentea* L., *Dinebra retroflexa* L. and sedges *Cyperus rotundus* L. Among the weed species, broad leaved weed species were predomination in the experimental field.

All the growth parameters, yield attributing characters, seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}), net monetary returns (Rs ha^{-1}), gross monetary returns (Rs ha^{-1}) and B:C ratio where found significantly higher with the application of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3), as compare to pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4). Weed management treatments did not evident significant impact on quality parameters.

On the basis of one year investigation it can be concluded that the adoption of plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) performed very well by giving yield about 1767 kg ha^{-1} which was aided with treatment of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3), which were given higher seed cotton yield 2019 kg ha^{-1} with higher gross monetary return, net monetary return and B:C ratio found productive, remunerative and profitable under rainfed condition for Marathwada region in Maharashtra

.

(Key words: High density planting, *Bt*. cotton (*Gossypium hirsutum* L.), Weed control, Pre-emergence herbicide, Post-emergence herbicides.**)**

CHAPTER-I

INTRODUCTION

CHAPTER - I

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is one of the most important and commercial fibre crop. It is also known as the king of fibre as well as white gold. It plays an important role in textile industries and its mean of livelihood for millions of farmers and those concerned with its trade, processing, manufacturing and other allied industries.

The cotton crop provides raw material for many textile industry accounting for 26% of the total fibre production worldwide (Anonymous 2021). Cotton belongs to family *malvaceae* and the genus is *Gossypium*. It is a native to tropical and sub-tropical region of the old and new worlds. There are about 50 *Gossypium* species out of which only 4 species are cultivated and other 46 species are wild type, of which two are diploid *Gossypium arborium, Gossypium herbasium* (Asian cotton) and the other two are tetraploids *Gossypium hirsutum* (American cotton), *Gossypium barbadense* (Egyptian cotton), which are also cultivated in India (Anonymous 2016).

The major cultivar of cotton in the world *i.e.* China, India, Pakistan, Turkey, Uzbekistan, Brazil, Indonesia, America, Mexico and Myanmar. The cotton production in the world was 25,923 thousand metric tonnes (Anonymous 2020).

India is the second largest producer of cotton next to China. In India area under cotton is 120.69 lakh ha^{-1} with production of 362.18 lakh bales and the productivity is 510 Kg lint ha^{-1}. In India, Maharashtra stands first in area and production of cotton followed by Gujarat. Area in Maharashtra under cotton is 39.36 lakh ha^{-1} with production of 89.86 lakh bales and productivity is 388 Kg lint ha^{-1}. In Marathwada region area under cotton is 12.85 lakh ha^{-1} with production of 19.64 lakh bales and productivity 245 Kg lint ha^{-1} (AICRP on cotton 2021-2022).

Cotton is the livelihood for an estimated 60 million Indians including 6 million farmers, mostly use small and marginal. Cotton cropping provide 60% of the fibre used in Indian textile industries, supplies more than one million metric tonnes of cooking oil and another million metric tonnes of quality animal feed and 40 million metric tonnes of biomass in the form of cotton stalks. Global demand for cotton consumption continues to grow and was driven by the fibre demands of the fast growing world economies like India and China and the growing world population. It is estimated that, the global demand for cotton will be about 48 million metric tonnes by 2030 against from current levels of 25 million metric tonnes.

High Density Planting System (HDPS) are commonly followed to obtain high yield across the world, specially in the major cotton growing countries such as China, India, Brazil, USA, Australia and Uzbekistan (Anonymous 2020). High Density Planting System (HDPS) increases yield and improve the boll quality. The results in saving of labour cost and cost of cultivation. High Density Planting System (HDPS) is more relevant to India to establish sustainable production system. So, it was necessary to conduct experiment to know the effect of high density planting and weed management on growth and yield of *Bt.* cotton (*Gossypium hirsutum* L.).

HDPS will provide a soil canopy in about 30 days as compared to 60-75 days for conventional row widths, which will shade out weeds and reduce their competitiveness. In view of the above, present research work carried out with the objective to find out the effect of High Density Planting System (HDPS) and weed management practices on yield and quality of *Bt.* cotton.

Plant population is one of the most important factor for efficient utilization of available sources like light, soil moisture, nutrients and CO_2. Changed planting system has shown effect on yield of *Bt.* cotton. In wider spacing reduction in yield due to less plants unit area where as in closer planting system the yield is less due to competition between the plants. So there must be optimization of plant population for increasing production. Pathrikar *et al.* (2018) reported that the increased yield of *Bt.* cotton at closer plant spacing of 60 x 10 cm^2 as compare to 60 x 15 cm^2 and 60 x 30 cm^2.

As plant density increases the total communal demand for sunlight, water proper temperature, moisture, air and nutrients. The relative availability of each these inputs will help shape, the individual response of plant growing in competition with each other. Due to increase in population and limited land availability, it becomes necessary to increase our production target and it can be achieved through changed planting system.

Optimum cotton yield and quality for high density planting cotton requires good weed control throughout the growing season. The weeds can severely decrease cotton productivity and can negatively affect the lint quality. A number of weed species infest the cotton field includes such as *Cynodon dactylon* (L.) *Pers*., *Trianthema portulacastrum* L., *Convolvolus arvensis* L., *Cyperus rotundus* L.,

Conyza canadensis L. and *Sorghum halepense* (L.) *Pers*. can be quoted as the most important examples (Kalivas *et al.* 2012; Dogan *et al.* 2014). Four plants of *E. indica* in one meter row of cotton crop were found to decrease number of bolls plant^{-1} by 25% and the cotton yield by >20% (Xiao-Yan *et al.* 2015). High Density Planting System (HDPS) will provide a soil canopy in about 30 days as compared to 60-75 days for conventional row widths, which will shade out weeds and reduce their competitiveness. In view of the above, present research work carried out with the objective to find out the effect of High Density Planting System (HDPS) and weed management practices on yield and quality of *Bt.* cotton.

Cotton being a wide spaced and relatively slow growing crop during its initial growth stages, suffers from severe weed competition and causing substantial reduction in seed cotton yields losses to the extent of 6.2-59.4 per cent (Singh and Rathore 2015) weed species in cotton field differ widely due to soil and environmental conditions. Poonguzhalan and Gokila (2013) reported that seed cotton yield loss increased in the duration of competition and maximum loss occurred 96.5 per cent due to full season competition, seed cotton yield increased significantly with the increase in initial duration of weed free condition upto 80 DAS. Beyond 80 DAS seed cotton yield was reduced considerably due to lower boll setting percentage. Critical period of weed competition was found to be 20 to 60 DAS, weeds when allowed to compere with cotton, severely affected the growth and yield attributes, yield and resource use efficiency.

So, use of herbicides is one of the best options to avoid the competition from weeds during the critical period of crop growth. Pre-emergence use of pendimethalin will control the weeds in early stages and there by ensure efficient utilization of inputs put in by the farmers. The weed (annual and perennial) which appear in the later period of crop growth could be controlled by combining cultural method and post-emergence application of herbicides like pyrathiobac-sodium and quizalofop-ethyl. Thus, it would solve the weed problem prove quite efficient and economical.

Weed in cotton field can be effectively killed or paralyzed in its growth at the germination stage itself by the use of suitable herbicide. They are capable of giving the crop a relatively better weed competition is passed over. Pre-emergence use of pendimethalin will control the weed in early stage and there by ensure efficient

utilization of input in by the farmers. The weed (annual and perennial) which appear in the later period of crop growth could be controlled by combining cultural methods and post-emergence application of herbicide like pyrathiobac sodium and quizalofop ethyl. Thus, it would solve prove quite efficient and economical.

Weed control need to be maintained for many weeks after cotton emergence to achive maximum cotton yields. Weeds also interfere with harvesting of cotton and they may reduce lint qulity too and weed that emerge late in the season may cause problem with defoliation, interfere with picking, contaminate lint, cause staining on the lint and produce large amount of seed, causing problems in later years. Grass weed, such as nutgrass, which grow in the *Bt*. cotton seed are genetically modified seeds in which one or more gene is added to give higher yield and offer improved resistance against pest attact mainly bollworm complex. The genetic modification of cotton involves introduction of the *Bt*. bacterial gene that codes for proteins which kills the bollworm. Cotton crop is unable to express its full potential because of biotic and abiotic stresses encountered during its life cycle. Among biotic stresses, weeds cause several direct or indirect negative impacts viz., reducing fiber quality, crop yield, increasing production costs and serving as hosts and habitats for insect pest.

Taking note of the fact highlighted above, it is felt necessary to conduct an field experiment entitled "Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt*. cotton'' will planned at central farm, College of Agriculture, Parbhani (Maharashtra) India with the following objective.

1. To study the effect of high density planting on growth, yield and quality of *Bt*. cotton under high density planting
2. To study the effect of weed control on growth, yield and quality of *Bt*. cotton under high density planting.
3. To study the effect of different herbicides pre and post emergence on growth and yield.
4. To study the economics of different treatments.

CHAPTER-II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

In this chapter important and relevant findings on the research work conducted on *Bt*. cotton hybrid regarding agronomic manipulation viz. plant density and weed management and their effect on plant growth, development, yield attributes, quality and economics of *Bt*. cotton have been reviewed brief.

2.1 High density planting

2.1.1 Effect of high density planting on growth of *Bt.* cotton.

Gunasekaran *et al*. (2014) observed that the absence of monopodial branch envisages to accommodate more number of plants per unit area without competition for light. Further, that the bolls closer to the main stem received better nutrition and ultimately expected to produce lint of good quality. Production of fewer bolls is compensated by the accommodation of 6 - 10 plants m^{-2} row length.

Singh (2015) observed that plant height, sympods, boll weight and biomass were not significantly affected by plant geometries. However, monopods and bolls per plant differed significantly. Statistically higher number of bolls per plant (44.6) was recorded in plant geometry of 67.5×75 cm^2 over that 67.5×60 cm^2 (40.9).

Shekar *et al*. (2015) revealed that among plant densities, population at 37,037 plants ha^{-1} (90 x 30 cm) recorded significantly lower sympodial branches $plant^{-1}$ (19.81) and bolls $plant^{-1}$ (20.76) over that of 24,691 plants ha^{-1} (90 x 45 cm^2) and 18,518 plants ha^{-1} (90 x 60 cm^2).

Kumar *et al.* (2017) observed that in normal plant density (100%) was registered higher plant height (102.6 cm), no of sympodia (17.33 $plant^{-1}$), leaf area (27.02 dm^2) and dry matter weight (58.13 g $plant^{-1}$) but higher leaf area index (3.430) was recorded with higher plant density (200%).

Parihar *et al.* (2018) observed that taller plant height, maximum leaf area index and crop growth rate was found with higher plant densities. Whereas more leaf area and total dry matter production were increased with decreased plant densities. Similar trend was obtained with seed cotton yield (g) $plant^{-1}$ and single boll weight. The highest seed cotton yield (2428.89 kg ha^{-1}) was recorded with high density, during both seasons.

Maheswari *et al*. (2019) resulted that the sympodia plant^{-1} was higher under 75 x 30 cm^2 plant spacing and it was significantly superior over rest of the plant spacings during both the years of study. The increase in number of sympodia plant^{-1} under wider spacing of 75 x 30 cm^2 was mainly due to availability of adequate amount of nutrients, moisture and higher light interception which resulted in optimum growth and development leading to production of more number of sympodia plant^{-1}.

Singh *et al.* (2020) noted that plant height was found significantly higher in closer spacing whereas monopodial branches plant^{-1} (1.73, 1.60), sympodial branches plant^{-1} (16.66, 12.33), bolls plant^{-1} (20.33, 17.44), average boll weight plant^{-1} (3.30, 3.23), seeds plant^{-1}(452.99, 411.66) and lint weight (g) plant^{-1} (17.61, 14.02) were recorded higher in 80 x 80 cm^2 followed by 60 x 60 cm^2, and 30 x 30 cm^2.

Solanki *et al.* (2020) observed that significantly maximum plant population and plant height were noted when crop was sown at closer paired row spacing of (S_1) (60 x 30 cm^2) during individual years and in pooled results, accordingly. *Bt.* cotton sown at wider spacing of (120 x 45 cm^2) (S_2) recorded maximum sympodial branches, least number of monopodial branches per plant^{-1}, maximum number of bolls and boll weight during individual years.

Thakur (2020) noted that the plant density, spacing of 90 x 60 cm^2 recorded more monopodia and sympodia, maximum, picked bolls and seed cotton yield plant^{-1} than 90 x 45 cm^2. On the contrary higher plant density under 90 x 45 cm^2 spacing increased plant height, LAI, FPE and seed cotton yield kg ha^{-1}.

2.1.2 Effect of high density planting on yield of *Bt.* cotton.

Shukla *et al*. (2014) observed that a closure spacing (60 x 90 cm^2) exhibited its superiority by recording higher sympodial branches plant^{-1} (16.4), lint yield (345 kg ha^{-1}) and seed cotton yield (910 kg ha^{-1}), whereas bolls picked plant^{-1} (12.9) and seed cotton yield plant^{-1} (38.2 g) were higher under wider spacing (90 x 60 cm^2).

Pandagale (2015) observed that plant geometry 120 x 45 cm^2 recorded highest growth, yield attributing characters, seed cotton yield (2395 kg ha^{-1}) and net returns (Rs. 43,148 ha^{-1}) followed by plant geometry of 150 x 30 cm^2.

Paslawar *et al. (*2015) observed that less number of bolls and boll weight was observed in dense planting, whereas more bolls and boll weight were found in wider spacing 60 × 15 cm^2. Leaf Area Index (LAI) was highest with dense plant population 2.22 lakh ha^{-1} during 2012-13 and 2013-14 respectively with 2.22 lakh ha^{-1}. Also concluded that seed cotton yield was significantly highest with 45 × 10 cm^2 (3218 and 3008 kg ha^{-1}) and which was at with 60 × 15 cm^2 (2916 and 2128 kg ha^{-1}) during both the years of experimentation. Similar results were noticed with biological yield. Due to higher plant density utilised all natural resources like solar radiation, moisture, nutrients and space

Divya *et al*. (2016) revealed that among the plant spacing, 120 × 45 cm^2 with improved production technologies recorded highest seed cotton yield (4226 kg ha^{-1}) which was significantly superior over plant spacing 120 × 90 cm^2, 150 × 60 cm^2 followed by 120 × 60 cm^2 and also on par with spacing of 150 × 45 cm^2 along with improved production technologies.

Khargkharate *et al.* (2017) conducted the field experiment during *Kharif* season 2012 and 2013 at Farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to evaluate the Effect of high plant density and nutrient management and moisture conservation practices on economics and nutrient uptake of *Hirsutum* cotton. The result revealed that plant density 1,66,666 plants ha^{-1} at spacing (60 x 10 cm^2) record highest gross monetary returns (Rs. 99,157 ha^{-1}) but plant density of 1,11,111 plant ha^{-1} at spacing (60 x 15 cm^2) recorded highest net monetary return and BC ratio (Rs. 58814 ha^{-1} and 2.61) in pooled analysis and highest uptake of nutrients of N, P_2O_5 and K_2O recorded with plant density of 1,66,666 plants ha^{-1}.

Nagender *et al.* (2017) observed that the plant densities, during 2015 and 2016 even though the plant density of P_1: 18,518 plants ha^{-1} showed more number of bolls $plant^{-1}$ (42, 40), boll weight (5.16, 5.0 g) and harvest index (43.3, 41.2 per cent) but the plant density of P_2: 55,555 plants ha^{-1} significantly more kapas yield (3319, 2726 kg ha^{-1}). However, remaining two plant densities P_1: 18,518 plants ha^{-1} and P_3: 1,48,148 plants ha^{-1} were shown comparable yields.

Pradeep *et al.* (2017) concluded that significantly higher number of picked bolls plant^{-1} (15.56) and seed cotton yield plant^{-1} (25.67 g) were under wider plant spacing of 45 x 30 cm^2 of *arborium* cotton due to large ground area for development of individual plant in wider plant spacing. Also concluded that sowing of cotton at 45 x 15 cm^2 plant spacing produced considerably highest seed cotton yield (2063 kg ha^{-1}). At 60 x 10 cm^2 spacing seed cotton yield (1798 kg ha^{-1}) was decreased because the reduction in yield plant^{-1} due to both inter-plant and intra- plant competition for resources was more than compensated by increase in the number of plants per unit area.

Meena and Kumhar (2017) conducted a field experiment at Agricultural Research Station, Borwat Farm, Banswara during *kharif* -2010 to find out the two plant geometries (90 x 60 cm^2 and 90 x 45 cm^2). The maximum seed cotton yield (1754 kg ha^{-1}) was observed under wider plant geometry of 90 x 60 cm^2 than closer plant geometry of 90 x 45 cm^2. Though, yield attributing parameters such as bolls plant^{-1} and boll weight were statically improved in wider as compared to closer spacing it could be increase the seed cotton yield.

Pathrikar *et al.* (2018) recorded that the highest seed cotton yield (kg ha^{-1}) was recorded in higher plant density 1,66,666 plants ha^{-1} (60 × 10 cm^2) as compare to 55,555 plants ha^{-1} (60 × 30 cm^2) and 1,11,111 plants ha^{-1} (60 × 15 cm^2).

Ganvir *et al.* (2019) conducted a field experiment during *kharif* seasons of 2013-14 and 2014-15 at Research farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola the number of picked bolls plant^{-1} were significantly highest in plant density of 60 X 15 cm^2 (1,11,111 plants ha^{-1}, P_1). The number of picked bolls in plant density of 60 X 10 cm^2 (1,66,666 plants ha^{-1}, P_2) was 16.7 per cent less than P_1 which was statistically equal with the plant density of 45 X 10 cm^2 (2,22,222 plants ha^{-1}, P_3) with 22.4 per cent less bolls than P_1 and 6.8 per cent less than P_2 during 2013-14. Similar trend prevailed during 2014-15 but P_2 too proved significantly more over P_3. The reduction in number of bolls in P_2 and P_3 were 17.6 and 27. Per cent, respectively.

Veeraputhiran (2020) observed that the spacing of 75 x 30 cm^2 recorded significantly more bolls production and higher seed cotton yield than the wider spacing of 75 x 45 cm^2 during both the years of study. The effect of both 125 (100:50:50 NPK kg ha^{-1}) and 100 (80:40:40 NPK kg ha^{-1}) percent RDF on a number of bolls m^{-2} was on par. Application of 125 (100:50:50 NPK kg ha^{-1}) per cent RDF registered comparable seed cotton yield during 2017-18 and significantly higher than 100 (80:40:40 NPK kg ha^{-1}) percent RDF during 2018-19.

10.1.3 Effect of high density planting on quality of *Bt*. cotton.

Arunvenkatesh and Rajendran (2015) observed that the fibre quality parameters viz., fibre length, fibre strength, micronaire, elongation percentage were significantly influenced by different cotton genotypes. The oil content and fibre quality was not significantly influenced by plant densities.

Gacche and Gokhale (2017) recorded that ginning percentage, seed index and other quality parameters 2.5 per cent span length bundle strength and fibre fineness were not affected due to either planting spacing.

Madavi *et al.* (2017) observed that growing *Bt.* cotton at plant density of 1,11,111 plants ha^{-1} normal planting by adopting spacing of 60 x 15 cm^2, without significant effect on lint index, ginning per cent and seed index was found to be effective to get significantly higher kapas yield (3134 kg ha^{-1}).

Pradeep *et al.* (2017) observed that quality characters *viz.* ginning percentage, lint index and harvest index were not significantly influenced by various spacing under study.

Pandagale *et al*. (2018) resulted that the ginning out turn was not statistically differed due to plant geometry and number of plants $hill^{-1}$. Similar results for plant geometry were reported during 2008-10 by Pandagale *et al.* (2015).

2.1.4 Effect of high density planting on economics.

Manjunatha *et al.* (2014) resulted that the Mallika *Bt*. hybrid recorded significantly higher gross returns, net returns and B:C ratio (Rs. 1,52,640 ha^{-1}, Rs. 1,01,612 ha^{-1} and 2.97, respectively as compared to other hybrids. However, these were on par with Brahma *Bt.* (Rs. 1,50,223 ha^{-1}, Rs. 99,409 ha^{-1} and 2.93, respectively).

Veeraputhiran (2020) concluded that the genotypes GSHV 177 and CCH 15-1 registered higher total income, net income, and Benefit-Cost ratio (B.C ratio) than BGDS 1033 and CCH 14-1.

2.2. Weed management

2.2.1 Weed flora in cotton

Bharathi *et al*. (2011) conducted experiment at Regional Agriculture Research Station, Lam Guntur, (A.P.) during 2008-10 and reported that *Cyprus rotundus*, *Commalina bengalensis*, *Corchorus acutangulus*, *Amaranthus iridis*, *Butilon indicum*, *Phyllanthus niruri*, *Celosia argentia*, and *Parthenium spp*. were dominated in cotton filed.

Nalini *et al.* (2011) weed flora of the experimental field was taken at 30 DAS in the control plot. Seventeen weeds were observed in the experimental fields and out of the 17 weeds observed, *Cynodon dactylon* and *Dactyloctenium aegypticum* were the dominant grasses, *Cyperus rotundus* was the only sedge and *Trianthema portulacastrum*, *Digera arvensis* and *Parthenium hysterophorus* were the predominant broad leaved weeds.

Memon *et al*. (2014) carried out for the composition of weed flora of cotton crop of Khairpur district, Sindh, Pakistan. Thirty six weed species belonging to 16 families were noted. Poaceae was found to be most dominant family representing seven species followed by Asteraceae and Papilionaceae, each with five species. There are some species *Alhagi maurorum, Amaranthus virdis, Atylosia platycarpa, Bergia aestivosa, Brachiaria eruciformis, Celosia argentea, Cenchrus ciliaris, Cleome viscosa, Convolvulus arvensis, Conyza bonariensis, Corchorus aestuans, Corchorus tridens, Cressa cretica, Crotalaria medicaginea, Cucumis melo, Cynodon*

dactylon, Cyperus rotundus, Dactyloctenium aegyptium, Desmostachya bipinnata, Digeria muricata, Eclipta prostrata, Euphorbia serpens, Ipomoea aquatica, Launaea procumbens, Mukia maderaspatana, Oxystelma esculentum, Phragmites australis, Phyla nodiflora, Physalis peruviana, Pluchea lanceolata, Sesbania bispinosa, Setaria pumila, Tephrosia villosa, Trianthema portulacastrum, Tribulus terrestris, Xanthium stromarium.

Ozaslan *et al.* (2015) conducted survey results showed that the most common weeds in cotton production fields were *Xanthium strumarium* L. (common coclebur), *Sorghum halepense* (L.) *Pers*. (Johnsongrass), *Amaranthus retroflexus* L. (common amaranth), *Cynodon dactylon* (Bermudagrass), *Physalis spp*. (ground cherry) [*Physalis philadelphica* Lam. (Mexican groundcherry) and *Physalis angulata* L. (cutleaf groundcherry)] , *Solanum nigrum* L. (black nightshade), *Portulaca oleracea* L. (purslane), *Cyperus rotundus* L. (nutgrass).

Kumar (2015) revealed that diverse weed flora associated with *Bt.* cotton crop was observed in experiment field in weed check. The observed weed species from monocot and broad leaved were *Cynodon dactylon Pers, Commelina benghalensis* L., *Eichnochloa Colonum* L., *Cynotis spp, Paethenium hysterophorus* L., *phyllanthus niruri* L., *Convolvulus arvensis* L., *Digera arvensis* L., *physalis minima* L., *Euphorbia hirta* L., and sedges *Cyperus rotundus* L. in the experimental field at M. P. K.V., Rahuri (M.S.).

Jabran (2016) reported in a cotton field that was infested with three different types of weed, sedges, grasses and broad leaves can be noted to compete with cotton crop. The most important weeds in cotton crop include *Amaranthus palmeri* S. Watson, *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Chenopodium album* L., *Convolvulus arvensis* L., *Cucumis melo* L., *Cynodon dactylon* (L.) Pers., *Conyza canadensis* (L.) Cronquist, *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., *Portulaca oleracea* L., *Solanum nigrum* L., *Sorghum halepense* (L.) Pers., and *Xanthium strumarium* L. as major weed flora in the experiment plot in *Bt.* cotton at Department of Plant Protection, Adnan Menderes University Aydin, Turkey.

Chaudhari *et al.* (2017) observed that pre-dominant weed in cotton at Anand, Gujarat were *Eleusine indica, Commelina benghalensis, Eragrostis major*, *Digitaria sanguinalis* and *Cyperus iria* among the monocot and *Digera arvensis, phyllanthus niruri Euphorbia hirta, Oldenlandia umbellate* and *Boerhavia diffusa* among dicot.

Nakala *et al.* (2019) conducted a field experiments at Professor Jayashankar Telangana State Agricultural University, Rajendranagar during kharif 2017 for the evaluation of diuron in two different soils. The weed flora of the experimental field in red soil was dominated by *Cynodon dactylon*, *Rottboellia exaltata*, *Parthenium hysterophorus*, *Trianthema portulacastrum* and *Commelina benghalensis*. While in case of black soil predominant flora was *Cynodon dactylon, Cyperus rotundus*, *Parthenium hysterophorus*, *Euphorbia geniculata*, *Tridax procumbens*, *Cyanotis cristata*, *Digera arvensis* and *Celosia argentea*.

2.2.2 Crop Weed Competition

Ayyadurai and Poonguzhalan (2010) carried out an experiment to determine the critical period of crop weed competition in zero-till cotton (*Gossypium hirsutum* L.) during the summer season of 2007, at Karikal and revealed that keeping the field weed free for first 40 days reduced the weed dry weight by 50 per cent. Critical period of weed-competition was found to be 20 to 60 DAS.

Ayyadurai and poonguzhalan (2011) carried out an experiment to determine the critical period of crop weed competition in cotton (*Gossypium hirsutum*. L.) during the summer season (Febuary to July) of 2007. Twelve treatments consisting of weed free and weedy periods at 20, 40, 60, 80 and 100 DAS and at harvest along with a weedy and weed free check were arranged in randomized block design with three replications. The predominant weed species in the experimental field were *Echinochola colona, Leptochloa chinensis, Cyperus rotundus, Trianthema portulacastrum*, *Rotala densiflora*, *Eclipta alba* and *Phyllanthus maderaspatensis*. Seed cotton yield loss increased in the duration of competition and maximum loss (96.5 per cent) occurred due to full season competition. Seed cotton yield increased significantly with the increase in initial duration of weed free condition upto 80 DAS. Beyond 80 DAS, seed cotton yield was reduced considerably due to lower boll setting percentage. Critical period of weed competition was found to be 20 to 60 days after sowing.

Poonguzhalan and Gokila (2013) reported that seed cotton yield loss increased in the duration of competition and maximum loss occurred 96.5 per cent due to full season competition, seed cotton yield increased significantly with the increase in initial duration of weed free condition upto 80 DAS. Beyond 80 DAS seed cotton yield was reduced considerably due to lower boll setting percentage. Critical period of weed competition was found to be 20 to 60 DAS, weeds when allowed to compare with cotton, severely affected the growth and yield attributes, yield and resource use efficiency.

Tursun *et al*. (2015) reported that regardless of the nitrogen application rate, the relative yield of cotton decreased with increasing duration of weed interference and increased with increasing duration of weed free period. Weed free condition need to be established as early as one week after crop emergence and maintained as late as eight weeks after crop emergence to avoid more than 5 per-cent loss in cotton yield.

Ramachandra *et al*. (2016) reported that in India the first GM crop to be introduced was *Bt*. cotton. In the current planted with *Bt*. cotton is 93 per cent of the cotton acreage. However, the average yield is lower than of other countries suggesting on opportunity to increase yield further. One of the major factor affecting yield is weed competition which reduces yield by 50 to 85 per cent.

Tariq *et al*. (2020) the weeds are becoming a major challenge for cotton production across the world, and the crop is infested by broad leaves, grasses, and sedges. Although the presence of weeds is deleterious for potential yield, the extent of losses depends on weed type, density, duration, and crop growth stage. Some weeds like *Datura stramonium* L., *Amaranthus palmeri* L., *Amaranthus retroflexus* L., and *Ambrosia trifida* L. cause significant yield losses at very low densities in comparison with *Cucumis melo* L. and *Eleusine indica* L. The cotton crop is very sensitive at early growth stages where weed presence during the first 2 months of growth may reduce yield from 10 to 90 per cent.

2.2.3 Effect of weed control on growth of *Bt.* cotton.

Singh and Rathore (2015) conducted a field experiments during 2012 and 2013 to evaluate the efficacy of different herbicides for weed management in cotton. Highest seed cotton yield (3537.3 kg ha^{-1}) was recorded in weed free plots followed by pendimethalin @1.0 kg a.i. ha^{-1} as pre-emergence + quizalofop-ethyl @50g a.i. ha post emergence at 2-4 weed leaf stage + one hoeing (3318.9 kg ha^{-1}) owing to improved number of bolls per plant and boll weight.

Leela Rani *et al*. (2016) carried out the field experiment at college farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif*, 2014 with ten weed management practices with an object to find out the most effective weed management practice in *Bt*. cotton. Uncontrolled weed growth during crop growing season resulted in yield loss of upto 86 per cent. Increased yield of 62.6 to 85.9 per cent was observed with various weed management practices. More number of boles per plant (23) kapas yield $plant^{-1}$ (92 g $plant^{-1}$) and kapas yield (1427 kg ha^{-1}).

Shahzad *et al*. (2017) evaluated to the influence of different sowing methods and planting densities on growth, yield, quality and economic returns of cotton. Sowing methods included pit planting (1 × 1 m^2 pits), bed planting (75 cm apart beds), ridge planting (75 cm apart ridges) and line sowing with varied inter row spacing (25, 50 and 75 cm). Sowing methods significantly affected growth and yield of cotton. Pit planting imposed maximum increase in plant height (152 cm), number of monopodial branches (4.7) and sympodial branches (22.6) per plant, number of unopened (9.4) and opened bolls (41.1) per plant, and average boll weight (3.0 g) of cotton. However, highest seed cotton yield (2944.5 kg ha^{-1}).

Madavi *et al*. (2017) noted that among the plant densities, the plant density of 1,11,111 plants ha^{-1} normal planting (60 x 15 cm^2) produced significantly more kapas yield (3134 kg ha^{-1}), reduced weed dry matter with higher weed control efficiency (61.88 per cent) as against high plant density of 1, 11,111 plants ha^{-1} paired row planting and 1, 48,148 plants ha^{-1}. Among the weed management practices, pre-emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of

pyrithiobac sodium 62.5 g ha^{-1} + quizalofop-ethyl 50 g ha^{-1} at 20, 40 and 60 DAS recorded more kapas yield (3119 kg ha^{-1}), with higher weed control efficiency (73.24 per cent) with reduced weed dry matter.

Aslam *et al*. (2018) conducted a field experiment at Adaptive Research Farm during the year 2016 and 2017 of Rahim Yar Khan District. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The various planting methods i.e (flat sowing, ridge sowing and bed sowing) significantly affected the plant population m^2, plant height (cm), number of mature bolls $plant^{-1}$, seed cotton boll weight (g), and seed cotton yield kg ha^{-1}. The various planting methods was significantly affected almost all the characters related to growth and yield of *Bt*. cotton variety IUB-2013. The average of two years result revealed that significant maximum plant population m^2 i.e 6.8, plant height (cm) i.e 147.9, number of bolls $plant^{-1}$ i.e 43.9, boll weight (g) i.e 3.1 and maximum seed cotton yield i.e 2168.6 kg ha^{-1} was obtained when cotton sown on ridges compared with flat and bed sowing.

Tariq *et al*. (2018) conducted a field experiment to compare the performance of pre and post-emergence herbicides for grassy and broadleaf weeds in cotton. The maximum number of bolls per plant (22.1), boll weight (3.02 g), seed cotton yield (2099 kg ha^{-1}) and economic returns (Rs. 47,638 ha^{-1}) were recorded with S- metolachlor application.

Khan *et al*. (2021) revealed that ridge sowing of cotton reduced the weed density by 25 per cent in comparison to flat sowing. However, bed sowing of cotton increased the sympodial branches, opened bolls $plant^{-1}$, lint yield, seed index, and seed cotton yield by 48, 52, 38, 39, and 50 per cent respectively as compared to flat sowing. Higher planting density found to be more efficient in weed reduction, however, lower planting density improved the monopodial branches (18 per cent), total bolls $plant^{-1}$ (14 per cent), boll weight (16 per cent), seed index (17 per cent), and seed cotton yield (23 per cent) than higher planting density.

10.2.4 Effect of weed control on yield of *Bt.* cotton.

Rao (2011) conducted the field experiment during *kharif* 2009-10 and 2010-11 at Regional Agricultural Research Station, Lam, Guntur (A.P.). He reported that post emergence application of pyrithiobac sodium 32 g + quizalofop-ethyl 25 g ha^{-1} recorded the lowest weed dry weight and highest seed cotton yield (2270 kg ha^{-1}).

Ikram *et al*. (2012) reported that all the herbicides significantly reduced the density and dry weight of *Cyperus rotundus* and *Trianthema portulacastrum* compared to control. Among the various herbicides pyroxasulfone + pendimethalin @ 75 + 910 g a.i. ha^{-1} resulted in minimum weed density (*C. rotundus* 1.75 and *T. portulacastrum* 6.50 m^{-2} at harvest), dry weight (*C. rotundus* 2.09 g m^{-2} at harvest) and resulted in the maximum seed cotton yield (2284.19 kg ha^{-1}).

Ali *et al*. (2013) conducted a field experiments during 2006 and 2007 to develop an effective integrated method of weed control for conventional flat-sown cotton. Highest seed cotton yields 2578 and 3613 kg ha^{-1} were recorded with application of pendimethalin in combination with Inter-culturing + hand-weeding, followed by 2468 and 3396 kg ha^{-1} with application of pendimethalin in combination with hand-weeding during 2006 and 2007, respectively.

Patel *et al.* (2014) conducted a field experiment during *kharif* seasons of the years 2010, 2011 and 2012 at DWSR- Anand Center, B. A. College of Agriculture, Anand Agriculture University, Anand (Gujarat) to study the performance of different weed management practices on weed and yield of *Bt.* Cotton. results revealed that inter-culturing and hand weeding carried out at 15, 30 and 45 DAS recorded the minimum weed dry weight of monocot, dicot and total weeds at 25 DAS and at harvest with maximum seed cotton yield (3127 kg ha^{-1}) as well as additional profit over control (46367 kg ha^{-1}).

Hiremath *et al*. (2014) conducted a field experiment during the growing season of 2012-13 at Agricultural College Farm, Bheemarayanagudi, Shahapur (Karnataka) under UKP command area to develop effective weed management strategy in *Bt.* Cotton. The experiment comprised of 14 treatments

having two PRE (diuron, pendimethalin) and five POST (propaquizalofop, quizalofop p tefuryl, fenoxaprop p ethyl, quizalofop-ethyl and pyrithiobac sodium applied twice at 20 and 40 DAS individually or in sequence with pendimethalin PRE) herbicides and weedy and weed-free check. Pyrithiobac sodium 10 EC used alone twice or in sequence with pendimethalin PRE recorded lower weed dry weight and higher weed control efficiency throughout. Of all the herbicidal treatments, pendimethalin 38.7 CS @ 1.5 kg a.i. ha^{-1} PRE fb pyrithiobac sodium 10 EC @ 1.25 kg a.i. ha^{-1} POST + IC at 60 DAS recorded the lowest weed dry matter, weed index, nutrient depletion, highest seed cotton yield (2569 kg ha^{-1}).

Pawar *et al.* (2015) conducted a field experiment at Farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapith, Akola (M.S.), the results indicated that application of pyrithiobac sodium 10 EC @ 0.062 kg a.i. ha^{-1} PoE *fb* quizalofop-ethyl 10 EC @ 0.075 kg a.i. ha^{-1} PoE 20-25 DAS + hoeing at 45 DAS was superior over rest of the weed control treatments as regards all yield attributing traits namely weight of number of balls picked $plant^{-1}$, seed cotton $plant^{-1}$ and seed index revealing the beneficial effect of weed free environment resulting in no competition between weed and crop plant.

Kumar *et al*. (2016) conducted field experiment during *kharif* season of 2012 and 2014 at C. S. Azad University of Agriculture and Technology, Kanpur to study the effect of different uses of herbicide on growth and yield attributes and seed cotton yield in *hirsutum* cotton. Dada indicated that application of pendamithalin @1 kg a.i. ha^{-1} as PE + quizalofop-ethyl @50 g a.i. ha^{-1} 30 DAS + one hoeing 50 DAS and weed free plot improved significantly all the growth and yield attributes characters over weedy check. Weed free check plot produced significantly highest seed cotton yield (1311 kg ha^{-1}) and lint yield (442 kg ha^{-1}) than weedy check.

Anmulwad *et al*. (2017) conducted a field experiment during the rainy season of 2014-2015 on Vertisol, to study the effect of different pre and post emergence weedicides on high density planting system (HDPS) cotton among the tested weedicides, the highest seed cotton yield (1741 kg ha^{-1}) was recorded with weed free check followed by pendimethalin 38.7 EC PE @ 1.25 kg a.i. ha^{-1} fb hoeing at 30 DAS and one hand weeding at 45 DAS.

Kaur *et al.* (2019) conducted a field experiment over two consecutive cropping seasons at Punjab Agricultural University (PAU), Ludhiana, India. Pyrithiobac sodium plus quizalofop-ethyl at 100 – 125 g ha^{-1} significantly reduced density and dry biomass of annual grasses and broadleaved weeds in both years; it gave effective control (>88%) of *Trianthema portulacastrum* L., *Dactyloctenium aegyptium*, *Digitarias anguinalis* and *Acrachner acemosa*, fair to good control (<80%) of *Digera arvensis* and no control of *Cyperus rotundus*. Pyrithiobac sodium plus quizalofop-ethyl at 125 g ha^{-1} gave the highest seed cotton yield (2226 – 2367 kg ha^{-1}).

Nandagavi and Halikatti (2021) conducted a field experiment for two years during *kharif* 2011-12 and 2012-13 to study the bio efficacy of sequential application of herbicides in *Bt.* Cotton. Ten weed control treatments were tested in randomised block design and they were replicated thrice. The mean of two years data indicated that, all the herbicide treatments significantly reduced dry weight of weeds over unweeded control. Among the herbicide treatments sequential application of pyrithiobac sodium at 0.125 kg ha^{-1} as pre-emergence followed by (fb) pyrithiobac sodium at 0.125 kg ha^{-1} as post emergence, butachlor at 1.5 kg ha^{-1} fb butachlor at 1.5 kg ha^{-1} and pendimethalin 38.7 per cent CS 0.68 kg ha^{-1} fb pendimethalin 38.7 per cent CS 0.68 kg ha^{-1} were quite effective in controlling weeds which reflected in significantly decreased weed dry weight and increased weed control efficiency. These three herbicide treatments also recorded significantly higher yield (2863, 2830 and 2725 kg ha^{-1}, respectively).

10.2.5 Effect of weed control on quality of *Bt.* cotton.

Smith *et al.* (2000) reported that the Palmer amaranth on mechanical harvesting, ginning, and fiber quality in dryland cotton was documented. Only the highest Palmer amaranth density (3,260 weeds ha^{-1}) reduced lint and seed yields.

Deshmukh *et al*. (2013) reported that the quality parameters of cotton seed were not affected significantly due to various herbicidal treatments. The quality parameters viz. oil (16.98 per cent) and protein (23.00 per cent) was maximum with treatment 03 hoeing and 03 hand weedings (T_6) followed by treatment of application of Pyrithiobac sodium @ 62.5 g. a. i. ha^{-1}.

Hakoomat *et al.* (2017) revealed that among the weed management practices, manual weeding significantly improved GOT percentage (43.2 and 42.3 per cent) than other weed control treatments followed by S-metolachlor + glyphosate (40.8 and 40.7 per cent) and pendimethalin + glyphosate (40.3 and 40.4 per cent). All other treatments gave non-significantly higher percentages of ginning out turn than control treatment.

10.3 Performance of herbicides for weed control on *Bt.* cotton

10.3.1 Pendimethalin

Madhu *et al.* (2014) conducted a field experiment during *kharif*, 2011 at the Agricultural College Farm, Bapatla to study the economics of rainfed *Bt.* cotton as influenced by sequential application of herbicides. Results indicated that higher weed control efficiency, bolls plant^{-1}, seed cotton yield, net returns and benefit cost ratio were found with the farmer's practice. Among the herbicidal combinations, pre-emergence application of pendimethalin @ 1.5 kg a.i. ha^{-1} followed by post emergence application of pyrithiobac @ 63 g a.i. ha^{-1} resulted in higher weed control efficiency, bolls plant^{-1}, seed cotton yield, net returns and benefit cost ratio.

Veeraputhiran and Srinivasan (2015) estimated that the higher total income and net income were associated with pre-emergence application of pendimethalin followed by postemergence application of quizalofop-ethyl + one hoeing, post-emergence application of pyrithiobac sodium + quizalofop-ethyl + one hoeing and pre-emergence application of pendimethalin + 1 hoeing in both the years of study.

Singh *et al*. (2016) conducted field experiment to evaluate weed control efficiency of different herbicides for weed management and their effect on cotton crop. Weed control efficiency was highest under weed free check i.e. 90.3 per cent followed by pendimethalin @ 1.0 kg ha^{-1} + quizalofop-ethyl @ 50 g ha^{-1} + one hoeing 71.0 per cent, where as minimum for weedy check 25.5 per cent.

Malarkondi (2017) concluded that the integrated weed management practices like, application of PE pendimethalin at 1.0 kg ha^{-1} + power weeding on 40 DAS recorded higher seed cotton yield and economic return.

Hariharasudhan (2017) conducted a field experiment at Tamil Nadu Agricultural University, Coimbatore during 2015-16 to evaluate efficacy of pre and post emergence herbicides response to weeds and cotton productivity in varied environment condition. Result indicate that pre-emergence pendimethalin 38.7 per cent CS followed by post-emergence pyrithiobac sodium 5 per cent EC 62.5 g ha^{-1} recorded lower weed density (80.6 m^{-2}) dry weight (42.7 g m^{-2}) and higher weed control efficiency (86.0 per cent) at 40 DAS in 1st August sowing. Higher weed density and weed dry weight drastically increased in beyond 15th August sowing. Better growth, higher yield parameters and seed cotton yield.

Kalyani *et al*. (2018) carried out a field experiment for tow consecutive years at the Research Farm of Regional Agriculture Research Station, Nandyal during *Kharif* 2016-17 and 2017-18 with an objectives to find out the effective and economic method of weed control in *Bt*. Cotton. among different herbicide application, pendimethalin 1.0 kg ha^{-1} as pre-emergence fb glyphosate 1.0 kg ha^{-1} as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS were significantly superior in reducing weed density and dry weight of weeds.

Kalaisudarson and Srinivasaperumal (2019) conducted a field experiment during winter season 2015 at Annamalai University Experimental Farm, Annamalai nagar, to study the effect of chemical method on weed management in hybrid cotton. Results of the experiment, it can be concluded that combined application of pre-emergence herbicide pendimethalin 0.68 kg ha^{-1}+ post emergence herbicide paraquat 0.75 kg ha^{-1} on 40 DAS is the most remunerate approach for obtaining higher seed cotton yield and maximum economic returns in hybrid cotton besides obtaining broad spectrum weed control throughout the crop growth period.

Shekara *et al*. (2020) noted that the seed cotton yield was significantly influenced by weed management practices. Among herbicidal treatments, pendimethalin (38.75 EC) @ 0.75 kg a.i. ha^{-1} followed by Glyphosate @ 1.0 kg a.i.

ha^{-1} as directed spray at 2 - 4 leaf stages of weed, significantly recorded higher seed cotton yield (1750 kg ha^{-1}), which was on par with tank mixture of pyrithiobac sodium (10 SC) @ 62.5 g a.i. ha^{-1} + quizalofop-ethyl (5 EC) @ 37.5 g a.i. ha^{-1} at 2 to 4 leaf stages of weeds (1702 kg ha^{-1}) and superior over pendimethalin (38.75 EC) @ 0.75 kg a.i. ha^{-1} at 3 DAS (1335 kg ha^{-1}). The weedy check recorded lower seed cotton yield (550 kg ha^{-1}).

10.3.2 Pyrithiobac sodium

Pawar *et al*. (2015) conducted a field experiment at Farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra), India; during *Kharif* season 2013-14. The results indicated that 1 Hoeing at 20 DAS fb Glyphosate 41SL @ 1.00 kg a.i. ha^{-1} 45-55 DAS proves better in controlling weed, dry matter accumulation, weed control efficiency. Fenoxyprop ethyl 10EC @ 0.1 kg a.i. ha^{-1} PoE 20-25 DAS + hoeing at 45 DAS recorded the maximum plant height (121.73 cm), number of functional leaves $plant^{-1}$ and leaf area per plant and maximum dry matter accumulation $plant^{-1}$ recorded in farmers practice (2H + 1HW). Application of Pyrithiobac sodium 10EC @ 0.062 kg a.i. ha^{-1} PoE fb Quizalofop-ethyl 10EC @ 0.075 kg a.i. ha^{-1} PoE 20-25 DAS + hoeing at 45 DAS was superior over rest of the weed control treatments as regards all yield attributing traits and seed cotton yield + cotton stalk yield (kg ha^{-1}).

Hiremath *et al*. (2014) conducted a field experiment during the growing season of 2012-13 at Agricultural College Farm, Bheemarayanagudi, Shahapur (Karnataka) under UKP command area to develop effective weed management strategy in *Bt.* Cotton. The experiment comprised of 14 treatments having two PRE (diuron, pendimethalin) and five POST (propaquizafop, quizalofop p tefuryl, fenoxaprop p ethyl, quizalofop-ethyl and pyrithiobac sodium applied twice at 20 and 40 DAS individually or in sequence with pendimethalin PRE) herbicides and weedy and weed-free check. Pyrithiobac sodium 10 EC used alone twice or in sequence with pendimethalin PRE recorded lower weed dry weight and higher weed control efficiency throughout. Of all the herbicidal treatments, pendimethalin 38.7 CS @ 1.5 kg a.i. ha^{-1} PRE fb pyrithiobac sodium 10 EC @ 1.25 kg a.i. ha^{-1} POST + IC at 60 DAS recorded the lowest weed dry matter, weed index, nutrient depletion, highest

seed cotton yield (2569 kg ha^{-1}) and gross returns (107885 Rs. ha^{-1}). Pendimethalin 38.7 CS PRE followed with quizalofop-ethyl 5 EC @ 0.05 kg a.i. ha^{-1}or propaquizalofop 10 EC @ 0.1 kg a.i. ha^{-1} at 30-35 DAS were the next efficient treatments.

Kaur *et al*. (2019) conducted a field experiment at Punjab Agricultural University (PAU), Ludhiana, India. Pyrithiobac sodium plus quizalofop-ethyl at 100–125 g ha−1 significantly reduced density and dry biomass of annual grasses and broadleaved weeds in both years; it gave effective control (>88 per cent) of *Trianthema portulacastrum* L., *Dactyloctenium aegyptium*, *Digitaria sanguinalis* and *Acrachne racemosa*, fair to good control (<80 per cent) of *Digera arvensis* and no control of *Cyperus rotundus*.

10.3.3 Quizalofop-ethyl

Singh & Rathore (2015) conducted the field experiments during 2012 and 2013 to evaluate the efficacy of different herbicides for weed management in cotton. Highest seed cotton yield (3537.3 kg ha^{-1}) was recorded in weed free plots followed by pendimethalin @1.0 kg a.i ha as pre-emergence + quizalofop -ethyl @50g a.i ha^{-1} post emergence at 2-4 weed leaf stage + one hoeing (3318.9 kg ha^{-1}) owing to improved number of bolls per plant and boll weight. Statistically least yield was recorded under weedy check (1435.4 kg ha^{-1}).

Kalasare *et al*. (2016) conducted the field experiments during *kharif* 2009 at MARS, Dharwad to study the effect herbicides on yield of chilli + onion + cotton intercropping system. Results revealed that, pre-emergence application (PRA) of oxyfluorfen 0.15 kg ha^{-1} + post-emergent application (POE) of oxyfluorfen 0.15 kg ha^{-1} HW at 30 and 60 DAT recorded significantly higher chilli equivalent yield (7.43 t ha^{-1}) than all other treatment combinations, including the farmers practice (5.81 t ha^{-1}). The yields were influenced by number of green chilli fruits per plant, weight of onion bulb, number of bolls and mean boll weight in cotton.

Pandagale *et al.* (2018) evaluate that efficacy of PE and PoE weedicides in *Bt.* cotton during 2012-13 to 2014-15 under rainfed condition at Cotton Research Station, Nanded (M.S., India) for three years in *kharif* season. The trial was laid out in randomized block design having eight treatments with three replications. Weedicides, Pendimethalin (PE), Quizalofop-ethyl (PoE), Pyrithiobac sodium (PoE) and Glyphosate (PoE – directed spray) were evaluated as single or in combination along with weed free check and weedy check. The weedicide treatments recorded increase in seed cotton yield to the tune of 75.52 to 150.44 per cent as compared to weedy check.

Kalaisudarson and Srinivasaperumal (2019) conducted a field experiment during winter season 2015 at Annamalai University Experimental Farm, Annamalai nagar, to study the effect of chemical method on weed management in hybrid cotton. The experiment was laid out in Randomized Block Design with three replications and twelve treatments. The treatments were,T_1 - Unweeded control, T_2 - Alachlor 1.5 kg ha^{-1} , T_3 - Pendimethalin 0.68 kg ha^{-1}, T_4 - Alachlor 1.5 kg ha^{-1} + Quizalofop-ethyl 0.025 kg ha^{-1} on 40 DAS, T_5 - Pendimethalin 0.68 kg ha^{-1} + Quizalofop-ethyl 0.025 kg ha^{-1} on 40 DAS, T_6 - Alachlor 1.5 kg ha^{-1} + Paraquat 0.75 kg ha^{-1} on 40 DAS, T_7 - Pendimethalin 0.68 kg ha^{-1} + Paraquat 0.75 kg ha^{-1} on 40 DAS, T_8 - Two hand weeding on 20 and 45DAS, T_9 - Alachlor 1.5 kg ha^{-1} + hand weeding on 45 DAS, T_{10}- Pendimethalin 0.68 kg ha^{-1} + hand weeding on 45 DAS, T_{11}- One hand weeding on 20DAS + Quizalofop-ethyl 0.025 kg ha^{-1}on 40 DAS, T_{12}- One hand weeding on 20 DAS + Paraquat 0.75 kg ha^{-1} on 40 DAS. Observations on total weed count, weed biomass and weed control efficiency were recorded. Cotton growth and yield attributes and seed cotton yield.

10.4 Economics of weed control

Prabhu *et al.* (2012) revealed that among the weed management treatments, weed free check recorded significantly higher uptake of nutrients (111.01, 31.21 and 129.11 NPK kg ha^{-1}) and was followed by pendimethalin 38.7 CS (PRE) + quizalofop-ethyl 5 EC (POE) + IC and HW at 60 DAS (T_{12}). With regards to yield and economics, pendimethalin 38.7 CS (PRE) + quizalofop-ethyl 5 EC (POE) + IC and HW at 60 DAS (T_{12}) gave significantly higher seed cotton yield (14.06 q ha^{-1}) and higher gross returns (Rs 35,150 ha^{-1}), net returns (Rs 11,857 ha^{-1}) and BC ratio (1.51).

Hiremath *et al*. (2013) conducted a field experiment was conducted during growing season of 2012-13 at Agricultural College Farm, Bheemarayanagudi, Shahapur (KA.) under UKP command area to develop an effective weed management strategy and reported that, The maximum gross return was obtained in weed free check Rs 1,13,187 which was on par with pendimethalin + pyrithiobac + intercultivation i.e. Rs 1,07,885 but B:C ratio higher with pendimethalin + pyrithiobac + intercultivation 3.35.

Pawar *et al*. (2015) reported that treatment pyrithiobac-sodium 10 EC @ 0.062 kg a.i. ha^{-1} PoE fb quizalofop-ethyl 10 EC @ 0.075 kg a.i. ha^{-1} POE 20-25 DAS + hoeing at 45 DAS recorded significantly highest gross monetary returns Rs 53862 ha^{-1}, whereas highest net monetary retums Rs 16072 ha^{-1} and B:C ratio 1.46 were recorded with one hoeing at 20 DAS glyphosate 41 SL @ 1.00 kg a.i. ha^{-1} 45-55 DAS. The lowest gross monetary returns, net monetary returns and B:C ratio were observed with weedy check.

Nandagavi and Halikatti (2016) gross returns, net returns and B:C ratio were significantly higher in the sequential application of PE application of pendimethalin 38.7% CS @ 0.68 kg ha fb pyrithiobac-sodium 10% EC 0.125 kg ha^{-1} or quizalofop-p-ethyl 5 EC @ 0.05 kg ha^{-1} as PoE as compared to other herbicide treatments.

Kamble *et al*. (2017) the highest net returns and maximum B:C ratio value was observed with oxyfluorfen PE @ 0.1 kg ha^{-1} fb pyrathiobac-sodium POE @ 75 g ha^{-1} at 45 DAS + one inter culturing through mechanical weeder at 60 DAS and pendimethalin PE @ 1.0 kg ha^{-1} fb pyrathiobac-sodium PoE @ 75 g ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS.

Singh *et al*. (2016) observed that highest gross monetary returns and net monetary returns was recorded under weed free check but highest B:C ratio with Glyphosate @ 1.5 kg a.i. ha^{-1} as directed spray at 45 DAS. Glyphosate @ 1.5 kg a.i. ha^{-1} as directed spray at 45 DAS was found most effective in controlling weeds and increasing seed cotton yield.

Kumar *et al.* (2016) conducted a field experiment during *Kharif* seasons of 2012 and 2014 at C. S. Azad University of Agriculture & Technology, Kanpur to study the effect of different uses of herbicides on growth and yield attributes and seed cotton yield in *hirsutum* cotton. Resulted that lowest dry weight (3.98 g m^{-2}) of weeds was recorded with direct spray of glyphosate 45 per cent SL @ 1 kg a. i. ha^{-1}. Higher weed control efficiency (83.3 per cent) was recorded with direct spray of glyphosate 45 per cent SL @ 1 kg a. i. ha^{-1} followed by pendimethalin @ 1 kg a. i. ha^{-1} as PE + quizalofop-ethyl @ 50 g a. i. ha^{-1} 30 DAS + one hoeing 50 DAS (63.5 per cent). Highest net returns (Rs. 19,824 ha^{-1}) and B:C ratio (1.56) were obtained with herbicidal application of pendimethalin @ 1 kg a. i. ha^{-1} as PE + quizalofopethyl @ 50 g a. i. ha^{-1} 30 DAS + one hoeing 50 DAS.

Chaudhari *et al.* (2017) resulted that pre-emergence application of pendimethalin 1000 g ha^{-1} fb HW at 20 and 50 DAS recorded maximum gross, net returns and B:C ratio of 1,40,900 ha^{-1}, 8,27,100 ha^{-1} and 2.42, respectively followed by pyrithiobac + quizalofop (62.5 + 50 g ha^{-1}) PoE fb directed spray of glyphosate 2000 g ha^{-1} at 60 DAS, which recorded the values of 1,31,600 ha^{-1}, 75,130 ha^{-1} and 2.33, respectively.

Sreena *et al.* (2019) conducted that pyrithiobac sodium 10EC @ 125g a.i. ha^{-1} as POE @ 2-5 leaf stages of weeds fb IC @ 60DAS was recorded higher net return (Rs 90,332 ha^{-1}), gross returns (Rs 1,39,226 ha^{-1}) and B: C ratio (2.85) with the graining of higher seed cotton yield (2578 kg ha^{-1}). Weedy check was recorded lower B:C ratio (1.61) and lower net returns (27,050) over all other treatments.

CHAPTER-III

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

The field experiment was conducted to study "Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton under rainfed condition during *kharif* 2021-2022 at central farm department of agronomy and college of agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S) India. The details of material and methods adopted during the investigation are presented in this chapter under appropriate headings.

3.1 General Description

3.1.1 Location of experimental site

The field experiment was conducted at central farm V.N.M.K.V., Parbhani (M.S) India. The laboratory works were done in the Department of Agronomy, and Department of Soil Science and Agricultural Chemistry, V.N.M.K.V., Parbhani (M.S.) India.

3.1.2 Soil type of the experimental site

The soil was well drained. In order to study the physical and chemical properties of soil, soil sample from 0-30 cm depth at 10 different randomly selected location were collected from the experimental area before laying out the experiment. The composite sample was analysed for physical and chemical properties of soil and presented in Table 3.1 along with analytical methods used.

It was observed that, the soil of experimental site was clayey in texture. The chemical composition according to criteria laid by Subbiah and Asija (1956) indicate that, soil was low in available nitrogen 193.28 kg ha^{-1}, low in available phosphorus 19.34 kg ha^{-1} and very high in potassium 596.53 kg ha^{-1}. The soil was alkaline in reaction (pH 8.2) with electrical conductivity of 0.25 dSm^{-1}.

Table 3.1: Physical and chemical properties of soil of experimental field

Sr. No.	Particulars	Content	Method adopted
A	**Mechanical composition**		
1	Coarse sand (%)	6.60	International pipette method (Piper, 1966)
2	Fine sand (%)	12.30	
3	Silt (%)	28.40	
4	Clay (%)	53.60	
B	**Chemical composition**		
1	Organic carbon (%)	0.58	Walkely and black method (Jackson, 1967)
2	Available nitrogen (kg ha^{-1})	193.28	Alkaline permagnate method (Subbiah and Asija, 1956)
3	Available phosphorus (kg ha^{-1})	19.34	Olsens method (Olsen *et al.* 1954)
4	Available potassium (kg ha^{-1})	596.53	Flame photometer method (Piper, 1966)
5	Soil pH	8.2	1:2 soil water suspension by glass electrode pH meter (Jackson, 1967)
6	Electrical Conductivity (mmhos cm^{-3} at 25^0C)	0.256	Electrical conductivity bridge (Jackson, 1967)

3.1.2 Climate and weather Conditions

Geographically Parbhani is situated at 19^0 16' North latitude and 76^0 47' East longitude and at 409 altitudes above mean sea level and has a semi-arid climate. The weekly meteorological data pertaining to mean total rainfall, rainy days, maximum and minimum temperature, mean RH, mean evaporation (mm) and mean bright sunshine hours per day of corresponding weeks prevailed during crop growth was recorded from July to November 2021 at Agricultural Meteorological Observatory. V.N.M.K.V., Parbhani presented in Table 3.2.

Total rainfall received during the crop growth period was **1296** mm. During this period, the mean maximum temperature during the investigation period was **30.89**^{0}C and the mean minimum temperature was **20.94**^{0}C, the mean maximum relative humidity was **88.75%** while minimum relative was **58.65%** respectively.

3.2 Experimental details

3.2.1 Design of experiment

The present experiment entitled “Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton. Was laid out in split plot design with three replications. The experiment consisted of twelve treatment combinations. The treatments were randomly allotted in each replication. The gross and net plot size were 6.3 m × 5.4 m and 4.5 m × 3.6 m, respectively. The distance between two replication was 1 m and 0.70 m between two plots. Details of the treatments along with symbols used are presented below. The plan of layout is depicted in figure No.3.2

3.2.2 Treatment details

1. Main treatment

Density

D_1- 90 x 45 cm^2 (24,691 plants ha^{-1})

D_2- 90 x 30 cm^2 (37,037 plants ha^{-1})

D_3- 90 x 20 cm^2 (55,555 plants ha^{-1})

2. Sub treatment

Weed management

W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1}(a.i) followed by two hand weeding and one hoeing.

W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha^{-1} @ 25- 30 DAS.

W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 Days hand weeding.

W_4: Weedy check.

Table 3.2: Weekly weather data prevailed during the experimental period 2021 at Agriculture Meteorological Observatory Parbhani.

WKs (2021)	RF	Temperature ^{0}C		Humidity (%)		EVP (mm)	BSS (Hrs.)	WS (Kmph)
		Max	Min	RH1	RH2			
27	41.1	33.4	23.8	82	54	5.3	5.9	4.2
28	389.7	29.7	22.0	96	78	1.1	2.4	3.7
29	126.7	30.1	22.6	92	73	3.0	5.7	4.1
30	9.9	30.5	21.4	89	65	3.4	4.5	5.3
31	1.4	30.9	21.6	84	63	3.3	2.7	5.8
32	2.3	33.1	22.5	84	52	4.9	6.2	4.2
33	48.5	29.4	22.2	89	70	3.6	4.7	4.6
34	5.9	30.6	22.4	92	64	3.1	5.2	2.9
35	48.8	30.0	22.7	78	59	3.0	3.4	2.8
36	233.1	28.2	21.8	94	78	1.6	3.9	3.3
37	44.4	30.9	22.0	90	69	3.4	6.6	4.3
38	48.6	30.9	22.3	105	71	4.0	5.1	3.7
39	133.9	28.9	21.8	94	75	1.6	2.2	3.6
40	112.9	32.7	22.4	94	59	3.5	7.3	2.4
41	3.0	33.0	21.2	92	46	4.4	7.8	2.3
42	45.8	31.1	19.6	89	48	4.2	7.0	2.9
43	0.0	31.5	15.9	86	30	5.0	9.4	2.1
44	0.0	31.2	15.7	79	36	5.5	8.5	3.7
45	0.0	30.9	14.3	85	29	5.0	7.6	3.3
46	0.0	30.8	20.6	81	54	4.1	4.5	4.6
MEAN/ TOTAL	**1296**	**30.89**	**20.94**	**88.75**	**58.65**	**3.65**	**5.53**	**3.69**

3.1.4 Previous crop history

Table 3.3: The cropping pattern followed in the experimental plot during preceding three years

Sr. No.	Year	Season		
		Kharif	Rabi	Summer
1	2018-19	Cotton	Soybean	Follow
2	2019-20	Red gram	Fallow	Fallow
3	2020-21	Cotton	Soybean	Follow
4	2021-22	*Bt*. cotton (Ajeet-5) hybrid experiment)	--	--

3.2.3 Other experimental details

1) Season : Central Farm of VNMKV, Parbhani
2) Soil type : Vertisol
3) Crop : *Bt*. cotton
4) Hybrid : Ajeet-5
5) Name of Design : Split plot design
6) Treatment : 12
7) Replication : 03
8) Number of plots : 36
9) Plot size : Gross = 6.3 m× 5.4 m
   Net = 4.5 m × 3.6 m
10) Distance between plot : 0.70 m
11) Distance between replication : 1 m
12) Spacing : As per treatment
13) Method of sowing : Dibbling
14) Date of sowing : 8 July 2021
15) Site : At field of Central Farm,
    Balsa, VNMKV, Parbhani.

3.3 Cultural practices

3.3.1 Land preparation

The land is brought to the fine tilth with one deep ploughing and two cross-wise harrowing. The residues of the previous crop and weeds were removed from the experimental area. The land was leveled with plank. The schedule of important cultural operations carried out in the field of experiment during the *Kharif* season 2021 is given in Table 3.5.

The twelve treatments were laid out in a split design with three replications. Plan of layout is presented in Fig 3.2.

3.3.2 Manures and fertilizer application

The application of fertilizer was done with recommended dose of 120:60:60 NPK kg ha^{-1}. Half quantity of nitrogen, full dose of Phosphorus and Potassium was applied as basal application just before dibbling of *Bt.* cotton seed. Fertilizers used were urea, single super phosphate and murate of potash which were applied along the marked lines (i.e. line placement) 5 cm below the soil surface in the moist zone, and then covered properly, with soil. The remaining half dose of nitrogen is applied at 30 DAS.

3.2.4 Plan of layout

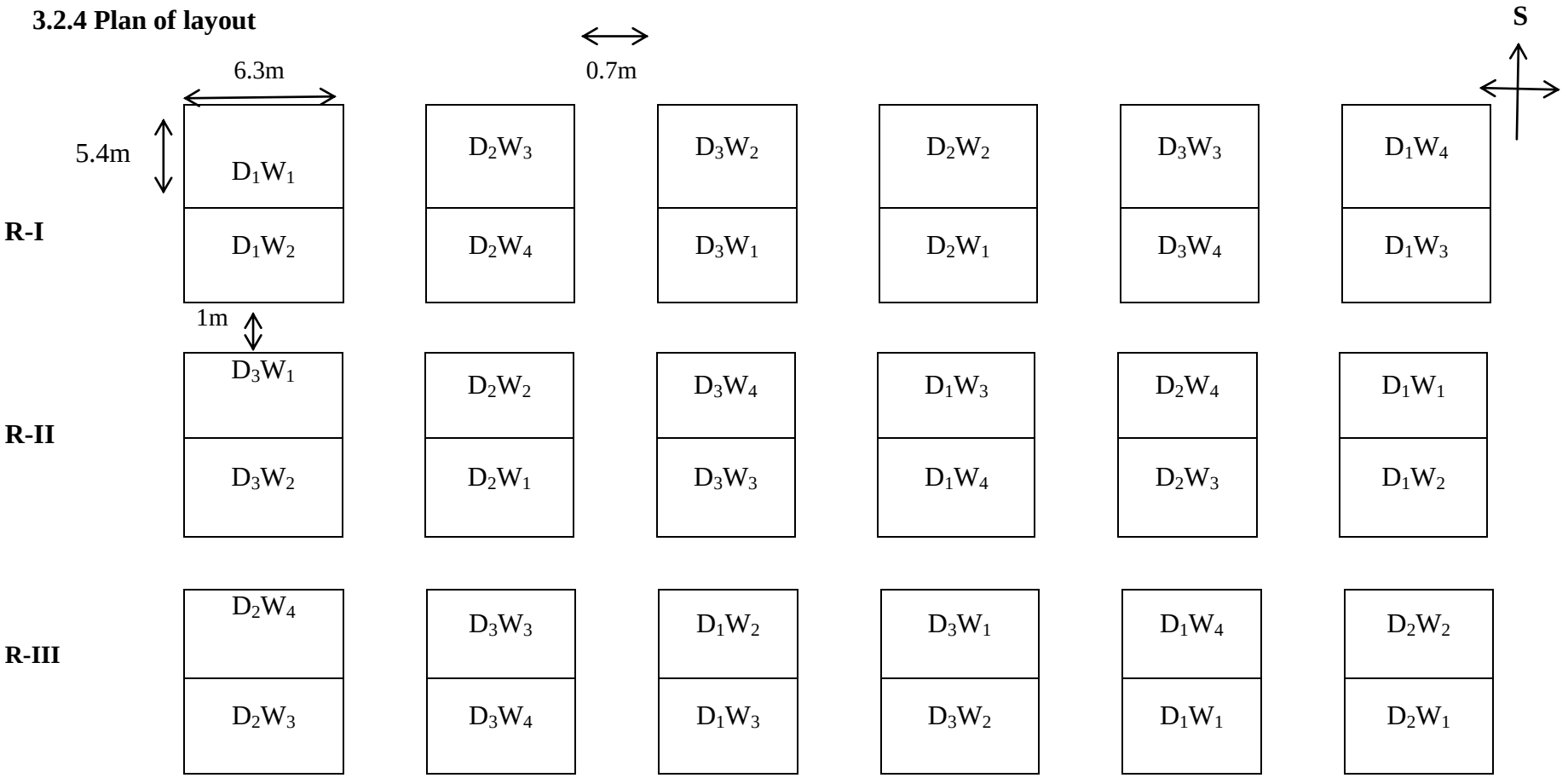


Fig 3.2: Plan of layout of experimental field during the year 2021-22

3.3.3 Treatment combination

Table 3.4: Treatment combination of various factors

Sr. No.	Treatment combination	Symbols
1	Plant density of 90 cm x 45 cm (24,691 plants ha^{-1}) with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	D_1W_1
2	Plant density of 90 cm x 45 cm (24,691 plants ha^{-1}) with pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	D_1W_2
3	Plant density of 90 cm x 45 cm (24,691 plants ha^{-1}) with post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	D_1W_3
4	Plant density of 90 cm x 45 cm (24,691 plants ha^{-1}) with weedy check.	D_1W_4
5	Plant density of 90 cm x 30 cm (37,037 plants ha^{-1}) with pre emergence application of pendimethalin @ 1 kg ha^{-1}(a.i) followed by two hand weeding and one hoeing.	D_2W_1
6	Plant density of 90 cm x 30 cm (37,037 plants ha^{-1}) with pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha^{-1} @ 25-30 DAS.	D_2W_2
7	Plant density of 90 cm x 30 cm (37,037 plants ha^{-1}) with post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	D_2W_3
8	Plant density of 90 cm x 30 cm (37,037 plants ha^{-1}) with weedy check.	D_2W_4
9	Plant density of 90 cm x 20 cm (55,555 plants ha^{-1}) with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	D_3W_1
10	Plant density of 90 cm x 20 cm (55,555 plants ha^{-1}) with pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha^{-1} @ 25-30 DAS.	D_3W_2
11	Plant density of 90 cm x 20 cm (55,555 plants ha^{-1}) with post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	D_3W_3
12	Plant density of 90 cm x 20 cm (55,555 plants ha^{-1}) with weedy check.	D_3W_4

Table 3.5: Field operations carried out during the period of crop growing season

Sr.no.	Particulars	Frequency	Implements used	Date of operation
A	Preparatory tillage			
1	Ploughing	1	Tractor operated Iron plough	10/05/2021
2	Harrowing	2	Tractor operated Harrow	25/06/2021
3	Layout of experiment	1		05/07/2021
B	Sowing			
1	Marking rows	1	Manually	07/07/2021
2	Sowing of seed by dibbling	1	Manually	08/07/2021
3	Gap filling	1	Manually	20/07/2021
4	Thinning	1	Manually	01/08/2021
C	Manures and fertilizer application			
1	Nitrogen as per treatments basal and split	2	Manually	08/07/2021and 09/08/2021
2	Phosphorus as per treatments	1	Manually	08/07/2021
3	Potassium as per treatments	1	Manually	08/07/2021
D	Interculture operation			
1	Applicartion of herbicide			
A	Pendimethalin (30% EC)	1	Knapsack Sprayer	10/07/2021
B	Pyrithiobac-sodium(10% EC)	1	Knapsack Sprayer	02/08/2021
C	Quizalofop-ethyl (5% EC)	1	Knapsack Sprayer	02/08/2021
2	Hand weedings	2	Manual labour	18/07/2021 and 12/08/2021
3	Hoeing	1	Hand hoe	16/07/2021
E	Plant protection measures			
1	Spinetoram 11.7% SC, Thiamethoxam (12.6%)+Lambdacyhalothrin (9.5%) ZC and profenopos+cypermethrin	1	Power sprayer	17/08/2021, 19/09/2021 and 16/10/2021
G	Harvesting			
1	Picking	2	Manual labour	18/11/2021 and 25/12/2021

3.3.3 *Bt.* cotton hybrid

A *Bt.* cotton hybrid Ajeet-5 (ACH-5 BG-II) Mahyco Seeds Ltd. was used for the study. The hybrid is recommended for irrigated cultivation in Maharashtra, Gujarat, Madhya Pradesh, Chhattishgarh, Andhra Pradesh, Telangana, Karnataka. It has high yield potential and medium duration maturity (130-140 days).

3.3.4 Sowing and gap filling

Sowing was done on 8 July 2021 by dibbling 2 seeds at each hill after receding sufficient rains at an optimum soil moisture level by keeping distance as per treatment. The plant population was maintained by gap filling at 12 DAS by dibbling the seeds wherever the previous dibbled seeds did not germinated and subsequently by thinning with keeping one plant per hill. The emergence of seed was started from 7 days after sowing and completed by 20 DAS.

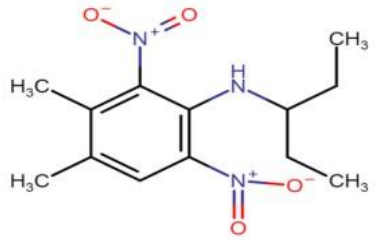
3.3.5 Application of herbicide

The pre-emergence herbicides viz., Pendimethalin was sprayed next two days after sowing and post–emergence herbicide viz., Pyrithiobac sodium and Quizalofop-ethyl were applied 25-45 days after sowing as per treatments by using hand operated knapsack sprayer, fitted with flat fan nozzle. The quantity of water and herbicides required to be applied per plot were calculated on an area basis. The quantity of spray volume (water) required to be applied per plot was estimated by calibrating the sprayer. The treatment wise herbicide quantity required to be sprayed per plot was computed based on active ingredient, then mixing the respective herbicides in spray volume (water) the application of pre and post-emergence herbicides were undertaken.

3.3.5.1 Detail of herbicide used:

3.3.5.1.1 Pendimethalin

Molecular Structure:



Nomenclature

Common name	:	Pendimethalin
Trade name	:	Stomp, Pendilene, Tata Penida
Chemical name	:	N-(1-ethyl-propyl)-3,4-dimethyl-2,6 dinitrobenzen amine
Herbicidal group	:	Dinitro anilines.
Type of herbicide	:	Selective
General doses	:	1.0-1.5 kg a.i. ha^{-1}
Application	:	Pre-emergence and early post emergences
Formulation	:	30% EC

Mode of action:

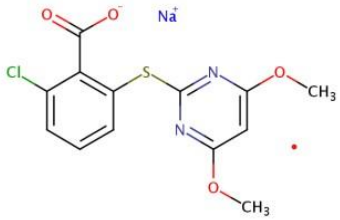
The primary mode of action of pendimethalin is to inhnibit microtubule formation in cells of susceptible weeds. As a result of restricted cell division, growth of the emerging weed seedling was prevented, eventuating in death due to lack of food reserves. Because Stomp does not translocate a great deal from the site for uptake within the plant, it is necessary for the emerging weed seedling's roots to absorb pendimethalin from the soil.

Important weed control:

Pendimethalin controls most annual grasses and certain broad leaves weeds in many crops. It is mostly used in cotton, soybean, groundnut, pea, sunflower and certain transplanted vegetables, which have shown physiological electivity to it. Trianthema spp. is very susceptible to soil applied pendimethalin.

3.3.5.1.3 Pyrithiobac sodium

Molecular Structure:



Nomenclature

Common name	:	Pyrithiobac sodium 10% EC
Trade name	:	Hit weed
Origin	:	Godrej
Chemical name	:	Sodium(sodium2-chloro-6-[(4,6 dimethoxypyrimidin-2-yl) thio] benzoate
Chemical formula	:	C13H10ClN2NaO4S
Chemical group	:	Pyrimidinyloxybenzoic analogue
Type of herbicide	:	Selective
General doses	:	62.5 g a.i ha^{-1}
Formulation	:	10% EC

Mode of action:

Inhibition of acetyl CoA carboxylase (ACCase). Systemic post-emergence herbicide absorbed by foliage and roots and translocated throughout the plant. Treated grasses cease growth within 3-4 days, show chlorosis of younger plant tissues, followed by a progressive collapse of the entire plant 10- 20 days later.

Important weed control :

Pyrithiobac-sodium is a selective herbicide for use against broadleaf weeds and some grasses in cotton, including bromoxynil-resistant varieties. Primary targets are Abutilon theophrasti, Amaranthus spp, Ipomoea spp, Sesbania exaltata, Sida spinosa, Solanum nigrum, S. sarrachoides, Xanthium strumarium, etc.

3.3.5.1.4 Quizalofop-ethyl (Rao, 2000)

Structural formula :

Nomenclature

Common name	: Quizalofop-ethyl 5% EC
Trade name	: Turga super
Origin	: Dhanuka Pesticide Ltd. In technical collaboration With m/s Nissan Chemical Industries Ltd.,Tokyo, Japan.
Chemical name	: (R)-2 4-(6 chloro-2-quinoxalinyl) oxy) -phenoxyl propanoic acid
Herbicidal group	: Aryloxyphenoxy propionics
Type of herbicide	: Selective
General dosage	: Annual grass weed: 75-100 g ha^{-1} Perennial grassy weeds: 35-80 g ha^{-1} Recommended @ 50 g ha^{-1}
Application	: Post emergence at 3-6 leaf stage of annual grassy and at 10-15 cm height of perennial.
Formulation	: 5% EC.

Mode of action:

It is a biochemicaly Acetyl CoA carboxylase inhibitor; inhibition of fatty acid biosynthesis and mode of action systemic herbicide, absorbed from the leaf surface, with translocation throughout the plant, moving in both the xylem and phloem, and accumulating in the meristematic tissue.

Important weed control:

Selective post emergence control of annual and perennial grass weeds in potatoes, soyabean, sugar beet, peanuts, oilseed rape, sunflowers, vegetables, cotton, and flax. Most non-graminaceous crops are tolerant. Various weed controlled effectively are Barnyard grass, large crab grass, Jonhson grass, wild oat, bermuda grass and wild grass.

3.5.6 Plant protection measures

To avoid incidence of sucking pests one spray of Spinetoram 11.7% SC (250 ml) was given in 500 litre of water for one ha.

3.3.6 Intercultural operations

Hoeing by hand hoe and hand weedings by manual labour undertaken to maintain the crop weed free. Only one hoeing was done as per the treatments 20-25 days after herbicide spray. The schedule of intercultural operations undertaken is mentioned in Table 5

3.3.7 Harvesting

Picking of seed cotton was done as soon as the 50 percent bolls were bursted with help of manual labours. In all two pickings were undertaken. After picking of seed cotton, plants were cut from soil surface manually. Plants were subjected to sun drying for recording dry weight as a stalk yield separately for each net plot.Y

3.4 Collection of Experimental Data or Biometric Observations

Data on important biometric observations were collected on fixed five randomly selected plants in each plot throughout the crop life.

3.4.1 Pre-harvest studies

3.4.1.1 Emergence count

Emergence count was taken on 21 days after sowing and final plant stand from each net plot was recorded.

The field emergence was calculated by following formula:

$$\text{Emergence (\%)} = \frac{\text{Number of seedlings emerged}}{\text{Total number of seed sown}} \times 100$$

3.4.1.2 Final plant stand

The number of plants net^{-1} plot were recorded one day before harvesting.

3.4.2 Growth Studies

3.4.2.1 Plant height (cm)

The plant height on five randomly selected and tagged plants were measured from the base of the plant to the tip of the terminal bud (growing point) at 30, 60, 90, 120 and at harvest. The average height of five plants was worked out and expressed in centimeters (cm)

3.4.2.2 Number of monopodial and sympodial branches plant^{-1}

The number of monopodial (vegetative) and sympodial (fruiting) branches in the five randomly selected and tagged plants were recorded at 30 days interval from 60 DAS. The mean number of branches plant^{-1} was worked out and expressed in number plant^{-1}

3.4.2.3 Number of leaves plant^{-1}

Progressive number of functional leaves and fully opened green leaves present in each of the five randomly selected and tagged plants were counted at 30 days interval from 30 DAS. The mean number of leaves plant^{-1} was worked out and expressed in number plant^{-1}

3.4.2.4 Leaf area plant^{-1} (dm^2)

Leaf area was calculated by using the plant samples taken for the dry matter studies from each net plot. The leaves were aerated into leaflets and grouped into three group viz., small, medium and large. The maximum length and breadth of five leaflets from each group was measured and the mean leaf area per plant worked out by following formula.

$A = (L \times W \times 0.771)\ n$

Where,

A	:	Leaf area in dm^2 under particular group.
L	:	Length of leaflet in dm^2
W	:	Maximum width of leaflet in dm^2
0.0771	:	Leaf area constant for *Gossypium* spp. (Ashley *et al*., 1993)
N	:	Number of leaves $plant^{-1}$

3.4.2.5 Days to 50% flowering

Days required for 50% flowering was recorded in each net plot.

3.4.2.6 Days to 50% boll bursting

Days required for 50% boll bursting was recorded in each net plot.

3.4.2.7 Total dry matter accumulation $plant^{-1}$ (g)

The dry matter accumulation were recorded by randomly taking and uprooting one plant from each net plot at 30 days interval for dry matter studies. Roots were discarded for dry matter studies. The plant was kept in brown paper bags, for sun dry first and then plants were air dried in hot air oven at 65^0C until their constant weight was obtained.

3.4.3 Plant growth analysis

The data on growth characters viz., LAI, AGR of height and AGR of dry matter and RGR $plant^{-1}$ were further analysed for the growth function. Data on these growth functions were not statistically analysed. Inferences were drawn on mean value.

3.4.3.1 Leaf Area Index (LAI)

Leaf area index was worked out by dividing the leaf area plant^{-1} by land area occupied by that plant (Watson, 1952).

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (cm^2)}{\text{Land area occupied by the plant}\ (cm^2)}$$

3.4.3.2 Absolute growth rate (AGR)

AGR of growth variable viz., plant height and total dry matter per plant were worked out by formula (Hunt, 1980) and expressed as cm day^{-1}and g day^{-1}, respectively.

$$\text{AGR for plant height} = \frac{H_2 - H_1}{t_2 - t_1}\ (\text{cm day}^{-1}\ \text{plant}^{-1})$$

$$\text{AGR for dry matter} = \frac{W_2 - W_1}{t_2 - t_1}\ (\text{g day}^{-1}\ \text{plant}^{-1})$$

Where,

H_1, H_2 and W_1, W_2 refers to the plant height (cm) and dry matter dry matter (g) at the time t_1 and t_2, respectively.

Absolute growth rate is the total gain in height and dry matter by plant within a stipulated time interval.

Table 3.6: Schedule of biometric observations and post-harvest observations recorded plot wise in experimental field

Sr. No.	Particulars	Frequency	Days after sowing (DAS)
A	Crop stand		
1	Emergence count	1	30 DAS
2	Final stand	1	At harvest
B	Biometric observation		
1	Plant height (cm)	5	30,60,90,120 DAS and at harvest
2	Number of functional leaves per plant	5	30,60,90,120 DAS and at harvest
	i) Sympodial branches	4	60,90,120 DAS and at harvest
	ii) Monopodial branches	2	60 and 90 DAS
3	Leaf area per plant (cm^2)	4	60,90 and 120 DAS
C	Yield contributing characters		
1	Number of picked bolls per plant	1	At harvest
2	Average boll weight (g)	1	At harvest
3	Seed cotton yield per plant (g)	1	At harvest
D	Yield studies		
1	Seed cotton yield (kg ha^{-1})	2	At I^{st} and II^{nd} picking
2	Biological yield (kg ha^{-1})	1	At harvest
3	Harvest Index	1	At harvest
E	Studies on weed		
1	Weed count (m^2)	3	30, 60 and at harvest
	i) Monocot		
	ii) Dicot		
	iii) Total count		
2	Weed dry matter		
3	Weed control efficiency		
4	Weed index		
F	Soil moisture studies		
1	Soil moisture content	5	30,60,90,120 DAS and at harvest
G	Economic studies		
1	Gross monetary returns (Rs ha^{-1})	1	After harvest
2	Net monetary return (Rs ha^{-1})	1	After harvest
3	Benefit cost ratio	1	After harvest

3.4.3.3 Relative growth rate (RGR)

The relative growth at which a plant adds new material into its substance is measured by relative growth rate (RGR) of height.

Blackman (1919) pointed out that increase in the height of the plant is continuous process of compound interest where the increment at any interval adds to the capital for subsequent growth. The rate of increment was called as relative growth rate.

It was computed by using following formula and expressed in cm day^{-1} $plant^{-1}$

$$RGR = \frac{\log e\ W_2 - \log e\ W_1}{t_2 - t_1} \quad (g\ g^{-1}\ day^{-1})$$

Where,

W_1 = Dry matter weight (g) at time t_1

W_2 = Dry matter weight (g) at time t_2

t_1 = Initial time of observation

t_2 = Final time of observation

Log e = Natural logarithms (logarithms to the base of 2.3026)

RGR = Increase in plant height in g $g^{-1}day^{-1}$ $plant^{-1}$.

3.4.4 Post harvest studies

3.4.4.1 Number of bolls $plant^{-1}$

At the time of each picking, number of bolls picked from five randomly selected and tagged plants in each treatment was counted and average was worked out and expressed as number of bolls picked $plant^{-1}$

3.4.4.2 Boll weight plant^{-1} (g)

The weight of picked bolls from five randomly selected and tagged plants in each treatment was taken and weighed. The average was worked out and expressed as boll weight plant^{-1} in grams.

3.4.4.3 Seed cotton yield plant^{-1} (g)

The total picked boll from five randomly selected and tagged plants in each treatment were taken and the seeds cotton was separated. The average seed cotton yield of cotton was weighed and worked out which is expressed as seed cotton yield plant^{-1} in grams.

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

Seed cotton from each net plot was picked and the same was weighted separately at each picking. The total yield per net plot was worked out by summation of quantity of seed cotton picked in each picking from the total yield per plot including five plants yield and multiplied with hectare factor and expressed as seed cotton yield hectare^{-1} for each treatment.

3.4.4.5 Stalk yield (kg ha^{-1})

After picking of complete seed cotton, the plants in the net plot were cut at ground level and kept separately in each plot. After sun drying the weight was recorded per plot and multiplied with hectare factor and expressed as stalk yield hectare^{-1} treatment wise.

3.4.4.6 Biological yield (kg ha^{-1})

Before picking of complete seed cotton, the plants in the net plot were cut at ground level and kept separately in each plot. After sun drying the weight was recorded per plot and multiplied with hectare factor and expressed as seed yield hectare^{-1} treatment wise.

Biological yield (kg ha^{-1}) = Seed cotton yield (kg ha^{-1}) + Stalk yield (kg ha^{-1})

3.4.4.7 Harvest index (%)

The harvest index was calculated by dividing seed cotton yield per hectare by total biological yield and expressed in percentage.

$$HI = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

3.4.5 Available nutrient status of soil

3.4.5.1 Nitrogen

Available nitrogen was determined by alkaline permanganate method using microprocessor based automatic distillation system (Subbiah and Asija, 1956).

3.4.5.2 Phosphorus

Available phosphorus was determined by Olsen's method using 0.5 M sodium bi-carbonate as an extractant using UV based double beam spectrophotometer (Watanabe and Olsen, 1965).

3.4.5.3 Potassium

Available potassium was determined by neutral normal ammonium acetate method using flame photometer (Knudsen and Peterson, 1982).

3.4.6 Moisture studies

3.4.6.1 Available soil moisture

After emergence of *Bt*. cotton, soil moisture observations were taken from the depth of 30 cm at 30 days interval. Soil samples for moisture studies were taken with the help of screw auger from each plot randomly. Then samples were transferred immediately to aluminium boxes and covered with polythene sheet to avoid sun heating in field. The soil samples from respective depth were weighed immediately on electrical top balance and 50 g soil sample (W_1) was taken for drying and then transferred to hot air oven. The samples were dried at 5^0C + 105^0C for 8-12 hours till constant weight was obtained (W_2). The moisture per cent was worked out with gravimetric method as follows,

$$\text{Moisture per cent} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

W_1 - Weight of 50 g wet soil sample

W_2 - Weight of 50 g oven dried soil sample

3.4.8 Weed studies

3.4.8.1 Weed flora

The important weed species associated with *Bt.* cotton crop in the experimental area were recorded, identified and grouped according to nature of cotyledons as monocot, dicot and sedges weeds.

3.4.8.2 Weed count

For weed population study a quadrate of 1m×1m area was randomly placed in each net plot. Number of weeds observed in that area was counted, identified and grouped according to nature of cotyledons as monocot and dicot weeds at 30, 60 DAS and harvest of the crop. The treatment wise weed count was recorded and expressed as number m^{-2}.

3.4.8.3 Dry matter of weeds

The data on weed dry matter was recorded at 30, 60 DAS and at harvest by using 1m x 1m quadrat randomly placed in net plot. The total weeds enclosed in the quadrat were carefully cut close to the ground level with the help of weeding hook. All the weeds from each quadrat were collected, air dried and then oven dried at 65±5°C temperature till the constant weight was obtained. Thereafter by, treatment wise total dry matter of weed was recorded and expressed as g m^{-2}

3.4.8.4 Weed control efficiency (WCE)

Weed control efficiency at 30, 60 and harvest was worked out based on weed dry matter m^{-2} by adopting the formula given by Mani *et al*. (1973).

$$WCE\ \% = \frac{DMC - DMT}{DMC} \times 100$$

Where,

WCE = Weed control efficiency in per cent

DMC = Dry matter of weeds in control plots

DMT = Dry matter of weeds in treated plots

3.4.8.5 Weed index (WI)

The weed index was calculated by the formula proposed by Gill and Vijay Kumar (1969).

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

Where,

WI = Weed index in per cent

X = Yield from weed free plot

Y = Yield from treated plot

3.4.7 Economics

3.4.7.1 Gross monetary returns (ha^{-1})

The gross monetary returns (ha^{-1}) occurred due to different treatments in the present study were worked out by considering market prices of economic product, by product and crop residues during the experimental year. GMR = Total output of the crop x Price of unit output

3.4.7.2 Cost of cultivation (ha^{-1})

The cost of cultivation (ha^{-1}) of each treatment was worked out by considering the price of inputs, charges for cultivation, labour, land and other charges. Treatment wise cost of cultivation was worked out and given in Appendix I and II.

3.4.7.3 Net monetary returns (ha^{-1})

The net monetary returns (ha^{-1}) of each treatment were worked out by deducting the mean cost of cultivation (ha^{-1}) of each treatment from the gross monetary returns (ha^{-1}) gained from the respective treatments.

NMR = GMR - Cost of cultivation

3.4.7.4 Benefit:cost ratio

The benefit:cost ratio of each treatment was calculated by dividing the gross monetary returns by the mean cost of cultivation.

$$B:C = \frac{\text{Gross monetory returns}}{\text{Total cost of cultivation}}$$

3.5 Statistical Analysis

The experimental data was analyzed by Fisher's method of analysis of variance (Panse and Sukhatme, 1978). Critical differences were calculated at probability of 5 per cent wherever F value. Whenever differences were significant, C.D. values were indicated for comparison otherwise only the values of SE + were indicated. Graphical illustrations of data have been given at appropriate places. The statistical analysis was carried out with computer. The critical difference was worked out whenever the treatment effects were statistically significant.

Plate 1: Layout of experimental trial at Central Farm, VNMKV, Parbhani

Plate 2: Sowing of *Bt*. cotton in experimental field

Plate 3: *Bt.* cotton crop at emergence

Plate 4: Application of post emergence in experimental field

Plate 5: Weedy plot

Plate 6: Treated plot

Plate 7: General description of plot

Plate 8: General view of experimental field

CHAPTER-IV

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSION

The results of the experiment conducted during *kharif* season of the year 2021-22 at the experimental central farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) to investigate the "Effect of high-density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt*. cotton" are presented in this chapter. This chapter also embodies the discussion of the experimental findings obtained in field studies. The effect of high density planting and weed management practices were measured in terms of growth parameters, yield attributes, yield, equivalent yield, land equivalent ration, economics, monetary advantage

In this chapter, the effect of various factors, the interaction effects between two factors viz, high-density planting and weed management practices have been discussed wherever these were found signification. However whenever interaction effect was significant, the effect individual factors was discussed.

4.1 Days for emergence

Data regarding days required for emergence of cotton as influenced by different treatments is presented in Table 4.1. On an average four days required for emergence of *Bt*. cotton hybrid.

4.1.1 Effect of plant density

Days required for emergence due to various plant density found to be statistically non-significant.

4.1.2 Effect of weed management

None of the weed management treatment was non-significant in relation to the days required for emergence.

4.1.3 Interaction effect

The interaction was found to be non-significant.

4.2 Initial plant and final stand (per cent):

Data pertaining to initial plant stand after emergence and final plant stand at harvest as influenced by different treatments is presented in Table 4.1. The average initial plant stand was 92.32 per cent and the average final plant was 90.41 per cent at harvest.

4.2.1 Effect of plant density

The difference in initial plant stand after emergence and final plant stand at harvest were non-significant due to different plant density.

Table 4.1: Days for emergence, Initial plant stand and Final plant stand of *Bt.* cotton hybrid as influenced by different treatments.

Treatment	Days for emergence	Initial plant stand (%)	Final plant stand (%)
A. Density			
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	4.22	22,476 (91.03)	22,372 (90.61)
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	4.22	34,081 (92.02)	33,403 (90.19)
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	4.23	51,705 (93.07)	49,755 (89.56)
SE(m)±	0.01	0.21	0.15
CD at 5 %	NS	NS	NS
B. Weed Management			
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	4.24	36,024 (92.15)	35,426 (90.62)
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	4.22	36,001 (92.09)	35,274 (90.23)
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 D AS) followed by 40 days hand weeding.	4.26	36,498 (93.36)	35,598 (91.06)
W_4: Weedy check.	4.21	36,185 (92.56)	35,415 (90.59)
SE(m)±	0.01	0.30	0.29
CD at 5 %	NS	NS	NS
Interaction (D X W)			
SE(m)±	0.02	0.67	0.33
CD at 5 %	NS	NS	NS
GM	**4.23**	**36,138 (92.32)**	**35,320 (90.41)**

4.2.2 Effect of weed management

The initial plant stand and final stand (per cent) was satisfactory but not influenced significantly by various treatments. Thus, results clearly showed that there was no adverse effect of different herbicide applied either as pre and post emergence on plant population of cotton.

4.2.3 Interaction effect

The interaction was found to be non-significant.

Biometric observation

4.3 Plant height (cm):

Data on mean plant height as influenced by different treatments recorded periodically is presented in Table 4.2 and graphically depicted in Fig 4.1. A glance of data would indicate increase in mean plant height with successive stage of crop growth up to harvest. The mean plant height at different growth stages ranged from 13.34 cm at 30 DAS to 96.34 at harvest. Increase in plant height was declined subsequently.

4.3.1 Effect of plant density

Plant height (cm) was significantly influenced by various plant densities throughout the crop growth period except at 30 DAS. Plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) recorded significantly higher plant height than D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}) from 60 DAS onwards till the harvest.

Due to more number of plants per unit area resulted maximum height $plant^{-1}$, which may be due to increased competition for sunlight and carbon dioxides.

It was observed that reduction in plant height under wider plant spacing was due to suppression of apical dominance as against closer spacing which induced more vertical growth for receiving more sunlight due to congestion of plant per unit area. Similar results were observed by Ram and Giri (2006) and Paslawar *et al*. (2015)

Table 4.2: Mean plant height (cm) of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

Treatment	30DAS	60DAS	90DAS	120DAS	At harvest
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	12.26	56.29	73.96	82.99	84.90
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	13.78	61.40	81.62	95.40	97.87
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	13.97	65.68	89.42	104.63	106.30
SE(m)±	1.07	1.27	1.63	1.93	2.64
CD at 5 %	NS	3.99	6.40	7.59	10.37
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	13.78	63.53	83.50	95.63	97.73
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha^{-1} @ 25-30 DAS.	13.38	58.46	80.07	92.94	94.70
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	13.72	65.57	86.17	97.10	101.04
W_4: Weedy check.	12.47	52.91	70.30	83.69	84.23
SE(m)±	0.66	1.79	2.16	2.20	2.67
CD at 5 %	NS	5.34	6.42	6.56	8.04
Interaction (D X W)					
SE(m)±	1.15	3.12	3.74	3.82	4.66
CD at 5 %	NS	NS	NS	NS	NS
Gm	**13.34**	**61.13**	**81.67**	**94.37**	**96.34**

4.3.2 Effect of weed management

The effect of different weed management treatment on mean plant height was found significant at all stages of crop growth except at 30 DAS. Maximum plant height was recorded with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lowest plant height was recorded by treatment weedy check (W_4) at all growth stages.

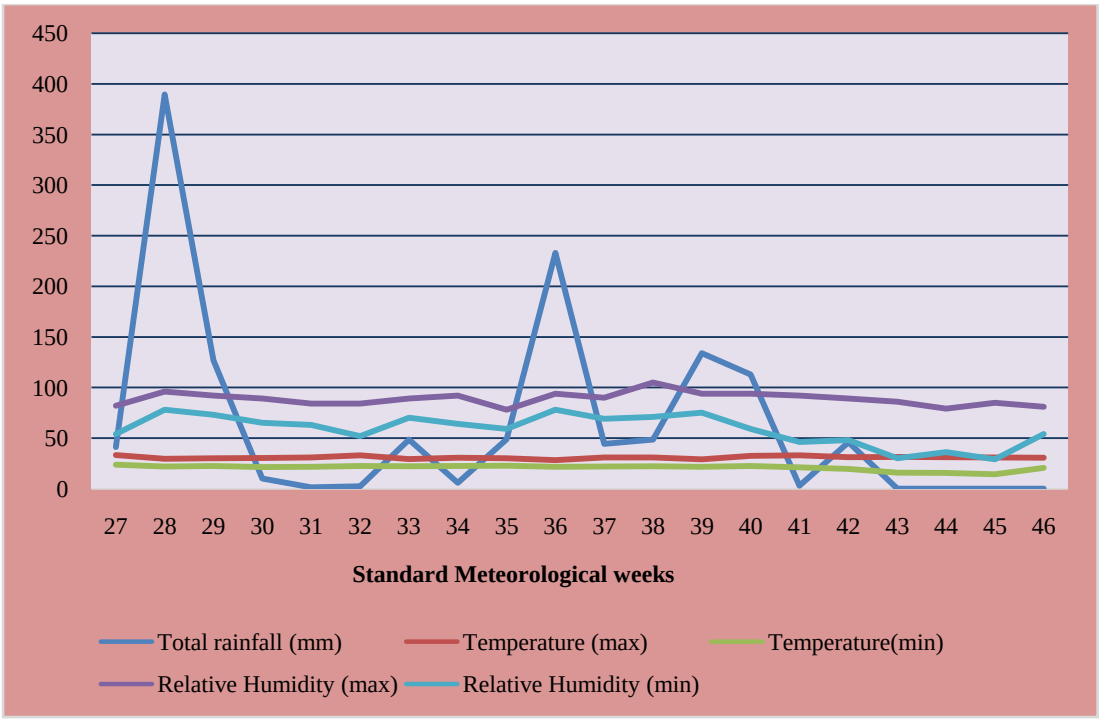


Fig 3.1: Weekly weather data prevailed during the experimental period 2021 at Meteorological Observatory Parbhani.

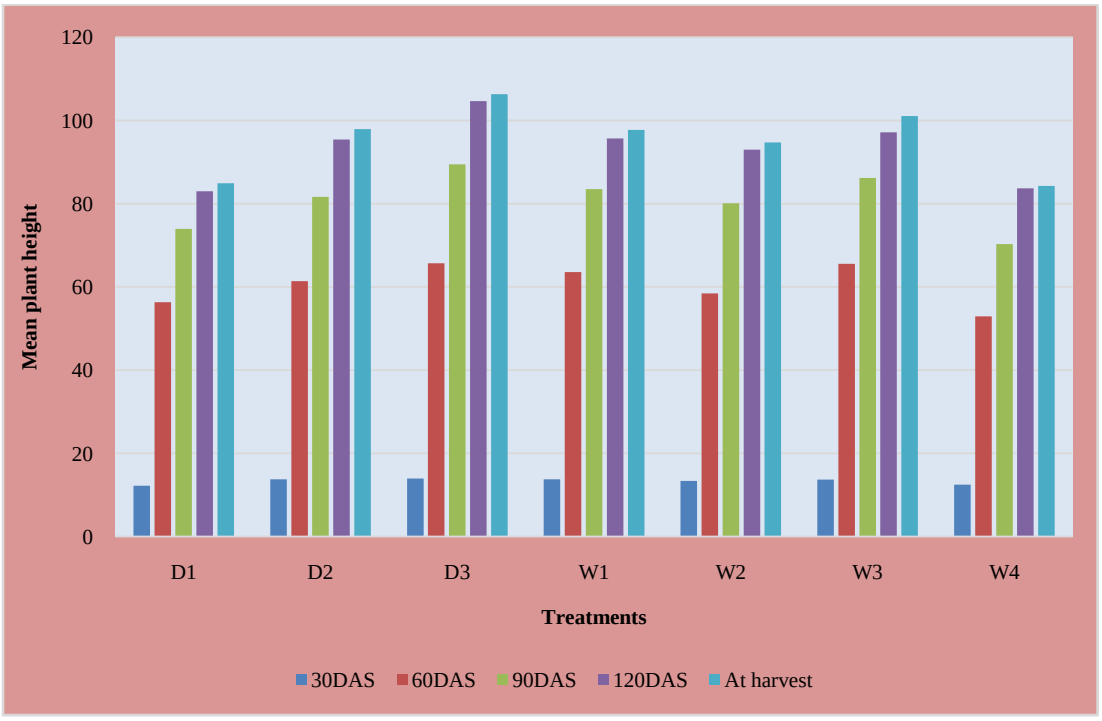


Fig 4.1: Mean plant height (cm) of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

Plant height and its rate of increase weed found to be significant amongst different weed management treatments. The treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) was significantly higher in respect of plant height compared to rest of the treatments. Whereas other growth attributes viz., number of functional leaves plant^{-1}, leaf area (dm^2) plant^{-1}, number of monopodial branches plant^{-1}, sympodial branches plant^{-1} of *Bt*. cotton were also higher in post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). But It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other with respect to growth attributes. This may be attributed due to crop get weed free situation in early stage of the crop growth in these treatments for their growth and development as compared to other treatments and also may be because weed control period in these treatments coincide with the critical period of crop weed competition for cotton which has reflected in higher growth characters. These results were in accordance with the findings reported by Asher *et al*. (2002), Sadangi and Barik (2007), Sangle *et al*. (2007) and Veeramani *et al*. (2009).

The lowest plant height was recorded by treatment weedy check (W_4) might be due to severe infestation of weeds which competed for natural resources like moisture, nutrients and light. Further, decrease plant height might also be due to inhibitory effect of allele chemicals that produced from these weeds. These findings are in conformity with that of reported by Anjum *et al*. (2007) and Bouchagier *et al*. (2008).

4.3.3 Interaction effects

The interaction was found to be non-significant in respect of plant height.

4.3.2 Number of functional leaves plant^{-1}

The data in respect of mean number of functional leaves plant^{-1} recorded at various growth stages of crop growth is presented in Table 4.3. and graphically depicted in Fig 4.2. The mean number of functional leaves plant^{-1} was found to increase from 30 to 120 DAS and decrease thereafter. The rate of leaf production was maximum during of 30 to 90 DAS. The rate of leaf production of leaves at maturity stage of *Bt*. cotton crop was declined due to dropping of older leaves by leaf senescence.

4.3.2.1 Effect of plant density

The difference due to various plant density in respect of number of functional leaves plant^{-1} were significant at all progressive stages except at 30 DAS. Increase in plant spacing shows increase trend in regards with number of functional leaves plant^{-1} were recorded in plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) as compared to the plant of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) at all stages of *Bt*. cotton crop growth. It was mainly due to the wider spacing and less plant density under D_1-90 cm X 45 cm (24,691 plant ha^{-1}). Plant utilized light (solar energy), moisture and nutrients efficiently when planted less densed as compared to closer plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) and D_2-90 cm X 30 cm (37,037 plant ha^{-1}), where more competition was occurred among plant for production factors. Such type offindings were also reported by Pendharkar *et al*. (2011).

Table 4.3: Number of functional leaves plant^{-1} of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

Treatments	Days after sowing				
	30	60	90	120	At harvest
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	4.88	28.79	67.24	79.86	53.91
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	4.71	26.82	62.12	73.65	50.21
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	4.49	24.40	57.76	68.18	47.03
SE(m)±	0.17	0.25	0.95	1.27	0.72
CD at 5 %	NS	1.0	3.75	4.99	2.82
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	5.15	27.57	62.86	74.22	51.33
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	4.69	26.58	61.77	74.15	50.94
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	5.48	28.87	67.73	78.87	53.48
W_4: Weedy check.	3.47	23.67	57.13	68.36	45.79
SE(m)±	0.16	0.36	1.41	1.49	0.61
CD at 5 %	NS	1.06	4.19	4.44	1.81
Interaction (D X W)					
SE(m)±	0.34	0.62	2.45	2.58	1.06
CD at 5 %	NS	NS	NS	NS	NS
GM	**4.70**	**26.67**	**62.37**	**73.90**	**50.38**

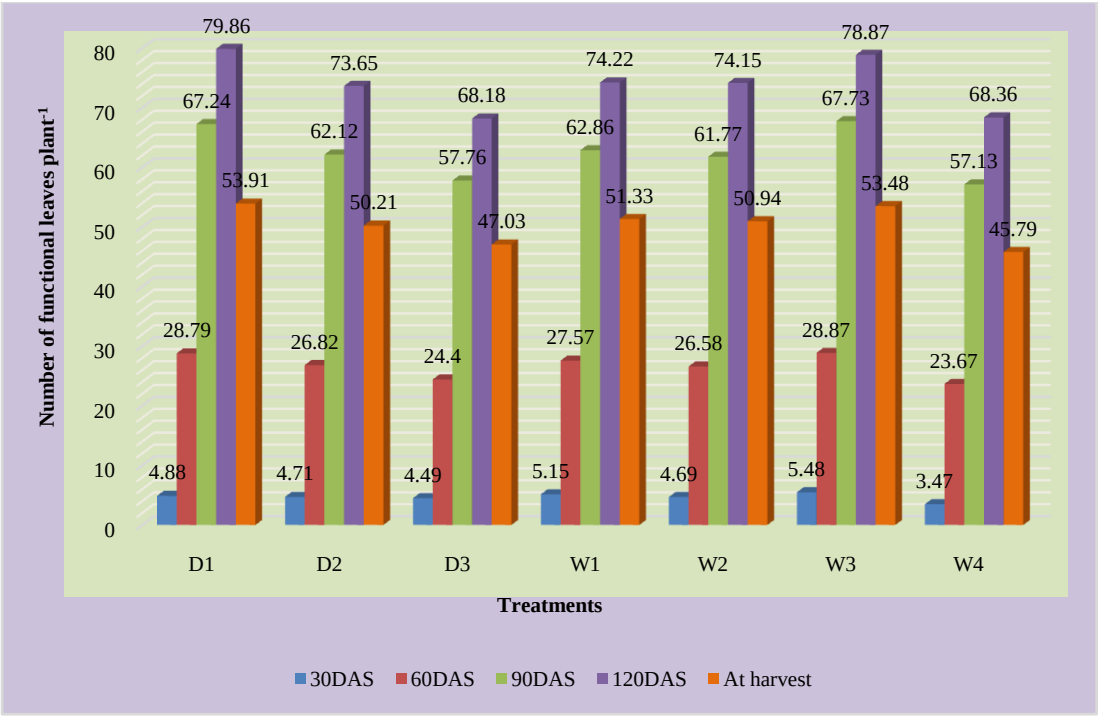


Fig 4.2: Number of functional leaves plant^{-1} of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

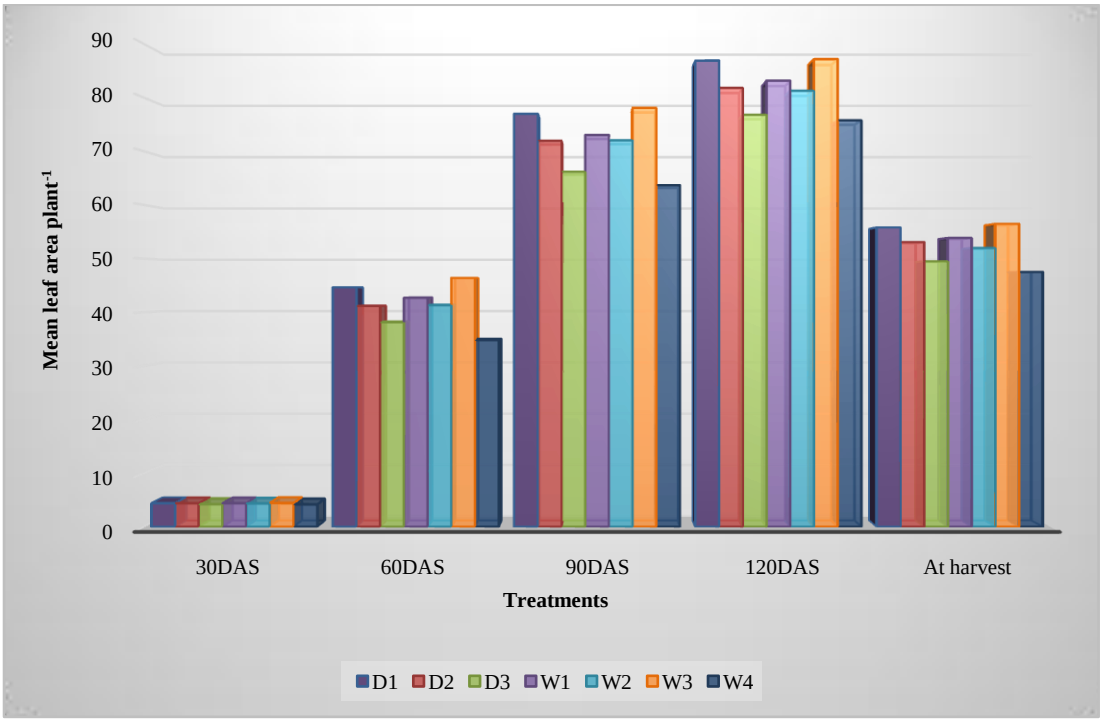


Fig 4.3: Mean of leaf area (dm^2) plant^{-1} of *Bt.* cotton as influenced by different treatments at various growth stages.

4.3.2.2 Effect of weed management

Weed management treatment significantly increased the number of functional leaves plant^{-1} at all stages of crop growth except at 30 DAS. It was observed that the functional leaves plant^{-1} were significantly maximum with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lowest number of functional leaves was recorded by treatment weedy check (W_4) at all growth stages.

4.3.2.3 Interaction effects

30, 60, 90,120 DAS and at harvest the interaction effect showed non-significant difference amongst all the treatment combinations.

4.3.3 Mean leaf area (dm^2) plant^{-1}

Data on leaf area plant^{-1} as influenced by different treatments is presented in Table 4.4. and graphically depicted in Fig 4.3. leaf area plant^{-1} expanded progressively and declined subsequently due to leaf senescence towards harvest stage. The leaf area expansion was maximum between 30 to 90 DAS.

4.3.3.1 Effect of plant density

At 30 DAS mean leaf area plant^{-1} statistically non-significant. It was observed that the wider plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) produced significantly more leaf area plant^{-1} than closer spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) at all stages of *Bt*. cotton crop growth.

Further it was observed that variation in wider and closer spacing with respect to leaf area plant^{-1} become more apparent as the age of crop advanced towards grand growth and boll development stage, where closer spacing exhibited declined trend. Early retention of boll and partitioning of more photosynthates towards sink might have reduced number of leaves and consequently leaf area in closer spacing.

The mean number of functional leaves plant^{-1} (Table 4.3) and leaf area plant^{-1} (Table 4.4) was increased substantially with decrease in plant density. Higher plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded higher number of leaves and higher leaf area as compared to lower plant spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) due to less competition for sunlight, nutrient and moisture which might have affected the formation of new leaves. Such type of findings were also obtained by Pendharkar *et al*. (2011), Pathrikar *et al.* (2018).

Table 4.4: Mean of leaf area (dm^2) plant^{-1} of *Bt.* cotton as influenced by different treatments at various growth stages.

Treatments	Days after sowing				
	30	60	90	120	At harvest
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	4.42	44.65	76.97	86.88	55.80
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	4.40	41.15	71.96	81.80	53.08
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	4.24	38.12	66.18	76.80	49.48
SE(m)±	0.05	0.74	1.22	1.21	0.74
CD at 5 %	NS	2.92	4.79	4.76	2.26
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	4.40	42.69	73.02	83.14	53.85
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	4.37	41.32	72.04	81.27	51.97
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	4.44	46.41	78.07	87.16	56.48
W_4: Weedy check.	4.20	34.81	63.66	75.74	47.51
SE(m)±	0.06	0.71	1.11	1.17	0.44
CD at 5 %	NS	2.12	3.31	3.47	1.30
Interaction (D X W)					
SE(m)±	0.11	1.23	1.93	2.02	0.76
CD at 5 %	NS	NS	NS	NS	NS
GM	**4.35**	**41.31**	**71.71**	**81.82**	**52.45**

4.3.3.2 Effect of weed management

At all stages of crop growth, leaf area plant^{-1} was significantly affected due to different weed management treatment except at 30 DAS. It was observed that the leaf area plant^{-1} were significantly maximum with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The minimum leaf area plant^{-1} was recorded by treatment weedy check (W_4) at all growth stages.

4.3.3.3 Interaction effects

The interaction effect between plant density and weed management treatment with respect to leaf area plant^{-1} was found to be non- significant at all the stages of *Bt*. cotton crop growth.

4.3.4 Dry matter accumulation plant^{-1} (g)

The data in respect of dry matter accumulation plant^{-1} as influenced by different treatments at different growth stages of *Bt*. cotton is presented in Table 4.5. and graphically depicted in Fig 4.4.

The dry matter accumulation plant^{-1} was increased progressively from 30 DAS up to 120 days, from 4.01 to 132.14 g plant^{-1}, respectively. Maximum dry matter accumulation was observed at 120 DAS, thereafter subsequent declined in dry matter production plant^{-1} up to harvest was observed due to half senescence and picking of burst bolls. The rate of increase in dry matter accumulation plant^{-1} was quite less at 30 DAS while maximum rate of dry matter accumulation was observed between 90 to 120 DAS.

4.3.4.1 Effect of plant density

Effect of plant density on the dry matter accumulation plant^{-1} was observed to be significant at all stages of crop growth except 30 DAS. Plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded significantly highest dry matter over D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) at all stages of *Bt*. cotton crop growth.

Table 4.5: Total dry matter (g) accumulating of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

Treatments	Days after sowing				
	30	**60**	**90**	**120**	**At harvest**
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	4.11	43.87	74.74	147.59	87.68
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	4.03	39.69	68.91	134.50	83.79
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	3.90	33.11	61.50	94.33	64.54
SE(m)±	0.09	0.69	1.28	3.01	1.29
CD at 5 %	NS	2.73	5.03	11.83	3.87
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	3.99	39.94	70.00	127.89	74.39
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	3.98	38.72	68.01	125.08	73.79
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	4.12	43.89	73.90	137.89	82.38
W_4: Weedy check.	3.98	33.01	61.65	111.12	64.59
SE(m)±	0.07	0.93	1.27	3.17	1.97
CD at 5 %	NS	2.77	3.77	9.41	5.91
Interaction (D X W)					
SE(m)±	0.13	1.61	2.20	5.49	3.95
CD at 5 %	NS	NS	NS	NS	NS
GM	**4.01**	**38.89**	**68.39**	**125.47**	**75.29**

Significantly highest dry matter plant^{-1} in lower plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) was due to more availability of light (solar energy), moisture and nutrients plant per unit area. This have resulted in achieving maximum leaf area with improved rate of biomass synthesis and consequently higher plant because of dry

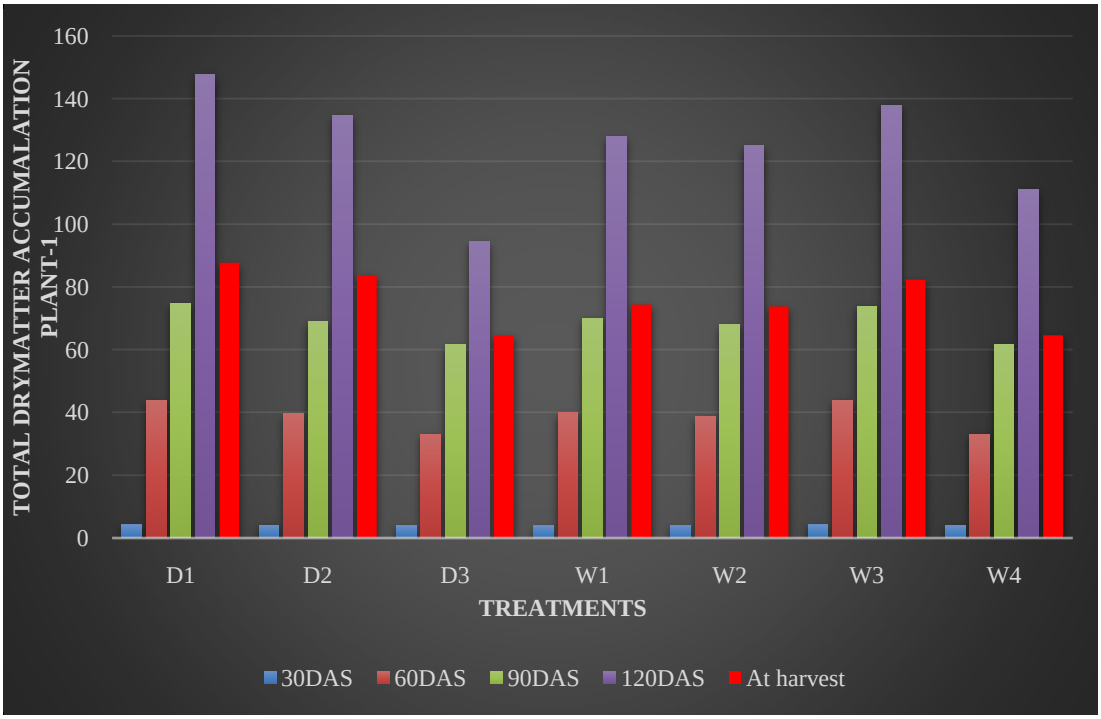


Fig 4.4: Total dry matter (g) accumulation of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

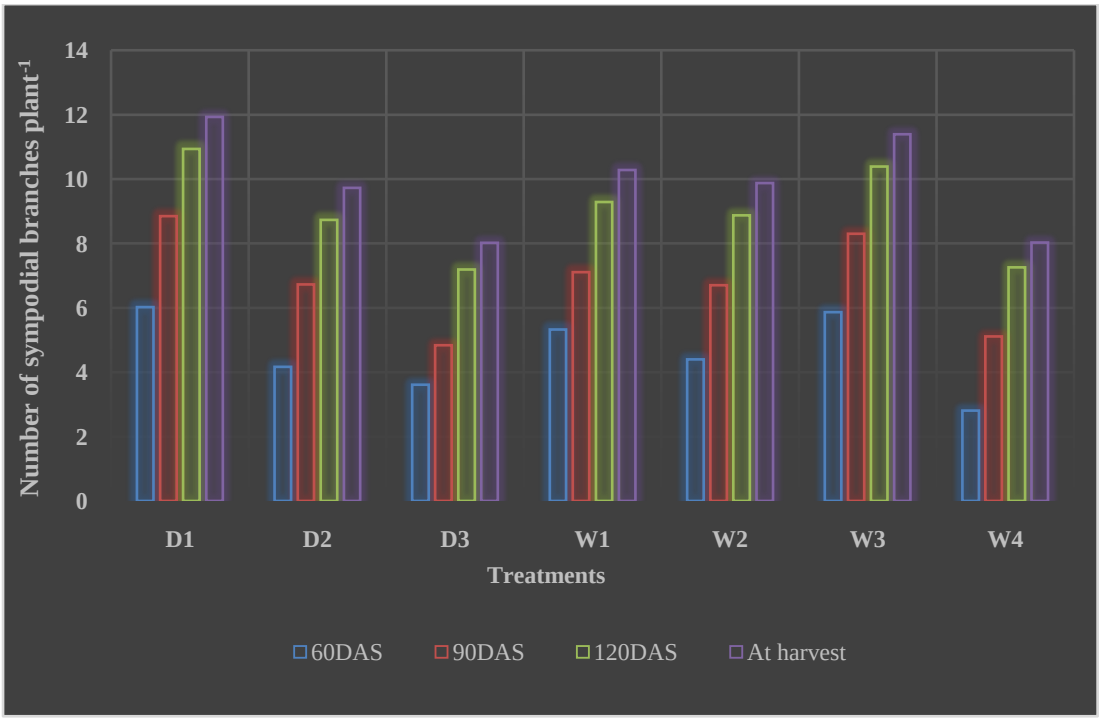


Fig 4.5: Number of sympodial branches plant^{-1} of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

matter accumulation is directly correlated with photosynthesis. Thus, plant under wider spacing have more photosynthetic activity than closer spacing. The significant decrease in dry matter plant¹ with increase in population pressure. Similar results on decrease in dry matter accumulation plant¹ due to dense planting were also reported by Jagtap and Bhale (2010).

4.3.4.2 Effect of weed management

At 30DAS mean dry matter accumulation plant^{-1} statistically non-significant. It was recorded that the higher production of dry matter accumulation plant^{-1} with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower dry matter accumulation plant^{-1} was recorded by treatment weedy check (W_4) at all growth stages.

Increase in dry matter accumulation plant^{-1} was cumulative effect of increase in various growth characters like plant height (cm), number of functional leaves plant^{-1}, leaf area plant^{-1}, number of monopodial branches plant^{-1}, sympodial branches plant^{-1}, number of bolls plant^{-1}. The mean total dry matter accumulation plant^{-1} was influenced due to different weed management treatments. Significantly highest dry matter accumulation plant^{-1} was recorded by post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). but It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. This might be due to larger leaf area with these treatments which resulted in more photosynthetic activities and more accumulation of carbohydrates which in turn increased dry matter accumulation Veeramani *et al*. (2009) also reported higher dry matter accumulation plant with use of pre and post emergence herbicides. Treatment weedy check (W_4) recorded lowest dry matter of plant might be due to severe infestation of weeds which competed for natural resources like moisture, nutrients and light. These findings are in conformity with that of reported by Bouchagier *et al*. (2008).

4.3.4.3 Interaction effects

Interaction effect was found to be non-significant at 30, 60, 90, 120 DAS and at harvest stage in respect of dry matter accumulation plant^{-1}.

4.3.5 Number of monopodial branches plant^{-1}

Number of monopodial branches plant^{-1} recorded from 60 DAS and 90 DAS of *Bt*. cotton hybrid is presented in Table 4.6. Number of monopodial branches plant^{-1} increased from 1.14 (60 DAS) and 1.28 (90 DAS).

Table 4.6: Number of monopodial branches plant^{-1} of *Bt.* cotton hybrid as influenced by different treatments.

Treatments	Days after sowing	
	60	90
A. Density		
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	1.20	1.57
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	1.11	1.27
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	1.08	1.09
SE(m)±	0.02	0.05
CD at 5 %	NS	0.20
B. Weed management		
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	1.16	1.35
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	1.14	1.26
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	1.19	1.53
W_4: Weedy check.	1.03	1.05
SE(m)±	0.02	0.05
CD at 5 %	0.06	0.16
Interaction (D X W)		
SE(m)±	0.03	0.09
CD at 5 %	NS	NS
GM	**1.14**	**1.28**

4.3.5.1 Effect of plant density

Monopodial branches plant^{-1} were significantly increased with decrease in plant density. Wider plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded significantly highest monopodial over D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) at 60 and 90 DAS.

Maximum number of monopodial branches plant^{-1} recorded at 90 DAS (1.57) in the spacing of D_1-90 cm X 45 cm as against of D_2-90 cm x 30 cm (1.27) and D_3-90 cm x 20 cm (1.09). It was due to the availability of space for lateral expansion of branches and chance to enhance auxillary buds of plant as compared to closer plant density, which recorded more competition for space, light and nutrient. Similar results were reported earlier by Srinivasulu *et al*. (2007). They reported that lower plant density recorded significantly higher vegetative branches than higher plant density.

4.3.5.2 Effect of weed management

It was recorded maximum number of monopodial branches plant^{-1} with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The minimum number of monopodial branches plant^{-1} was recorded by treatment weedy check (W_4) at 60 and 90 DAS.

4.3.5.3 Interaction effects

The interaction effect was found to be non-significant at all the stages of the crop growth in respect of number of monopodial branches plant^{-1}.

4.3.6 Number of sympodial branches plant^{-1}

Sympodial branches plant^{-1} was recorded from 60 DAS onwards at an interval of 30 days. Sympodial branches plant^{-1} was found to be increased with the age of crop and attained maximum number at harvest. Number of sympodial branches plant^{-1} increased from (4.60) 60 DAS to (9.90) at harvest. The maximum rate of increase in sympodial branches was recorded during 60-90 DAS. The data on mean number of sympodial branches is presented in Table 4.7. and graphically depicted in Fig 4.5.

Table 4.7: Number of sympodial branches plant^{-1} of *Bt.* cotton hybrid as influenced by different treatments at various growth stages.

Treatments	Days after sowing			
	60	**90**	**120**	**At harvest**
A. Density				
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	6.02	8.85	10.94	11.93
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	4.17	6.73	8.73	9.73
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	3.61	4.84	7.19	8.02
SE(m)±	0.10	0.11	0.16	0.19
CD at 5 %	0.35	0.46	0.62	0.77
B. Weed management				
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	5.33	7.11	9.29	10.28
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	4.40	6.70	8.87	9.88
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	5.87	8.30	10.39	11.39
W_4: Weedy check.	2.81	5.11	7.26	8.03
SE(m)±	0.11	0.18	0.17	0.21
CD at 5 %	NS	0.52	0.52	0.61
Interaction (D X W)				
SE(m)±	0.19	0.31	0.30	0.36
CD at 5 %	NS	NS	NS	NS
GM	**4.60**	**6.81**	**8.95**	**9.90**

4.3.6.1 Effect of plant density

The sympodial branches plant^{-1} were significantly increased with decrease in plant density. Under wider plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded significantly more number of sympodial branches plant^{-1} than closer plant spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) at all stages of *Bt*. cotton crop growth.

Plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) than closer plant spacing of D_3-90 cm X 20 cm and recorded maximum number of sympodial branches plant (11.93) under wider plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) at harvest

stage as against D_3-90 cm X 20 cm (55,555 plant ha^{-1}) and D_2-90 cm x 30 cm (37,037 plant ha^{-1}) plant spacing. Under closer spacing increasing the plant population per unit area might have increased competition for light and congestion in the growing crop plants which induced more vertical growth through inter nodal elongation. Thus most of the photosynthates consumed in vertical growth restricted lateral spread (branching). Such significant increase in number of sympodial $plant^{-1}$ under wider row spacing was also reported by Reddy and Kumar (2010).

4.3.6.2 Effect of weed management

It was recorded maximum number of sympodial branches with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The minimum number of sympodial branches was recorded by treatment weedy check (W_4) at all growth stages.

4.3.6.3 Interaction effects

Interaction effect among the plant density and weed management treatment was found to be non-significant in respect to sympodial branches $plant^{-1}$.

4.4 Growth analysis parameters

The growth function are measures of the growth rate in different growth parameters of plant. The data calculated on this aspect were not subjected to "T" test of variance and the results are interpreted on the basis of mean values.

4.4.1 Leaf area index (LAI)

Data on leaf area index as influenced by various treatments at different crop growth stages are given in Table 4.8. Data showed that LAI was increased up to 120 DAS and decreased there after due to leaf senescence.

4.4.1.1 Effect of plant density

Data for leaf area index differed significantly due to different plant density at all the stages of growth during one the years of experimentation. The plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) resulted in significantly highest values of leaf area index at all the stages of growth over plant spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}).

This indicates that the highest plant density produced maximum leaf area per unit land area over lower plant densities. Paslawar *et al*. (2015) also reported significantly highest leaf area index under higher plant density than lower plant density.

Table 4.8: Leaf area index (LAI) plant^{-1} of *Bt.* cotton crop as influenced by different treatments.

Treatments	Days after sowing				
	30	**60**	**90**	**120**	**At harvest**
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	0.110	1.116	1.924	2.172	1.387
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	0.162	1.524	2.634	3.029	1.965
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	0.235	2.117	3.676	4.267	2.748
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	0.172	1.673	2.861	3.258	2.110
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	0.170	1.619	2.823	3.185	2.036
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	0.173	1.965	3.059	3.416	2.213
W_4: Weedy check.	0.164	1.364	2.494	2.968	1.861
GM	**0.169**	**1.625**	**2.781**	**3.185**	**2.045**

4.4.1.2 Effect of weed management

The mean leaf area index plant^{-1} was influenced significantly due to different treatments. The application of treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded significantly higher leaf area index plant^{-1} than rest of treatments (W_1), (W_2) and (W_4).

4.4.2 Absolute growth rate (AGR) for dry matter (g day^{-1} plant^{-1})

The mean value of AGR based on dry matter (g day^{-1} plant^{-1}) obtained at various growth stages during the crop period is presented in Table 4.9. Which indicate that AGR based on total dry matter accumulation plant^{-1} day^{-1} was very slow during 0-30 DAS and very fast during 31-120 DAS and slowed down thereafter.

Table 4.9: Absolute growth rate (AGR) for plant dry matter (g day^{-1} plant^{-1}) of *Bt.* cotton hybrid as influenced by different treatments.

Treatments	Days after sowing				
	0-30	31-60	61-90	91-120	120-At harvest
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	0.137	1.325	1.029	2.428	-1.997
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	0.134	1.189	0.974	2.186	-1.690
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	0.130	0.973	0.946	1.761	-1.160
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	0.133	1.198	1.002	2.152	-1.802
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	0.132	1.158	0.976	2.122	-1.756
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	0.137	1.326	1.003	2.355	-1.866
W_4: Weedy check.	0.132	0.968	0.955	1.871	-1.603
GM	**0.133**	**1.162**	**0.914**	**2.125**	**-1.696**

4.4.2.1 Effect of plant density

Higher plant spacing of D_1- 90 cm x 45 cm (24,691 plant ha^{-1}) recorded more values of AGR for dry matter because of dry matter $plant^{-1}$ was found significantly more as compared to rest of the treatments of plant spacing D_2-90 cm × 30 cm (37,037 plant ha^{-1}) and D_3-90 cm × 20 cm (55,555 plant ha^{-1}).

4.4.2.2 Effect of weed management

Treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) was found higher values of AGR for dry matter than rest of treatments pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4).

As regards to growth analysis, the significantly higher mean values of AGR of plant height and dry matter, RGR, LAI were reported with post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) followed by pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). The lowest values of growth functions were found in weedy check (W_4).

Effective control of weeds through manual weeding in treatments post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) resulted into less weed-crop competition throughout the growth stage of crop and created favorable 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 findings are in agreement with those of Sadangi and Barik (2007), Veeramani *et al*. (2009), and Prabhu *et al*. (2012).

4.4.3 Relative growth rate (RGR) for dry matter (g g^{-1} day^{-1})

Data computed on mean RGR at various crop growth stages shown in Table 4.10. The studies showed that the RGR was increased continuously from 0-60 DAS and decreased thereafter.

4.4.3.1 Effect of plant density

In various plant density RGR was recorded in plant spacing of D_1-90 cm × 45 cm (24,691 plant ha^{-1}) at all crop growth stages and maximum value of RGR was recorded between 31-60 DAS.

4.4.3.2 Effect of weed management

Treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) were found be effective in increasing RGR for dry matter.

Table 4.10: Relative growth rate (RGR) for plant dry matter (g g^{-1} day^{-1}) of *Bt.* cotton hybrid as influenced by different treatments.

Treatments	Days after sowing				
	0-30	31-60	61-90	91-120	120-At harvest
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	0.0471	0.0790	0.0206	0.0227	-0.0173
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	0.0464	0.0762	0.0184	0.0223	-0.0158
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	0.0453	0.0712	0.0178	0.0206	-0.0121
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	0.0461	0.0768	0.0188	0.0218	-0.0171
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	0.0460	0.0758	0.0187	0.0220	-0.0170
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	0.0471	0.0788	0.0208	0.0224	-0.0174
W_4: Weedy check.	0.0460	0.0705	0.0174	0.0215	-0.0163
GM	**0.0461**	**0.0754**	**0.0189**	**0.0219**	**-0.0161**

4.5 Soil moisture studies

4.5.1 Effect of plant density

Higher plant spacing of D_1-90 cm × 45 cm (24,691 plant ha^{-1}) recorded higher moisture per cent than lower plant spacing of D_2-90 cm × 30 cm (37,037 plant ha^{-1}) and D_3-90 cm × 20 cm(55,555 plant ha^{-1}) at all stages of growth stages.

Table 4.11: Moisture content (%) in soil as influenced by different treatments.

Treatments	Days after sowing				
	30	**60**	**90**	**120**	**At harvest**
A. Density					
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	21.58	26.00	27.24	21.01	14.23
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	20.85	25.13	26.83	19.00	13.16
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	18.97	21.31	25.06	18.03	11.78
B. Weed management					
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	21.43	25.45	27.02	19.02	13.01
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	21.30	25.25	26.97	18.13	12.97
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	23.08	26.20	27.97	20.01	13.29
W_4: Weedy check.	16.06	19.70	23.55	18.00	11.68
GM	**19.95**	**24.15**	**26.38**	**19.03**	**12.87**

4.5.2 Effect of weed management

Treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) was found higher soil moisture than rest of treatments pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4).

Among the various weed management treatments post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded significantly higher moisture content per cent in soil than rest of the

treatments followed by treatments pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4). This might be due to the fact that less competition for natural resources and water absorption between crop plants and weed under weed free treatment and also less weed density m^2 therefore lower absorption of water by weed, this results are corrugated with the findings earlier reported by Sheets and Harris (1965).

4.6 Yield contributory characters:

Data regarding mean number of picked bolls $plant^{-1}$, boll weight (gm), seed cotton yield $plant^{-1}$ (gm) as influenced by different plant density and weed management.

4.6.1 Number of picked bolls $plant^{-1}$

Data in respect of number of bolls picked $plant^{-1}$ as influenced by various treatments is presented in Table 4.12 and graphically depicted in Fig 4.6.

4.6.1.1 Effect of plant density

Planting density significantly influenced the number of bolls picked $plant^{-1}$. Plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded significantly more number of picked bolls $plant^{-1}$ than D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) during one year of experimentation.

The number boll $plant^{-1}$ decreased in higher plant density due to greater inter plant competition. However, the increase in number of plants per unit area at closer spacing compensate for this decline. Jost and Cother (2000) also observed a decrease in number boll $plant^{-1}$ but an increase in boll number in unit area at elevated population. Similarly, plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) produced more picked bolls $plant^{-1}$ than that of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}). These findings are in agreement with those of Chavan *et al*. (2011).

4.6.1.2 Effect of weed management

It was recorded that the higher number of bolls picked plant^{-1} with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower number of bolls picked plant^{-1} was recorded by treatment weedy check (W_4).

4.6.1.3 Interaction effects

The interaction was found to be non-significant.

Table 4.12: Number of picked bolls plant^{-1}, boll weight (g) plant^{-1} and seed cotton yield (g) plant^{-1} of cotton as influenced by different treatments.

Treatments	Days after sowing		
	Number of picked bolls plant^{-1}	**Average boll weight (gm)**	**Seed cotton yield plant^{-1} (gm)**
A. Density			
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	17.70	3.64	64.54
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	14.85	3.56	53.02
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	11.89	3.28	39.07
SE(m)±	0.38	0.12	1.65
CD at 5 %	1.47	NS	6.48
B. Weed management			
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	15.34	3.50	54.05
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	14.86	3.46	51.58
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	16.65	3.64	60.99
W_4: Weedy check.	12.42	3.37	42.21
SE(m)±	0.18	0.06	0.92
CD at 5 %	0.54	NS	2.73
Interaction (D X W)			
SE(m)±	0.31	0.07	1.59
CD at 5 %	NS	NS	NS
GM	**14.82**	**3.49**	**52.21**

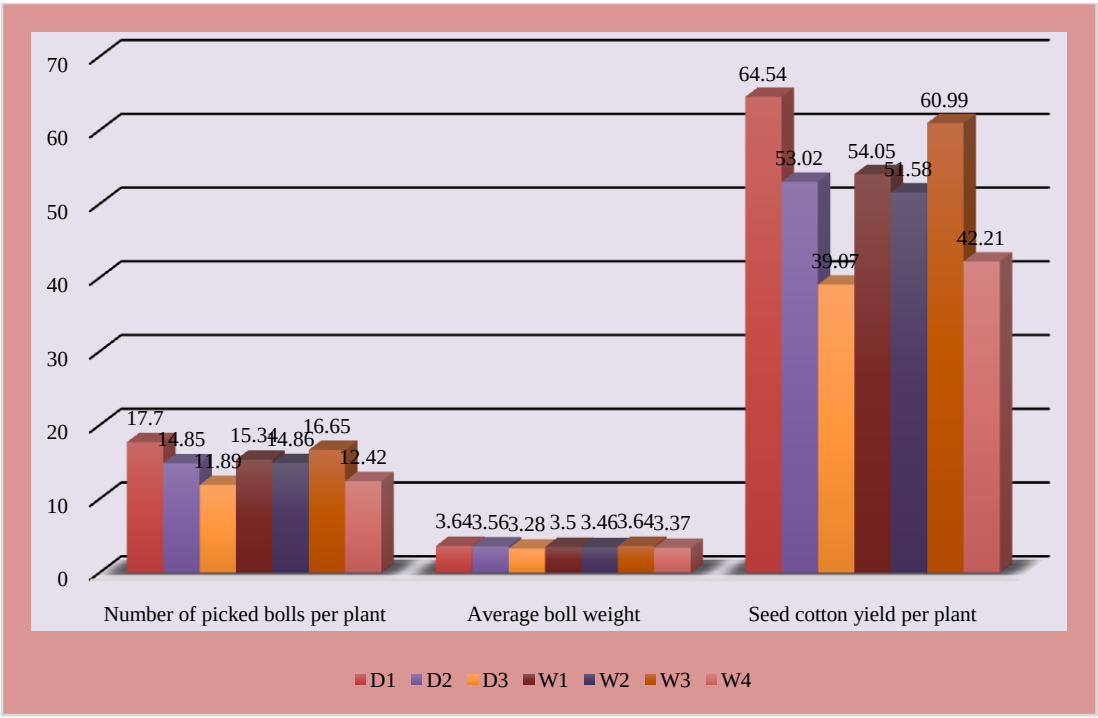


Fig 4.6: Number of picked bolls plant^{-1}, boll weight (g) plant^{-1} and seed cotton yield (g) plant^{-1} ofcotton as influenced bydifferent treatments.

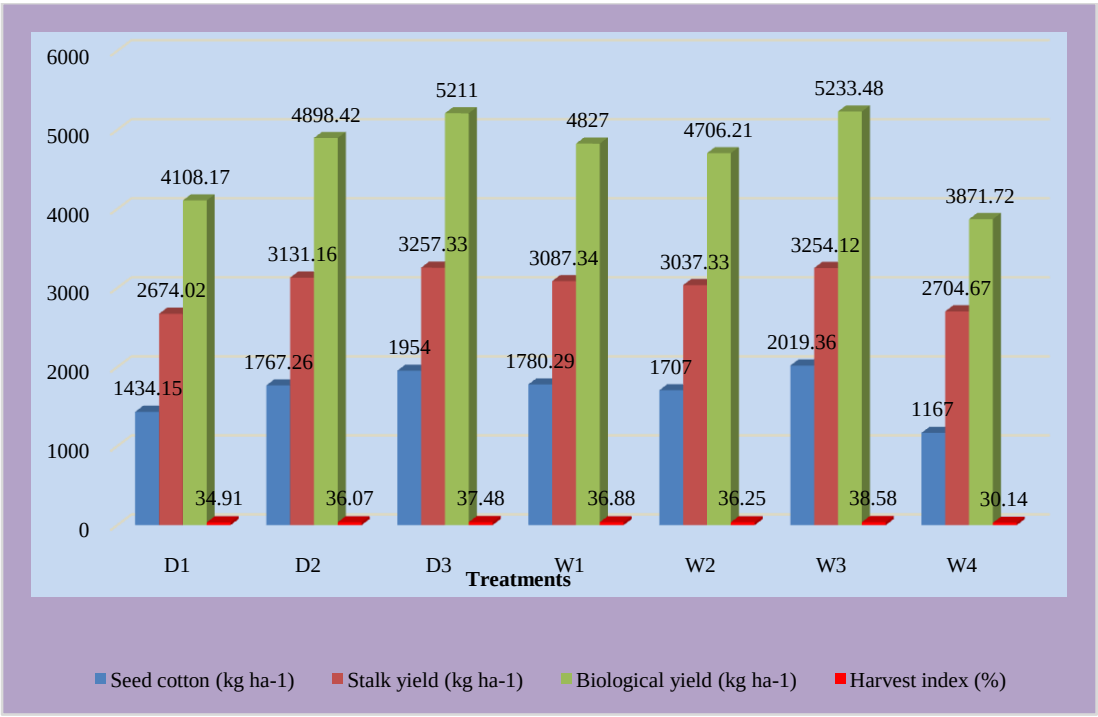


Fig 4.7: Seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}), Biological yield (kg ha^{-1}) and harvest index (%) of *Bt.* cotton hybrid as influenced by different treatments.

4.6.2 Average boll weight (gm)

Data regarding boll weight as influenced by plant density and weed management treatments are presented in Table 4.12 and graphically depicted in Fig 4.6.

4.6.2.1 Effect of plant density

The data reported in Table 4.12 indicate that the difference due to various plant density in respect of boll weight was significantly influenced. A plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) produced more boll weight 3.64 g over the plant spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) on an boll weight 3.56 g and 3.28 was recorded respectively.

The variation in boll weight in plant density was due to fact that the better aeration and adequate interception of light and lesser competition of nutrients at wider spacing, which resulted in synthesis of higher photosynthates and there by helped to produce higher boll weight.

4.6.2.2 Effect of weed management

It was recorded that the higher produced boll weight with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower boll weight was recorded by treatment weedy check (W_4).

4.6.2.3 Interaction effect

The interaction was found to be non-significant.

4.6.3 Seed cotton yield $plant^{-1}$ (gm)

Data regarding seed cotton yield $plant^{-1}$ (gm) as influenced by plant density and weed management treatments are presented in Table 4.12 and graphically depicted in Fig 4.6.

4.6.3.1 Effect of plant density

Treatment differences due to plant density were observed to be significant. Plant spacing of D_1-90 cm X 45 cm (24,691 plant ha^{-1}) recorded significantly higher yield of seed cotton $plant^{-1}$ as compared to plant spacing of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}). Higher plant spacing of D_1-90 cm X 45 cm 24,691 plants ha^{-1} produced on average of 64.54 g of seed cotton yield $plant^{-1}$.

This might be due to the wider spacing availability of photosynthates to individual plant was more that led to overall improvement in growth attributes and its positive effect on number of bolls $plant^{-1}$ was more to produce maximum seed cotton weight $plant^{-1}$ as compared to closer row spacing. The above result are in conformity with the findings of Bhalerao *et al*. (2008), Pawar *et al*. (2010) and Chavan *et al*. (2011).

4.6.3.2 Effect of weed management

It was recorded that the higher seed cotton $plant^{-1}$ with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower seed cotton $plant^{-1}$ was recorded by treatment weedy check (W_4) at all growth stages.

4.6.3.3 Interaction effects

The interaction was found to be non-significant

4.7 Yield studies

Data regarding mean number of seed cotton yield (kg ha^{-1}), stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}), and harvest index as influenced by different plant density and weed management are presented in Table 4.13.

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

Data pertaining seed cotton yield (kg ha^{-1}) as influenced by different treatments are presented Table 4.13 and graphically depicted in Fig 4.7. On an average yield of seed cotton was 1718 kg ha^{-1}.

4.7.1.1 Effect of plant density

Increased yield plant obtained with D_1-90 cm x 45 cm i.e. at the lowest plant density of 24,691 plant ha^{-1} was inadequate to compensate the loss in the plant population and thus resulted in significantly lower seed cotton yield (kg ha^{-1}) during one years of experimentation and in data over D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}). But it was at with plant spacing D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}) to each other.

The increased in seed cotton yield under lowest plant spacing of 90 cm x 20 cm (55,555 plant ha^{-1}) over highest plant spacing D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_1-90 cm x 45 cm (24,691 plant ha^{-1}). It was at par with plant spacing D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_2-90 cm x 20 cm (55,555 plant ha^{-1}) to each other. The increase in seed cotton yield (kg ha^{-1}) in closer spacing was due to significantly higher plant population per unit area. In comparison to closer spacing wider spacing recorded more number of picked bolls $plant^{-1}$ and yield $plant^{-1}$ but higher plant population, which compensated the yield $plant^{-1}$ even though there were lesser number of picked bolls and yield $plant^{-1}$. Lower plant population is the major cause for its low in the seed cotton yield. Similar result were also reported by Giri *et al*. (2008), Reddy and Gopinath (2008), Bhalerao and Gaikwad (2010) and Reddy and Kumar (2010).

4.7.1.2 Effect of weed management

It was recorded that the higher seed cotton yield (kg ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower seed cotton yield was recorded by treatment weedy check (W_4).

The higher seed cotton yield (kg ha^{-1}) in these treatment could be attributed to improved yield components viz., seed cotton yield $plant^{-1}$ and number of harvested boll $plant^{-1}$. This improvement in turn was due to improvement in growth attributes such as plant height, higher total dry matter production, leaf area index, and number of sympodial branches under post emergence pyrithiobac sodium + quizalofop-ethyl

(20-25 DAS) followed by 40 days hand weeding (W_3). The increased seed cotton yield (kg ha^{-1}) in this treatment could be attributed to the efficient utilization of growth resources and other environmental factors. This was consequence of reduced crop-weed competition due to good control of weeds. Analogous findings have been reported by Singh and Kokate (2010), Bharathi *et al*. (2011), Prabhu *et al*. (2012), Ali *et al*. (2013), Pawar *et al*. (2015) and Rani *et al*. (2016).

4.7.1.3 Effect of interaction

The data pertaining to interaction effects on seed cotton yield kg ha^{-1} of different treatments were found to be not evident.

4.7.2 Stalk yield (kg ha^{-1})

The data cotton stalk yield (kg ha^{-1}) as influenced by different treatments is presented in Table 4.13 and graphically depicted in Fig 4.7. The average cotton stalk yield was 3020 kg ha^{-1}.

4.7.2.1 Effect of plant density

Increased cotton stalk yield $plant^{-1}$ obtained with plant spacing D_1-90 cm X 45 cm i.e. at the lowest plant density of 24,691 plant ha^{-1} was inadequate to compensate the loss in the plant population and thus resulted in significantly lower cotton stalk yield $plant^{-1}$ during one years of experimentation and in data over D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}). It was at with plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) to each other.

The increased in stalk yield (kg ha^{-1}) under lowest plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) over highest plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}). It was at with plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) to each other. These result are in conformity with the findings of chavan *et al*. (2011)

4.7.2.2 Effect of weed management

It was recorded that the higher stalk yield (kg ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence

pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower stalk yield (kg ha^{-1}) was recorded by treatment weedy check (W_4).

The increase in stalk yield (kg ha^{-1}) under the weed free treatment could be attributed to higher vegetative growth, dry matter accumulation in plants via efficient utilization of growth resources and other environmental characters as well as less weed crop competition throughout the growth period. Significantly the lowest stalk yield and biological yield were recorded under weedy check (W_4). Deprived growth and development of the crop under the weedy check (W_4) owing to severe crop-weed competition for resources might have been responsible for poor yields. Analogous findings have been reported by Sangle *et al*. (2007), Bharathi *et al*. (2011), Hakoomat Ali *et al*. (2013) and Panwar (2001).

4.7.2.3 Effect of interaction

The interaction effects of different treatments were found to be not evident on stalk yield (kg ha^{-1}).

4.7.3 Biological yield (kg ha^{-1})

Data pertaining biological yield kg ha^{-1} as influenced by different treatment is pertaining in Table 4.13 and graphically depicted in Fig 4.7.

4.7.3.1 Effect of plant density

The increased in biological yield kg ha^{-1} under lowest plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) over highest plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}). It was at with plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) to each other

Significant improvement in biological yield kg ha^{-1} under high plant density of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) was due to higher seed cotton yield kg ha^{-1} and stalk yield kg ha^{-1} by accommodating more plant population of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) than that of D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}), but it was at par with plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) to each other. Similar results were also reported by Chavan *et al.* (2011) and Paslawar *et al.* (2015).

4.7.3.2 Effect of weed management

It was recorded that the higher biological yield (kg ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower biological yield (kg ha^{-1}) was recorded by treatment weedy check (W_4).

4.7.3.3 Effect of interaction

The interaction effects of different treatments were found to be not evident on biological yield (kg ha^{-1}).

Table 4.13: Seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) of *Bt.* cotton hybrid as influenced by different treatments

Treatments	Seed cotton yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
A. Density				
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	1434.15	2674.02	4108.17	34.91
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	1767.26	3131.16	4898.42	36.07
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	1954.00	3257.33	5211.00	37.48
SE(m)±	51.56	79.78	98.65	
CD at 5 %	198.23	312.76	380.03	
B. Weed management				
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	1780.29	3087.34	4827.00	36.88
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	1707.00	3037.33	4706.21	36.25
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	2019.36	3254.12	5233.48	38.58
W_4: Weedy check.	1167.03	2704.67	3871.72	30.14
SE(m)±	51.18	83.63	118.37	-
CD at 5 %	152.03	248.41	351.56	-
Interaction (D X W)				
SE(m)±	120.13	360.23	490.56	-
CD at 5 %	NS	NS	NS	-
GM	**1718.36**	**3020.83**	**4693.65**	**36.15**

4.7.4 Harvest index

Data in relation to harvest index as influenced by different treatments under study in reported in Table 4.13 indicate that the mean harvest index was 36.15%.

4.7.4.1 Effect of plant density

Lower plant spacing D_3-90 cm X 20 cm (55,555 plant ha^{-1}) resulted significantly maximum harvest index than higher plant spacing D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_1-90 cm X 45 cm (24,691 plant ha^{-1}).These similar result supported by the findings of Pendharkar *et al*. (2011)

4.7.4.2 Effect of weed management

It was recorded that the higher harvest index with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). The lower harvest index was recorded by treatment weedy check (W_4).

4.8 Weed studies

The weeds associated with *Bt.* cotton in the experimental field during the experimental period were identified and a list is presented in Table 4.14.

Table 4.14: Dominant weeds associated with *Bt.* cotton during 2021-22

Sr.No.	Local name	Botanical name	Family
a)	**Monocots weeds**		
i)	Hariyali	*Cynodon datylon*	Gramineae
ii)	Lona	*Dinebra retroflexa*	Gramineae
iii)	Kena	*Commelina benghalensis*	Commelinaceae
iv)	Shippi	*Brachiria eruciformis*	Gramineae
b)	Dicots		
i)	Reshim kata	*Alternanthera triandra*	Amaranthaseae
ii)	Gajar gavatt	*Parthenium hysterophorous*	Asteraceae
iii)	Kurudu	*Celocia argentia*	Amaranthaseae
iv)	Hazardani	*Phylanthus niruri*	Euphorbhiaceae
v)	Lajalu	*Mimosa pudica*	Legumenaceae
vi)	Ghol	*Portulaca oleraceae*	Portulacaeae
vii)	Dhudi(choti)	*Euphorbia geniculate*	Euphorbhiaceae
viii)	Dhudi(moti)	*Euphorbia hirta*	Euphorbhiaceae
c)	Sedges		
i)	Lavala	*Cyperous rotundus*	Cyperaceae

4.8.1 Weed count

Data regarding number of monocot and dicot weeds per square meter is presented in Table 4.15. The mean weed count m² for monocot and dicot was 17.80 and 13.13 at 30 DAS, 25.49 and 21.12 at 60 DAS, 36.01 and 32.63 at 90 DAS and 44.30 and 42.18 at harvest, respectively.

4.8.1.1 Effect of plant density

The weed count (m^2) was influenced significantly due to different plant densities. The spacing D_1-90 cm X 45 cm (24,691 plant ha^{-1}) was recorded significantly higher weed count (m^2) over the plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}), but plant spacing D_2- 90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}) was at par with each other.

4.8.1.2 Effect of weed management

Mean data on weed count of monocots, dicots recorded at harvest is furnished in Table 4.15. The differences in monocots weed count were found to be significant at harvest. The lower number of monocot and dicot weeds were recorded with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4). The highest count of monocot and dicot weeds at harvest was recorded under weedy check (W_4).

After critical examination Table 4.15 indicated that the weed count of monocot and dicot weeds recorded under treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) was significantly lower as compared to all other weed management treatments. Effective control of weeds by integration of pre-emergence and post emergence herbicides with hand weeding was responsible for lower weed intensity under treatment (W_3) Further, dense crop canopy under these treatments had suppressing effect on weeds. The unweeded treatment weedy check (W_4) had evidently the highest population of monocot, dicot weeds owing to uncontrolled condition in all stages of growth. Effectiveness of different application has been reported by Giri *et al*. (2006), Ikram (2012), Patel *et al*. (2014), Veeraputhiran and Srinivasan (2015) and Malarkodi *et al*. (2017), Pawar *et al*. (2022) and Singh *et al*. (2022).

Table 4.15: Weed count m^{-2} of *Bt.* cotton hybrid as influenced by different treatments

Treatments	30 DAS		60 DAS		90 DAS		At Harvest	
	Monocot	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**
A. Density								
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	20.16	15.44	28.97	23.46	38.46	35.06	46.97	46.19
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	17.00	12.08	24.73	20.31	35.02	32.01	43.92	41.57
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	16.24	11.85	22.77	19.54	34.49	30.83	42.01	38.76
SE(m)±	0.43	0.38	0.52	0.43	0.58	0.58	0.60	0.75
CD at 5 %	1.70	1.48	2.02	1.69	2.28	2.27	2.35	2.94
B. Weed management								
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	14.36	9.63	21.96	17.67	31.70	29.09	40.32	37.03
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS.	16.72	12.02	23.80	20.02	33.64	31.14	43.48	40.46
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	9.38	4.68	15.85	12.68	27.88	24.54	35.67	34.25
W_4: Weedy check.	30.73	26.18	40.35	34.03	50.73	45.77	57.73	56.97
SE(m)±	0.43	0.39	0.57	0.43	0.63	0.51	0.64	1.07
CD at 5 %	1.27	1.17	1.68	1.28	1.87	1.52	1.91	3.18
Interaction (D X W)								
SE(m)±	0.74	0.68	0.98	0.74	1.10	0.89	1.12	1.85
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS
GM	**17.80**	**13.13**	**25.49**	**21.12**	**36.01**	**32.63**	**44.30**	**42.18**

4.8.1.3 Interaction effects

The interaction was found to be non-significant.

4.8.2 Weed dry matter (g m^{-2})

Data regarding number of monocot and dicot weeds per square meter is presented in Table 4.16. The mean weed dry matter g m^{-2} for monocot and dicot was 10.28 and 15.95 at 30 DAS, 18.29 and 20.70 at 60 DAS, 23.14 and 29.53 at 90 DAS and 32.55 and 33.16 at harvest, respectively.

4.8.2.1 Effect of plant density

The weed dry matter (g m^{-2}) was influenced significantly due to different plant densities. The spacing D_1-90 cm X 45 cm (24,691 plant ha^{-1}) was recorded significantly higher weed dry matter over the plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}), but plant spacing D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plan hat^{-1}) was at par with each other.

4.8.2.2 Effect of weed management

Mean data on weed dry matter (g m^{-2}) of monocots, dicots recorded at harvest is furnished in Table 4.16. The differences in monocots and dicot weed dry matter (g m^{-2}) were found to be significant at harvest. The lower number of monocot and dicot weeds were recorded with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4). The highest weed dry matter of monocot and dicot weeds at harvest was recorded under weedy check (W_4).

Table 4.16: Weed dry matter (g m^{-2}) of as influenced by different treatments

Treatments	30DAS		60DAS		90DAS		At Harvest	
	Monocot	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**
A. Density								
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	12.17	18.08	21.92	24.58	25.04	31.37	34.91	35.29
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	9.83	15.17	17.07	19.67	22.78	29.20	31.96	32.68
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	8.84	14.59	15.86	17.84	21.59	28.01	30.77	31.50
SE(m)±	0.26	0.27	0.39	0.50	0.32	0.34	0.38	0.50
CD at 5 %	1.02	1.08	1.55	1.98	1.28	1.34	1.51	1.96
B. Weed management								
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	7.46	12.46	12.34	14.43	17.68	23.35	25.96	26.59
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 20-25 DAS.	8.77	13.78	14.55	17.02	19.88	25.55	28.39	29.78
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	5.78	10.05	9.87	11.78	13.96	19.63	21.89	23.08
W_4: Weedy check.	19.11	27.50	36.37	39.56	41.03	49.58	53.96	53.17
SE(m)±	0.36	0.40	0.74	0.77	0.56	0.57	0.51	0.78
CD at 5 %	1.07	1.21	2.20	2.28	1.67	1.68	1.53	2.31
Interaction (D X W)								
SE(m)±	0.62	0.71	1.28	1.32	0.97	0.98	0.89	1.35
CD at 5 %								
GM	**10.28**	**15.95**	**18.29**	**20.70**	**23.14**	**29.53**	**32.55**	**33.16**

Data presented in Table 4.16 clearly showed that among the weed control treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) produced significantly lower weed dry matter. This was due to lower weed population recorded under these treatments could be attributed to the effective weed control at early stage by pre-emergence herbicides application and later through post emergence application. While post-emergence application of pyrithiobac sodium was found effective to reduce dry weight due to lower contribution of dicot weeds in weed flora and application of quizalofop-ethyl effective to reduce dry weight of monocot weeds. Higher dry matter of weeds was observed under weedy check (W_4) at all the successive crop growth stages. The maximum weed dry weight might have been due to the maximum weed density in weedy check. These observations are almost in line with those of reported by Panwar *et al*. (2001), Giri *et al*. (2006), Nalini *et al*. (2011), Ikram *et al*. (2012), Patel *et al*. (2014) and Malarkodi *et al*. (2017).

4.8.2.3 Interaction effects

The interaction was found to be non-significant.

4.8.3 Weed control efficiency (%)

The data pertaining to the weed control efficiency of monocot and dicot is presented in Table 4.17. The mean weed control efficiency for monocot and dicot weed were 53.95 and 49.01 at 30 DAS, 58.01 and 55.63 at 60 DAS, 50.87 and 47.02 at 90DAS 46.29 and 43.91 per cent at harvest, respectively.

4.8.3.1 Effect of plant density

The weed control efficiency (%) was influenced significantly due to different plant densities. The plant spacing of D_3-90 cm X 20 cm (55,555 plant ha^{-1}) was recorded significantly higher weed control efficiency (%) over the spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_1-90 cm x 45 cm (24,691 plant ha^{-1}).

4.8.3.2 Effect of weed management

The highest weed control efficiency in both the cases i.e. monocot and dicot weeds at 30, 60 DAS, 90 DAS and at harvest was recorded by treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). At all the observations the lowest weed control efficiency in both monocot and dicot was noticed in case of the weedy check (W_4).

Among different weed management treatments, the highest weed control efficiency was registered under post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than rest of treatments pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). The lowest weed control efficiency of zero per cent as well as the highest weed index of 46.30 per cent was recorded under weedy check (W_4) which indicated that unrestricted weed growth reduced the yield of seed cotton. This similar result observed by Giri *et al*. (2006), Thorat *et al*. (2007) Hiremath *et al*. (2013), Shelke *et al*. (2013), Singh and Rathore (2015), Veeraputhiran and Srinivasan (2015).

Table 4.17: Weed control efficiency (%) of as influenced by different treatments

Treatments	30 DAS		60 DAS		90 DAS		At Harvest	
	Monocot	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**	**Monocot**	**Dicot**
A. Density								
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	36.31	34.25	39.75	37.87	38.97	35.72	35.30	33.62
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	48.84	44.83	53.06	50.28	44.48	41.10	40.77	38.53
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	53.74	46.94	56.39	54.90	47.38	43.50	42.98	40.75
B. Weed management								
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	60.96	54.69	66.07	63.52	56.91	52.90	51.89	49.98
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 20-25 DAS.	54.10	49.93	59.98	57.02	51.54	48.46	47.37	43.97
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	69.75	63.46	72.86	70.22	65.97	60.40	59.43	56.59
W_4: Weedy check.	-	-	-	-	-	-	-	-
GM	**53.95**	**49.01**	**58.01**	**55.63**	**50.87**	**47.02**	**46.29**	**43.91**

4.8.4 Weed index (%)

Data on weed index as influenced by different treatments under study indicate that the mean weed index was 17.46 per cent are presented in Table 4.18.

4.8.4.1 Effect of plant density

The weed index (%) was influenced significantly due to different plant densities. The plant spacing of D_1-90 cm x 45 cm (24,691 plant ha^{-1}) was recorded significantly higher weed index (%) over the spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_3-90 cm x 20 cm (55,555 plant ha^{-1}).

Table 4.18: Weed index (%) of *Bt.* cotton hybrid as influenced by different treatments

Treatments	Weed index (%)
A. Density	
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	28.98
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	12.48
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	7.25
B. Weed management	
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	11.84
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 20-25 DAS.	15.48
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	3.98
W_4: Weedy check.	42.21
GM	**17.46**

4.8.4.2 Effect of weed management

Among the herbicidal treatments, lower weed index 3.98 per cent was recorded by treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4). The highest value of weed index 42.21 per cent was noticed in case of treatment weed check (W_4).

Among different weed management treatments, the lowest weed index under post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than rest of treatments. The lowest weed control efficiency of 0.00 per cent as well as the highest weed index of 42.21 per cent was recorded under weedy check (W_4) which indicated that unrestricted weed growth reduced the yield of seed cotton. The findings are in agreement with those of Giri *et al*. (2006), Thorat *et al*. (2007) Hiremath *et al*. (2013), Shelke *et al*. (2013), Singh and Rathore (2015), Veeraputhiran and Srinivasan (2015).

4.9 Economics studies:

Data on pertaining to the gross monetary returns, net monetary returns, and B:C ratio of *Bt*. cotton under different treatment are furnished in Table 4.19.

4.9.1 Gross monetary returns (GMR):

Data on gross monetary returns obtained under different treatment are presented in Table 4.19. Mean gross monetary return were Rs. 1,74,896 ha^{-1}.

4.9.1.1 Effect of plant density

Plant density significantly differed gross monetary returns (Rs ha^{-1}), where in plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) recorded significantly higher gross monetary returns (Rs ha^{-1}) as compared to plant spacing D_2-90 cm x 30 cm (37,037 plants ha^{-1}) and D_1-90 cm x 45 cm (24,691 plants ha^{-1}) during one year experiment. Plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) and D_2-90 cm x 30 cm (37,037 plants ha^{-1}) in gross monetary returns (Rs ha^{-1}) were remained at par with each other. In analysis, the highest gross monetary returns (Rs ha^{-1}) were recorded in the plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) more than D_2-90 cm x 30 cm (37,037 plants ha^{-1}) and D_1-90 cm x 45 cm (24,691 plants ha^{-1}). It was due to higher seed cotton (kg ha^{-1}) and stalk yield (kg ha^{-1}) under high plant spacing D_1-90 cm x 20 cm (55,555 plants ha^{-1}). These results are agreement with Raut *et al*. (2005), Chavan *et al*. (2011) and Paslawar *et al*. (2015).

4.9.1.2 Effect of weed management

It was recorded that the higher gross monetary returns (Rs ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower gross monetary returns (Rs ha^{-1}) was recorded by treatment weedy check (W_4).

Data pertaining to economic studies revealed that post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded significantly higher gross monetary returns Rs.2,05,974 ha^{-1} over rest of the treatments but it was statistically at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The higher gross monetary returns (Rs ha^{-1}) attributed higher seed cotton kg ha^{-1} and stalk yield kg ha^{-1} on account of better control of weeds with these treatments. Similar results were reported by Hiremath *et al*. (2014) and Pawar *et al*. (2015).

4.9.1.3 Effect of interaction

The interaction effect of different treatments were not influenced significantly for gross monetary returns (Rs ha^{-1}).

4.9.2 Net monetary returns (NMR):

Data on net monetary returns (Rs ha^{-1}) obtained under different treatment are presented in Table 4.19. Mean net monetary returns were Rs. 97,894 ha^{-1}.

4.9.2.1 Effect of plant density

Plant density significantly differed net monetary returns (Rs ha^{-1}), where in plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) recorded significantly higher net monetary returns (Rs ha^{-1}) as compared to plant spacing D_1-90 cm x 45 cm (24,691 plants ha^{-1}) during one year experiment. But Plant spacing D_3-90 cm x 20 cm (55,555

plants ha^{-1}) and D_2-90 cm x 30 cm (37,037 plants ha^{-1}) in net monetary returns were remained at par with each other. Maximum net monetary returns were recorded in the plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) and D_2-90 cm x 30 cm (37,037 plants ha^{-1}) more than D_1-90 cm x 45 cm (24,691 plants ha^{-1}). Due to higher plant density 55,555 plants ha^{-1} increased the cost of cultivation than 37,037 plants ha^{-1}, because of higher seed rate ha^{-1}. Similar findings were also reported by Raut *et al*. (2005).

The above results indicated that higher plant density i.e. 55,555 and 37,037 plants ha^{-1} was economically viable with higher net returns (Rs ha^{-1}). It might be attributed viable with higher net returns (Rs ha^{-1}). Similar results were reported by Bhalerao *et al*. (2008), Bhalerao and Gaikwad (2010) and Reddy and Kumar (2010). They estimated highest net returns and returns per rupee invested under closer spacing than wider spacing.

4.9.2.2 Effect of weed management

It was recorded that the higher net return (Rs ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. The lower net return (Rs ha^{-1}) was recorded by treatment weedy check (W_4).

The significantly maximum net return (Rs ha^{-1}) were recorded by post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) Rs.1,22,678 ha^{-1}. It was at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other. In case of cost of cultivation, among all the weed management treatments post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded significantly higher cost of cultivation Rs. 83,297 ha^{-1} over rest of the treatments. Lower cost of cultivation was recorded by weedy check

(W_4). This might due to be keeping the land free of weeds throughout the crop growing period is practically impossible for the farmers since it involves huge cost on labour. The highest net returns (Rs ha^{-1}) and maximum B:C value with treatment (W_3), might be due to higher gross returns (Rs ha^{-1}) (W_3) and comparatively less cost of production compared to rest of the treatments. The results confirm the findings of Prabhu *et al*. (2012), Nandagavi and Halikatti (2016) and Kamble and Danawale (2017).

4.9.2.3 Effect of interaction

The interaction effects of different treatments were not influenced significantly for net monetary returns (Rs ha^{-1}).

4.9.3 Cost of cultivation

Data on cost of cultivation (Rs ha^{-1}) obtained under different treatment are presented in Table 4.19. Mean cost of cultivation were Rs. 77,001 ha^{-1}.

4.9.3.1 Effect of plant density

Plant density significantly differed cost of cultivation (Rs ha^{-1}), where in plant spacing D_3-90 cm x 20 cm (55,555 plants ha^{-1}) recorded significantly higher cost of cultivation (Rs ha^{-1}) as compared to plant spacing D_2-90 cm x 30 cm (37,037 plants ha^{-1}) and D_1-90 cm x 45 cm (24,691 plants ha^{-1}) during one year experiment.

4.9.3.2 Effect of weed management

It was recorded that the higher cost of cultivation (Rs ha^{-1}) with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). The lower cost of cultivation (Rs ha^{-1}) was recorded by treatment weedy check (W_4).

4.9.4 Benefit cost ratio (B:C ratio):

Data on B:C ratio obtained under different treatment are presented in Table 4.19. Mean B:C ratio were 2.27.

4.9.4.1 Effect of plant density

During one the years of study and in result, lower plant spacing D_2-90 cm x 30 cm (37,037 plants ha¹) significantly improved the benefit cost ratio over higher plant spacing D_1-90 cm x 45 cm (24,691 plants ha^{-1}).

More benefit cost ratio was recorded with plant spacing D_2-90 cm x 30 cm (37,037 plants ha¹) than plant spacing D_1-90 cm x 45 cm (24,691 plants ha^{-1}). Similar increase in benefit cost ratio under higher plant density were reported by Bhalerao and Gaikwad (2010), Reddy and Kumar (2010), Chavan *et al*. (2011), and Pawar *et al*. (2011).

4.9.4.2 Effect of weed management

It was recorded that the higher benefit cost ratio with treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2). The lower benefit cost ratio was recorded by treatment weedy check (W_4).

The maximum B:C ratio 2.47 was recorded by post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3). This was due to the expenditure incurred on weed management in these treatments was lower besides comparable yield of cotton. Which indicates the treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) more economical than other weed control treatments. The lowest B:C ratio in weedy check (W_4) due to lower economic yield and higher cost of cultivation. These results are in conformity with those reported by Prabhu *et al*. (2012) and Hiremath *et al*. (2014).

Table 4.19: Gross monetary return (Rs ha^{-1}), Net monetary return (Rs ha^{-1}) and B:C ratio of *Bt.* cotton as influenced by different treatments at harvest.

Treatments	Days after sowing			
	Gross monetary returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net monetary return (Rs ha^{-1})	Benefit cost ratio
A. Density				
D_1-90 X 45 cm^2 (24,691 plant ha^{-1})	146283	70110	76173	2.08
D_2-90 X 30 cm^2 (37,037 plant ha^{-1})	180260	74446	105814	2.42
D_3-90 X 20 cm^2 (55,555 plant ha^{-1})	198145	82449	115696	2.40
SE(m)±	5248	-	5065	-
CD at 5 %	20605	-	19856	-
B. Weed management				
W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing.	181589	79935	100654	2.27
W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 20-25 DAS.	174089	77756	97333	2.23
W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding.	205974	83297	122678	2.47
W_4: Weedy check.	119037	61017	58020	1.95
SE(m)±	4201	-	4123	-
CD at 5 %	12483	-	12210	-
Interaction (D X W)				
SE(m)±	7276	-	7034	-
CD at 5 %	NS	-	NS	-
GM	**174896**	**77001**	**97894**	**2.27**

CHAPTER-V

SUMMARY AND CONCLUSIONS

CHAPTER-V

SUMMARY AND CONCLUSIONS

An agronomic investigation the "Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton" was carried out at Central Farm, Balsa, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* season 2021-22. The soil of the experimental plot was slightly alkaline in reaction and clayey in texture. It was low in available nitrogen, medium in available phosphorus and high in available potassium content.

The experiment was laid out in split plot design, which consisted of twelve treatment combinations comprising of three treatments of plant density as a main plots and four treatments of weed management as a sub plots and were replicated three times. The plant density consisted of D_1-90 cm X 45 cm (24,691 plant ha^{-1}), D_2-90 cm X 30 cm (37,037 plant ha^{-1}) and D_3-90 cm X 20 cm (55,555 plant ha^{-1}) and four weed management treatment of W_1: Pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing, W_2: Pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS, W_3: Post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding and W_4: Weedy check were included in the investigation. The gross and net plot size were 6.3 m x 5.4 m and 4.5 m x 3.6 m, respectively. The crop was sown as per treatments with different densities. Besides yield data, periodical observations were recorded on growth and yield contributing characters of *Bt.* cotton

The observations on growth and yield attributes were recorded at periodical intervals to evaluate the treatment effects. The important findings recorded during the course of investigation are summarized below.

The data on emergence count and final plant stand at harvest was uniform, indicating that the difference obtained were due to treatment differences only.

5.1 Effect of plant density

Data on plant height reported that the height of *Bt.* cotton hybrid was continued to increase up to harvest. The rate of increase in height was very fast up to 90 days, fast between 30-90 days and showed downwards trend from 90 days to at harvest. The plant height was higher in plant spacing of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) and lower plant height was observed in plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) and D_1-90 cm x 45 cm (24,691 plant ha^{-1}) at all crop growth stages.

The other growth character viz., number of functional leaves $plant^{-1}$, leaf area $plant^{-1}$, number of monopodial branches $plant^{-1}$, number of sympodial branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ favorably influenced by higher plant spacing of D_1-90 cm x 45 cm (24,691 plant ha^{-1}) at all crop growth stages.

The yield attributing character viz., number of picked bolls $plant^{-1}$, boll weight and seed cotton yield $plant^{-1}$ were considerably higher under higher plant spacing of D_1-90 cm x 45 cm (24,691 plant ha^{-1}), while highest seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was obtained under lower plant spacing of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) but at par with D_2-90 cm x 30 cm (37,037 plant ha^{-1}). However harvest index was also higher in lower plant spacing of D_3-90 cm x 20 cm (55,555 plant ha^{-1}).

Highest moisture percentage observed in higher plant spacing of D_1-90 cm x 45 cm (24,691 plant ha^{-1}) than rest of the plant spacing.

Greater values for gross monetary returns , net monetary returns and benefit: cost ratio were recorded under plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) than plant spacing of D_2-90 cm x 20 cm (55,555 plant ha^{-1}) and D_1-90 cm x 45 cm (24,691 plant ha^{-1}).

5.2 Effect of weed management

The application of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) showed significant favorable effect on various growth character i.e. plant height, number of functional leaves $plant^{-1}$, leaf area $plant^{-1}$, number of monopodial branches $plant^{-1}$, number of

sympodial branches plant^{-1}, dry matter accumulation plant^{-1}, but at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other, but significantly superior over the treatment of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3).

Highest number of picked bolls plant^{-1}, boll weight and seed cotton yield plant^{-1}, seed cotton yield (kg ha^{-1}), cotton stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) was recorded in the treatment were found of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) significantly superior, but at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other.

Higher moisture percentage recorded in treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) and lower in treatment (W_1), (W_2) and (W_4).

In the weed management treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded highest gross monetary returns (Rs ha^{-1}), net monetary returns(Rs ha^{-1}) and benefit:cost ratio, but at par with pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1) and pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) to each other.

5.3 Interaction

The interaction effect between plant density and weed management treatment was found to be non-significant.

5.4 Conclusions

The following conclusions could be drawn from the one year of investigation :

Plant spacing of D_1-90 cm × 45 cm (24,691 plant ha^{-1}) recorded higher growth (functional leaves $plant^{-1}$, leaf area $plant^{-1}$, monopodial branches $plant^{-1}$, sympodial branches $plant^{-1}$, dry matter accumulation $plant^{-1}$) than other two plant spacing.

Plant spacing of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) registered higher seed cotton yield (kg ha^{-1}), stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}), gross and net monetary returns (Rs ha^{-1}) and found at par with D_2-90 cm x 30 cm (37,037 plant ha^{-1}) than D_1-90 cm × 45 cm (24,691 plant ha^{-1}).

Maximum B:C ratio was obtained with plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) than the plant spacing of D_3-90 cm x 20 cm (55,555 plant ha^{-1}) and D_1-90 cm × 45 cm (24,691 plant ha^{-1}).

Weed management treatment of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) recorded higher growth attributes, seed cotton yield (kg ha^{-1}) and net monetary returns (Rs ha^{-1}), than rest of the pre emergence application of pendimethalin @ 1 kg ha^{-1} (a.i) followed by two hand weeding and one hoeing (W_1), pre emergence pendimethalin followed by post emergence of pyrithiobac sodium 6% + quizalofop-ethyl 4% (75+50) gm. a.i. ha @ 25-30 DAS (W_2) and weedy check (W_4).

Maximum B:C ratio was obtained with weed management treatment post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3) than treatments (W_1), (W_2) and (W_4).

The plant density and weed management treatments did not affect quality parameters.

On the basis of one year investigation it can be concluded that the adoption of plant spacing of D_2-90 cm x 30 cm (37,037 plant ha^{-1}) performed very well by giving yield about 1767 kg ha^{-1} which was aided with treatment of post emergence pyrithiobac sodium + quizalofop-ethyl (20-25 DAS) followed by 40 days hand weeding (W_3), which were given higher seed cotton yield 2019 kg ha^{-1} with higher gross monetary return, net monetary return and B:C ratio found productive, remunerative and profitable under rainfed condition for Marathwada region in Maharashtra.

Future line of work

- ✓ Application of pre and post-emergence herbicides sequential and mix application need to be tested.
- ✓ The study should be conducted under different agro-ecological situations of the zone to make valid recommendation for the farmers
- ✓ For calculating the relative dominance of different weeds, dry weight of individual weed species should be recorded.
- ✓ A detailed study can be planned on management of weed by tillage, soil solarisation, suicidal germination, physical, chemical and integrated approach.

LITERATURE CITED

LITERATURE CITED

(AICRP on cotton 2020-2021). https://www.aiccip.cicr.org.in/home-legacy.html

Ali, H., Abid, S. A., Ahmad, S., Sarwar, N., Arooj, M., Mahmood, A. & Shahzad, A. N. (2013). Impact of integrated weed management on flat-sown cotton (*Gossypium hirsutum* L.). *Journal Animal Plant Science*, **23**(4), 1185-1192.

Ali, H., Afzal, M. N., Ahmad, F., Ahmad, S., Akhtar, M. & Atif, R. (2011). Effect of sowing Z dates, plant spacing and nitrogen application on growth and productivity on cotton crop. *International Journal Science Engg Res*, **2**(9), 1-6.

Anjum, F. H., Tanveer, A., Nadeem, M. A., Tahir, M., & Aziz, A. (2007). Effect of split application of nitrogen and integrated weed management on nutrient uptake by Trianthema portulacastrum (Itsit) in cotton. *Pak J Agric Sci*, **44**(3), 423-9.

Anmulwad, S. R., Ingole, P. G., Yenpreddiwar, M. D., Paslawar, A. N. & Deotalu, A. S. (2017). Effect of herbicides on growth, weed control efficiency and seed cotton yield of HDPS cotton. *Journal of Cotton Research and Development*, **31**(2), 262-267.

Anonymous, 2016 Annual Progress Report of Cotton. https://www.cci.com/

Anonymous, 2020 Annual Progress Report of Cotton. https://www.cci.com/

Anonymous, 2021 Annual Progress Report of Cotton. https://www.cci.com/

Arunvenkatesh, S. & Rajendran, K. (2015). Evaluation of plant density and cotton genotypes (*Gossypium hirsutum* L.) on yield and fibre quality. *Madras Agri. J.*, 102.

Asher, B. S., Keeling, J. W., & Dotray, P. A. (2002). Weed Management in Transgenic and Non-Transgenic Cotton (*Gossypium hirsutum*) in the Texas High Plains. *Texas Journal of Agriculture and Natural Resources*, *15*, 27-36.

Ashley, D. A., Doss, B. D. & Bennet, O. L. (1963). A method of determining leaf area in cotton. *Agron. J.* 55: 584- 585.

Aslam, M., Ahmed, T., Sanghi, A. H., & Khalid, L. (2018). Demonstration and evaluation of the effect of the yield response of seed cotton yield to

various planting methods in ecological zone of Rahim Yar Khan. *Inter J Adv Res Biol Sci*, *5*, 95-99.

Ayyadurai, P., & Poonguzhalan, R. (2010). Effect of Weed Control on Nutrient Depletion by Weeds and Nutrient Uptake by Cotton in Rice-FallowCotton. *Madras A gricultural Journal*, **97**(7-9), 249-25.

Ayyadurai, P., & Poonguzhalan, R. (2011). Critical period of crop-weed competition in zero-till cotton. *Indian Journal of Weed Science*, **43**(3&4), 228-230.

Bhalerao, P. D., & Gaikwad, G. S. (2010). Productivity and profitability of *Bt*. cotton (*Gossypium hirsutum*) under various plant geometry and fertilizer levels. *Indian Journal of Agronomy*, **55**(1), 60-63.

Bhalerao, P. D., Gawande, P. P., Ghatol, P. U., & Patil, B. R. (2008). Performance of *Bt*. cotton hybrids for various spacing under rainfed condition. *Agricultural Science Digest*, **28**(1), 54-56.

Bharathi, S., Pavani, M., & Narayana, E. (2011). Response of *Bt*. cotton to post emergence herbicides in Vertisols of Krishna zone.

Blackman, V. H. 1919. The compound interest law and plant growth. *Ann. Bot.* **33**: 353-360.

Bouchagier, P., Efthimiadou, A., Katsileros, A., Bilalis, D., & Efthimiadis, P. (2008). Adverse effect of bermudagrass on physiological and growth components of cotton. *Journal of Agronomy*.

Chaudhari, D. D., Patel, H. K., Mishra, A., Patel, V. J., Patel, B. D., Patel, R. B., & Motka, G. N. (2017). Integrated weed management in cotton under irrigated condition of middle Gujarat.

Chavan, N. H., Nagrare, I. M., Patil, D. B., Patil, N. A., & Sathe, H. D. (2011). Effect of spacing and fertilizer levels on yield attributes and economics of *Bt.* cotton. *Journal of Soils and Crops*, **21**(1), 148-151.

Deshmukh, M. S., Patil, V. D., Jadhav, A. S., Gadade, G. D., & Dhamak, A. L. (2013). Assessment of soil quality parameters and yield of rainfed *Bt*. Cotton as influenced by application of herbicides in Vertisols. *Int. J. Agric. Sci*, *3*, 553-557.

Divya, S., Saravanan, P., Kathiravan, J., & Venkatesan, P. (2016). Effect of plant spacing on yield and economics of extra long staple (ELS) *Bt*. cotton hybrid.

Doğan, M. N., Jabran, K., & Unay, A. (2014). Integrated weed management in cotton. In *Recent advances in weed management* (pp. 197-222). Springer, New York, NY.

Gacche, A. T. & Gokhale, D. N. (2017). Effect of planting geometry and integrated nutrient management on nutrient uptake and fibre quality of *Bt.* cotton. *Bioinfolet-A Qu. J. Life Sci.,* **14**(1), 75-78.

Ganvir, M. M., Karunakar, A. P., Bhale, V. M., Nagdeve, M. B., Gabhane, V. V., & Wanjari, S. S. (2019). Influence of Weather Variability, Plant Density and Fertilizer Regimes on Growth and Yield of Cotton under Rainfed Condition. *Int. J. Curr. Microbiol. App. Sci,* **8**(1), 1090-1105.

Gill, G. S. & Vijayakumar. 1969. "Weed index" A new method for reporting weed control trials. *Indian J. Agron.,* 16: 96-98.

Giri, A. N., Aundhekar, R. L., Kapse, P. S., & Suryavanshi, S. B. (2008). Response of *Bt.* cotton hybrids to plant densities and fertilizer levels. *Journal of Cotton Research and Development*, **22**(1), 45-47.

Giri, A. N., Deshmukh, M. N., & Gore, S. B. (2006). Effect of cultural and intergrated methods of weed control on cotton, intercrop yield and weed-control efficiency in cotton-based cropping systems. *Indian Journal of Agronomy*, **51**(1), 34-36.

Gunasekaran, M., Premalatha, N., Kumar, M., Mahalingam, L., Sakthivel, N., Senguttuvan, K., & Geetha, S. (2014). Cotton CO17-A short duration, high yielding compact variety suitable for high density planting system. *Electronic Journal of Plant Breeding*, **11**(04), 993-1000.

Hakoomat, A., Arooj, M., Sarwar, N., Areeb, A., Shahzad, A. N. & Hussain, S. (2017). Application of pre and post emergence herbicide under improved field irrigation system proved a sustainable weed management strategy in cotton crop. *Planta Daninha*, *35*.

Hariharasudhan, V. (2017) Effect of Pre and Post Emergence Herbicides on Growth and Yield of *Bt.* cotton under Varied Agro Meteorological Environments.

Hiremath, R., Yadahalli, G. S., Yadahalli, V. G., Chittapur, B. M., Koppalkar, B. G., & Vinoda, K. S. N. (2014). Evaluation of post emergent herbicides in *Bt.* cotton (*Gossypium Hirsutum* L.) under UKP command area of Karnataka, India. *Ecology, Environment and Conservation*, **20**(1), 325-330.

Hunt, R. 1980. Plant growth analysis. 1st Edition. Prentice Hall of India Pvt. Ltd., New Delhi.

Ikram, R. M., Nadeem, M. A., Tanveer, A., Yasin, M., Mohsin, A. U., Abbas, R. N., & Irfan, M. (2012). Comparative Efficacy of Different Pre-Emergence Herbicides In Controlling Weeds In Cotton. *Pakistan Journal of Weed Science Research*, **18**(2).

Jabran, K. (2016). Weed flora, yield losses and weed control in cotton crop. *Julius-Kühn-Archiv*, (452), 177.

Jackson, M. L. 1967. "Soil chemical analysis". Prentice Hall India Pvt. Ltd., New Delhi, pp. 183-192.

Jagtap, D. N., & Bhale, V. M. (2010). Effect of different plant spacing and nitrogen levels of desi cotton hybrid. *International Journal of Forestry and Crop Improvement*, **1**(2), 77-79.

Jost, P. H., & Cothren, J. T. (2000). Growth and yield comparisons of cotton planted in conventional and ultra narrow row spacings. Crop Science, **40**(2), 430-435.

Kalaisudarson, S. & Srinivasaperumal, A. P. (2019). Effect of chemical method on weed management in hybrid cotton. *Plant Archives*, **19**(1), 809-812.

Kalasare, R. S., Babu, R., Kumar, B. A., Panpatte, D. G., & Shitap, M. S. (2016). Effect herbicides on weeds in chilli+ onion+ cotton intercropping system. *BIOINFOLET-A Quarterly Journal of Life Sciences*, **13**(1a), 69.

Kalivas, D. P., Vlachos, C. E., Economou, G., & Dimou, P. (2012). Regional mapping of perennial weeds in cotton with the use of geostatistics. *Weed Science*, ***60***(2), 233-243.

Kalyani, D. L., Sarma, A., & Reddy, Y. R. (2018). Sequential application of herbicides for control of weeds in rainfed *Bt.* cotton.

Kamble, A. B., & Danawale, N. J. (2017). Integrated weed management in *Bt.* cotton.

Kaur, T., Bhullar, M. S. & Kaur, S. (2019). Weed control in *Bt.* (Bacillus thuringiensis) cotton with pre mix of pyrithiobac sodium plus quizalofop-ethyl in north-west India. *Crop Protection, 119*, 69-75.

Khan, B., Ishfaq, M., Murtza, K., Batool, Z., Ali, N., Aslam, M. S., & Anjum, S. A. (2021). 12. Effect of varying planting density on weed infestation, crop phenology, yield, and fiber quality of cotton under different sowing methods. *Pure and Applied Biology (PAB)*, **10**(3), 676-691.

Kharagkharate, V. K., Ghanbahadur, M., Hiwale, S., Chirde, P. & Shaikh, S. A. (2017). Effect of high density planting, nutrient management and moisture conservation on economics and nutrient uptake of *hirsutum* cotton under rainfed condition. *International Journal of Pure and Applied Bioscience*, **5**(6), 1210-1217.

Knudsen, D. & Peterson, G. A. 1982. In : Methods of Soil Analysis, Part II, Chemical and Microbiological Methods by Page, A. L., R. H. Miller and D. R. Keeney. (eds.), Agronomy Monograph No. 9 (2nd edition) American Society of Agronomy and Soil Science Society of America, Madison., Wisconsin, USA. 228-231.

Kumar, J., Srivastava, S. K., Asrey, R., & Prakash, H. G. (2016). Effect of different herbicides on growth and yield attributes and seed cotton yield in *hirsutum* cotton. *Research on Crops*, **17**(1), 103-105.Z

Kumar, P., Karle, A. S., Singh, D., & Verma, L. (2017). Effect of high density planting system (HDPS) and varieties on yield, economics and quality of desi cotton. *Int. J. Curr. Microbiol. App. Sci.*, **6**(3), 233-238.

Kumar, R. *integrated weed management in Bt. cotton* (Doctoral dissertation, MPKV, university library).

Madavi, B., Rani, P. L., Sreenivas, G., Madhavi, A. & Surekha, K. (2017). Impact of High Density Planting and Weed Management Practices on Yield attributes, Yield and Quality Characters of *Bt. c*otton. *Int. J. Curr. Microbiol. App. Sci.*,**6**(8), 194-202.

Madhu, G., Srinivasulu, K., Rani, P. P. & Rao, A. S. (2014). Economics of rainfed *Bt.* cotton as influenced by sequential application of herbicides. *Journal of Cotton Research and Development*, **28**(2), 257-259.

Maheswari, M. U., Krishnasamy, S. M., Kumar, M., & Sakthive, N. (2019). Impact of high density planting system and growth retardants on root growth and yield attributes in machine sown cotton. *The Pharma Innovation J*, **8**(3), 123-130.

Malarkodi, N. (2017). Integrated weed management effect on weeds and seed cotton yield. *International Journal Environment Agriculture and Biotechnology*, *2*, 597-606.

Mani, V. S., Pandita, M. L., Gautam, S. K. & Bhagawadas. 1973. Weed killing chemicals in potato cultivation. *PAN*, **23**(8): 17-18.

Manjunatha, S. B., Biradar, D. P., & Aladakatti, Y. R. (2014). Response of *Bt*. cotton to nutrients applied based on target yield. *Res. Environ. Life Sci*, **7**(4), 247-250.

Meena, H., & Kumhar, B. L. (2017). Performance of Inter Specific Cotton Hybrids under Various Plant Geometries and Nutrient Levels. *International Journal of Forestry and Crop Improvement*, **8**(1), 49-52.

Memon, R. A., Bhatti, G. R., Khalid, S., & Ahmed, S. (2014). Illustrated weed flora of cotton crop of Khairpur district, Sindh, Pakistan. *Pak. J. Bot*, **46**(1), 5-12.

Nagender, T., Reddy, D. R., Rani, P. L., Sreenivas, G., Surekha, K., Gupta, A. & Sreekanth, P. D. (2017). Response of nitrogen fertilization and plant densities on *Bt.* and Non- *Bt.* cotton (*Gossypium hirsutum* L.) hybrids. *Int. J. Curr. Micro. App. Sci.*, **6**(9), 3199-3207.

Nakala, V., Ramprakash, T., Madhavi, M., & Suneetha Devi, K. B. (2019). Influence of weed control practices on nutrient uptake in cotton plant. *Journal of Research in Weed Science*, **2**(2), 115-126.

Nalini, K., Muthukrishnan, P., & Chinnusamy, C. (2011). Evaluation of pendimethalin 38.7 EC on weed management in winter irrigated cotton. *Madras Agricultural Journal*, **98**(4-6), 165-168.

Nandagavi, R. A., & Halikatti, S. I. (2016). Bio-efficacy of herbicides in *Bt.* cotton. *Journal of Farm Sciences*, *29*(2), 182-186.

Nandagavi, R. A., & Halikatti, S. I. (2021). Bio efficacy of sequential application of herbicides in cotton. *Journal of Pharmacognosy and Phytochemistry*, **10**(1), 2078-2083.

Olsen, S. R., Watanable, P. S. & Dean, L. A. 1954. "Estimation of available phosphorus in soil by extraction with sodium bicarbonate". USDA Circular No. 939.

Özaslan, C., Songül, A. K. I. N., & GÜRSOY, S. (2015). Weed control and crop production practices in cotton production in Diyarbakır Province of Turkey. *YüzüncüYıl Üniversitesi Tarım Bilimleri Dergisi*, **25**(1), 41-47.

Pandagale, A. D., Baig, K. S., Rathod, S. S. & Namade, T. B. (2018). Effect of number of plants per hill in respect to plant geometry in *Bt.* cotton (*Gossypium hirsutum* L.) under rainfed condition. *Journal. Pharmacognosy. Phytochemistry.*, **7**(5), 477-479.

Pandagale, A. D., Baig, K. S., Rathod, S. S., Kadam, G. L. & Namade, T. B. (2018). Effect of various weedicides on weed control, yield and economics in *Bt*. cotton (*Gossypium hirsutum* L.). *International Journal of Tropical Agriculture*, **36**(4), 1091-1101.

Pandagale, A. D., Khargkharate, V. K., Kadam, G. L. & Rathod, S. S. (2015). Response of *Bt*. cotton (*Gossypium hirsutum* L.) to varied plant geometry and fertilizer levels under rainfed condition. *J. Cotton Res. and Dev.*, **29**(2), 260-263.AKH–081 under rainfed condition of Vidharbha. *Pt. archives*, **15**(2), 1075-1077.

Panse, V. G. & Sukhatme, P. V. 1985. Statistical Methods of Agricultural Woekers. 4th Ed. Indian Council of Agricultural Research, New Delhi. 157-165

Panwar, R. S., Malik, R. S., Rathi, S. S., & Malik, R. K. (2001). Chemical weed control in cotton. *Indian Journal of Weed Science*, **33**(1and2), 14-17.

Parihar, L. B., Rathod, T. H., Paslawar, A. N., & Kahate, N. S. (2018). Effect of High Density Planting System (HDPS) and Genotypes on Growth Parameters and Yield Contributing Traits in Upland Cotton. *Int. J. Curr. Microbiol. App. Sci*, **7**(12), 2291-2297.

Paslawar, A. N., Deotalu, A. S., & Nemade, P. W. (2015). High density planting of cotton variety AKH–081 under rainfed condition of Vidharbha. *Plant archives*, **15**(2), 1075-1077.

Patel, B. D., Patel, R. B., Sheta, B. T., Patel, V. J., Patel, R. A., & Parmar, D. J. (2014). Influence of integrated weed management practices on weeds and yield of *Bt*. cotton. *Research on Crops*, **15**(2), 503-507.

Pathrikar V.B, Khargakharate. V. K, Gaikwadand & Ghuge R. S. (2018). Response of *hirsutum* cotton to high density planting and nutrient management on growth and yield under Marathwada region. An International refereed, peer reviwed and indexed quarterly Journal In Science, Agriculture and Engineering. Vol.Vii, Specisal Issue ICAAASTSD, ISSN 22777601.

Pawar, P. M., Thakare, S. S., Deshmukh, J. P., Shingrup, P. V. & Chirde, P. N. (2015). Efficacy of pre and post emergence herbicides in *Bt*. cotton (*Gossypium hirsutum*) under rainfed condition. *Plant Archives*, **15**(1), 475-478.

Pawar, S. B., Karle, A. S., Gokhale, D. N., & Mane, S. G. (2022). Growth and yield of *Bt*. cotton (*Gossypium hirsutum* L.) as influenced by tillage and weed management practices under rainfed condition.

Pawar, S. U., Gitte, A. N., Bhosle, G. P., & Suryawanshi, S. B. (2010). Effect of fertilizer levels and plant densities on yield, gross and net monetary returns of *Bt.* cotton hybrids. *Journal of Cotton Research and Development*, **24**(2), 182-185.

Pendharkar, A. B., Solanke, S. S., Lambade, B. M., Dalvi, N. D., & Navale, S. S. (2011). Response of *Bt.* cotton hybrids to different plant spacing under rainfed condition. *Journal. Agriculture. Research. Technology*, **36**(1), 54-57.

Piper, C. S. 1966. Soil & Plant analysis. New York: *Interscience Publishers*, 368

Poonguzhalan, P. A. R., & Gokila, J. (2013). Effect of crop-weed competition in cotton (*Gossypium hirsutum* L.)-review. *Agricultural Reviews*, **34**(2), 157-161.

Prabhu, G., Halepyati, A. S., Pujari, B. T & Desai, B. K. (2012). Weed management in *Bt*. cotton (*Gossypium hirsutum* L.) under irrigation. *Karnataka Journal of Agricultural Sciences*, **25**(2), 183-186.

Pradeep Kumar, Karle, A.S., Deshraj Singh & Lalita Verma (2017). Effect of high density planting system (HDPS) and varieties on yield, economics and quality of desi cotton. *Int. J. Curr. Microbio. and Applied Sci*., ISSN:2319-7706 Volume **6**(3) pp. 233-238.

Ram, M., & Giri, A. N. (2006). Response of newly released cotton (*Gossypium hirsutum*) varieties to plant densities and fertilizer levels. *Journal of Cotton Research and Development*, **20**(1), 85-86.

Ramachandra, D., Ramamohan, G., Bhan, A., & Suresh, P. J. (2016). Weed management in cotton: The potential of GM crops.

Rani, P. L., Yakadri, M. & Ramprakash, T. (2016). Effect of Integrated Weed Management Practices on Growth and Yield of *Bt.* cotton in Telangana State, India. *Int. J. Curr. Microbiol. App. Sci*, **5**(2), 17-25.

Rao, A. S. (2011). Evaluation of pyrithiobac alone and in combination with grassy herbicides on weed control in cotton. In *World Cotton Research Conference-5, Mumbai, India, 7-11 November 2011* (pp. 406-409). Excel India Publishers.

Raut, R. S., Thokale, J. G., & Mehetre, S. S. (2005). Response of cotton cultivars to varying spacing and fertility levels. *Journal of Cotton Research and Development*, **19**(2), 191-193.

Reddy, P. R. R., & Gopinath, M. (2008). Influence of fertilizers and plant geometry on performance of *Bt.* cotton hybrid. *Journal of Cotton Research and Development*, **22**(1), 78-80.

Reddy, P. R. R., & Kumar, B. D. (2010). Fertilizer response studies in *Bt.* cotton hybrid. *Journal of Cotton Research and Development*, **24**(1), 76-77.

Sadangi, P. K., & Barik, K. C. (2007). Effect of weed-management practices on nutrient depletion by weeds, yield and economics of winter-irrigated cotton (*Gossypium hirsutum*). *Indian Journal of Agronomy*, **52**(2), 172-175.

Sangle, B. B., Patil, H. M., Khairnar, A. V., & Wani, A. G. (2007). Effect of crop geometries and weed control treatments on yield and quality parameters of irrigated cotton (*Gossypium hirsutum* L.). *Journal of Farming Systems Research & Development*, **13**(2), 260-262.

Shahzad, M. A., Anjum, S. A., Zohaib, A., Ishfaq, M., & Warraich, E. A. (2017). Effect of different sowing methods and planting densities on growth, yield, fiber quality and economic efficacy of cotton. *Pakistan Journal of Agricultural Research*, **30**(1).

Sheets, T. J., & Harris, C. I. (1965). Herbicide residues in soils and their phytotoxicities to crops grown in rotations. *Residue Reviews/ Rückstandsberichte*, 119-140.

Shekar, K., Ramana, M. V., & Kumari, S. R. (2015). Response of hybrid cotton to chloro mepiquatchloride and detopping under high density planting. *Interaction (Dx C)*, **31**(91), 3-6.

Shekara, B. G., Yogesh, T. C. & Chikkarugi, N. M. (2020). Chemical weed management in hybrid cotton under southern dry zone of Karnataka. *IJCS*, **8**(6), 143-146.

Shelke, D. V., Paslawar, A. N., Deotalu, A. S., Dandge, M. S., & Joshi, M. S. (2013). Weed control efficiency as influenced by weedicides in cotton and bio-mulching under dry land conditions. *Annals of Plant Physiology*, **27**(1/2), 92-95.

Shukla, U. N., Bhale, V. M., Wanjari, S. S., & Khadse, V. A. (2014). Production potential and economics of cotton (*Gossypium hirsutu*m) hybrids under different plant spacing and NPK levels. *Indian Journal of Agronomy*, **59**(4), 668-671.

Singh, B., Garg, R., Satpal, J. K., & Kumar, S. (2022). Integrated Weed Management in *Bt.* cotton Under Semi Arid Conditions–A Review. *Journal of Agriculture Research and Technology*, **47**(3), 353.

Singh, K. & Rathore, P. (2015). Efficacy evaluation of selected herbicides on weed control and productivity evaluation of cotton in Punjab *Bt. Journal of environmental biology*, **36**(4), 993-998.

Singh, K., & Rathore, P. (2015). Effect of different defoliants and their rate and time of application on American cotton cultivars under semi-arid conditions of north-western India. *Research Crop*, *16*, 258.

Singh, K., Singh, H. P., & Singh, K. (2016). Weed management in cotton with pre- and post-emergence herbicides.

Singh, Kulvir (2015). Effect of agronomic manipulations on growth, yield attributes and seed cotton yield of American cotton under semi-arid conditions. *International. Journal. Agriculture. Sciences.* **11**(1): 134-137.

Singh, M., & Kokate, K. D. (2010). Weed management and its effect on cotton (*Gossypium hirsutum* L.). *Annals of Plant Protection Sciences*, **18**(2), 484-487.

Singh, P., George, P. J., Ramtweke, P. W., & Paul, A. (2020). Performance of Bollgard I with different plant spacing and in presence of refuge crops. *Journal. Pharmaco. and Phytochemistry*, **9**(2), 78-81.

Smith, D. T., Baker, R. V. & Steele, G. L. (2000). Palmer amaranth (Amaranthus palmeri) impacts on yield, harvesting, and ginning in dryland cotton (*Gossypium hirsutum*). *Weed Technology*, **14**(1), 122-126.

Solanki, R. M., Malam, K. V., Vasava, M. S. & Chhodavadia, S. K. (2020). Response of *Bt.* cotton on to high density planting and nitrogen levels through fertigation. *Journal Pharmaco. and Phytochemistry.*, **9**(5), 1952-1958.

Sreena, K. S., Yadahalli, G. S., Chittapur, B. M., Ajayakumar, M. Y., Bhat, S. N. & Naik, N. (2019). Economic Attributes of *Bt*. cotton (*Gossypium hirsutum* L.) using Sequential Application of Herbicides under TBP Command Area. *International. Journal. Curr. Microbiol. App. Sci*, **8**(9), 1958-

1964.Cotton Varieties Under Irrigated Condition. *Madras Agri.J.*, **107**(march (1-3)), 1.

Srinivasulu, K., Hema, K., Narayana, E., Prasad, N. V. V. S. D., & Rao, A. N. H. P. (2007).Agronomic evaluation of *Bt*. hybrid (NCS-207 *Bt*) in vertisols of Andhra Pradesh under rainfed condition. *Journal of Cotton Research and Development*, **21**(2), 191-193.

Subbaiah, B. V. & Asija, G. L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.* 25: 259

Tariq, M., Abdullah, K., Ahmad, S., Abbas, G., & Khan, M. A. (2020). Weed management in cotton. In *Cotton Production and Uses* (pp. 145-161). Springer , Singapore.

Tariq, M., Afzal, M. N., Ahmad, M., Qayyum, A., & Khan, M. A.(2018). Performance of pre and post-emergence herbicides for weed control in cotton (*Gossypium hirsutum* L.). *Pakistan Journal of Weed Science Research*, **24**(2)

Thakur, M. R. (2020). Square formation, boll retention, yield and quality parameters of *Bt*. and non-*Bt*. cotton in relation to plant density and NPK levels. *International Journal of Chemical Studies*, **8**(1), 2741-2753.

Thorat, V. B., Paturde, J. T., Dongarwar, U. R., Karunakar, A. P., & Mandhare, S. K. (2007). Evaluation of post emergence herbicides for weed control in cotton. *Annals of Plant Physiology*, **21**(2), 171-174.

Tursun, N., Datta, A., Tuncel, E., Kantarci, Z., & Knezevic, S. (2015). Nitrogen application influenced the critical period for weed control in cotton. *Crop Protection*, *74*, 85-91.

Veeramani, A., Prema, P., & Ganesaraja, V. (2009). Effect of pre and post sowing weed management on weeds, growth and yield of summer irrigated cotton. *International Journal of Agricultural Sciences*, **5**(1), 182-186.

Veeraputhiran, R. "Optimization of spacing and fertilizer requirement for pre-release cotton varieties under irrigated condition." *Madras Agricultural Journal* 107, no. march (1-3) (2020): 1.

Veeraputhiran, R., & Srinivasan, G. (2015). Post-emergence herbicides effect on weeds, yield and economics of *Bt* cotton. *Indian Journal of Weed Science*, **47**(4), 379-382.

Watanabe, F. S., & Olsen, S. R. 1965. Test of an Ascorbic Acid Method for Determining Phosphorus in Water and $NaHCO_3$ Extracts From Soil. *Soil Sci. Soc. Am. J.* 29:677-678.

Watson, D. J. 1952. The physiological basis of variation in yield *Adv. Agron*. **4**:101-145.

WU, H. W., Jiang, W. L., & Yan, M. A. (2015). Goosegrass (Eleusine indica) density effects on cotton (Gossypium hirsutum). *Journal of Integrative Agriculture*, *14*(9), 1778-1785.

APPENDIX

APPENDIX

Appendix I: Price of inputs and outputs per unit.

Sr. No.	Particulars	Quantity / frequency	Unit price (Rs ha^{-1})
A	**Land preparation**		
1	Ploughing	1	4000
2	Harrowing	2	3000
B	**Input charges**		
1	Fertilizer		
I	Urea	260 kg	1160
II	DAP	375 kg	3640
III	MOP	100 kg	3000
2	Seeds	2 packet	1500
3	Herbicides		
I	Pendimethalin	2.50 litre	560
II	Pyrathiobac-sodium	0.63 litre	900
III	Quizalofop-ethyl	1.00 litre	900
4	Plant protection measures		
I	Spinetoram 11.7% SC	200 ml	2700
II	Profenopos 40% + cypermethrim 4% EC	500 ml	2800
5	Weeding	2	7000
6	Hoeing	1	1200
7	Labours wages		
I	Men	20	200
II	Women	60	150
8	Picking	2	10 kg^{-1}
C	**Output charges**		
1	Seed cotton yield	1 q	10,200
2	Straw	1 q	200

Appendix II: Details of cost of cultivation of *Bt*. cotton in different treatments (Rs ha^{-1})

Sr. No.	Particulars	D_1W_1	D_1W_2	D_1W_3	D_1W_4	D_2W_1	D_2W_2	D_2W_3	D_2W_4	D_3W_1	D_3W_2	D_3W_3	D_3W_4
1	Ploughing	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
2	Harrowing	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
3	Rotator	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200
4	Layout preparation	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5	Stubbles collection	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200	3200
6	Seed	2250	2250	2250	2250	3375	3375	3375	3375	5250	5250	5250	5250
7	Sowing	3000	3000	3000	3000	3500	3500	3500	3500	4500	4500	4500	4500
8	FYM	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
9	Fertilizer & application	7750	7750	7750	7750	7750	7750	7750	7750	7750	7750	7750	7750
10	Gap filling	900	900	900	900	1200	1200	1200	1200	1500	1500	1500	1500
11	Hoeing	1200	--	--	--	1200	--	--	--	1200	--	--	--
12	Plant protection spray	10050	10050	10050	10050	11000	11000	11000	11000	11600	11600	11600	11600
13	Weeding	14000	--	7000	--	14000	--	7000	--	14000	--	7000	--
14	Herbicides												
a)	Pendimethalin	560	560	--	--	560	560	--	--	560	560	--	--
b)	Pyrathiobac-sodium	--	900	900	--	--	900	900	--	--	900	900	--
c)	Quizalofop-ethyl	--	900	900	--	--	900	900	--	--	900	900	--
15	Spraying	1200	3600	2400	--	1200	3600	2400	--	1200	3600	2400	--
16	Kapas picking cost	14300	15416	16834	12268	17633	18675	20956	15225	18817	19222	22426	13200
Total cost of cultivation		**78110**	**68226**	**74884**	**59118**	**84918**	**74360**	**81881**	**57225**	**89277**	**78682**	**87126**	**66700**

CURRICULUM VITAE

CURRICULUM VITAE

Name of the Candidate : **RATHOD NITIN SUBHASH**

Date of Birth : 03/05/1999

Nationality : Indian

Department : Department of Agronomy

Permanent Address : At. Post. Sakhara, Tal- Sengaon, Dist- Hingoli (Pin. Code- 431542)

Mobile No. : 8390783613/8806460987

Email id : nitin03051999@gmail.com

Thesis Title : **"Effect of high density planting and weed management practices on weed dry matter, weed indices and seed cotton yield of *Bt.* cotton"**

Academic Qualification

Course / Degree	Name of the college / Institute	University / Board	Year of Passing	Percentage % / CGPA	Class / Grade
SSC	Mahakali Madhyamik Ashram School Hatta Tal. Sengaon	Maharashtra State Board	2014	76.80	First
HSC	Late Haribai Wadpurkar jr. College Pedgaon Dist. Parbhani	Maharashtra State Board	2016	77.40	First
BSC (Agri.)	College of Agriculture, Parbhani	VNMKV, Parbhani	2020	74.30	second

Place : Parbhani

Date : 28 /11 /2021

(RATHOD NITIN SUBHASH)