Adoption of Insect Resistance Management Practices in Bt-Cotton Cultivation in India

ICAR-NATIONAL ACADEMY OF AGRICULTURAL RESEARCH MANAGEMENT
(ISO 9001:2015 CERTIFIED)
Rajendranagar, Hyderabad-500 030, Telangana, India

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Sponsored by Mahyco-Monsanto Biotech (India) Pvt. Ltd.

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Foreword

Cotton plays an important role in the Indian economy as the country's textile industry is predominantly cotton based. The adoption of Bt cotton by farmers resulted in a significant increase in production and decrease in expenditure on pesticide in the country. India tops in area under the crop (12.2 million hectares) as well as its production (6.7 million tonnes or 37 million bales of 170 kg each) in the world. Besides, India exported 6.9 million bales in 2017-18. About 60 million people rely upon cotton cultivation, marketing, processing and exports for their livelihood. In the recent past, the crop has become a matter of concern due to surge in pink bollworm incidence in cotton growing states of India. To tackle the incidence various organizations including government departments, KVKs, agribusiness companies etc. have approached to create awareness and to provide training to cotton farmers as well as other stakeholders in adoption of different insect resistant management (IRM) practices.

Responding to the growing concern of Pink Bollworm infestation in India, the present project has been sponsored to the Academy by Mahyco Monsanto Biotech (India) Pvt. Ltd, Mumbai. The study covers the intricacies of pest infestation, adoption level of IRM practices and its effects on cotton production in three states- Gujarat, Maharashtra and Karnataka. I believe that the project will provide adequate information about farmers' perception of Bt cotton cultivation practices to recognize the concurrent issues at ground level.

I am pleased to publish the project report on *Adoption of Insect Resistance Management Practices in Bt- Cotton Cultivation in India* prepared by the research team. I thank to the sponsoring agency for their financial support and sharing their insights throughout the project period. I congratulate the project team for the successful completion of the study with the outstanding outcomes. I believe that the information given in the report would be helpful for all the stakeholders in cotton economy- farmers, ginners, agri-input companies, agri-departments and policy makers to prepare the future action plan for better productivity and profitability for the cotton growers in India.

Hyderabad **(Ch. Srinivasa Rao)**

Preface

Cotton is one of the important crops on which more than four million farmers in India depend for their livelihood. Though India has become the top country in terms of cotton production globally, the crop has become a matter of concern due to surge in pink bollworm (PBW) incidence in the recent past. Cotton crop has high pesticide usages than any other crop, however, pest incidence is reported to be increasing due to resistance developed against the pesticides. Several interventions have been suggested to combat the PBW infestation, collectively called as Insect Resistance Management (IRM) practice. Attempts have been made to disseminate the practice among the farmers to minimise the losses in cotton production. In order to ascertain the level of adoption of these IRM measures among the farmers and their effectiveness, the study was undertaken on request received from Mahyco Monsanto Biotech (India) Private Limited.

The study necessitated primary survey of cotton farmers and ginners. For the purpose, the states of Gujarat, Maharashtra and Karnataka were selected and in all, 611 farmers were surveyed. Eleven practices were identified which are considered as IRM measures to assess the level of adoption of IRM. The effectiveness and the benefits due to the adoption of the practices were studied.

The field survey was carried out with the help of students from agricultural universities in the three states. The MBA (Agribusiness) students of Junagadh Agricultural University; undergraduate students of college of Dairy Science, Yavatmal and post-graduate students of Agricultural College, Raichur were engaged for field survey in Gujarat, Maharashtra and Karnataka states, respectively. The project team is grateful to the students and coordinating faculty members of these colleges who helped in coordinating the survey activities.

We are very much thankful to Mahyco Monsanto Biotech (India) Private Limited (MMB) for entrusting us this study. We express our sincere gratitude to Dr. Ch. Srinivasa Rao, Director, ICAR-NAARM for unconditional support in carrying out the project within the stipulated time.

We hope the report will bring additional dimensions towards the IRM practices in cotton cultivation and will certainly act as a guide for policy makers and other agencies for possible interventions in managing the insect incidence.

Hyderabad **Project Team**

Executive Summary

India is one of the largest cultivators of cotton in the world with the area of about 12 million hectares (Mha) in 2017-18. Cotton is grown in many states of the country. Maharashtra, Gujarat, Telangana, Andhra Pradesh and Karnataka are the frontiers of the country accounting for more than three-fourth of India's cotton production. Moreover, cotton is exposed to several biotic and abiotic stress. Several studies have reported that there has been indiscriminate use of pesticides in cotton cultivation to an extent of about 12-13 number of sprays within a short span of time. Despite heavy application of pesticides, the effect on the intended organism is diminishing over the years. There are reports that certain cotton pests like American bollworm, Pink bollworm and white fly have developed resistance to pesticides and other new technologies intended to control them.

There was a paradigm technological shift in cotton cultivation worldwide including in India through the introduction of Bt cotton. The Bt gene that is inserted into the seed is derived from the naturally occurring soil bacterium, *Bacillus thuringiensis* (Bt). The crop with Bt-gene releases proteins which are toxic to certain pests. The Bollgard-I was introduced in India in the year 2002, contains only one gene, the Cry 1Ac from Bt, while Bollgard II contains the Cry 2 Ab gene, in addition to Cry 1Ac. While Bollgard I offers protection against only the major cotton pest, the American bollworm (*Helicoverpa armigera*), Bollgard II is contemplated to provide season long control of key pests of cotton including Cotton Leafworm, Pink Bollworm and American Bollworm. Bollgard –II, the event developed by Mahyco Monsanto Biotech (MMB) was approved in India 2006 for commercial release. Consequently, Bollgard II cotton hybrid seeds are developed and sold by several different seed companies. During these years (2002-2018), cotton acreage has increased from 7.67 Mha to 12.1 Mha and productivity also increased steeply from 191 kg/Ha to 520 kg/Ha of lint. More importantly, currently more than 90% of cotton grown are Bt cotton in India, mostly Bollgard II hybrids.

During 2014 onwards, various reports have highlighted the outbreak of pink bollworm, termed as PBW (*Pectinophora gossypiella*) on Bt cotton crops using both the technologies namely, Bollgard I and Bollgard II in states namely, Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh. Despite of having narrow host range, the PBW has been frequently noticed from the middle of the crop season. Within hours after emergence, the PBW larvae enter the fruiting bodies and the pin holes of entry close down by excreta of larvae. Therefore, it is difficult to exercise any target specific control measure against the pest. Many studies have attributed the outbreak to the development of resistance of pests to Bt technology and indiscriminate use of insecticides.

Various organizations including government departments, KVKs, agribusiness companies etc. have come forward to spread awareness and to train farmers in the adoption of various insect resistant management (IRM) practices in cotton. The standard IRM practices include:

1. Crop rotation (cycle)/ breaks with non-host crops
2. Using branded or certified seeds
3. Selection of varieties with early maturity
4. Cultivation of non-Bt refuge crop
5. Insecticidal Sprays based on ETL
6. Use of Pheromone traps
7. Harvested along with other cotton farmers in the village (synchronized harvest)
8. Destruction of green bolls at the end of the cropping season
9. Destruction of cotton stubbles
10. Deep Summer ploughing
11. Keeping the field weed-free during off-season

However, in practice, owing to various factors, the farmers are adopting only a select few of the above practices. These IRM practices not only help in controlling the incidence of pests but also delay the resurgence of resistance against the toxins in a larger geographic area and over a longer period. In this background, the study was taken up to examine the effects of adoption of IRM practices with the following specific objectives:

- To evaluate the extent of adoption of IRM measures on pest mitigation, especially pink bollworm through farmers' perception;
- To evaluate the effectiveness of integrated pest management measures promoted by stakeholders in the selected states of India;
- To estimate the tangible and intangibles benefits from IRM practices adopted by Bt farmers; and
- To suggest suitable mode of information dissemination for stimulating diffusion of best cultivation practices.

The study was taken up in three major cotton growing states of India namely, Gujarat, Maharashtra and Karnataka. In Gujarat four districts (Amreli, Bhavnagar, Junagadh and Surendranagar), in Maharashtra and Karnataka, two districts each (Yavatmal and Jalna & Raichur and Gadag) were selected. In total, 611 sample farmer households were chosen randomly for the study of which 304 were from Gujarat, 129 were from Maharashtra and 178 were from Karnataka.

The major findings of the study are summarized as below:

❖ The perception of cotton growers on the pest infestation level revealed that pink bollworm was the predominant pests for the last two years with an infestation level of over 80 per cent. They also perceived that pink bollworm infestation is increasing this year as compared to the last year. This perception is similar across the selected states. White fly and spotted bollworm were other major pests whose degree of infestation is very high.

❖ The insect resistance management (IRM) which includes eleven recommended practices were adopted at different levels by the farmers. The classification based on the number of IRM practices adopted, i.e., up to 4 as Low, 5-8 as moderate and 9-11 practices as high level of adopters, shows that Karnataka has almost equal number of medium and high adopters. While in Gujarat state, majority of cotton growers fall under medium adopters. Maharashtra state also has moderately higher number of medium adopters.

❖ There is a huge variation in the adoption of various IRM practices by the farmers. While practices like deep summer ploughing and usage of branded seeds were adopted the most, factors like adoption of pheromone trap, cultivation of non-Bt cotton as refuge crops were the least adopted technique.

- The study showed that farmers in Gujarat are using more number of agrochemicals including pesticides and herbicides. While Maharashtra was using few number of agrochemicals than that of Karnataka cotton growers.

- There is a heavy reliance on cotton stubble for cooking purpose and hence they were reluctant to destroy it after the harvest. Instead, they cut the stubbles and store them either on the boundary of their field or near their home, mostly on the thatched roof of animal shelter. Some of the farmers, mostly with larger crop area, leave the stubbles in the field itself, till the next season starts.

- Further, many farmers are not clearing the field immediately after 2-3 pickings with the hope to get small harvest of cotton crop many times. Some cut their crop just before summer ploughing and some just before the field preparation activity of the next year crop.

- In Gujarat, those who were adopting high level of IRM practices were using more of plant protection chemicals (PPC). It reveals that the farmers are not confident in containing pests through adoption of IRM practices. They tend to spray indiscriminately in spite of adopting more IRM practices.

- Pheromone traps were used by some farmers only in Gujarat state and by very few sample farmers in Karnataka and Maharashtra states.

- In Gujarat, most of the farmers were doing three pickings, while in Karnataka and Maharashtra, farmers were going up to five pickings. However, they expressed that 4^{th} and 5^{th} pickings were severely affected by pink bollworm leading to very poor realization.

- Though none of the farmers has received exclusive IRM training, they were advised by the input dealers and in some cases, by agricultural department/ agricultural universities to follow practices like growing refuge crop, crop rotation, keeping field weed free during off-season, etc.

- There is a significant savings in the cost and increase in the net returns due to the adoption of IRM practices. In all the three states, the higher the adoption of IRM practices, the more net returns one gets.

- The survey of ginning mills reveals that even though it is maintained in a good and clean condition, there is possibility of maintaining continuity in the life cycle of pests especially pink bollworm due to storage and handling of infested seed cotton and not maintaining pheromone traps.

Following policy recommendations are proposed:

a) Implementation of Refuge-in-Bag system to be ensured immediately. However, to ensure quality of non-Bt seed, random check of the seed packet from the open market, may be done to check for trait purity.

b) Implementation of integrated communication strategy about IRM, for which 2-3 progressive farmers from each village may be grouped together for short-term training at taluka level.

c) Developing short video clips in vernacular languages and distributing to the farmers through the seed dealers.

d) All the ginning mills should be instructed to keep pheromone and light trap in operation in their campuses where seed cotton is stocked. There should be strict monitoring and compliance of the instruction.

e) Convincing the farmers for not going for long duration crop or stop picking after January-end, so that the field can be kept clear from cotton stubbles for at least 90 days.

f) Simplification of IRM practices for the farmers so that farmers do not need to follow more than 3 activities under IRM.

g) Free distribution of pheromone trap through seed and fertilizer dealers in the cotton growing area.

h) Development of suitable crop variety with insect resistance traits which can assure higher yield to the farmers as compared to existing cultivars.

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1. Introduction

1.1 Background

Cotton is an important fiber crop of global significance, which is cultivated in tropical and sub-tropical regions of more than seventy countries the world over. Globally cotton is cultivated in 31.8 million hectares (2017-18). India has 12.2 million hectares (M ha) under cotton, largest in the world, with the productivity of 524 kg lint /ha and has now become first in production as well (Figure 1.1). India surpassed China with 6.2 million tonnes of cotton (lint) production in 2017-18. It accounts for about 25% of the world cotton production and has the largest area under cotton cultivation. The total area under cotton is expected to be almost same (12.1 M ha) in the year 2018-19. According to the Directorate of Cotton Development Board, cotton was cultivated in several states of the country, Maharashtra has the highest area (4.2 M ha), followed by Gujarat (2.6 M ha), Telangana (1.9 M ha) and Andhra Pradesh (0.7 M ha) during 2017-18.

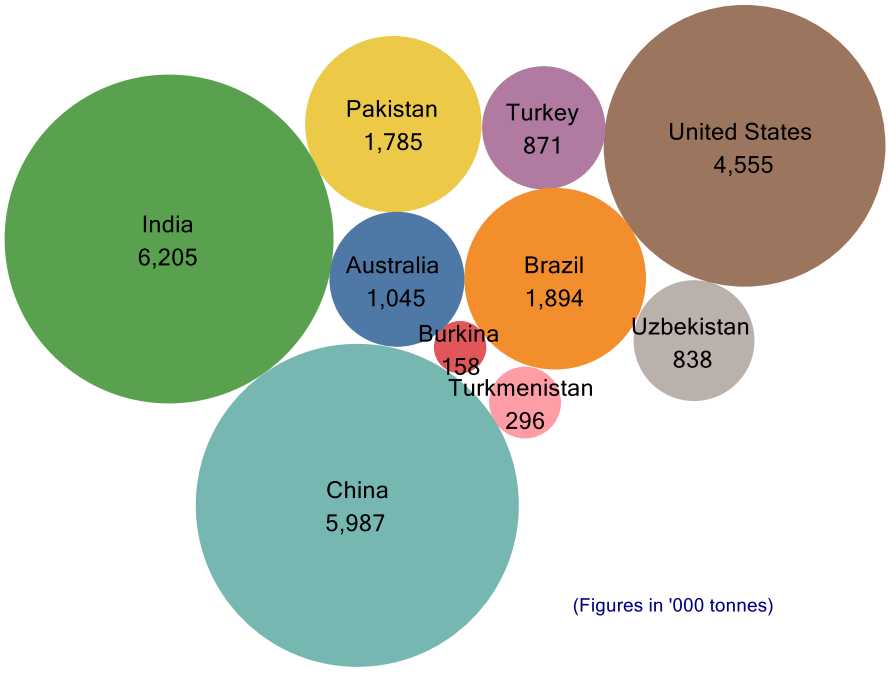

Figure 1.1: Top 10 Cotton producing countries (2017-18)

However, in terms of productivity, India ranks 34th position, much below the other major cotton producing countries in the world. Among top 10 cotton producing countries, the cotton yield is highest in Turkey (1,884 kg/ha) which is also global highest, followed by Australia (1,814 kg/ha,), China (1,787 kg/ha), Brazil (1,675 kg/ha), USA (955 kg/ha) and Pakistan (726 kg/ha). The yield-wise depiction of countries is given in Figure 1.2.

Figure 1.2: Cotton yield in different countries in the world (2017-18)

The cotton crop is highly prone to damage by insects and pests as compared to other commonly grown crops. It is attacked by about 150 species of insects. Among those, important pests are jassids (*Amarasca bigutulla*), aphids (*Aphis gossypii*), white fly (*Bemesia tabaci*), spotted bollworm (*Earias vitella*), pink bollworm (*Pectiniphora gossypiella*) and American bollworm (*Helicoverpa armigera*). Because of plethora of pest problem, more chemical pesticides are used in cotton than in any other crop. Cotton accounts for 16% of global insecticides production. In India, even though cotton occupies less than 5% of total cultivated area, its share in total pesticide use is between 40 to 45% (Venugopal, 2004). In central and southern India, cotton growers typically use 12-15 sprays per season. Pesticide use is particularly heavy in irrigated cotton area. Despite the heavy reliance on pesticides, cotton growers often find them to be ineffective partially or totally. This is because some of the cotton pests such as the

American bollworm and white fly have developed resistance to most of the insecticides used to control them (Birthal, Sharma and Kumar, 2000).

1.2 Storm in the Cotton Field

Since the year 2014, various findings and news revealed outbreak of pink bollworm (PBW) insect, badly damaging the crop in certain cotton growing geographies of Western and Central India. High levels of PBW infestation (ranging from low to high) and crop damage were reported in the fields in Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh during kharif season of 2015 (Kranti 2015), and in the early part of the 2016 season in Saurashtra, Gujarat and Haveri, Karnataka. These incidences caused great concerns in the cotton value chain because of the impact on cotton output and reduced market price of pink bollworm-damaged cotton. It also created huge concerns among the scientific fraternity because BG-II the second generation insecticidal technology was supposed to protect crops against the pink bollworm. Now, the pest is considered to develop resistant to the Bt proteins/toxins produced by the technology/trait. As a result, cotton farmers now spend more on pesticides. At the same time, none of the major cotton growing countries have reported rising resistance of pink bollworm in Bt cotton.

In this condition, two school of thoughts emerged. Cotton researchers in India broadly agree that the pink bollworm grew resistant because in India cotton is grown for longer duration (5- 7 months) and most of the cotton acreage is under hybrid cultivation when compared to other countries. They further proclaim that when Monsanto licensed its BG and BG-II traits to Indian seed companies, the agreement restricted the introduction of these traits to hybrids only. Moreover, it is evident that hybrids are more attractive to Indian seed companies because they offer a 'value capture mechanism'. On the other hand, Mahyco-Monsanto believes that the emergence of pink bollworm in BG-II cotton field is due to complex mechanism, both off the field (seed quality including trait purity) and on the field (farm practices) than the technological failure. Accordingly, it also introduced several interventions for popularizing insect resistance management (IRM) practices including, refuge planting, ETL based sprays, use of phenome traps for PBW monitoring, awareness

campaign on crop termination and pest management and training programme to farmers during the post-harvest, pre-season and mid-season, using field personnel for face to face farmer meetings, posters on managing pink bollworm and IRM practices, providing advisory on pest management through Monsanto "Farm-Rise" platform.

In absence of any field level investigation done in the past to examine the adoption of IRM practices, the present study has been undertaken to investigate and document the IRM measures followed by the farmers. It will eventually help in formulating suitable strategies for different stakeholders to upscale these activities in the cotton growing regions of the country to contain the resistance of bollworm in cotton.

1.3 Objectives

Following are the specific objectives of the study:

i. To evaluate the extent of adoption of IRM measures on pest mitigation, especially pink bollworm through farmers' perception;

ii. To evaluate the effectiveness of IRM measures promoted by stakeholders in the selected states of India;

iii. To estimate the tangible and intangible benefits from IRM practices adopted by Bt farmers; and

iv. To suggest suitable strategies for stimulating diffusion of best cultivation practices.

2. Insect Resistance Management in Cotton

2.1 Cotton Cultivation in India

Cotton, often referred to as the White Gold, is an important cash crop of India and it plays a key role in the Indian economy. Presently, nearly 60 million people depend on cotton cultivation, marketing, processing and exports for their livelihood (Chockalingam, 2015). There are evidences of cotton cultivation during Indus Valley of Civilization around 3000 B.C. Cotton has played a very important role since then. India had always been a major exporter of cotton in the history. There are four cultivated species of cotton viz. *Gossypium arboreum, Gossypium herbaceum, Gossypium hirsutum* and *Gossypium barbadense*. India has the sole distinction of growing all the four cultivated species of cotton and their intra- and inter-specific hybrids. The hybrid cotton era started from 1970 when first hybrid cotton was developed in Surat, Gujarat state, which was later commercially cultivated in Gujarat and Maharashtra.

The introduction of Bt cotton has changed the entire cotton value chain in India. Since its introduction in 2002, there has been significant spurt in cotton production and productivity. Production of cotton in India has increased to around 35 million bales[1] in 2017-18. When compared to pre-Bt cotton years, the total cotton production has increased 345 per cent from merely 9.4 million bales in TE 2002-03 to 32.5 million bales in TE 2017-18. During this period, area under cotton has also expanded from 8.4 million hectares (M ha) to 11.2 M ha, respectively. Consequently, India became the number one exporter of cotton globally. Thus, the productivity has dramatically increased from about 190 kg/ha in TE 2002-03 to 493 kg/ha in TE 2017-18, recording about 260 per cent increase (Figure 2.1).

In India, cotton is grown in three distinct agro-ecological zones comprising 11 states viz., Northern (Punjab, Haryana and Rajasthan), Central (Gujarat, Maharashtra and Madhya Pradesh and Odisha) and Southern zone (Andhra Pradesh, Telangana, Tamil Nadu and Karnataka). Gujarat is the largest producer of cotton with 126 lakh bales in 2017-18 followed by Maharashtra and Telangana. The top three states account for

[1] 1 Bale = 170 kg of lint cotton

around two-third of the country's total production. Although, in terms of area under cotton crop, Maharashtra accounts the largest area (42 lakh ha), almost 60% more than that in Gujarat state, but harvested only 52% as that of Gujarat state in 2017-18 (Figure 2.2).

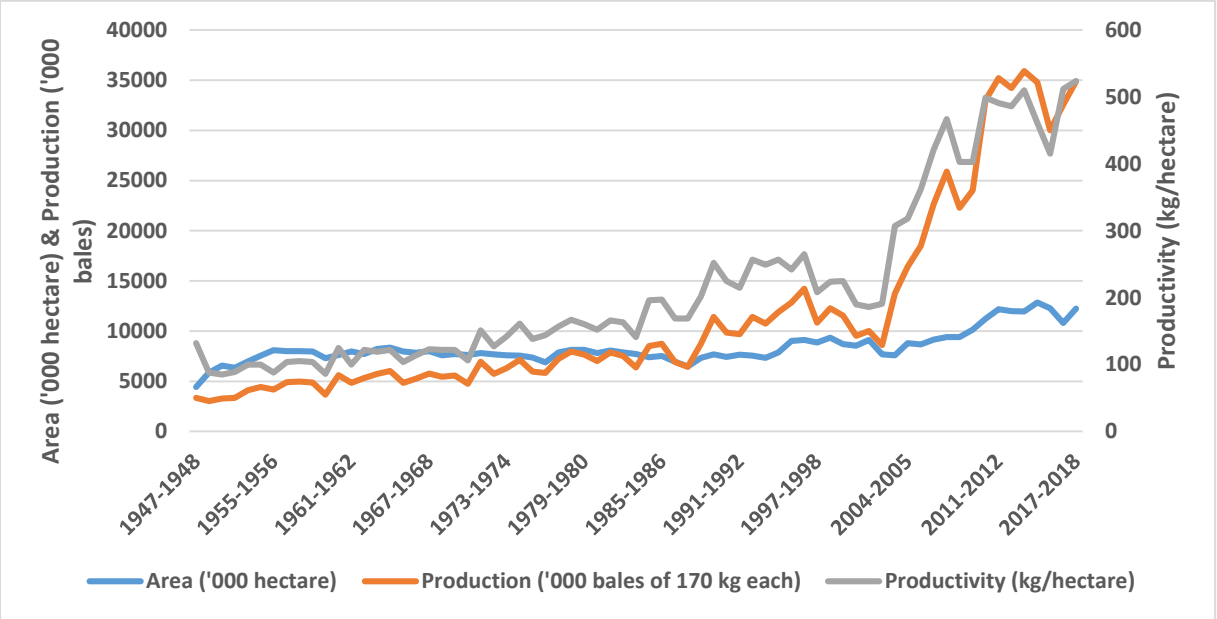

Figure 2.1: Year wise area, production and productivity of cotton in India

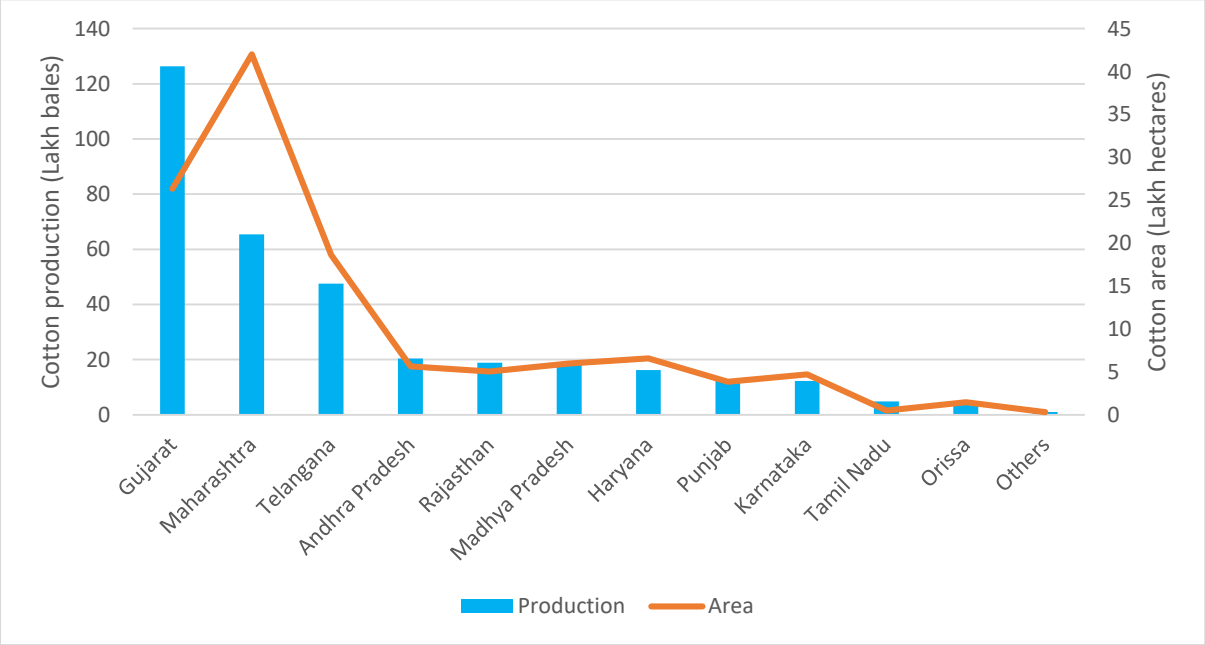

Figure 2.2: State wise cotton area and production in India (2017-18)

2.2 Bt Cotton in India

There was a paradigm technological shift in cotton cultivation worldwide including in India through the introduction of Bt cotton. The Bt gene, derived from the naturally occurring soil bacterium, *Bacillus thuringiensis* (Bt) is inserted into the cotton genome. The crop with Bt- gene releases proteins which are toxic to certain pests. The Bt cotton (Bollgard I®, BG-I) confers resistance to Lepidopteron pests of cotton. The Bt cotton was first time introduced in USA in the year 1996. In India, Mahyco introduced Bt cotton in the name of Bollgard® (BG) in the year 2002, which contained only one gene, the Cry 1Ac. While Bollgard II® (BGII), which was introduced in 2006 contains the Cry 2Ab gene, in addition to Cry 1Ac. While Bollgard offers protection against cotton bollworms, Bollgard II® is contemplated to provide additional protection against *Spodoptera litura*.

Bt cotton was initially approved by Genetic Engineering Appraisal committee (GEAC) Ministry of Environment, Forests and Climate Change, Government of India, only for the Central (Gujarat, Maharashtra & Madhya Pradesh) and South zone states (Tamil Nadu, Andhra Pradesh & Karnataka). Later on, GEAC approved the commercial cultivation of Bt cotton in North Zone from the year 2005-06. During 2007-08, GEAC approved the Bollgard II®, a proprietary technology by Monsanto (from now onward will be mentioned as BGII) of Bt hybrids for its commercial cultivation. (Directorate of Cotton Development GOI, 2017). In India, other than Bollgard and Bollgard II technologies, there are four other Bt cotton technology approved, but are not in commercial use at present. In India, Mahyco-Monsanto Biotech (MMB) has sub-licensed Bollgard technologies to more than 40 Indian seed companies. Each of them introduced Bt technology into their own germplasm and sought regulatory approval for commercialization. Thus, Indian cotton growers got a choice of over 800 Bt cotton hybrid seeds. Monsanto collects royalty (trait value) from these seed companies for Bt technology use. During these years (2002-2018), cotton acreage has increased from 7.67 Mha to 12.1 Mha and productivity also rose steeply from 191 kg/ha to 520 kg/ha of lint (Kranthi, 2015).

Currently, about 90% of cotton grown in India are Bt cotton, mostly Bollgard II hybrids. Bt cotton area in India during 2002-03 was barely 0.3 million hectares (Mha) out of 7.67 Mha which has now increased to 10.8 Mha out of total cotton area of 12.1 Mha in 2017-18 (Figure 2.3).

Figure 2.3: Year wise area under Bt cotton in selected states

Maharashtra witnessed highest adoption of Bt cotton and has crossed 80% of total cotton area in the state in only six years of adoption in 2002, whereas Gujarat reached 54%, while Karnataka lagged behind with only 36% area during the same period. But after the introduction of Bollgard II, within 3-4 years, the area under Bt cotton surpassed 90% in all the states. The Bt technology has brought many tangible and intangible benefits to the cotton farmers (James, 2009, Subramanian and Qaim, 2010, Kiresur and Ichangi, 2011). The benefits include less pesticide use, increased yield and overall more production and eventually higher return.

2.3 Insect Resistance Management: Concept and Definition

Before the introduction of Bt cotton, cotton growers were mainly using the synthetic insecticides to combat the pests. As a result, bollworms, developed resistance to almost all major classes of pesticides. Development of transgenic cotton resulted in an immense increase in seed cotton yield and reduction in insecticidal sprays (Barwale et al., 2004) and it helped the farmers to manage the population of *H. armigera*, the most important pest causing about 31.0 per cent loss in non-transgenic cotton (Grover and Pental, 2003). Globally, all insecticide resistance management (IRM) strategies have been designed with emphasis on efficient use of insecticides to conserve the ecosystem for better pest management. In essence, all IRM strategies aim at optimizing the use of insecticides in a manner that maximizes their efficacy, minimizes intensity of selection pressure, and mitigates the adverse effect on ecosystems and the environment.

Traditionally, the integrated pest management (IPM) strategies in India were designed to reduce the dependence on insecticides and are based on the use of a rational and sensible sequence of insecticides that are effective on the target species, cause least disturbance to beneficial fauna and minimize selection pressure. The strategies include, cultivation of sucking pest tolerant genotypes and chemical seed treatment to help in delaying the first spray, thereby conserving the initial build-up of natural enemies (Kairon and Kranthi, 1998). The ICAR- Central Institute of Cotton Research (CICR), Nagpur recommends very specific package of practices under insect resistance management (IRM) guidelines. Accordingly, it also releases weekly advisory for different cotton growing regions in India. Key features of the guidelines issued by the ICAR-CICR are given in the Box.

IRM in cotton pests in 'a nut shell'

- Cultivate 'sucking pest tolerant' cultivars and/or seed treatment
- Zero insecticide till 60 days
- Based on economic threshold the following simple ' window strategy can be adopted
- No 'organophosphate' till 90 days
- Endosulfan - not beyond 90 days
- Biorationals eg: HaNPV, neem,etc'if applicable' at 70-90 days
- Pyrethroid only after 110days

Source : http://www.cicr.org.in/IRM.html

Specific to the central and southern cotton growing region in India, the IRM strategies suggested by the institute are given in Table 2.1.

Table 2.1: IRM strategies by ICAR-CICR for cotton pest management- Central and South India

Particulars	July	August	September	October	November	December
Insect Pest	Jassids, Aphids	Jassids, Aphids, Thrips	Helicoverpa, Whiteflies, Jassids	Helicoverpa, Whiteflies	Pink bollworm	Pink bollworm, Red cottonbug
Economic Threshold Level		Jassid – 2/leaf Thrips – 50/leaf	Helicoverpa – 10 larvae/20 plants	Helicoverpa – 20 larvae/20 plants	10% damaged bolls	
Management options	Imdaclorid as seed treatment for hybrids Grow Jassid resistant genotypes	Endosulfan or neem seed extract	HaNPV	Endosulfan	Quinalphos/ Chlorphyriphos/ Profenofos	Methomyl or thiodicrab	Pyrethroid + sesamum oil
Crop Stage	Vegetative	Vegetative	Squares & Flowering & Bolls	Square & Flowering & Bolls	Square & Flowering & Bolls	Bolls
Crop Age	0-30 days	30-60 days	60-90 days	90-120 days	120-150 days	150-180 days

Source: *http://www.cicr.org.in/IRM.html*

According to the communications received, Mahyco-Monsanto Biotech (MMB) implemented several interventions at different levels to contain Pink Bollworm (PBW). Those interventions are:

At farmers' level:

- Refuge planting
- Mass trapping of PBW moths using pheromone traps (in Saurashtra region)
- Promotion of pheromone traps for PBW monitoring
- Awareness campaigns and training programs to farmers during post-harvest, pre-season and mid-season
- Posters on importance on managing PBW and IRM practices
- Advisories on pest management through Monsanto's "Farm-Rise" platform

At traders' level:

- Awareness and poster campaigns

At ginners' level:

- Awareness campaigns
- Pheromone trap monitoring

Thus, MMB has promoted basically following IRM strategies:

1. Use of Pheromone traps: promotion, installation and demonstration since 2014 season, starting from Saurashtra region of Gujarat, later expanding to other regions in Gujarat, MP, Maharashtra.

2. Refuge planting: demonstration of refuge in bag (RIB) concept in comparison with farmer practice (no refuge planting), across various geographies since 2013 season

3. Scouting and ETL based sprays: village campaigns, farmer meetings, posters

4. Crop agronomy: Avoid early planting, terminate early to arrest perpetuation of the pest.

5. Field sanitation and crop termination advisories

6. Gin sanitation: pheromone trap installation, sanitation of gins.

In December 2016, the Ministry of Agriculture and Farmers Welfare, Government of India (GoI) in a notification endorsed the implementation of 'refuge-in-bag' (RIB) for Bt cotton and specified Bt trait purity standards and proportion of non-Bt refuge seeds in the blend (Komarlingam, 2018). Moreover, some of the long-term researches carried out globally suggest that use of refuge non-Bt cotton and cultivation of short duration crop are the most important strategies to delay the development of resistance among the bollworms in cotton.

"The hybrid plants tend to have higher yield than the parent plants, and the second-generation hybrids cost less, so it's a market-driven choice for immediate advantages, and it promotes sustainability. The primary strategy for delaying resistance is providing refuges of the pests' host plants that do not make Bt proteins. This allows survival of insects that are susceptible to Bt proteins and reduces the chances that two resistant insects will mate and produce resistant offspring. Our results show 96 percent pest suppression and 69 percent fewer insecticide sprays. This study gives a new option for managing resistance that is very convenient for small-scale farmers and could be broadly helpful in developing countries like China and India. A great thing about this hybrid seed mix strategy is that we don't have to worry about growers' compliance or regulatory issues"

Bruce Tabashnik and Kongming Wu (2017)

3. Methods and Data

3.1 Data Collection

The information required for the project is collected through primary survey as well as from secondary sources. The primary survey is conducted to elicit information from farmholds about farm operations, IRM practices and costs and returns. Three states- Gujarat, Maharashtra and Karnataka- were purposively selected as they have considerable area under cotton cultivation and the sponsoring agency viz. MMB has significant presence in terms of its IRM intervention. These 3 states together account for more than 60% of total cotton crop area in the country and contributes about 58% in total cotton production based on the data showing triennium ending (TE) average of 2017/18 i.e. 3-year average (2015/16 to 2017/18). The details of sample selected is given in

Table 3.1.

Table 3.1: District wise sample size in the study

State	District	Mandal	No. of samples
Gujarat	Amreli (88)	Jafrabad	34
		Rajula	25
		Savarkundla	29
	Bhavnagar (94)	Mahuva	32
		Palitana	30
		Talaja	32
	Junagadh (92)	Kodinar	29
		Una	30
		Visavadar	33
	Surendranagar (30)	Lakhtar	15
		Limbdi	15
Karnataka	Gadag (88)	Gadag	30
		Nargund	30
		Ron	28
	Raichur (90)	Manvi	30
		Raichur	30
		Sindhnur	30
Maharashtra	Jalna (91)	Ambad	31
		Ghansawangi	30
		Jafferabad	30
	Yavatmal (38)	Pusad	38
Total sample size of cotton growers			**611**

Four districts from Gujarat and two each from Karnataka and Maharashtra were selected based on large area under cotton cultivation. In total, 611 samples were selected randomly. Information pertaining to cotton procurement and processing at ginning mills, village merchants and input dealers were also collected. The secondary sources of information used in the study such as area, production, productivity and prices of cotton were collected from online sites like agricoop.nic.in, indiastat.com, agmarknet.nic.in, etc.

3.2 Methodology Adopted

After consulting different literatures, considering advisory of ICAR-CICR and that of MMB, 11 activities were identified for the adoption of IRM (Table 3.2). Farms adopting four or less number of practices were categorized as **'Low adopters'**, while farms adopting five to eight practices and above 8 practices were categorized as **'Medium adopters'** and **'High adopters'**, respectively.

Table 3.2: Recommended IRM practices

S. No.	Adoption practices
1.	Crop rotation (cycle)/ breaks
2.	Using branded or certified seeds
3.	Selection of varieties with early maturity
4.	Cultivation of non-Bt refuge crop
5.	Insecticidal Sprays after 20-25 days of formation of bolls
6.	Use of Pheromone traps
7.	Harvested along with other cotton farmers in the village (synchronized harvest)
8.	Destruction of green bolls at the end of the cropping season
9.	Destruction of cotton stubbles
10.	Deep Summer ploughing
11.	Keeping the field weed-free during off-season

Figure 3.1: Sample districts for the study

4. Cotton Cultivation in the Study Area

4.1 Cotton Production in Selected States

Gujarat, Maharashtra and Karnataka are the three important cotton growing states in India. These states have witnessed significant increase in acreage allocation under cotton crop, mainly after the introduction of Bt cotton. From Figure 4.1, it may be observed that the acreage under cotton has increased in all the 3 states as well as in the country. When we compare the crop area and yield with respect to just before the introduction of BG-II technology in the year 2006, the area increased 2 to 6% annually. There was huge expectation of productivity improvement with new BG-II technology in the cotton. Though, the growth in crop yield has remained muted, except in Karnataka state.

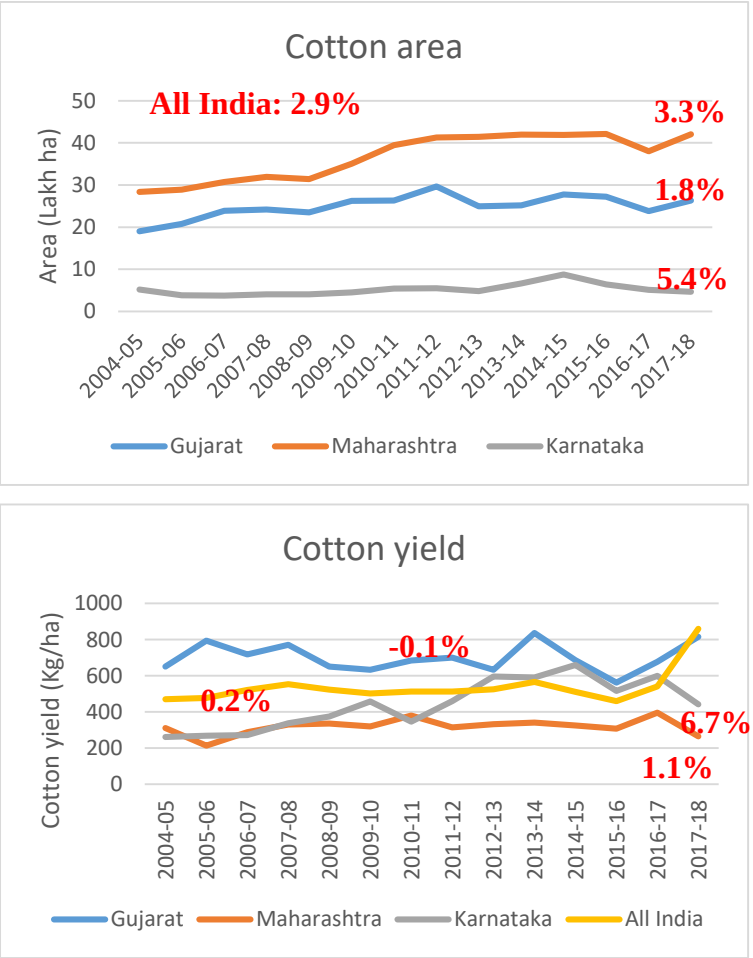

Figure 4.1: Trend in Cotton area and yield in 3 states
(Annual compound growth rates are given in %)

It can also be observed that the cotton yield in Maharashtra state is substantially lower than that in Gujarat state or in Karnataka state, particularly after 2010-11. This may be due to the fact that cotton is mostly grown without irrigation in Maharashtra (Lalitha et al., 2009). It is also due to poor farm practices, a lack of adequate irrigation network and frequent dry-spells in the cotton growing region of the state (Pattanayak, 2015).

4.2 Socio-economic Profile of Cotton Growers

For dissemination of information, literacy plays an important role. Studies have found positive influence of education on the adoption of technologies (Shiferaw et al., 2009 & 2014). Accordingly, medium for information dissemination needs to be selected for better decision making. The profile of the sample farmers is depicted in Table 4.1. More than half of the farmers in the study area have school education, whereas one-fifth are illiterate. Less than ten percent have university degree in all the three selected states.

Table 4.1: Socioeconomic profile of the sample farmers (all figures in percent of total sample size in the respective state)

Particulars	Gujarat	Maharashtra	Karnataka	Total
Sample size	304	129	178	611
Age (years)	48	48	46	47
Educational level				
Illiterate	19.47	25.78	23.03	21.84
Primary	29.70	18.75	21.35	24.96
Secondary	34.98	2.81	17.98	29.56
Higher secondary	11.22	15.61	29.21	17.4
Graduate and above	4.62	7.03	8.43	6.24
Family size				
Up to 4	22.77	30.47	36.52	28.4
5-9	66.67	58.59	56.74	62.1
10 and above	10.56	10.94	6.74	9.52
Source of irrigation				
Canal	8.91	3.13	46.63	18.7
Open well	75.91	74.22	0.56	53.5
Bore well	24.09	11.72	12.92	18.2
River	2.64	0.78	2.81	2.3
Tank	0	1.56	0.56	0.49
Soil testing done				
Yes	20.23	9.6	15.25	15.11

Family size was found to be relatively large in the study villages, as more than 60% of households have 5 to 9 members. However, the proportion of nuclear family with number of members up to four were also in sizeable proportion.

The survey area in Gujarat and Maharashtra has more of open well and bore well as source of irrigation whereas Karnataka farmers were using canal as major source of

irrigation. Open well is major source of irrigation in Gujarat and Maharashtra whereas, canal in Karnataka. But open well is found to have very less water, and in many cases, wells went dry. Therefore, farmers have to depend on monsoon for irrigation in selected districts of Gujarat and Maharashtra. Hence, monsoon plays a major role in cotton production. Soil testing helps in increasing the productivity of soil by identifying the soil nutrients that limit plant growth. It increases fertilizer use efficiency by specifying correct rates for different soils. The survey area in all three selected states revealed very less number of households having their field tested.

4.3 Cropping Pattern

The selected states have different cropping pattern, which can be evident from Table 4.2. Cotton is found to be the major crop in all the three states. In Gujarat, it is cultivated as sole crop in more than three-fourth of the area. In Bhavnagar, few farmers grow cotton along with groundnut as intercrop. Junagadh district has much diversified cropping pattern. Though two-third cotton acreage is under sole cotton crop, in other areas, it is grown with groundnut, pigeon pea and castor separately as intercrop. In Maharashtra, cotton is mainly grown with pigeon pea or soybean as intercrops. In some cases, farmers also opt for other crops like jowar, bajra and tomato. On the other hand, in Karnataka, around two-third of the area has cotton as sole crop. While small proportion of farmers, also grow cotton as intercrop with pigeon pea and chickpea.

Table 4.2: Cropping pattern in the sample districts of selected states

Gujarat							
Amreli		Bhavnagar		Junagadh		Surendranagar	
Crop	*% area*	*Crop*	*% area*	*Crop*	*% area*	*Crop*	*% area*
Cotton	91.2	Cotton	91.5	Cotton	73.7	Cotton	87.3
Groundnut	5.4	Groundnut	7.0	Groundnut	8.8	Wheat	11.3
Onion	2.3	Cotton+ Groundnut	1.1	Cotton+ Groundnut	5.7	Groundnut	1.5
Wheat	1.2	Bajra	0.4	Cotton+ Pigeon pea	2.4		
				Cotton+ Castor	2.4		
				Others	7.06		

Maharashtra			
Jalna		Yavatmal	
Crop	*% area*	*Crop*	*% area*
Cotton+ Pigeon pea	53.0	Cotton+ Pigeon pea	58.8
Cotton	12.7	Cotton+ Soyabean	18.3
Wheat	8.3	Cotton	6.9
Orange	6.7	Cotton+ Jowar	5.7
Soyabean	4.4	Cotton+ Pigeon pea+ Tomato+ Onion	2.7
Cotton+ Green gram	3.3	Cotton+ Jowar+ Pigeon pea	2.3
Cotton+ Jowar	2.2	Others	5.3
Cotton+ Soyabean	2.2		
Cotton+ Pigeon pea+ Bajra	2.0		
Others	5.1		

Karnataka			
Raichur		Gadag	
Crop	*% area*	*Crop*	*% area*
Cotton	68.3	Cotton	63.7
Cotton+ Pigeon pea	8.0	Cotton+ Pigeon pea	6.0
Jowar	5.1	Jowar	5.3
Pigeon pea	4.5	Chickpea	10.0
Paddy	4.3	Pigeon pea	2.7
Cotton+ Chilli+ Pigeon pea	3.8	Wheat	1.7
Chickpea	2.2	Jowar+ Chickpea	1.6
Others	3.8	Maize	1.5
		Jowar+ Wheat+ Ragi	1.5
		Chilli	1.4
		Others	4.5

4.4 Seed Rate

There was significant difference in the seed rate applied by the cotton growers in the selected 3 states. The seed rate varied from 1.38 kg/ hectare in Gujarat to as high as 2.03 kg/ha in Karnataka state. High seed rate in Karanataka state may be due to the reason that some farmers

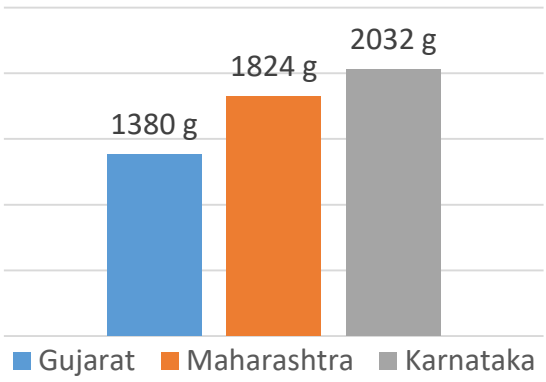

Figure 4.2: Seed rate in the selected states (g/ha)

in Karnataka are also cultivating non-Bt variety seed, in which they go for higher seed rate. However, in all the cases, farmers are using more quantity of seeds as compared to the recommendation of 1 packet of 450g per acre or 1125 g/ha. Higher seed rate is also costing the farmers more in Maharashtra and Karnataka state.

4.5 Fertilizer Application

In terms of application of farm yard manure (FYM) or chemical fertilizer, cotton growers of 3 states behave differently. In Gujarat, farmers apply more quantity of FYM, significantly higher than their counterpart in Maharashtra and Karnataka states. This may due to the reason that in Gujarat, most of the farmer households have livestock for milk production, while in other two states, cotton is cultivated in semi-arid tropic regions, where raising livestock is not so popular.

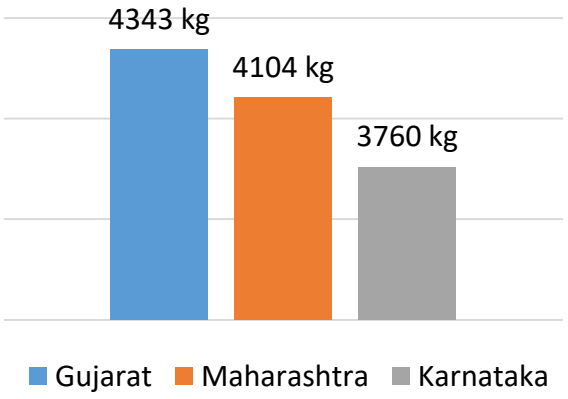

Figure 4.3: FYM application in the selected states (kg/ha)

However, farmers in other two states compensate the nutrient requirement of the crops through applying higher dosage of chemical fertilizer. Use of chemical fertilizer in cotton is the lowest in Gujarat state. Again, application of market-purchased chemical fertilizer adds significantly to the cost of cotton cultivation in Maharashtra and Karnataka states.

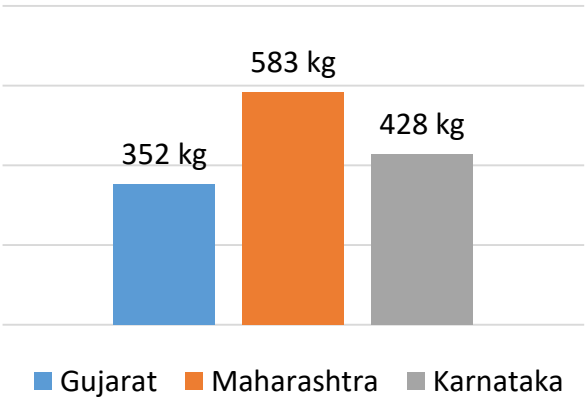

Figure 4.4: Chemical fertilizer application in the selected states (kg/ha)

4.6 Agrochemical Application

Pesticide use in India is comparatively less than many other countries. Though commercial crops including cotton has high pesticide consumption in the country, with the introduction of Bt cotton, insecticide usage has come down drastically (Carpenter 2010; Kathage and Qaim 2012; Krishna and Qaim 2012). There has been an increase in pesticide sprays against the outbreak of secondary pests such as jassids and aphids (Stone 2011; Nagrare et al 2009). There are many pesticides used in cotton cultivation which varies across states.

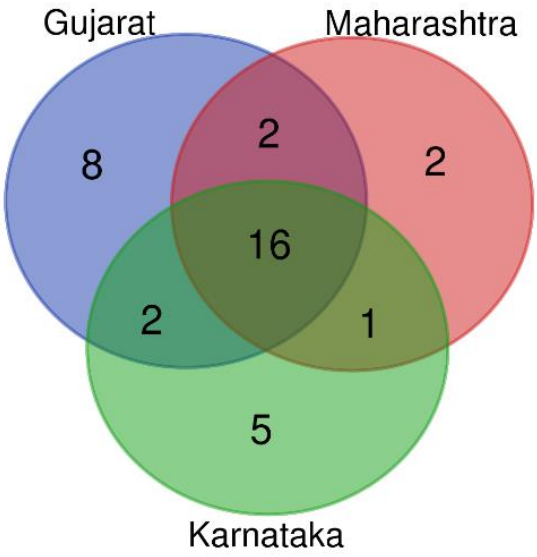

Figure 4.5: Number of different pesticides used in selected states

The study found total 36 different pesticides are being used in the selected states. About 16 pesticides are commonly applied in cotton field in all the selected states (Figure 4.5). Cotton growers in Gujarat state use maximum 28 different pesticides in cotton crop, out of that 8 are being used exclusively in the state. Farmers in other two states under study apply relatively lesser number of pesticides (21-24) in cotton crop.

Table 4.3: Pesticides used in cotton cultivation in selected states

States	Total	Pesticides
Gujarat, Maharashtra & Karnataka	16	Fipronil, Monocrotophos, Acephate, Chlorantraniliprole, Imidacloprid, Endosulfan, Acetamiprid, Quinalphos, Bio-Pesticide, Thiamethoxam, Profenofos, Dimethoate, Diafenthiuron, Dichlorvos, Chlorpyrifos, Lambda-cyhalothrin
Gujarat & Maharashtra	2	Cypermethrin, Emamectin benzoate
Gujarat & Karnataka	2	Flonicamid, Hexaconazole
Maharashtra & Karnataka	1	Buprofezin
Gujarat	8	Thiometon, Triazophos, Methamidophos, Ethion, Mancozeb, Carbendazim, Deltamethrin, Permethrin
Maharashtra	2	Pyrethroid, Propineb
Karnataka	5	Flubendiamide, Thiodicarb, Bensulfuron-methyl, Methomyl, Trichloromethane

Growth in cotton yield has been muted during last 10-12 years in India and in both the largest cotton growing states, despite of adoption of Bollgard- II technology. Though farmers continued to cultivate on same acreage under the crop.	Substantially lower cotton yield harvested in Maharashtra state may be due to multiple reasons: mostly unirrigated crop, high climatic variability, pests infestation as well as, cotton as intercrop with other crops (yield estimation issue).	Farmers are using mix of different brand seeds as well as variety of chemical pesticides to avoid any risk of crop failure. Some of the pesticides fall under highly hazardous category.

5. Pest Infestation and IRM Adoption

Extensive cultivation of crops genetically engineered to produce insecticidal proteins from the bacterium (Bt) has suppressed some major pests in cotton worldwide, reduced insecticide sprays, and increased farmers' profits. However, these benefits are being eroded by evolution of resistance in pests. There are several practices recommended by different research institutions for delaying the resistance of pests. However, studies suggested that the main strategy for delaying pest resistance to Bt crops aims to increase the survival of susceptible insects with 'refuges' of host plants that do not produce Bt toxins (Tabashnik et al, 2013). Whereas compliance with refuge requirements is considered a key factor that delayed evolution of pink bollworm resistance to Bt cotton in other countries, the scarcity of non-Bt cotton refuges probably hastened this pests' resistance in India (Dhruva and Gujar, 2011). Padmanabhan (2018) also stresses on advocating use of appropriate cotton variety for a given soil, proper assessment of pest density, use of refuge strategy and ensuring high Bt expression in the plant to delay resistance development. One school of thought also argues that while all other countries grow Bt cotton varieties, India is the only country growing Bt-cotton hybrids. The possible yield loss per plant due to varieties over hybrids may be compensated by substantially increasing the plant density. Hybrid Bt-cotton lend the plant susceptible to the secondary pests due to its long duration. Keeping all the above concerns, the present study captures the perception of cotton farmers in 3 states- Gujarat, Maharashtra and Karnataka about the pest infestation and also examined the adoption of different strategies considered to be part of insect resistance management.

5.1 Farmers' Perception about Pest Infestation

An inquiry was made to know the degree of various pest infestation in the cotton field in selected states during 2017-18 in comparison to that in previous year. The commonly occurring pests are Pink bollworm, American bollworm, Spotted bollworm, Aphids, Jassids, Spodoptera, Thrips and White fly. From Figure 5.1, it can be clearly observed that in all 3 states, majority of sample farmers expressed that the infestation of pink bollworm has not only increased as compared to previous year, but also there is high level of infestation. As many as 74 to 83% of farmers in 3 states

perceive the infestation level of pink bollworm is high. Moreover, cotton growers in Gujarat and Karnataka felt that infestation of American bollworm is not so serious. Though Maharashtra farmers felt increase in its infestation. Regarding other insect-pests, Gujarat farmers were not so anxious, though pests like spotted bollworm, aphids, jassids, etc. were present, but their intensity was low to medium. In Maharashtra also, these insects are posing medium level threat to cotton. In Karnataka, farmers were worried about variety of insect-pests, some of these are increasing also.

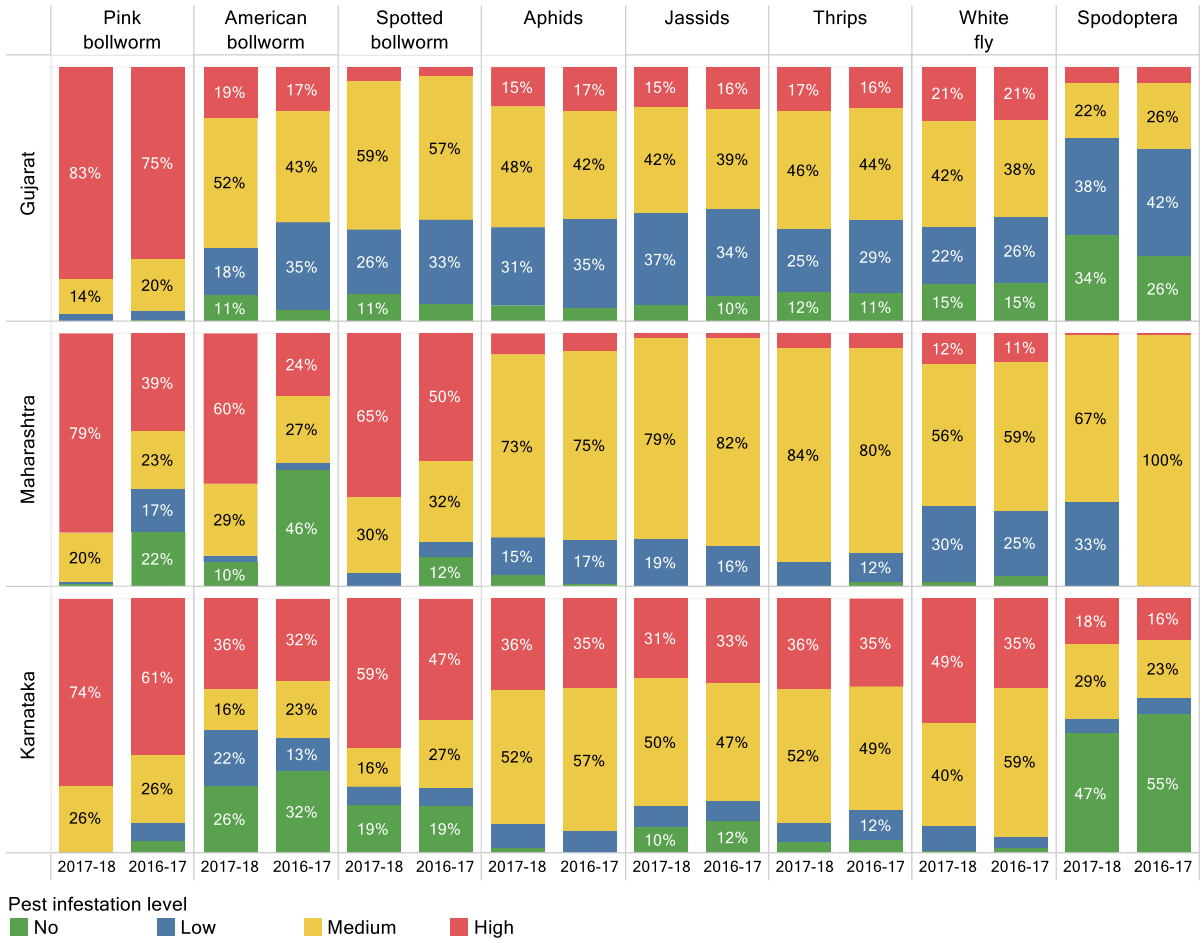

Figure 5.1: Perception of farmers (% of total) about degree of pest infestation in the study area during 2016-17 and 2017-18

The infestation level with respect to different IRM levels adopted by the farmers were also examined and the results are given in **Annexure-III**. It can be said that, infestation is still perceived to be at higher level even after following IRM practices. Though, it is worth highlighting the fact that no farmer has adopted all the IRM practices listed in

the study. It could be the reason for still high pink bollworm infestation level in three selected states.

5.2 IRM Adoption Level

A key component of any IRM strategy is a refuge, that is growing same crop that does not contain a Bt technology for controlling targeted insect pests. The United State Environmental Protection Agency (EPA) mandates a refuge for Bt technology. The primary purpose of a refuge is to maintain a population of insect pests that are not exposed to Bt proteins. The lack of exposure to Bt proteins allows susceptible insects emerging from the refuge to mate with the resistant insects that may emerge from the Bt crop, so as to pass on the susceptibility to their offspring. The standard IRM practice for cotton cultivation are collected by reviewing various sources and subjected to inquiry from the cotton farmers to assess their adoption level. The following 11 practices are identified:

1. Deep summer ploughing
2. Selection of varieties with early maturity
3. Using branded or certified seeds
4. Cultivation of refuge non-Bt cotton
5. Insecticide spray based on ETL
6. Use of pheromone traps
7. Harvesting along with other farmers
8. Grazing or destruction of left over green bolls
9. Destruction of cotton stubbles
10. Maintaining weed-free land during off-season
11. Crop rotation (cycle)/ breaks

None of the farmer across the selected states is found to adopt all the recommended IRM practices (Figure 5.2). There are certain practices which many farmers are not aware. For instance, more than three-fourth of the farmers in Maharashtra and Karnataka are not aware of pheromone trap as one of the recommended IRM practice for cotton cultivation. The same in Gujarat is 57%. Similarly, awareness related to cultivation of non-Bt cotton as refugee crop is also low. About 46, 43 and 31% of

farmers in Gujarat, Maharashtra and Karnataka, respectively are unaware of non-Bt cotton cultivation as refuge crop. There are cases where farmers have adopted a particular practice but left following in due course of time. Though these are very less in number (5-10%). Some farmers have used pheromone traps which were distributed by Agricultural universities and other agencies at some point of time in the past. But the practice was not continued afterwards and thus categorized as dis-adopted.

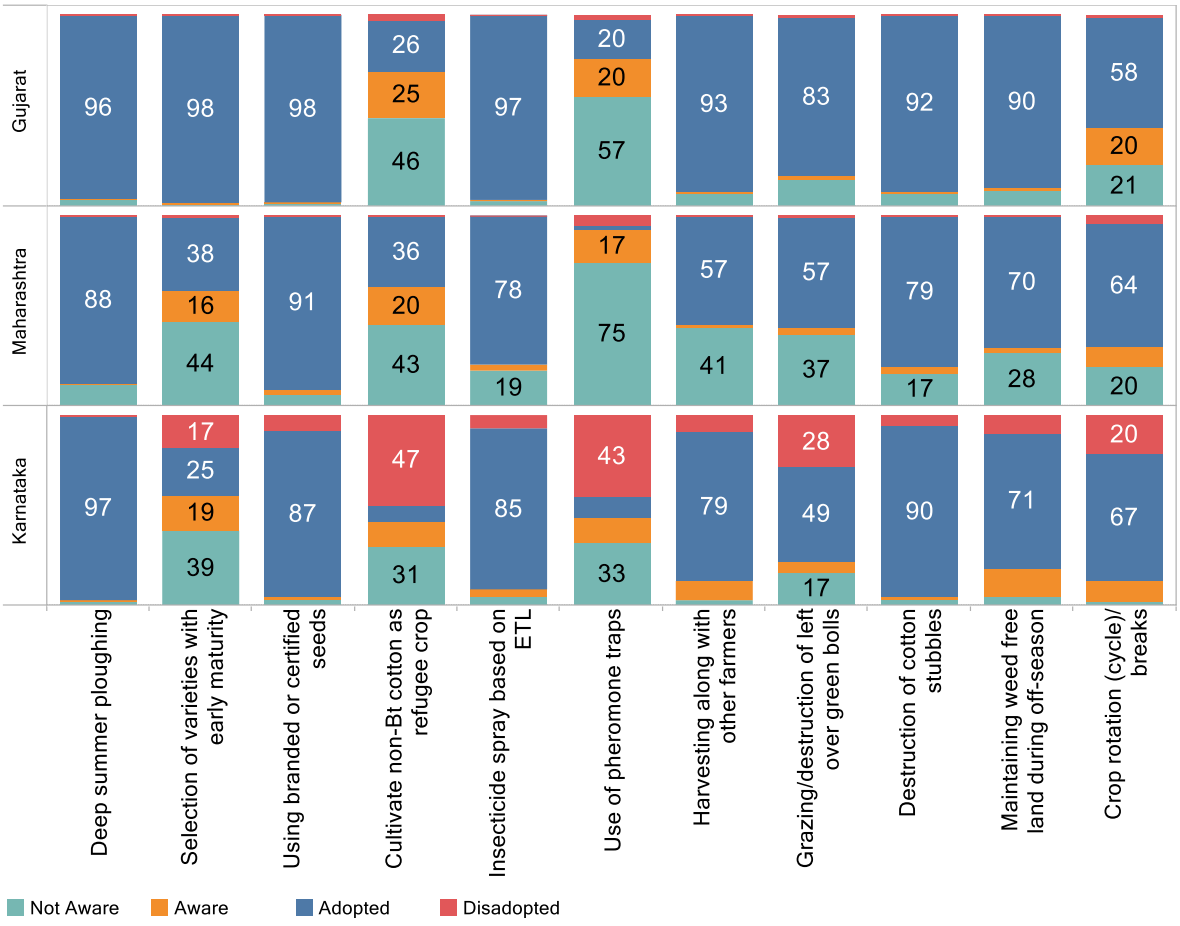

Figure 5.2: Farmers awareness and adoption of various IRM practices (% of total)

Summer deep ploughing is followed by most of the farmers in the selected states. This is particularly done to make the field ready for next cropping season. More than 90% in all the selected states are using branded seeds. But early maturity variety selection is not adopted equally in these states. In fact, in Maharashtra and Karnataka, many farmers are not aware of the practice of growing early maturity crop. In these states, many farmers are harvesting fourth and fifth pick extending the harvesting season up

to March-April month. Reason for this trend is, there is no cropping in the rabi season. More importantly, while field survey, it was observed that in most of the survey villages, some of the farmers have left the cotton crop standing in the field till month of May in all three states. Farmers leave the cotton crop in the field for longer duration in order to get some more quantity by following fourth and fifth pick. Or they till the plot, only when rainfall starts next year. While it is well established fact that the insects particularly pink bollworm, being monophagus easily get hibernated into plant parts and continue their life cycle in the field, when cotton stubbles are left in the field.

A. Cotton field in Gujarat during April 2018

B. Standing cotton stubbles in Maharashtra in May 2018

C. Cotton stubbles stored for fuel purpose near field in Maharashtra in May 2018

D. Cotton boll damaged by the pest in Karnataka

Figure 5.3 Cotton stubbles left standing in the cotton field in survey villages

For the study, all the sample farmers are divided into three categories on the basis of number of practices followed by them out of the 11 practices considered under IRM. The first category (labelled as "Low") includes the farmers who are following four or less IRM practices. "Medium" category includes the farmers who have adopted five

to eight practices and "High" category farmers are those who follow more than eight recommended IRM practices. It can be visualized from Figure 5.4 that Karnataka has relatively more "High" IRM adopters (47%) than other two states (38 and 20% in Gujarat and Maharashtra respectively). Gujarat has very less, 1% "Low" adopters and 62% "Medium" adopters. But in Maharashtra, 21% fall under "Low" category which is highest of "Low" category among the selected states. Interestingly, there is varying pattern of adoption across farm size category in 3 states (Figure 5.5).

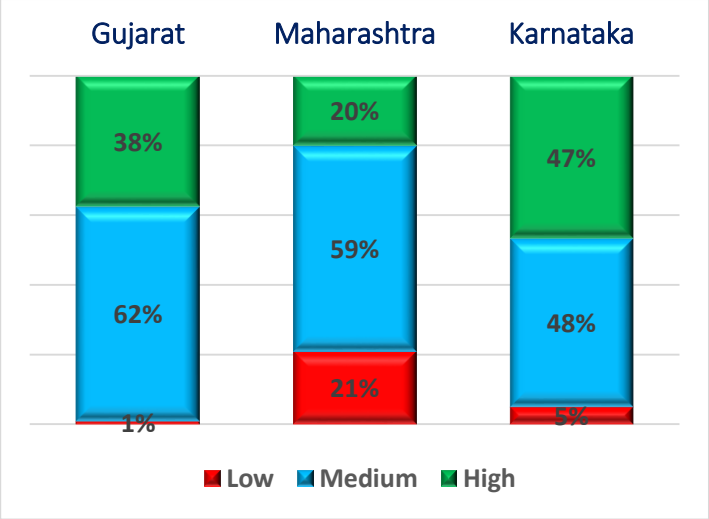

Figure 5.4: IRM adoption level of cotton farmers in selected states

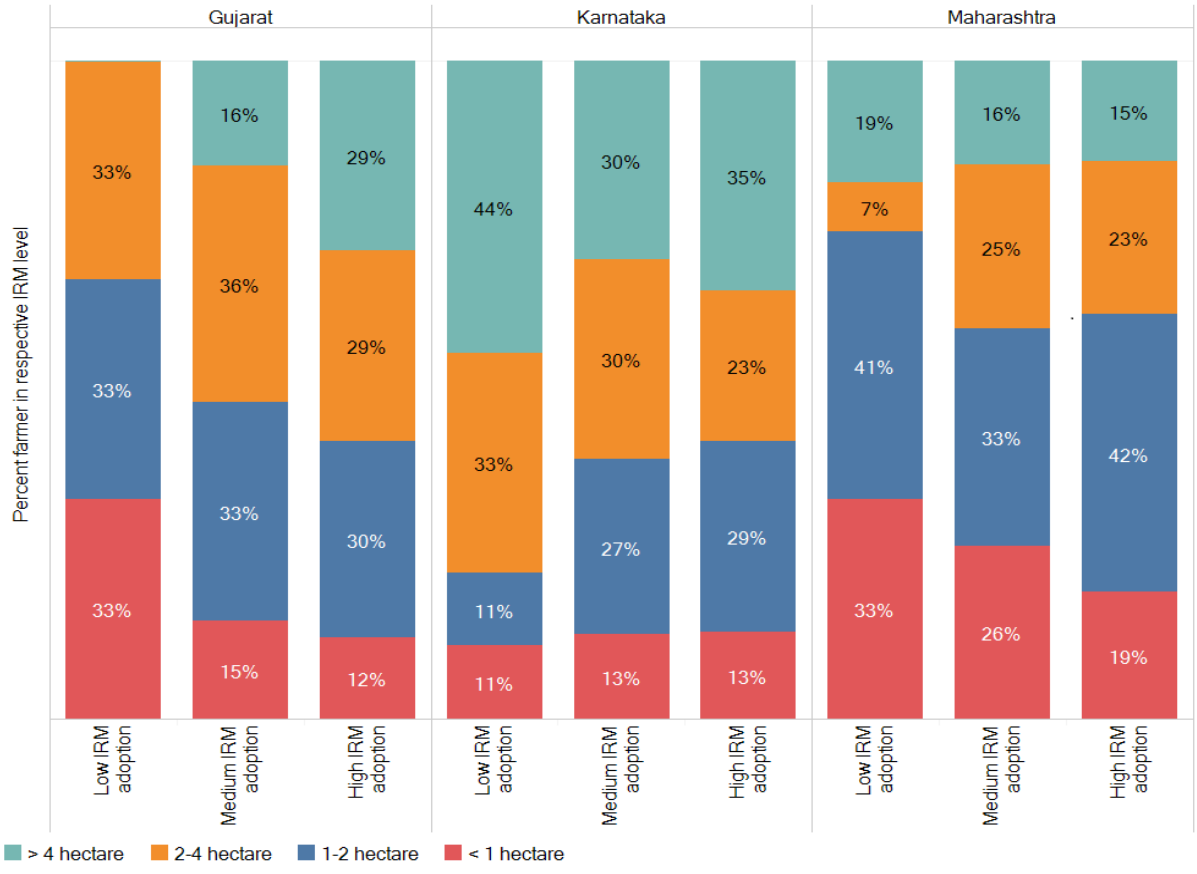

Figure 5.5: IRM adoption level across different farm size category of cotton farmers in selected states

In Gujarat and Karnataka states, high level of IRM adoption is distributed evenly among different farm size category of farmers. In Maharashtra, it is mainly small farmers who are adopting more number of IRM practices. At the same time, smallholders are largely low adopters of such technologies or practices in Gujarat and Maharashtra states. Having said that, it must be kept in mind that there were only few farmers who cultivate non-Bt cotton as refuge crop or use of pheromone traps. In fact, there has been large dis-adoption of use of pheromone trap. On the other hand, realizing the growing concerns and farmers' ire on account of damage of cotton crops by pink bollworm, seed companies as well as the governments are considering mixing of Bt cotton seed with non-Bt cotton seed in the same packet called as 'Refuge-in-Bag' (RIB). Seed mixtures of Bt and non-Bt seeds have several advantages, particularly convenience for farmers and elimination of possibility of non-compliance. As of now, farmers do not see any short-term gains from the IRM practices, particularly in apprehension of their fellow farmers not following the same, which may add some additional cost to the adopters.

Non-Bt seeds to be mixed with Bt cotton seed to fight PBW

'Refuge in the bag' (RIB) system is being recommended by the Monsanto company since decade. Since farmers are oblivious to the dangers of growing just Bt cotton, they throw away the non-Bt seeds supplied separately with Bt seeds. Under RIB, non-Bt seeds may be mixed up to 5% in the bag containing transgenic seeds. After long wait, the union government has recommended the RIB concept from 2018 crop season, wherein 25 grams of non-Bt cotton seed is mixed with 450 grams of Bt cotton seeds.

Source: Financial Express, June 28, 2018

According to perception of cotton farmers in all 3 states, infestation of different bollworms (ABW & PBW) has increased in 2017-18 as compared to previous year, badly affecting the yield.	Among different IRM practices, farmers had least interests in growing non-Bt cotton as refuge crop & using pheromone trap. Sanitization of the fields & surrounding area shall be enforced by end of January month.	Training and awareness campaign has not reached to all the cotton growers in all villages. From each village, 2-3 farmer-leaders should be given training during mid-season, who can motivate fellow farmers.

6. Benefits from IRM Adoption

The cotton farmers in India, both large and small holders benefitted from adoption of insect resistant technology in cotton viz. Bt Cotton, through reduced cost of cultivation, convenience of crop management and increased productivity. The yield increase in Bt cotton due to effective control of bollworms generally ranged from 31 to 63%, reduction in chemical sprays from 25 to 55% and increase in profit over non-Bt cotton from 50 to 110% equivalent to ₹5,000 to ₹10,000 per hectare depending upon the weather factors and intensity of non-target insect pests and diseases (Kumar and Swamy, 2014). Several other studies have also shown that farmers benefit considerably from adopting the technology in terms of reductions in pesticide use and higher effective yields (Bennett, Kambhampati, Morse, & Ismael, 2006; Crost, Shankar, Bennett, & Morse, 2007; Pray, Huang, Hu, & Rozelle, 2002; Qaim, Subra- manian, Naik, & Zilberman, 2006). The benefits can be evaluated in terms of cost and return with respect to IRM level.

6.1 Benefits of IRM Adoption on Cotton Yield

Adoption of insect resistance management practices are considered to give immediate gains to the farmers in terms of higher cotton yield across the region. To test this hypothesis, the cotton yield has been estimated across different adoption level category for all 3 states. The average cotton yield was also calculated for picking wise and presented in Figure 6.1. The results clearly exhibit the yield advantage for high IRM adopters as compared to those who adopted less IRM practices. The difference in these yields were statistically different across the states also. The cotton yield in Gujarat is always higher in all conditions- across adoption level as well as across different pickings. While cotton yield was the lowest for Maharashtra state for all the pickings as well. One reason for the lower yield in Maharashtra state may be due to the reason that most of the farmers in the state cultivate cotton as intercrop with pigeon pea or soybean or other crop. Secondly, the crop is grown mostly under rainfed condition, coupled with high climatic variability. It is evident from Figure 6.2 that total precipitation during sowing month (July) and later were considerably low in both the districts of Maharashtra and Karnataka in last 3 years, which restricts the cotton yield.

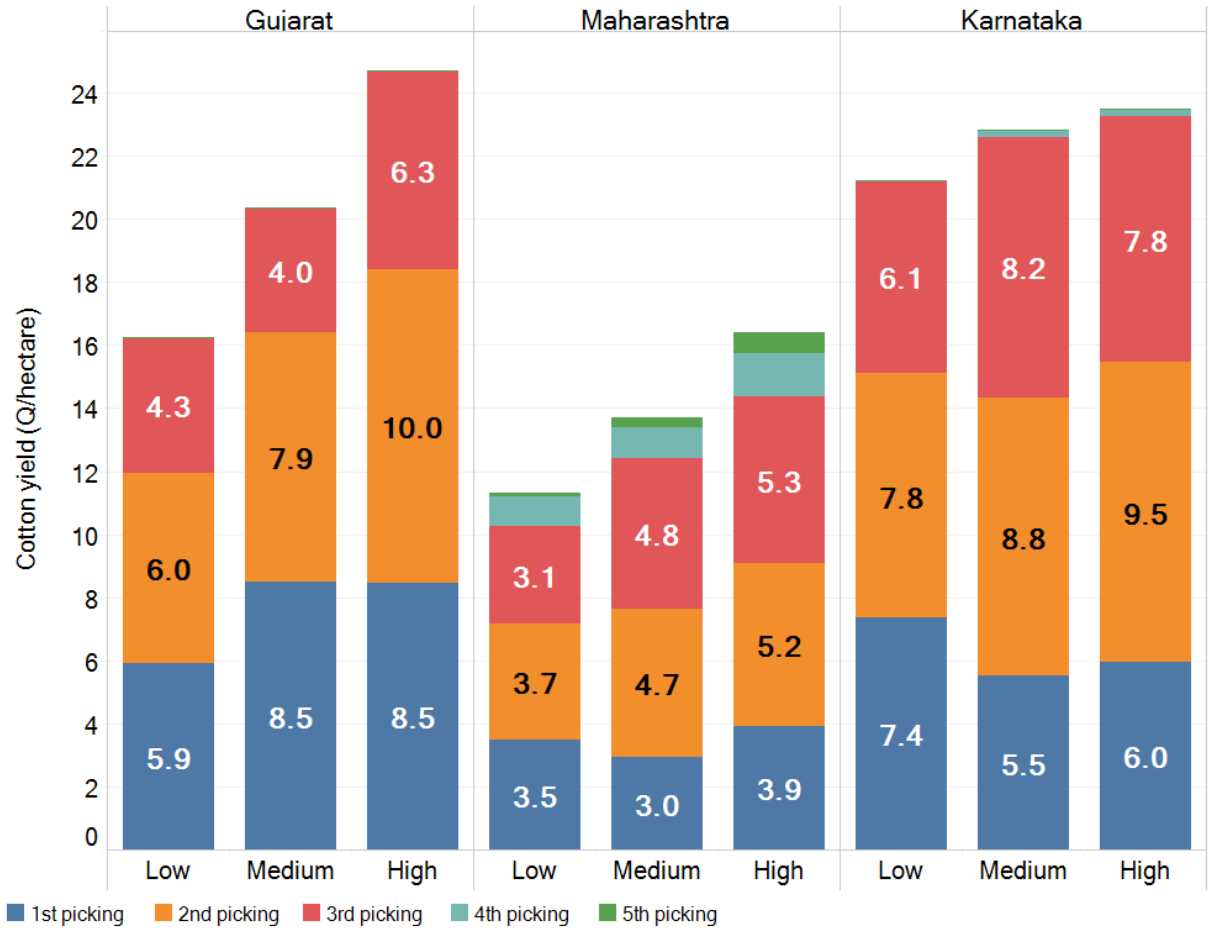

Figure 6.1: Picking wise cotton yield across different IRM adoption level

The cotton yield increases with increase in number of IRM practices which is evident in Figure 6.1. The "High" IRM level farmers are able to get higher total yield in all the selected states. The second pick invariably gave higher yield than other picks. The average total yield is estimated to be 24.75, 16.5 and 23.5 quintals/ha in the states of Gujarat, Maharashtra and Karnataka, respectively. Farmers in Gujarat are found to harvest cotton up to third pick, whereas in Karnataka, it is up to fourth pick, while in Maharashtra up to fifth pick.

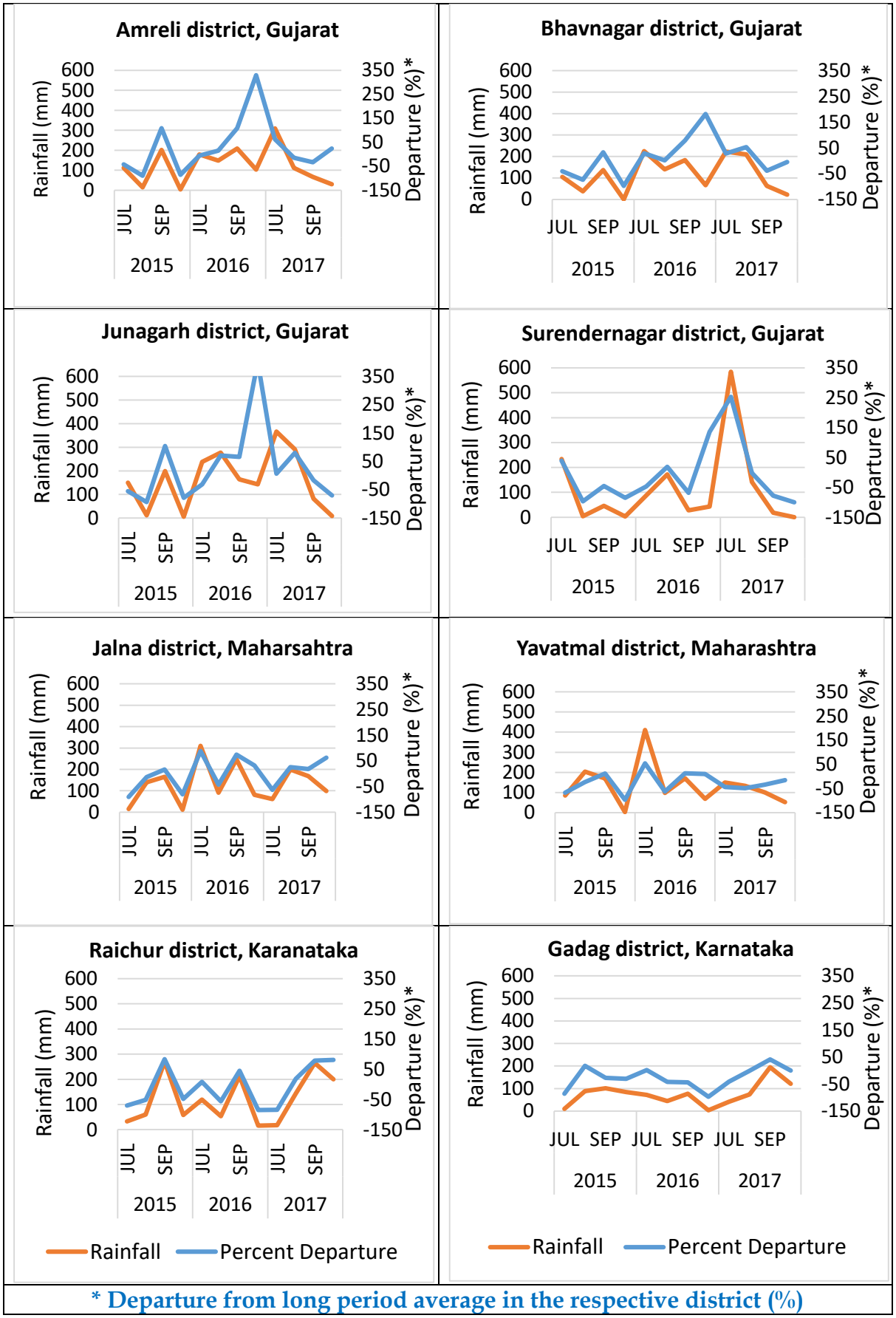

Figure 6.2: Rainfall pattern in the selected districts under study

6.2 Benefits of IRM Adoption on Net Return from Cotton Cultivation

The cost is worked out for the three IRM adoption level of farmers (Table 6.1). Return over each pick has also been estimated to find the picking number at which the farmer reached the break-even. In all the states, "High" IRM farmers are incurring higher total cost than the other category farmers. The gross return also increases due to increase in the yield for high IRM level farmers. The detailed cost of cultivation is presented in **Annexure-II**. In Gujarat, the total cost of cotton cultivation comes out to ₹35,198, ₹39,175 and ₹42,745 per hectare for low, medium and high IRM level farmers. Here, the farmer, irrespective of IRM level is able to recover the cost after first picking itself. The net return in cotton cultivation is ₹34,970, ₹52,343 and ₹67,855 per hectare for "low", "Medium" and "High" IRM level farmers respectively.

In case of Maharashtra, the "Low" IRM level farmers are able to recover the cost after third picking whereas other two category farmers recover after second picking. Here, the total cost of cotton cultivation is ₹33,645, ₹37,428 and ₹40,308 per hectare for "low", "Medium" and "High" IRM level farmers respectively. The net return in Maharashtra is lowest among the selected states which is ₹11,518, ₹17,530 and ₹25,613 per hectare.

In Karnataka, all IRM level farmers reach break-even after second picking. The total cost of cotton cultivation in the state is estimated to be ₹40,458, ₹45,510 and ₹46,283 per hectare for "low", "Medium" and "High" IRM level farmers respectively. The net return comes out to be ₹31,448, ₹46,283 and ₹47,258 per hectare for "low", "Medium" and "High" IRM level farmers respectively.

Table 6.1: Cost and returns in cotton cultivation (₹/hectare)

Particulars	IRM Adoption Level		
	Low	Medium	High
Gujarat			
Cost before harvesting	17,865	20,795	20,860
Total Cost	35,198	39,175	42,745
Average yield (Q/ha)	16.3	20.5	24.8
Average selling price (₹/quintal)	4318	4486	4473
Return over picking (1st pick)	19,025	30,543	30,125
Return over picking (2nd pick)	19,128	28,343	35,658

Return over picking (3rd pick)	15,068	14,130	22,808
Return over picking (4th pick)	-	93	-
Return over picking (5th pick)	-	-	-
Gross return	70,168	91,520	1,10,598
Net return	**34,970**	**52,343**	**67,855**
No. of Observation	3	185	116
Maharashtra			
Cost before harvesting	24,273	24,463	24,358
Total Cost	33,645	37,428	40,308
Average yield (Q/ha)	11.3	13.8	16.5
Average selling price (₹/quintal)	3,988	4,012	4,026
Return over picking (1st pick)	11,715	9,593	13,050
Return over picking (2nd pick)	12,365	15,455	17,080
Return over picking (3rd pick)	10,660	15,823	18,008
Return over picking (4th pick)	3,113	3,523	4,095
Return over picking (5th pick)	423	1,093	2,500
Gross return	45,163	54,958	65,920
Net return	**11,518**	**17,530**	**25,613**
No. of Observation	27	76	26
Karnataka			
Cost before harvesting	23,903	21,573	23,265
Total Cost	40,458	45,510	46,283
Average yield (Q/ha)	21.3	22.8	23.5
Average selling price (₹/quintal)	3383.8	4021.6	3984.7
Return over picking (1st pick)	18,833	18,110	19,338
Return over picking (2nd pick)	20,873	28,965	31,035
Return over picking (3rd pick)	15,390	27,095	27,123
Return over picking (4th pick)	-	588	580
Return over picking (5th pick)	-	88	93
Gross return	71,905	91,793	93,543
Net return	**31,448**	**46,283**	**47,258**
No. of Observation	40	115	23

Adoption of IRM practices has helped the farmers in better cotton yield as well as higher net return. Though, the farmers didn't adopt the crucial practice of using refuge non-Bt cotton in the same field.	Cotton yield is invariably highest in 2nd picking. Gujarat has the highest yield. Lower yield in Maharashtra needs a relook, whether it is compensated with the intercrop grown with cotton.	Gujarat farmers get their break even with 1st pick itself, while in case of Maharashtra & Karnataka, it needed 2nd or 3rd picking. That's why farmers prefer to go for 4th or 5th picking in latter both the states.

7. Challenges in the Cotton Value Chain

The emergence of pink bollworm in Bt cotton field has brought several stakeholders to play a significant role in the cotton value chain, right from seed production to seed marketing, cotton cultivation, cotton marketing, ginning and final uptake by the textile industry, domestically or abroad. While seed companies are ensuring to supply quality seed with appropriate insect resistance technologies, some of them have also come forward to provide training and creating awareness of the cotton growers. Besides, state agriculture department, state agricultural universities and ICAR-Central Institute of Cotton Research, Nagpur are also playing significant role in imparting the training and creating awareness. ICAR-CICR has quite comprehensive recommendation to control the pink bollworm under insect resistance management practices. According to Kranti (2007), the 12-15 point IRM strategies were implemented in a total of 196,000 ha in 1820 villages in 28 districts of 10 cotton-growing states of India during 2002-2007. This has resulted into total economic benefit of ₹120 crores. However, the complexity of the IRM package appears to be the major hindrance in wide scale adoption among the Indian cotton growers.

The present study conducted in 8 districts of 3 states could not find any farmer who has received training on Insect Resistance Management (IRM) practices. Though the trainings received by them focused mainly on cotton cultivation practices which addresses some of the IRM practices to be adopted during cotton cultivation. Government department including Krishi Vigyan Kendras (KVKs) and Agricultural Technology Management Agency (ATMA) are engaged in organizing training programme for the farmers. Private companies as well as some Non-Government Organizations (NGOs) are also imparting training to the farmers. There is contrasting difference across the sample states in terms of training organized. More number of farmers in Gujarat have received training whereas very less farmers have received training in Maharashtra and Karnataka. Training on use of pheromone trap was limited to the sample villages only in Gujarat which are near the Agricultural University (Junagadh Agricultural University).

Case of Ravinder, a cotton farmer in Telangana

Mr. Ravinder Pasula, a 48 years old progressive farmer in Narsapur village of Jayashankar Bhupalpally district in Telangana, has been cultivating cotton since he was 23 years old. He is also an agri-input dealer and a cotton trader. The cotton acreage has increased over years gradually replacing paddy. Now he is cultivating cotton in 14 acres of land whereas paddy has shrunk to just one acre. Even though, he has not received any training on IRM, he is adopting some of the Insect Resistant Management (IRM) practices like using branded or certified seeds; cultivation of early

Ravinder's Timeline

1993

Ravinder started cultivation of local variety of cotton
Seed rate & price - 2 kg/acre & ₹200/kg
Spraying - every 7th day (15-60 DAS) every 4th or 5th day (60-90 DAS) & every 7th day after that till 3rd picking total - **15-16 sprays.**
Major Pests: *Spodoptera litura* & bollworms
Minor Pests: sucking pests & green leaf hopper
Pickings: 5 times
Yield: 6-8 q/acre
Duration: 160 - 175 days

2003

Seed rate & price - 450gm/acre @ ₹1750
Spraying - only 2 times (60th and 90th DAS)
Cotton yield increased with increase number of bolls/plant.
Major Pests: No such attack
Minor Pests: Sucking pests & green leaf hopper
Pickings: 4 times
Number of **Spraying** increased to 4 in 2008
Yield increased from 8 ql/acre to 12 q/acre.
Duration: 140 - 150 days

2009

Seed rate & price - 900gm/acre & ₹750/450gm
Spaying - 4 sprays @ 2009 & 7-8 sprays @ 2016
Weeding cost reduced by ₹1500/acre using **herbicides**
Gradually the **pest infestation** (major & minor) also **increased** along with decline in yield.
Pickings: 4 times
Yield -15 q/acre @ 2009 & 12q/acre @ 2016
Duration: 140 - 150 days

2017

Heavy infestation **Pink Bollworm** (PBW)
Number of **sprays** increased to **8-10**
Yield dropped to **10 q/acre.**
Ginning mills informed **70%** of the procured cotton was **PBW infested (Grade B & C)**, irregular rainfall (moisture) had also triggered the PBW infestation.
Pickings: 3 times
Duration: 120 - 135 days

maturing cultivars; insecticide spray only after 20-25 days of bolls formation, and destruction of cotton stubbles.

Mr. Ravinder sells the seed-cotton to the nearby ginning mills. As engaged in cotton trading also, he procures seed-cotton from the nearby 4-5 villages and then sells to 5-6 different ginning mills depending on the prices offered. Farmers have the option to sell to the ginning mills or nearby Cotton Corporation of India (CCI) centres or to the village traders. Ginning mills prefer traders because of assurance of regular supply of seed-cotton. Additionally, due to complexity in selling process in the form of transport hurdles, loading-unloading charges, waiting in queue etc. at CCI centre, the farmers resort to sell the produce to the village trader at a price which is upto ₹200 lesser than CCI/ginning mill's price.

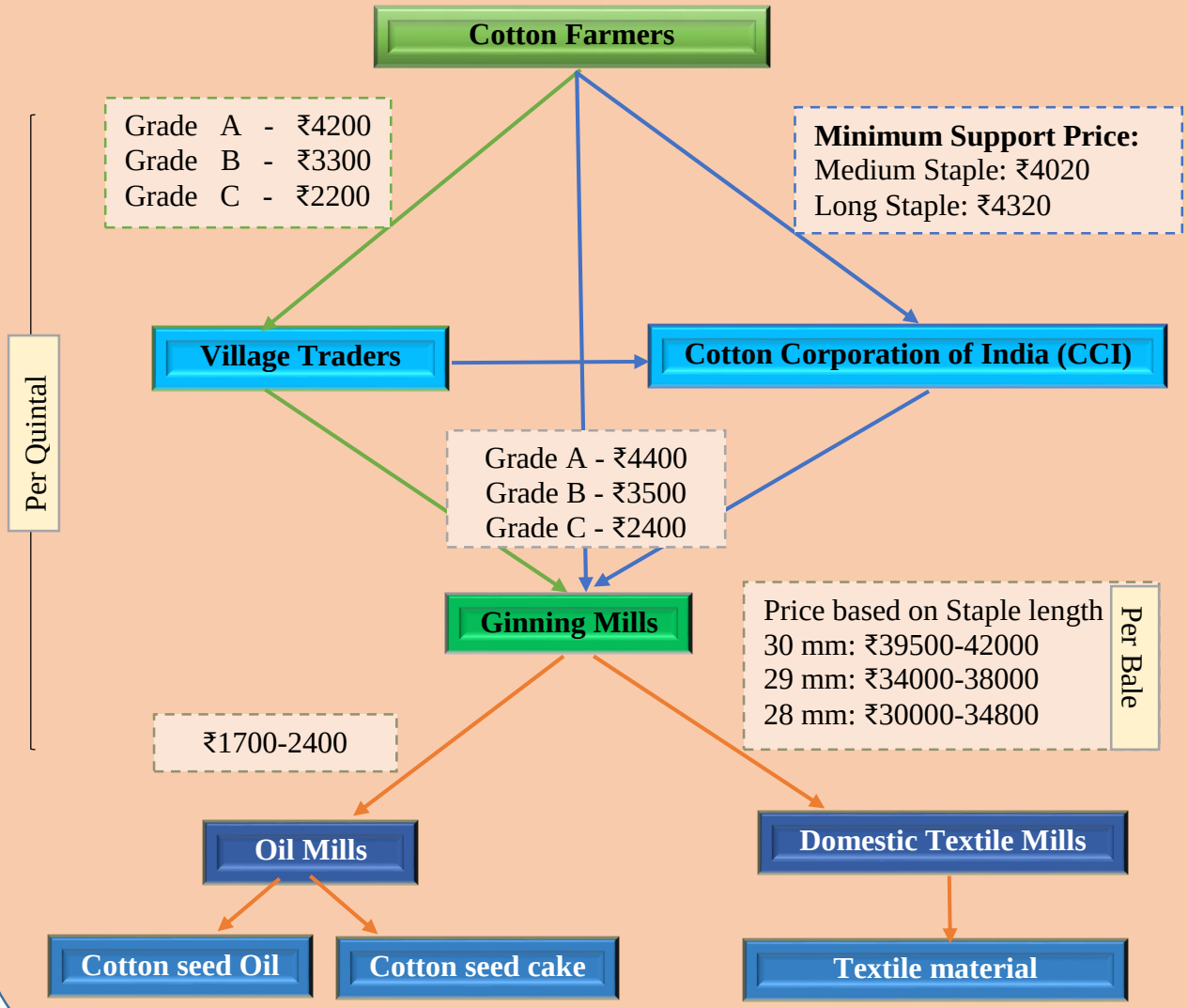

Figure 6.3: Cotton value chain

7.1 Market Arrival of Cotton

Mandi arrival data of cotton in the selected districts of 3 states exhibit interesting pattern. Figure 7.1 clearly shows that November to January is the peak period of cotton arrivals in APMC mandis in all 3 states, while May-June to September-October is lean season. Among all 7 districts under study, Gadag in Karnataka state is the smallest market, while Yavatmal in Maharashtra handles huge quantity of cotton. Interesting feature of these regions is that farmers keep harvesting or bringing cotton in the mandi till June month. The trend is more prevalent in Amreli district of Gujarat and Jalna and Raichur district in Maharashtra and Karnataka state, respectively. There may be two possible reasons- either farmers keep their crop in the field for 4th/5th picking, or farmers or village traders may be storing the cotton for future sale in expectation of high price during lean season.

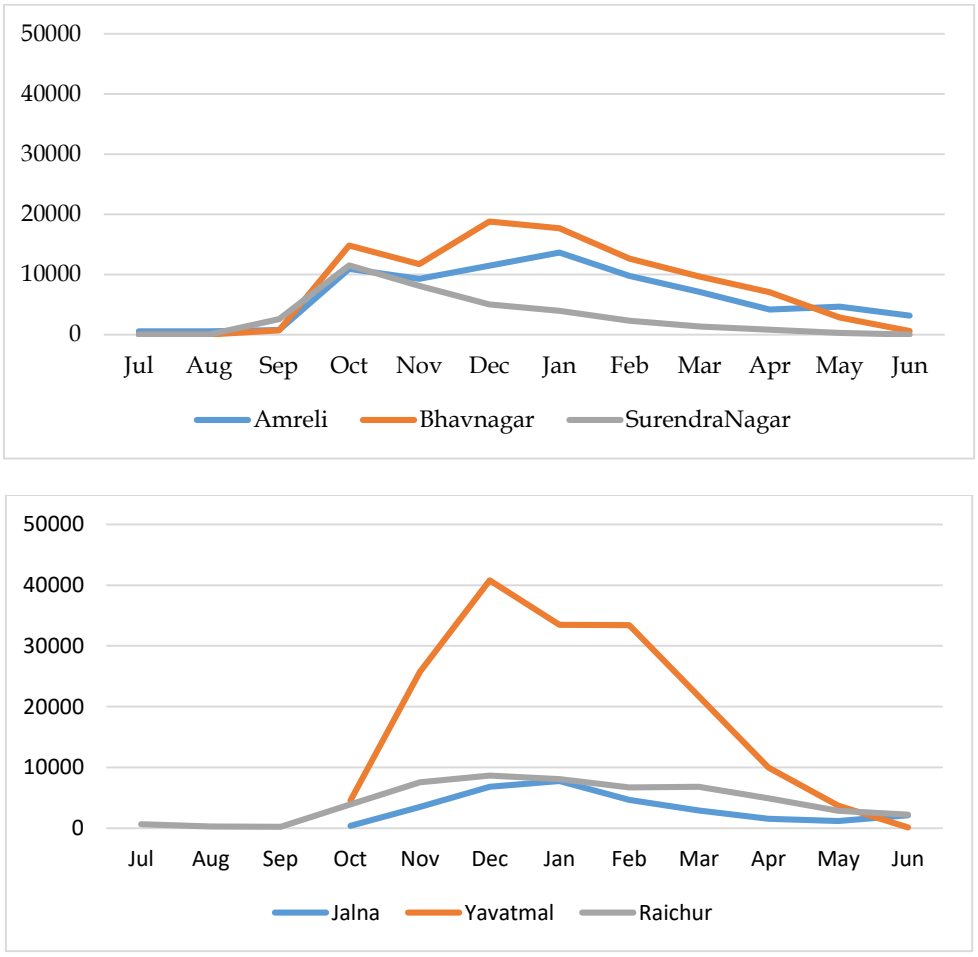

Figure 7.1: Monthly arrival quantity of cotton in APMC mandi of 3 states (2015-2018)

7.2 Roles and Awareness of Traders and Ginners

During the study, the research team also interacted with several traders and visited 2-3 ginning mills in each district. The traders play important role in cotton value chain. Cotton farmers sale the produce either in the mandi or to the traders in the village itself. In Gujarat, it was found that traders visit the villages and buy from the farmers. Cotton trading normally starts from October and reaches peak during November and continues till February of next year. In Karnataka, farmers are found to bring the produce to the Mandi for sale. Price discovery in cotton trading takes place by simple negotiation between farmers and the trader. Traders normally represents the ginners who purchase seed cotton from farmers. Farmers bring the produce to the commission agent where negotiation takes place. Commission agent charges 2% as commission. The farmer brings the entire lot in small carrier which weighs approx. 16-20 quintals or big lorry which weighs approximately 10 tonnes. After the deal is finalized, the farmer carries the produce to the ginning mill which are located in the nearby areas. The cost of bringing the produce to the entrance of ginning mills is about ₹1/kg and varies depending upon the distance.

The parameters which are looked into by the trader for bidding are:

- Cotton staple length: In majority of the cases in India it lies between 28-30 mm.
- Colour: White coloured fibers bid higher
- Infected and damaged cotton: Cotton infected by bollworm which becomes hard are removed in the first stage sieving process during ginning, resulting into lesser output after ginning.
- Moisture or water content: It increases the weight of cotton and thus bids less.

The pink bollworm infected cotton fetches less price because:

a) Wastage is higher due to hard lobes which are removed during ginning. The wastage may be as high as 2-3 kg per quintal.

b) The cotton becomes pale in colour and the staple length is also reduced, the lint of which fetches lesser price.

c) The good quality seed is normally used for edible oil extraction and cotton seed cake for livestock. The bollworm damaged seed results in lesser oil extraction as well as seed cake.

A. Seed cotton stocked in the ginning mill compound at Junagarh

B. Stained cotton infected with pink bollworm

C. Infected seed of cotton after ginning

D. Cotton seed stocked to be sold to oil extraction mill

E. Infected cotton seed at oil mill

F. Quality check happens mainly to fix the price by the traders

Figure 7.2: Stock of cotton and cotton seed at ginning mills and oil extraction mill

1 quintal seed yields (approx):
14 kg oil and 80 kg cake

Ginning continues throughout the year when production is good. In case of less production, the operation stops early. The ginners witness peak season during January-February. Rainfall also affects the cotton value chain. The seeds which come out of the ginning mill are sold to the oil millers. The oil mills remain in operation normally for six months (October-March). This oil is further refined at large refining units based at Mumbai.

To understand the awareness and preparedness of the ginning mills to handle the pink bollworm, we visited some of the ginning mills during its operation in the late evening (Figure 7.2). All the ginners were found to be aware about pink bollworm. They also know whether in the local region, pink bollworm has affected the crop or not. However, we could not find **any ginning mill having pheromone trap or light trap installed in their campus**. The infected cotton and flying moths can easily be located in their campuses. Even infected seed are stocked to be supplied to the oil-crushing mill, which after refining enters into human food chain.

Consequently, the effect of infestation of pink bollworm in cotton can only be seen at the time when farmers sell their harvest to the traders. The stock being small for individual farmer, the traders can easily detect visually about the infestation and accordingly buying price is reduced. Once the trader purchases the lot from several farmers, it gets mixed up and it doesn't get separated in downstream value chain. The ginning mills are least bothered about the PBW, unless significant portion of the lot coming to their mills appear to be infected.

Reaching and creating awareness about the IRM practices among the cotton growers in all villages are still a long way to go. Unified approach is essentially needed by seed sector-state government-research organizations.	Strict regulatory mechanism may be brought to instruct all the ginning mills to install pheromone and/or light trap near cotton stocking place. The place might be providing hibernating place for the insect during off-season.	There is urgent need of technological upgradation as well as regulatory mechanism for cotton seed oil extraction mill to stop the infected cotton seed from entering into food or feed value chain.

8. Conclusions and Policy Recommendations

8.1 Conclusions

The study was undertaken to evaluate the extent of adoption of IRM measures, its effectiveness, tangible and intangible benefits derived from the IRM practice in cotton cultivation. Additionally, it is also proposed to suggest suitable mode of information dissemination for stimulating diffusion of best cultivation practices.

The recommended IRM practices were subjected to inquiry about the level of awareness and adoption among the cotton farmers. For this survey was conducted during March-May 2018 in Gujarat, Maharashtra and Karnataka states. Total 611 cotton growers were personally interviewed in 8 districts of 3states. On the basis of adoption, the farmers were classified into low (up to 4), medium (5 to 8) and high (9 to 11) levels based on the number of different IRM practices adopted. Among 11 practices, use of pheromone traps, growing early maturity variety and cultivation of refuge crop are not followed by majority of the farmers.

It is also found that the expenditure on plant protection chemicals (PPC) and fertilizers is the major cost component among the materials used in cotton production. Due to higher seed rate and high dosage of chemical fertilizer, cost of cotton cultivation in Maharashtra and Karnataka are substantially higher, as compared to Gujarat state. There is wide range of pesticide sprays from 4 to 11, depending upon the incidences of pest infestations. There are 36 different pesticides used by farmers in cotton crop out of which six are highly hazardous as per the WHO classification.

Harvesting of cotton is a laborious process and huge expenditure is incurred towards this. In the study area, it was found that more than 50 percent of the total cost was spent for harvesting alone. The cost of harvesting also increases steeply if there were more infestations in the boll. There is a significant savings in the cost and increase in the net returns due to the adoption of IRM practices. In all the three states, the higher the adoption of IRM practices, the more net returns one gets.

In Karnataka and Maharashtra, it is also evident that the high IRM adopters have applied lesser quantities of PPC. The farmers in all the three states expressed that due to pink bollworm infestation, there is a massive reduction in the yield of fourth and fifth picking which becomes uneconomical to continue the pickings further. The evidence shows that Gujarat farmers could meet their incurred costs from 1st picking itself, whereas in Karnataka and Maharashtra, farmers could meet their incurred expenses after 2nd pickings.

Regarding training and awareness among farmers, there was huge gap between the strategy and execution by different agencies- seed companies, state agriculture department and research organizations. Most of the farmers in study area shown awareness about any training or demonstration in their villages about the IRM. Even the operators in ginning mills were also found to be unaware of IRM practices. The pheromone traps were missing or non-functional in the ginning mills. Most surprisingly, infected seed were entering into food and feed value chain through oil extraction mills without any hesitation. The operators and workers need to be trained on this aspect to form an effective barrier against resistance development in insects.

8.2 Policy Recommendations

Short-term strategies

i) **Implementation of integrated communication strategy about IRM:** State department, seed industries and research organizations should develop integrated communication strategy so that the message about IRM should reach to each and every cotton growing villages. From each village, 2-3 progressive farmers may be grouped together for short-term training at taluka level.

j) **Developing short video clips in vernacular languages:** All the seed dealers may be instructed to collect the mobile number of all the seed purchaser-farmers, so that small video clip regarding IRM may be sent to all the cotton growers in the country periodically throughout the crop season.

k) **Implementation of Refuge-in-Bag system:** Cultivation of refuge non-Bt cotton along with the Bt cotton has been recommended by several research groups. Therefore, mixing of 5% of non-Bt cotton seed should be ensured immediately. However, to eliminate the immoral profiteering activity by few seed companies by selling large proportion of non-Bt seed, random check of the seed packet from the open market may be done.

l) **Regulation of ginning mills:** All the ginning mills shall be instructed to keep pheromone and light trap in operation in their campuses where seed cotton is stocked. There should be strict monitoring and compliance of the instruction.

m) **Sanitization of field and neighbouring area:** Majority of the cotton growers were found leaving the standing cotton crop in the field after last harvest. While some of them bring the cotton stubbles for fuel purposes and stock near field. This issue needs to be handled at two levels: i) Convincing the farmers for not going for long duration crop or stop picking after January-end, so that the field can be kept clear from cotton stubbles for at least 90 days, and ii) rural entrepreneurship may be encouraged who can collect the stubbles from the cotton field after January and it into other value added product.

Medium-term strategies

n) **Simplification of IRM practices for the farmers:** Research organizations like ICAR-CICR and state agricultural universities should evaluate different IRM measures and simplify it so that farmers do not need to follow more than 3 activities under IRM.

o) **Free distribution of pheromone trap:** The pheromone trap should be freely distributed through seed and fertilizer dealers in the cotton growing area. Through dealer channel, it can be reached to all the villages and cotton growers.

p) **Training Programmes:** Training to trade, NGO and other stakeholders working with farmers on important aspects of IRM, for effective communication and implementation by farmers.

Long-term strategies

q) **Development of suitable crop variety:** In India, where more than 85% of farmers are smallholders, they can't compromise on crop yield. Under such condition, replacing Bt hybrid cotton with low yielding Bt variety may not be convincing idea for the smallholders. Therefore, suitable variety or hybrids may be developed with insect resistance traits which can assure higher yield to the farmers as compared to existing cultivars.

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Annexure

Annexure-I: List of major cotton cultivars grown in the study area (based on farmers' response

State	Seed Company	Name of Variety grown (All BGII)
Gujarat	Ajeet	Ajeet - 155, Ajeet - 133, Ajeet - 11, Ajeet - 33
	Rasi	RCH 659, RCH 134
	Solar Agrotech	Solar 60, Solar 76, Solar 77, Solar 56, Solar75
	Mahyco	VICH-15, Chaitanya (MRC-7377), NIKKI MRC 7017
	Ankur	3028
	Bayer	Surpass
	Tulasi	Tulsi 144, Tulsi 4, Tulsi Surya, Tulsi Surya 9
	Kaveri	Jaadoo KCH14K59, ATM KCH-311
Maharashtra	Ajeet	Ajeet - 155, Ajeet - 11, Ajeet - 33, Ajeet – 199
	Monsanto	Bramha
	Nuziveedu seeds	Bhakti BG II – NCS 245, NCS-954 Raja, Bunny NCS 145, Mallika Gold NCS 859
	Rasi	RCH 659, Magna
	Ankur	Swarna
	Green Gold Seeds Pvt.Ltd	Gold Vitthal
	Kaveri	Jaadoo KCH14K59
Karnataka	Kaveri	Jaadoo KCH14K59, ATM KCH-311, Money Maker, Jackpot
	Nuziveedu seeds	Kanak NCS 954, Bunny NCS 145
	Mahyco	Dr. Brent (MRC 7347)
	Bayer	Surpass First Class

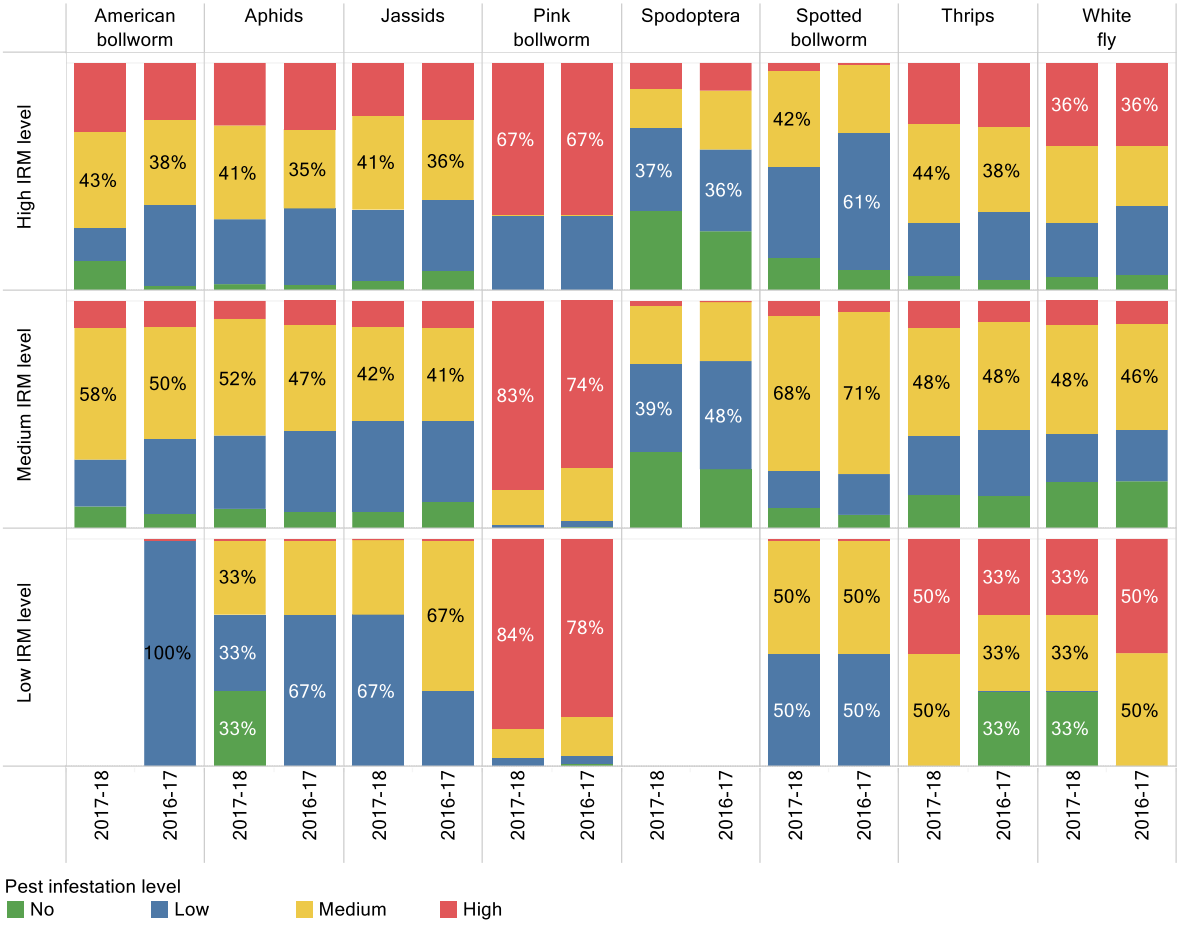
Source: Field Survey (2018)

Annexure-II: Detailed cost of cultivation of cotton in study area (in ₹/hectare)

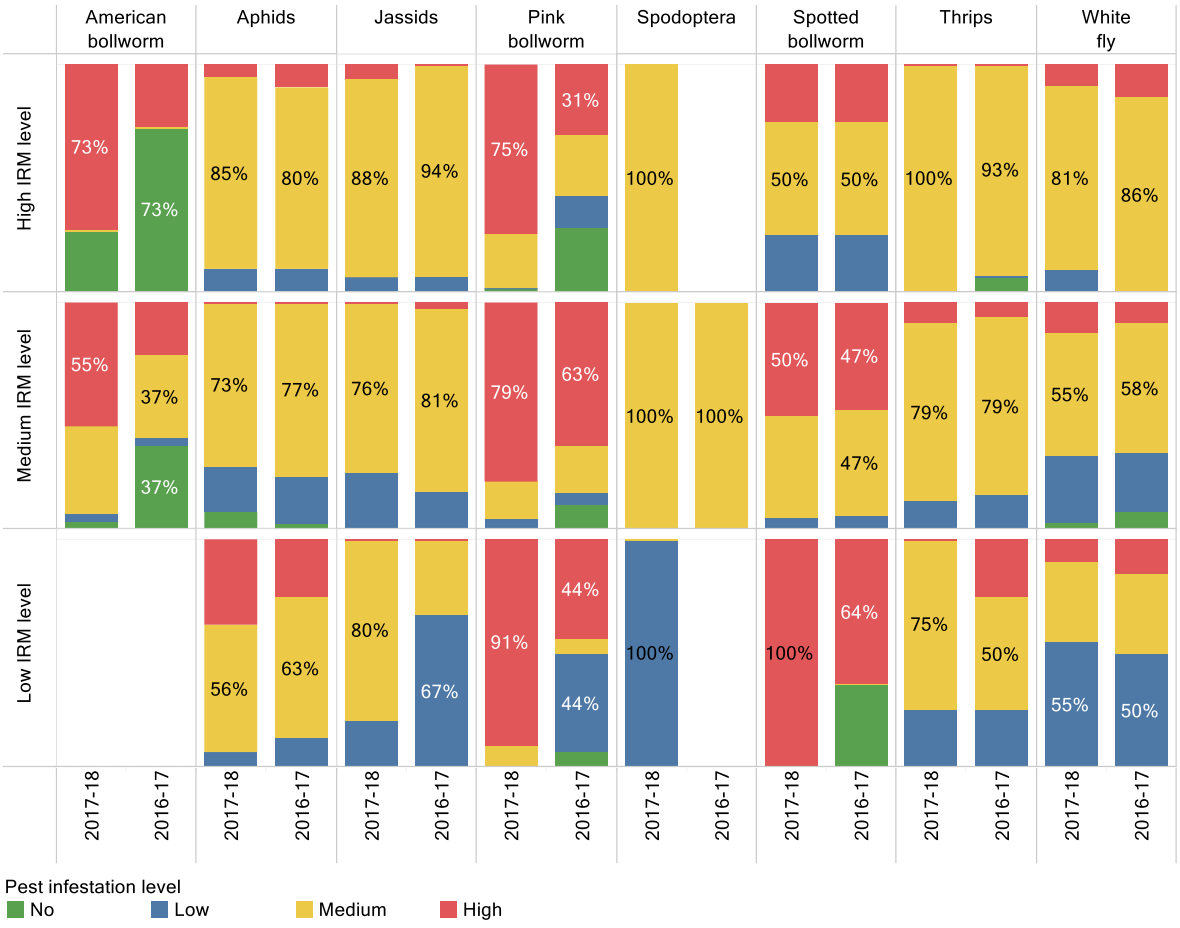
Particulars	Gujarat			Maharashtra			Karnataka		
IRM level adoption➔	Low	Medium	High	Low	Medium	High	Low	Medium	High
Seed Cost	2696	2633	2448	3691	3352	2957	3501	4042	3598
Land Preparation charges	2042	2526	2602	2903	2829	2699	2153	2452	2323
Total Fertilizers cost	4064	4855	4487	6089	6230	5981	6050	5044	5990
Fertilizer Labour Cost	1250	1365	1454	2536	3314	3409	3208	2078	2814
FYM application	0	1250	990	176	105	0	0	832	745
Plant Protection Chemicals	3979	4792	5541	5268	4741	5182	5332	3239	3735
Plant Protection Labour	1383	1483	1394	1782	1870	2260	1880	1681	1973
Cost of Pheromone Trap	200	52	303	0	0	0	0	6	10
Cost of manual weeding	1250	1203	811	1185	1448	1058	1111	1539	1639
Herbicide Application	1000	637	830	644	574	813	667	658	439
Cost of crop cultivation (Pre-harvest)	17865	20796	20859	24273	24463	24357	23902	21572	23265
Harvest cost- 1st picking	6667	7725	7304	2284	2227	3091	5583	3990	4618
Harvest cost- 2nd picking	6917	7101	8964	2400	3557	4068	6056	6558	7516
Harvest cost- 3rd picking	3750	3527	5616	2082	4302	4669	4917	6290	6572
Harvest cost- 4th picking	-	27	-	1913	1918	2490	-	3350	2750
Harvest cost- 5th picking	-	-	-	692	960	1633	-	3750	1563
Total cost of cultivation	35198	39176	42744	33644	37427	40308	40457	45511	46284
Net returns over 1st harvest	19026	30544	30126	11714	9593	13050	18832	18109	19337
Net returns over 2nd harvest	19128	28342	35658	12364	15455	17081	20873	28964	31035
Net returns over 3rd harvest	15068	14130	22809	10659	15822	18009	15391	27094	27121
Net returns over 4th harvest	0	94	0	3112	3522	4094	0	588	580
Net returns of 5th harvest	0	0	0	423	1092	2500	0	87	92
Average yield (Q/ha)	16.3	20.4	24.7	11.3	13.7	16.4	21.3	22.8	23.5
Average Price	4318	4486	4473	3988	4011	4026	3384	4022	3985
Gross Revenue	70168	91520	110598	45162	54957	65921	71905	91793	93542
Net Revenue	34970	52344	67854	11518	17529	25612	31448	46283	47258

Annexure-III: Perception of farmers with different IRM adoption level about degree of pest infestation

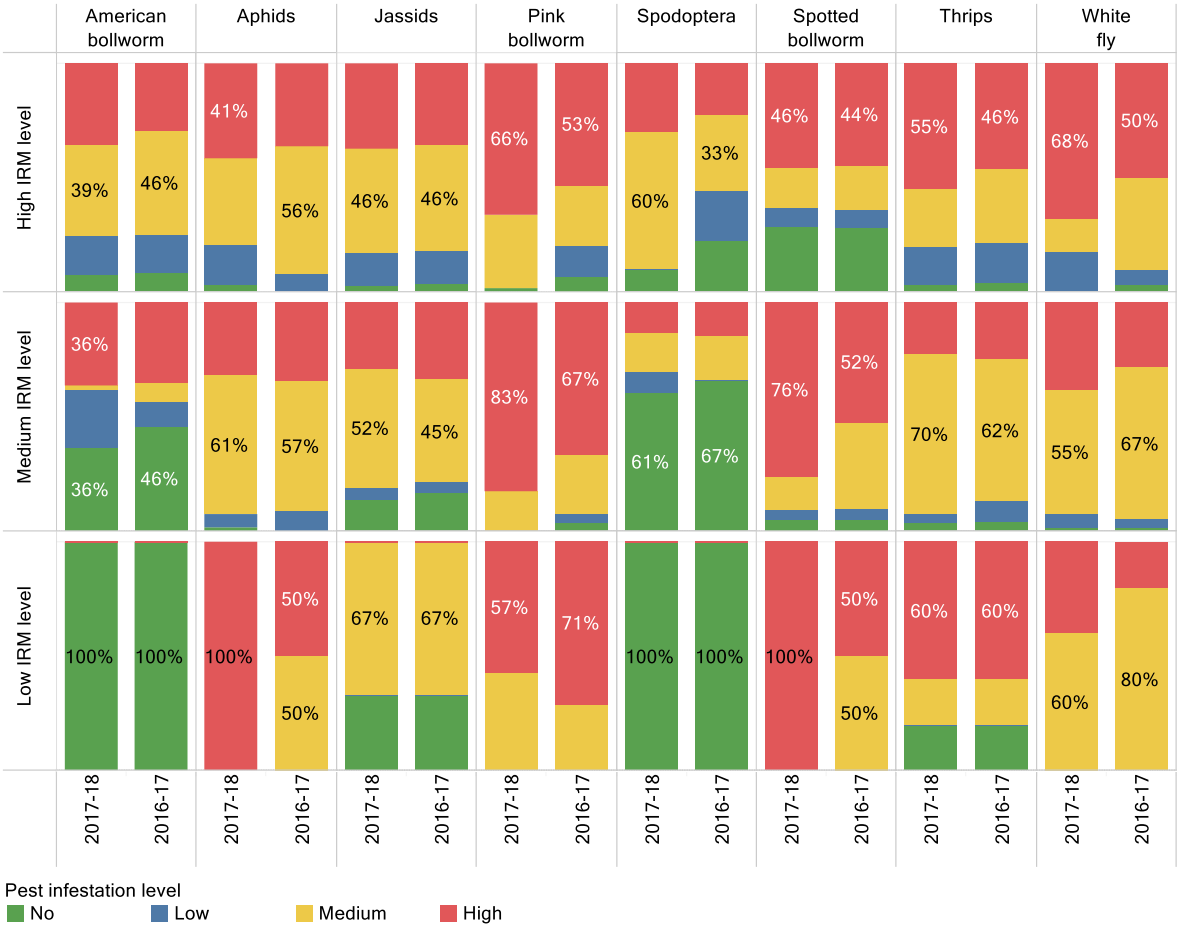
A. Gujarat



B. Maharashtra



C. Karnataka


American bollworm
Aphids
Jassids
Pink bollworm
Spodoptera
Spotted bollworm
Thrips
White fly
High IRM level
Medium IRM level
Low IRM level
39%
46%
41%
56%
46%
46%
66%
53%
60%
33%
46%
44%
55%
46%
68%
50%
36%
36%
46%
61%
57%
52%
45%
83%
67%
61%
67%
76%
52%
70%
62%
55%
67%
100%
100%
100%
50%
50%
67%
67%
57%
71%
100%
100%
100%
50%
50%
60%
60%
60%
80%
2017-18
2016-17
Pest infestation level
No
Low
Medium
High

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