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An Analysis of Bt Cotton Cultivation in Punjab, Pakistan Using the Agriculture Decision Support System (ADSS)

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Although commercial cultivation of Bt cotton was not officially allowed in Pakistan until very recently, the area under Bt cultivation has increased every year, and during the 2009/2010 cotton season it stood at around 70% of all cropland. This trend has raised many interesting questions, and this article attempts to answer some of these questions using the pest-scouting data of 3,000+ cotton farmers collected during the 2005/2006 season. We used the Agriculture Decision Support System to process and analyze the primary raw data. This article shows the relationship between Bt and non-Bt cotton cultivation with reference to (1) farm size, (2) pest and pesticide groups, (3) predators and pesticide sprays, (4) sucking pests, and (5) chewing pests. Results show that small landowners are mainly attracted by Bt cotton and that the bollworm complex (except the spotted bollworm) had a low incidence on Bt cotton; this was not true for sucking pests, especially the newly emerged mealybug pest. However, the growth regulator was found to control jassid and whitefly on Bt cotton.

Key words: Bt cotton, mealybug, Pakistan, pest, pesticide, predator, Agriculture Decision Support System (ADSS), agriculture data warehouse.

Introduction

Pakistan is the 4th top producer of cotton in the world (Table 1), yet in terms of yield it is at the distant 10th position. There are many possible reasons for low cotton yields in Pakistan—high prices of agricultural inputs (pesticides, fertilizers, etc.), higher intensity of insect and pest attacks, deficiency of water for irrigation, lack of advanced technologies and awareness, low literacy rate of farmers, adulteration in pesticides and agro-professionalism, etc. (AgroNews, 2009). Thus, crop yield cannot be attributed to just one or two factors. However, there are certain factors controlled by the government, such as price and availability of the seeds, and certain decisions that are in the domain of individual farmers, such as choice of the seed.

Bt cotton has been developed through the transfer of a gene from a soil bacterium, *Bacillus thuringiensis*. This gene, when expressed in cotton, produces Cry protein, which is harmful to the larvae of moths, butterflies, beetles, and flies. When insects feed on the plant, the toxin enters the body and binds to the insect's gut. Hence, it disrupts its feeding and digestion process and eventually leads to the death of the insect.

The popularity of transgenic varieties (such as Bt cotton) among the farmers is due to two factors: the potential of increase in yield per acre (for which Bt cotton is *not* engineered) and savings on pesticides and labor resulting from fewer pest attacks (for which Bt cotton *is* engineered). Bt cotton is genetically enhanced to resist three bollworms: cotton bollworm (*Helicoverpa armigera*), the spotted bollworm (*Earias insulana*), and the pink bollworm (*Pectinophora gossypiella*). Globally US$8.1 billion are used on pesticides annually; out of this, nearly $2.7 billion are used on cotton pesticides. Pesticides can be saved by cultivating Bt transgenic crops (Shelton, Zhao, & Roush, 2002). A reduction in the use of broad-spectrum pesticides on Bt cotton would result in the conservation of natural enemies as well as a decrease in soil and water contamination. Moreover, a reduction in pesticide usage will also bring health benefits to female Pakistani cotton pickers and others who come in contact with these pesticides. However cotton-leaf curl virus (CLCV) is still the major threat to Pakistani cotton along with the recently emerged and extremely damaging mealybug. Presently, no resistant cotton variety is available against these two menaces, and the Bt cotton is also vulnerable to them (Carroll, 2009).

Comparison with Previous Work

A recent study by Ali and Abdulai (2010) has looked at the relationship between Bt cotton adoption and poverty reduction in Pakistan. Using cross-sectional data from a survey of farmers in the Punjab province of Pakistan, they employed a propensity score-matching approach to examine the direct effects of adoption of Bt cotton on

Table 1. Cotton production and yield 2007/2008.

No.	Country	Prodn	Yield
1	China	37.00	1,299
2	India	24.00	554
3	United States	19.21	985
4	Pakistan	8.90	646
5	Brazil	7.36	1,488
6	Uzbekistan	5.35	815
7	Turkey	3.10	1,298
8	Syria	1.11	1,252
9	Egypt	0.97	880
10	Australia	0.64	2,144
11	Kazakhstan	0.63	680
12	Cameroon	0.21	327

Production (Million 480 lb bales) and lint yield (kg/ha)
Source: Foreign Agriculture Service/USDA, Office of Global Analysis

yields, pesticide demand, household income, and poverty. Generally, the findings revealed that adoption of the new technology exerts a positive and significant impact on cotton yields, household income, and poverty reduction, and a negative effect on the use of pesticides. However, the following reasons could explain why these findings may not represent what is actually happening.

- In the undivided India (from which Pakistan was created in 1947), the *beradri* or caste system has been in practice for centuries. People belonging to a certain caste in a certain geography act as per the collective wisdom of their *beradri*, and those who do not are excommunicated and literally outcasted. Therefore, there is likely to be insignificant "self selection" practiced in local villages (Ali & Abdulai, 2010, pp. 178, Equation 7).

- As reported in Table 1.1 of the 2000 Pakistani agricultural census, 25% of private farms have a landholding of 1-2.5 acres; this farm size represents the largest group of private farms, and the owners of such farms are considered poor farmers (Government of Pakistan, Agricultural Census Organization, 2003). However, in the said paper, the average landholding is shown as 31.3 acres (Ali & Abdulai, 2010: Table 1) with a standard deviation of 56.2 acres. Thus, the landowners surveyed were mostly large landowners, and only a small percentage of those surveyed (8.3%) were small landowners. Hence, the sample is not a true representation of Pakistan.

- The data was collected by surveying only 325 farmers, which is not representative of Pakistan; for example, in the Punjab province alone, cotton is cultivated on 5.8 million farms (Government of Pakistan, Agricultural Census Organization, 2003: Table 6.6). Furthermore, no statistical justification was provided as to how only 325 farmers can be representative of millions of Pakistani farmers (as per the title of the paper).

Among the top 12 cotton-producing countries of the world (Table 1), Australia has the highest yield per acre. In Australia, Bt cotton was introduced during the 1996/1997 season, when 30,000 ha (10% of the Australian cotton crop) was sown with Bt cotton; Bt cotton cultivation increased in subsequent years. Compared to conventional cotton in 2003/2004, Bollgard® II reduced chemical use by 90% (Murray, 2005). Although the adoption of Bt cotton has maintained profitability for cotton growers, reduced adverse environmental impacts of cotton production, and delivered benefits to rural communities, many growers want to retain the skills and ability to grow profitable conventional cotton. This provides insurance against unforeseen problems with Bt cotton, e.g., development of resistance to the toxins. Furthermore, profitable production of conventional cotton also maintains competition for Bt cotton and potentially helps place a ceiling on the cost of Bt transgenic technology. An integral part of the adoption of Bt cotton in Australia was the implementation of a resistance management plan (RMP) with the following key elements.

A. Effective refuge planting on each farm growing Bt cotton
B. Defined planting window for Bt cotton
C. Mandatory cultivation of Bt cotton crops and residues after harvest
D. Removal of volunteer Bt cotton plants
E. Bt resistance-level monitoring in field populations

It seems that in the context of Pakistan, RMP aspect "A" could be more viable for large landholders and progressive farmers, while RMP aspect "E" could be made one of the duties of the scouts of the Directorate General of Pest Warning and Quality Control of Pesticide (PW&QCP) Punjab, Pakistan.

In Argentina (Qaim & Janvry, 2005), the effects of insect-resistant Bt cotton on pesticide use and agricultural productivity was studied for 300 farmers. Farm survey data showed that Bt cotton reduces application rates of toxic chemicals by 50% while significantly increasing yields. In addition, gross benefits could be highest for smallholder farmers who had not adopted Bt cotton. The results also showed that rapid resistance buildup and associated pest outbreaks appear to be unlikely if minimum non-Bt refuge areas were maintained. Unlike in Pakistan, a farmer is considered "small" in Argentina if the landholding is less than 90 acres. The majority of farmers in Pakistan have a landholding of less than 2.5 acres; with 90 acres it may be feasible to maintain non-Bt refuge areas, but highly unlikely when the landholding is significantly less.

Our research contributes to the existing literature in three ways.

- First, we address several Bt cotton related questions with reference to area demographics, pesticide class (efficacy), pest and pesticide groups, predators and pesticide sprays, and pest classes (sucking and chewing), which other Pakistan-centric studies have not addressed.

- Second, we use primary-level pest-scouting data of two years consisting of 30+ attributes and tens of thousands of data sheets. It may be noted that digitization, cleansing, and handling large heterogeneous data sets extracted from the pest-scouting data sheets increases the complexity of the problem, thus requiring an Agriculture Decision Support System (ADSS). ADSS—or similar systems—have not been used or discussed in prior Pakistan-related Bt cotton studies.

- Third, since we use ADSS, therefore, we are able to process and use pest-scouting data of 3,000+ Pakistani farmers, which previous Bt cotton-related studies for Pakistan have not done. For example, previous studies have provided data analyses of less than 100 farmers (Arshad, Suhail, Asghar, Tayyib, & Hafeez, 2007), 225 farmers (Arshad et al., 2008), 138 farmers (Hayee, 2005), 325 farmers (Ali & Abdulai, 2010), and 208 farmers (Nazli, Sarkar, Meilke, & Orden, 2010).

Status of Bt Cotton in Pakistan

In Pakistan, cotton—also known as "white gold"—is an important cash crop. Cotton accounts for almost 8.2% of the value added in agriculture and about 3.2% of GDP; roughly 66% of the country's export earnings are from textiles, adding more than $2.5 billion to the national economy. In addition, hundreds of ginning factories and textile mills in the country are heavily dependent on cotton, and millions of people are employed in the cotton value chain (AgroNews, 2009). Pakistan is a major exporter of raw cotton and cotton products (i.e., cotton yarn, cotton fabric, and other items manufactured from cotton) to the United States and many other countries of the world. These statistics show the importance of cotton for farmers and the national economy (Shafiq-ur-Rehman, 2009).

In May 2005, indigenous Bt cotton (insect-resistant [IR]) varieties were developed for the first time in Pakistan by the National Institute for Biotechnology and Genetic Engineering. Subsequently, 40,000 kg of basic seed of Bt cotton varieties IR-FH-901, IR-NIBGE-2, IR-CIM-448, and IR-CIM-443 was provided and grown over 8,000 acres during the 2005/2006 season with encouraging results. These early users of Bt cotton have been tightly screened and evaluated by the Pakistan Atomic Energy Commission on the basis of their capacity to follow biosafety rules. The said fields were not visited by the scouts of PW&QCP, Punjab.

Pakistan's cotton production for 2009/2010 is forecasted at 10.5 million bales, with a possible expected shortfall of 12%, or more than one million cotton bales (Syed, 2009). While the Government of Pakistan approved field trials for only six Bt cotton cases, it is estimated that 70% of the 2009/2010 cotton crop was planted to Bt (Carroll, 2009). In 2006, 4% of the cultivated area in Punjab was estimated to be under Bt cotton cultivation (Rao, 2006), which is quite small as compared to China and India during the same period. However, the last four to five years have seen an exponential increase in Bt cotton cultivation in Pakistan, and this increase is higher than in China and India. Furthermore, in terms of individual farm area, the area under cultivation by Pakistani farmers is more equivalent to that of Chinese farmers; in terms of yield loss due to pests, Pakistan more closely resembles India (Showaltera, Heubergerb, Tabashnikc & Carrièred, 2009). Thus, Pakistan presents a unique case for the analysis of Bt cotton cultivation.

In some areas, certain Bt cotton varieties may be inappropriate for local growing conditions and may fail to produce satisfactory results (Rao, 2007). In the recent past, widespread planting of illegally acquired Bt cotton has posed serious problems. The seed was not developed for Pakistan's agronomic conditions and, under certain conditions, has proven to be a poor performer

(Shafiq-ur-Rehman, 2009). According to figures provided by PW&QCP Punjab, the incidence of CLCV in Punjab in 2009 was 83.1%, a sharp increase from the 2008 incidence rate of 54.34% (Kakakhel, 2009). This resulted in lower crop production than the target. These figures reveal that the CLCV infestation has reached the highest levels as compared to previous years, which could be due to increase in Bt cotton cultivation. A possible reason could be that CLCV is a local phenomenon for which the locally developed seed varieties may be more suitable.

In 2010, the Punjab Seed Council evaluated 11 proposals for Bt cotton/hybrid varieties evolved by research institutions of the government (Nuclear Institute for Bio-Technology and Genetic Engineering; Faisalabad Cotton Research Institute; and the Centre of Excellence in Molecular Biology, University of Punjab) and the private sector. In March 2010, the Council approved eight Bt cotton varieties and one hybrid variety for cultivation in Punjab, whereas two Bt cotton varieties were deferred (Anonymous, 2010). The approved varieties had shown effective resistance against bollworms.

Various administrative and research efforts are required for commercialization of a GM crop. Despite the efforts by different government departments and private sector organizations, Pakistan did not commercially adopt Bt cotton until the beginning of the 2010/2011 cotton season. This delay has resulted in the unregulated adoption of Bt cotton and selling of fake and substandard cotton seed (Anonymous, 2010), with almost 40 varieties of Bt cotton under cultivation (Pakistan Agricultural Research Council [PARC], 2008).

The Agriculture Decision Support System

For decades, a number of government organizations have been performing pest-scouting activities and collecting related Agriculture and Meteorological (Agro-Met) data. However, this dataset has never been digitized, cleansed, and integrated to give a complete picture, which is a prerequisite for a comprehensive analysis. The author conceived the idea of an Agriculture Decision Support System (ADSS), and after approval of the proposal, the ADSS project was launched at the Center for Agro-Informatics Research (C@IR), Islamabad, in July 2006, and successfully completed the project in August 2008. The ADSS concluding workshop was chaired by the Federal Minister for Agriculture and reported in a leading English-language newspaper in Pakistan.[1] This 26-month long, 35-person project was funded with approximately $0.5 million by the National Information and Communication Technologies Research and Development (ICT R&D) Fund.[2]

Materials and Methods

ADSS was developed to handle and process large multivariate agriculture datasets in order to answer critical questions. The major steps of the indigenous ADSS workflow will be briefly discussed in this section. These steps can also be used as guidelines for handling, processing, and subsequent analyzing of large and complex datasets for other crops.

Area under Consideration

Pakistan is administratively divided into four provinces; each province is subdivided into divisions, which are further divided into districts. Each district is then divided into tehshil, which are then further divided into markaz, and finally into mouza. The Punjab province is divided administratively into 8 divisions. There are a total of 34 districts, 124 tehsils and scores of markaz within a tehsil. A markaz is further divided into mouza with dozens of farmers within a mouza.

Among the four provinces of Pakistan, Punjab (land of five rivers) is the nation's most populated and culture-centric province. Nearly 60% of the nation's total population lives in this province. Rice and cotton are the major crops cultivated in the area; Punjab's share in cotton production is estimated to be approximately 81%. Multan, Lodhran, and Rahim Yar Khan (RYK) are some of the major cotton-growing districts within Punjab (Nia, 2000). For more than two decades, the Directorate General of PW&QCP Punjab has been performing pest scouting of different crops and vegetables.[3] Traditionally the pest-scouting data collected by PW&QCP personnel have been used only for comparing economic threshold level crossings of the current year versus previous year by considering a subset of pests at the district level.

Meetings with Stakeholders

The work on ADSS started with cooperation and collaboration mainly from stakeholders in public sector organizations. Two national workshops—both chaired by the

1. *http://www.dawn.com/2008/08/22/nat11.htm*
2. *Complete two-year ADSS project report is available online at http://www.ahsanabdullah.com/downloads.htm.*
3. *For more information, see http://www.agripunjab.gov.pk/index.php?f=5&m=0&l=0.*

Figure 1. Cotton pest scouting in progress.

Pakistan Agricultural Research Council (PARC)[4] Chairman—were held in order to meet requirements and gain approval, and these workshops also led to the signing of a memorandum of understanding with PARC. Other than these two workshops, internal and external meetings were routinely held with the stakeholders.

Primary Data Collection by Pest Scouting

The next important component of ADSS is the primary pest-scouting data. Pest scouting is a systematic field-sampling process that provides field-specific information on pest pressure and crop injury. For more than two decades, PW&QCP scouts have weekly sampled 50 points at field level in each tehsil of the cotton-growing districts of Punjab. The current strength of PW&QCP personnel is 500+ and is headed by a Director General. Presently, 60 tehsils are sampled on a weekly basis up to the mouza level, resulting in the sampling of 3,000 points (farmer fields) within Punjab, with approximately 150 such points located in District Multan (with three tehsils). Usually the sampled points are not revisited during a season, which results in increase in geographical coverage. It is estimated that the number of records accumulated of cotton pest-scouting data exceeds 1.5 million records and continues to grow.

Pest scouting broadly consists of two parts: (i) noting pest population demographics by inspecting the crop in the field and (ii) interviewing the corresponding farmer for necessary information such as variety sown, sowing date, pesticide used, etc. Pest infestation is established by inspection, which is performed by the standard procedures of the experienced and trained staff of the Directorate General of PW&QCP. Trained farmers also scout their crops for pests. Figure 1 shows cotton pest scouting in progress.

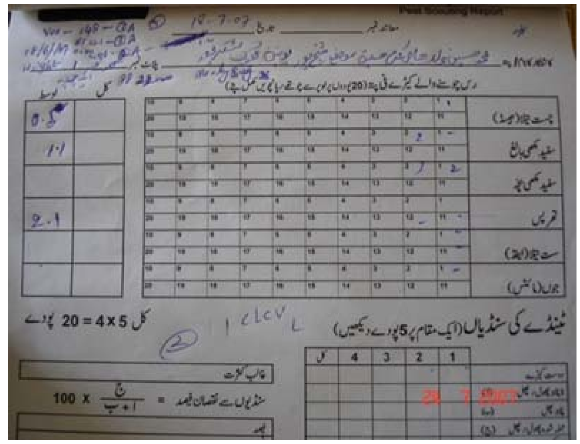
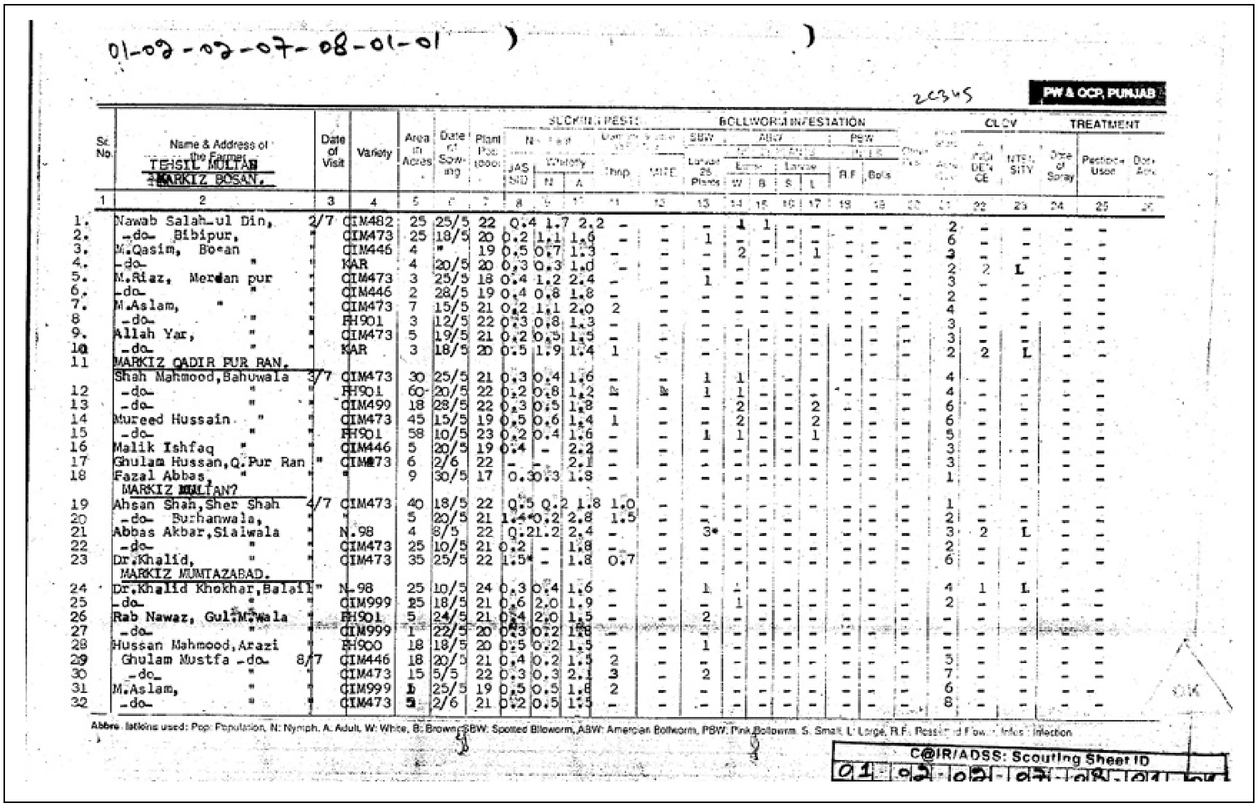


Figure 2. Pest-scouting report of an individual farmer on hand-held pad.

For noting pest population demographics, the first step is the random selection of plants. The scouts of PW&QCP visit three plants randomly, and examine leaves at the bottom, middle, and top of the plant for pests and note the findings. After collecting the data for 20-25 leaves, the average pest population per leaf is obtained. Depending on the type of pest, leaves may be examined by the naked eye or under a magnifying glass. Different metrics are used to establish the pest infestation for different pests. For example, in the case of jassid and whitefly, the methodology is similar to the above description; for thrips and mites, the infestation is based on visible damage; for spotted bollworm (SBW), it is the number of larva per 25 plants within a group of five plants; and so on. The scouts adopt different routes for scouting the field; for example, they could move in a zig-zag or diagonal direction across the field or walk between the rows of plants, etc. After scouting the fields, the scouts meet and interview the farmers and subsequently record the pest and farmer information on hand-held writing pads as shown in Figure 2. Once back in their office, the scouts transfer the data of individual farmers (noted in the hand-held pads) to the pest-scouting sheets.

A typical typed pest-scouting sheet is shown in Figure 3. Some of the attributes recorded in the pest-scouting sheet are (i) name and address of farmer; (ii) date of visit; (iii) area; (iv) variety sown; (v) sowing date; (vi) plant population; (vii) sucking pest population in different growth stages; (viii) bollworm population in different growth stages; (ix) predator population; (x) CLCV; (xi) and treatment (pesticide), including date of spray,

4. *http://www.parc.gov.pk*



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Sr. No.	Name & Address of the Farmer (TEHSIL MULTAN, MARKIZ BOSAN)	Date of Visit	Variety	Area in Acres	Date of Sowing	Plant Pop. (000)	Sucking Pest: JASSID	Whitefly N	Whitefly A	Thrip	MITE	SBW Larvae 25 Plants	ABW Eggs W	ABW Eggs B	ABW Larvae S	ABW Larvae L	PBW R.F.	PBW Bolls	Other Pest	Area	CLCV Incidence	CLCV Intensity	Date of Spray	Pesticide Used	Dose Acre
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1.	Nawab Salah-ul Din,	2/7	CIM482	25	25/5	22	0.4	1.7	2.2	-	-	-	1	1	-	-	-	-	-	2	-	-	-	-	
2.	-do- Bibipur,	"	CIM473	25	18/5	20	0.2	1.1	1.6	-	-	1	-	-	-	-	-	-	-	6	-	-	-	-	
3.	M.Qasim, Bosan	"	CIM446	4	"	19	0.5	0.7	1.3	-	-	-	2	-	-	1	-	-	-	3	-	-	-	-	
4.	-do- "	"	KAR	4	20/5	20	0.3	0.3	1.0	-	-	-	-	-	-	-	-	-	-	2	2	L	-	-	
5.	M.Riaz, Merdan pur	"	CIM473	3	25/5	18	0.4	1.2	2.4	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	
6.	-do- "	"	CIM446	2	28/5	19	0.4	0.8	1.8	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	
7.	M.Aslam, "	"	CIM473	7	15/5	21	0.2	1.1	2.0	2	-	-	-	-	-	-	-	-	-	4	-	-	-	-	
8	-do- "	"	FH901	3	12/5	22	0.3	0.8	1.3	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	
9.	Allah Yar, "	"	CIM473	5	19/5	21	0.2	0.5	1.5	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	
10	-do- "	"	KAR	3	18/5	20	0.5	1.9	1.4	1	-	-	-	-	-	-	-	-	-	2	2	L	-	-	
11	MARKIZ QADIR PUR RAN.																								
	Shah Mahmood, Bahuwala	3/7	CIM473	30	25/5	21	0.3	0.4	1.6	-	-	1	1	-	-	-	-	-	-	4	-	-	-	-	
12	-do- "	"	FH901	60	20/5	22	0.2	0.8	1.2	[illegible]	[illegible]	1	1	-	-	-	-	-	-	4	-	-	-	-	
13	-do- "	"	CIM499	18	28/5	22	0.3	0.5	1.8	-	-	-	2	-	-	2	-	-	-	6	-	-	-	-	
14	Mureed Hussain "	"	CIM473	45	15/5	19	0.5	0.6	1.4	1	-	-	2	-	-	2	-	-	-	6	-	-	-	-	
15	-do- "	"	FH901	58	10/5	23	0.2	0.4	1.6	-	-	1	1	-	-	1	-	-	-	5	-	-	-	-	
16	Malik Ishfaq "	"	CIM446	5	20/5	19	0.4	-	2.2	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	
17	Ghulam Hussan, Q.Pur Ran	"	CIM473	6	2/6	22	-	-	2.1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	
18	Fazal Abbas, "	"	"	9	30/5	17	0.3	0.3	1.8	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
	MARKIZ MULTAN?																								
19	Ahsan Shah, Sher Shah	4/7	CIM473	40	18/5	22	0.5	0.2	1.8	1.0	-	-	-	-	-	-	-	-	-	1	-	-	-	-	
20	-do- Burhanwala,	"	"	5	20/5	21	1.4	0.2	2.8	1.5	-	-	-	-	-	-	-	-	-	2	-	-	-	-	
21	Abbas Akbar, Sialwala	"	N.98	4	8/5	22	0.2	1.2	2.4	-	-	3*	-	-	-	-	-	-	-	3	2	L	-	-	
22	-do- "	"	CIM473	25	10/5	21	0.2	-	1.8	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	
23	Dr.Khalid, "	"	CIM473	35	25/5	22	1.5*	-	1.8	0.7	-	-	-	-	-	-	-	-	-	6	-	-	-	-	
	MARKIZ MUMTAZABAD.																								
24	Dr.Khalid Khokhar, Balail	"	N.98	25	10/5	24	0.3	0.4	1.6	-	-	1	-	-	-	-	-	-	-	4	1	L	-	-	
25	-do- "	"	CIM999	25	18/5	21	0.6	2.0	1.9	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	
26	Rab Nawaz, Gul M.wala	"	FH901	5	24/5	21	0.4	2.0	1.5	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	
27	-do- "	"	CIM999	1	22/5	20	0.3	0.2	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
28	Hussan Mahmood, Arazi	"	FH900	18	18/5	20	0.5	0.2	1.5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	
29	Ghulam Mustfa -do-	8/7	CIM446	18	20/5	21	0.4	0.2	1.5	2	-	-	-	-	-	-	-	-	-	5	-	-	-	-	
30	-do- "	"	CIM473	15	5/5	22	0.3	0.3	2.1	3	-	2	-	-	-	-	-	-	-	7	-	-	-	-	
31	M.Aslam, "	"	CIM999	[illegible]	25/5	19	0.5	0.5	1.8	2	-	-	-	-	-	-	-	-	-	6	-	-	-	-	
32	-do- "	"	CIM473	5	2/6	21	0.2	0.5	1.5	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	

Abbreviations used: Pop: Population, N: Nymph, A: Adult, W: White, B: Brown, SBW: Spotted Bollworm, ABW: American Bollworm, PBW: Pink Bollworm, S: Small, L: Large, R.F.: Rosetted Flower, Infes: Infection

OK

C@IR/ADSS: Scouting Sheet ID 01-02-02-07-08-01-01

Figure 3. A typed pest-scouting sheet with data of several farmers.

pesticide used, and dose per acre. A typical cotton pest-scouting sheet can have data from 25-30 farmers; ADSS has more than 24,000 cotton pest-scouting sheets. Part of these pest-scouting sheets actually form the basis of the data used for analysis in this article.

Data Validation

The pest-scouting data collected by the Agriculture or Field Officers (AO/FO) of PW&QCP are randomly checked by the Assistant Director (AD) and then further randomly checked by the Deputy Director (DD) at the district level. Only after this authentication, the reports/results are issued in hard-copy with the signature of the PW&QCP's Director General (DG). To further validate the data-gathering process, the ADSS team (including the author of this article) conducted a three-day tour of four cotton growing tehsils of Punjab in July 2007. The ADSS team verified and cross-checked relevant information from the pest-scouting sheets by interviewing 30 randomly-selected farmers from four tehsils—specifically Multan, Shujabad, Jalalpur Pirwala, and Rahim Yar Khan.

Data Acquisition for ADSS

Manually-filled or typed pest-scouting sheets have historically been filed without any particular order and stored in different cities by the staff of DG PW&QCP, Punjab. It is therefore a challenging task—if not impossible—to locate a particular sheet corresponding to a particular geography/time for the analysis of a particular pest, thus preventing any analysis to date that is similar to what is presented in this article using ADSS.

To acquire these sheets, ADSS teams routinely visited different cities and after obtaining the sheets, numbered, photo-copied, and packed them. Labeled packs of 300 sheets were made and subsequently placed in labeled cardboard boxes. These boxes were then sent on a daily basis to the project premises via courier. Upon receipt, the sheets were then sorted based on time and geography, labeled according to the unique C@IR ID (seen at the bottom of Figure 3), organized into separate labeled folders, and stored in the data room or databank. Preparing a single folder typically took 22 man-hours, or roughly three working days.

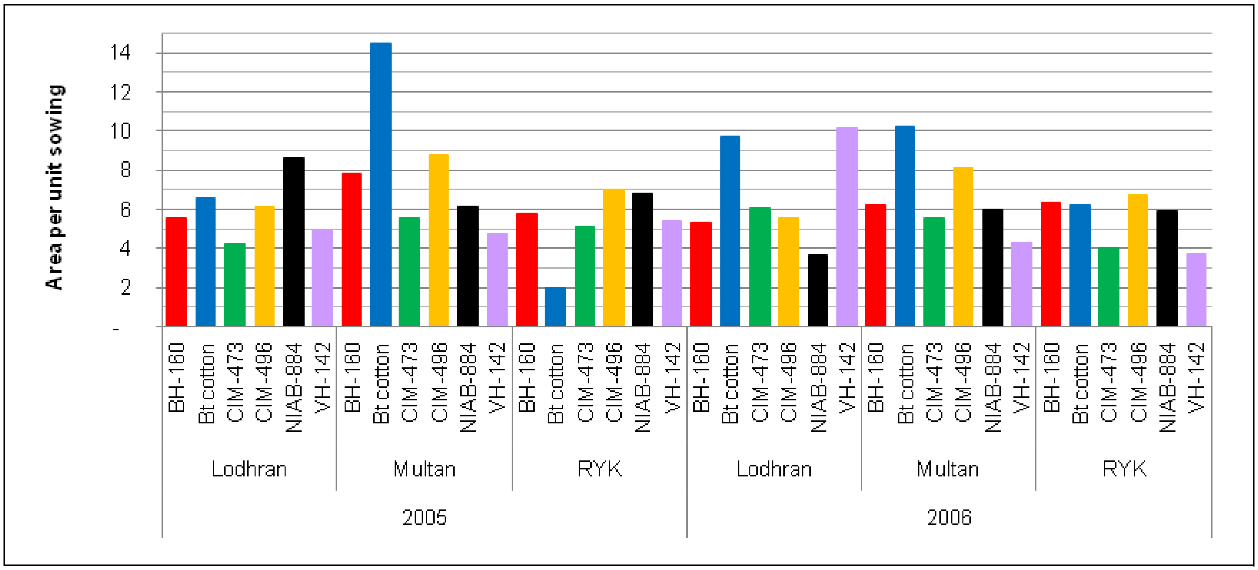

Figure 4. Area per unit sowing of major cotton varieties during 2005 and 2006.

Scanning of Sheets

Every pest-scouting sheet is scanned on a high-speed scanner with document feeder and saved in the computer in PDF format. The main purpose of scanning is to protect the sheets from wear-and-tear during data entry by providing the printout of the scanned sheet to the Data Entry Operator (DEO) rather than the actual data sheet. Due to the quality of the raw data sheets—some of them are hand-filled—optical character reader (OCR) software could not be used to electronically extract the data, thus requiring manual data entry as described in the next section. Note that scanning also ensures the safety of the data sheets from the hazards of moisture, termites, and fire.

Data Entry

A team of DEOs transforms manually-filled or typed data sheets (Figure 3) into digital form using a custom-built software tool. First, the sheets are categorized according to their quality, which is based on their legibility; then, the most recent sheets are selected, followed by older sheets. Two different teams of DEOs enter the same data. After data entry is completed by each team, the entered data are compared programmatically for each row and column and an error report is generated. The error report identifies those values (in the two sets of data entered) that are different, i.e., one of the two is incorrect. Subsequently, the original data sheet corresponding to these values is retrieved and checked against the entered value and corrected.

Data Profiling and Cleansing

Digitized data cannot be used in raw form, and due to the volume, have to be cleansed automatically. This is done using the Data Profiling Tool, which is centered around business rules and data quality metrics. Note that here, the business rules have nothing to do with trade or commerce; instead, these rules refer to covering the domain/process being considered. Only after undergoing the entire ADSS process, the data is finally ready for analysis. The analysis could be performed using the indigenous ADSS tools or other traditional tools and programs such as MS Excel or SPSS, etc. The results of such analysis are discussed in the next section.

Results and Discussion

Just analyzing the data of Bt cotton cultivation in isolation with other local cotton varieties may not give the complete and true picture; hence, throughout this section the results of Bt cotton will be compared with the most popular non-Bt cotton variety sown during 2005/2006, i.e., CIM-496, cultivated in three districts of Punjab (Multan, Lodhran, and RYK). Overall, the CIM-496 variety is the most commonly sown variety, as it matures early and produces a better yield.

Bt vs. Non-Bt Cultivation

In 2002, commercial Bt cotton cultivation was allowed in India, but it has been present in the Indian market as early as 1998 (GRAIN, 2007). Similarly in Pakistan, although Bt cotton was not allowed for commercial cultivation until the 2010/2011 season, it has been in the

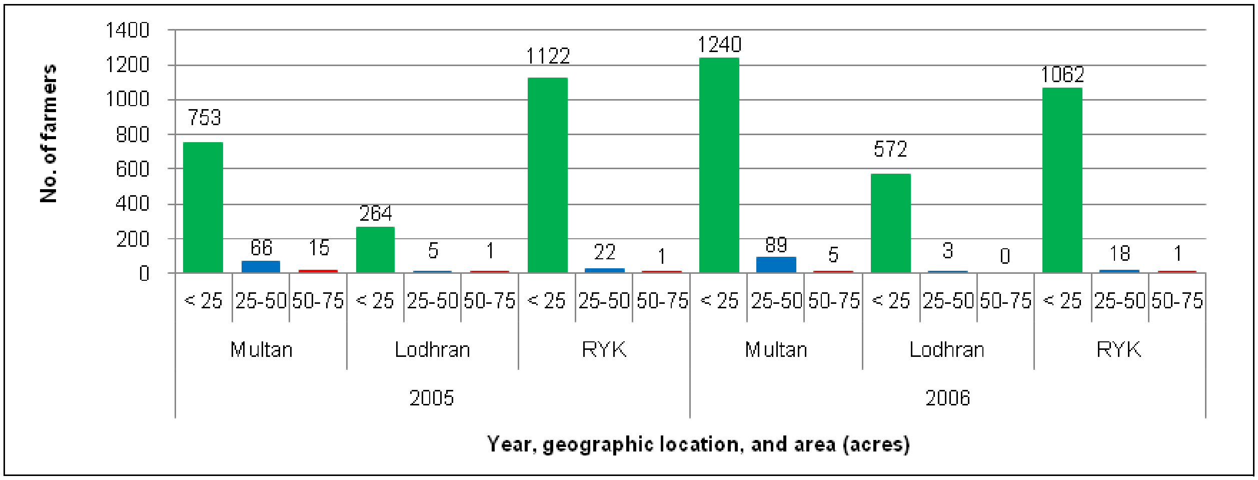

Figure 5. Cultivation of CIM-496 with respect to farm size in 2005 and 2006.

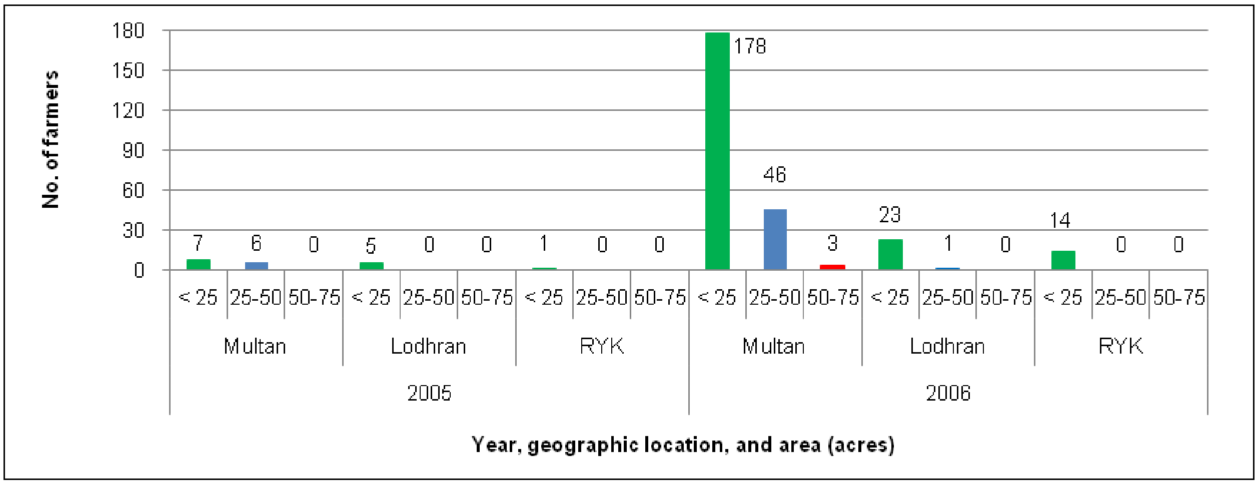

Figure 6. Cultivation of Bt cotton with respect to farm size in 2005 and 2006.

market since 2000 (Hayee, 2005). In this section, the breakdown of the Bt and non-Bt cotton cultivation will be given geographically, along with the breakdown based on the area of the cultivated plots.

Figure 4 shows the area per unit sowing (i.e., total sown area divided by total number of sowings) of the major cotton varieties during 2005/2006. Although the area over which Bt cotton has been sown increased from 2005 to 2006, the area per sowing has reduced for Multan. To ascertain the reasons for this, we need to go one step further.

Figure 5 shows the breakdown of the sowing of CIM-496 based on the segregation of the farm size in three ranges, i.e., (i) < 25 acres, (ii) 25-50 acres, and (iii) 50-75 acres. Almost similar sowing trends are observed in Districts Multan, RYK, and Lodhran in the year 2005 and 2006. Staff of PW&QCP informed us that farmers try to sow different cotton varieties on their farms to avoid the risk of the failure of any one variety.

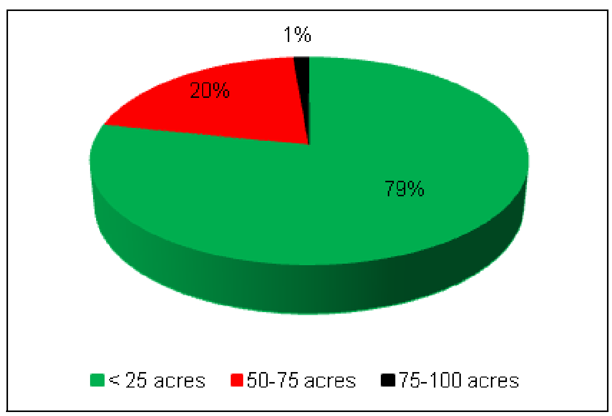

Figure 7. Farmers' interest in Bt cotton by farm size in Multan during 2006.

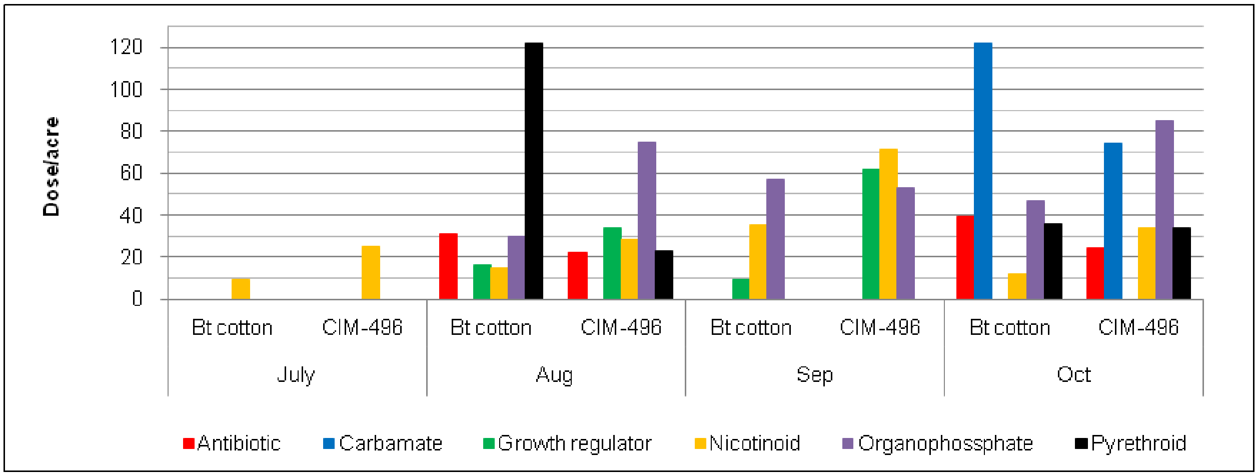

Figure 8. Different pesticide groups sprayed over Bt and non-Bt cotton.

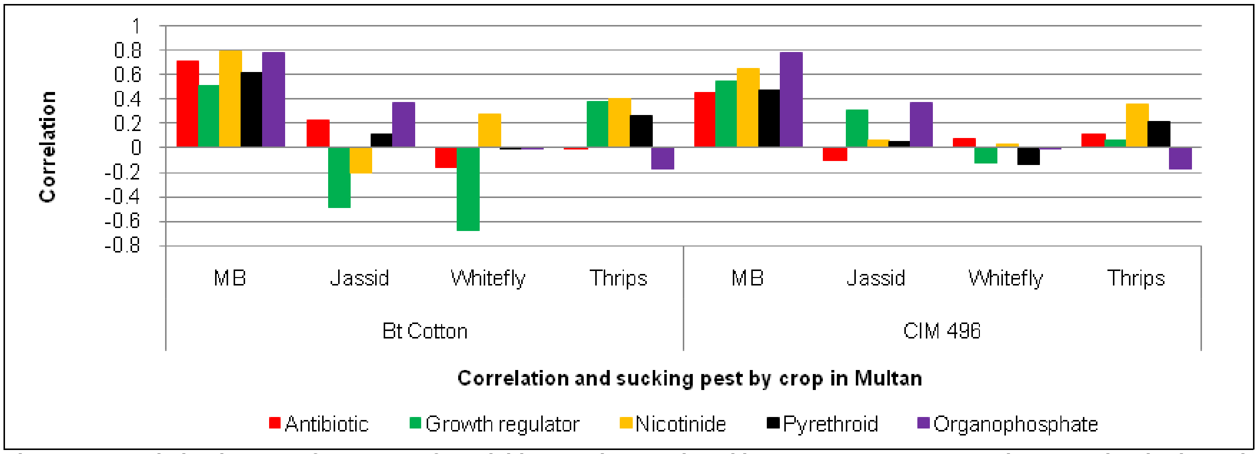

Figure 9. Correlation between frequency of pesticide sprayings and sucking-pests on Bt cotton and CIM-496 in District Multan in 2006.

From Figure 6 it can be seen that Multan is the main hub of Bt cotton seed dissemination, and it is the small landowners (area less than 25 acres) who seem to be playing the pivotal role. In Multan there is a 25-times increase in the small landowners cultivating Bt cotton from 2005 to 2006. Actually, in all three tehsils there is a significant increase in the Bt cotton sowings by the small landowners in 2006 as compared to 2005. The lower level of Bt cotton sowing found in District RYK might be due to the non-availability of Bt cotton seed, as it is located very far from District Multan. Figure 7 shows the relative share of Bt cotton sowing for Multan in 2006. Observe that our findings (Figure 7) are very similar to that of (Hayee, 2005).

Figures 4 through 6 show that a majority of the farmers who sowed Bt cotton are small landowners. Typically, the cost of Bt seed and high cost of inputs (fertilizer and irrigation) should have been a prohibitive factor, but the high cost of pesticides could have pushed the small farmers to cultivate more area under Bt cotton as opposed to the medium to large landowners.

Relationship between Pest and Pesticide Groups for Bt Cotton and CIM-496

In this section, the relationship between four sucking pests and six pesticide groups for Bt cotton and CIM-496 throughout the cropping season will be discussed.

Figure 8 shows that four out of six pesticide groups have a higher dose per acre (amount sprayed divided by the area) for CIM-496 than for Bt cotton; this is understandable, as Bt cotton is engineered for minimum or no application of pesticides for the bollworm complex. However, the exceptions are the Carbamate and Pyrethroid groups, for which the dose-per-acre sprayed is higher for Bt cotton than CIM-496. The explanation/analysis of this observation could be part of future work.

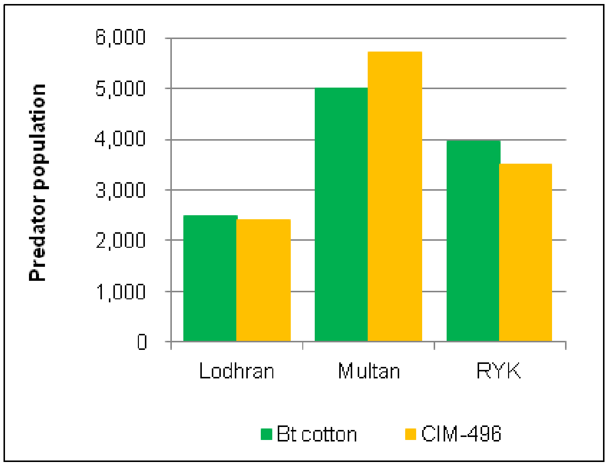

Figure 10. Comparison of predator populations on Bt and non-Bt cotton.

A strong positive correlation is observed between mealybug and the selected pesticide groups on Bt cotton and CIM-496 varieties (Figure 9), whereas a significant negative correlation is observed between jassid/whitefly population and the growth regulator pesticide group on Bt cotton. Figure 9 also shows that Bt cotton is more susceptible to sucking pests compared to bollworms. The negative correlation between jassid/whitefly and the growth regulator indicates the effectiveness of this pesticide against these particular pests.

The strong positive correlation between mealybug (MB) and Bt cotton for the five pesticide groups indicates that none of the pesticide groups has been able to control MB on Bt cotton. This is followed by a notable, but insignificant, positive correlation for thrips, but only for the nicotonoid group. The MB is further discussed in a later section.

Our finding about significant MB incidence on Bt cotton is similar to many reports from India (e.g., Anonymous, 2007), wherein the farmers incurred losses due to MB despite spraying pesticides worth $120 million in Chandigarh.

Population Dynamics of Predators on Bt Cotton and CIM-496

Figure 10 shows the predator population in three major cotton-growing districts of Punjab when both Bt and non-Bt varieties were treated with pesticides. It can be observed that the predator population (beneficial insects) is higher in the case of Bt cotton for Districts Lodhran and RYK. This could be explained by the apparently fewer sprays on Bt cotton (thus saving the predators); furthermore, the Bt-cotton toxin does not

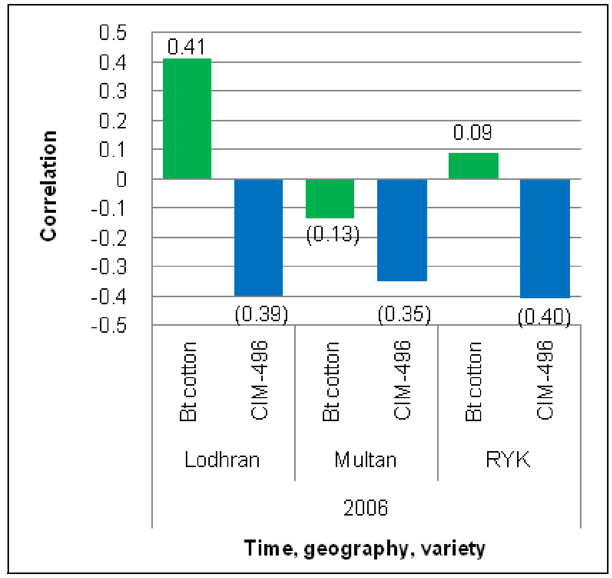

Figure 11. Correlation between predators and number of sprays for 2006.

directly target the predators. Further exploration of the data for Multan revealed that the predator population on Bt cotton was either more than, or close to, the predator population on CIM-496 except for the months of July and August.

Figure 11 shows the correlation between the predator population and number of sprays on Bt cotton and CIM-496 for three cotton-growing districts of Punjab at the field level. There is a high, though not significant, positive correlation between sprays and predator population in Lodhran for Bt cotton, thus indicating the rearing of predators on Bt cotton, as it is not engineered to target the predators; this also indicates that the pesticides used by the farmers for the sucking pests were not targeting the predators. This phenomenon is evident—though at a weaker level—in RYK. Surprisingly, the correlation of predator population with sprays on CIM-496 is consistently similar and negative (around -0.4) for all three cotton-growing districts.

One can observe that, similar to Naranjo (2005) and other researchers, our findings show that when non-Bt cotton was treated with more insecticides than Bt cotton, the density of predators was greater in Bt than in non-Bt cotton.

Sucking-pests Incidence. In this section, a comparative analysis of the attack of whiteflies, jassids, thrips, and mealybug on Bt cotton and CIM-496 from June through October will be discussed for Multan because of the comparatively large number of farmers sowing Bt cotton (Figure 6).

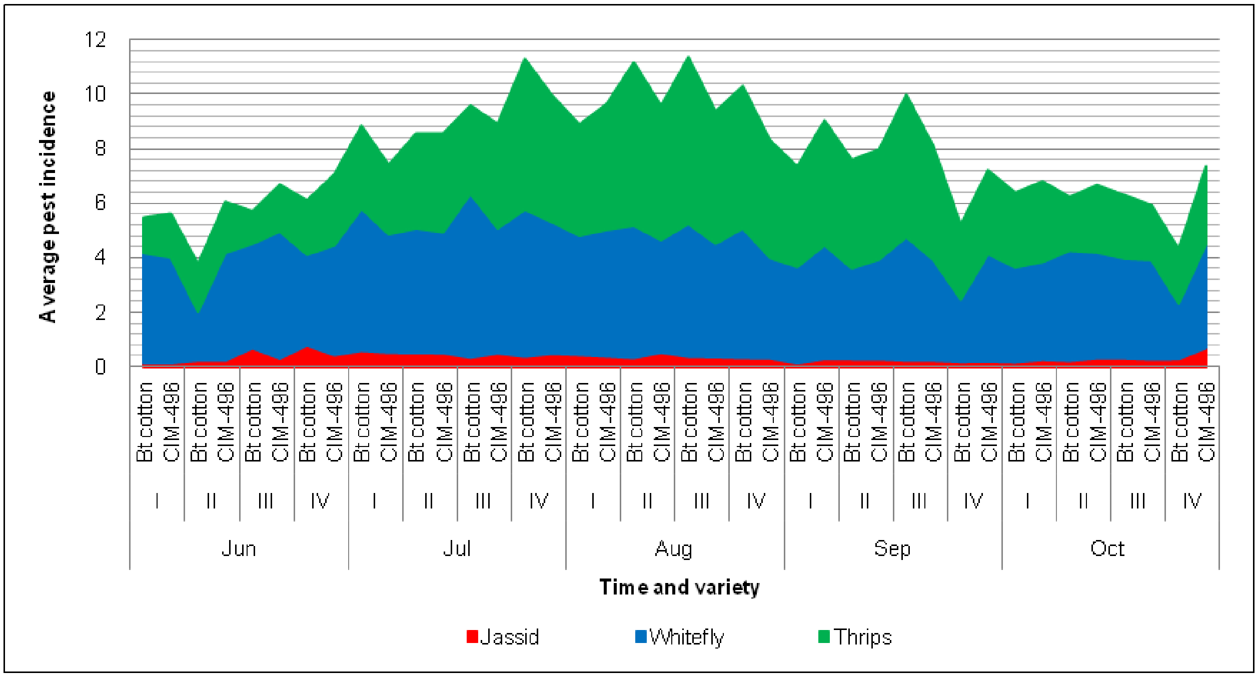

Figure 12. Sucking-pest incidence on Bt cotton and the CIM-496 varieties in District Multan for the year 2006.

One can see from Figure 12 that during 2006, the jassids appeared early in Multan and attained a relatively high level of incidence on Bt cotton in the third and fourth weeks of June. On the CIM-496 variety, the jassids maintained this level throughout the remaining period (July through September). The whitefly attained the highest level of incidence on Bt cotton in the third and fourth weeks of July, while the highest incidence level of thrips was achieved in the months of July, August, and September. An extremely high incidence level of thrips on Bt cotton as compared to that of the CIM-496 variety in both 2005 and 2006 indicates Bt cotton's susceptibility to the sucking pest thrips. If we view Figure 12 in conjunction with Figure 9, it can be concluded that peak populations of whitefly and thrips coincided with a decrease in spraying the corresponding pesticides (Pythertroid group), thus resulting in a significant negative correlation.

In more concrete terms for the 20 weeks considered in Figure 12, for 13 weeks (or 65% of the time) the incidence of whitefly on Bt cotton was higher compared to CIM-496, and for 55% of the time, the incidence of jassid was higher on Bt cotton compared to CIM-496.

Note that our findings are similar to the 3-year study conducted in China (Mena, Gea, Edwards, & Yardimc, 2005) in which it was concluded that Bt cotton did decrease the need for pesticides against the bollworm complex, but this relaxation from pesticides could cause an increase in the population of the sucking pests.

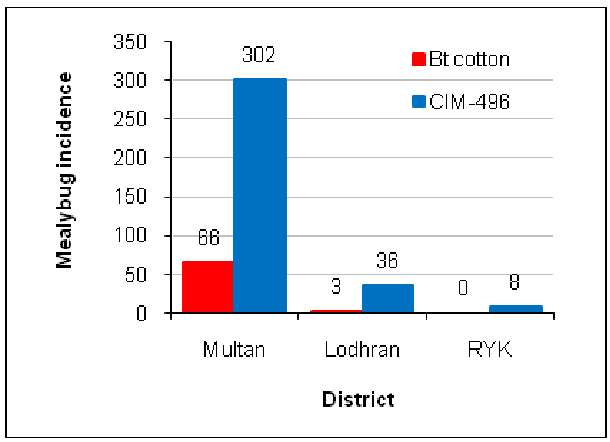

Figure 13. Mealybug incidence on Bt cotton and CIM-496.

Mealybug Incidence on Bt Cotton and CIM-496. The MB sucking-pest incidence is discussed in a separate section due to the unique nature of the pest incidence. This newly emerged sucking pest, the mealybug appeared in patches on some cotton plants and rapidly increased its population after a few days. It began spreading to nearby plants and fields. The MB's appearance in any field is considered to be its economic threshold level. As the MB pests start appearing, farmers try to control them with applications of different pesticide

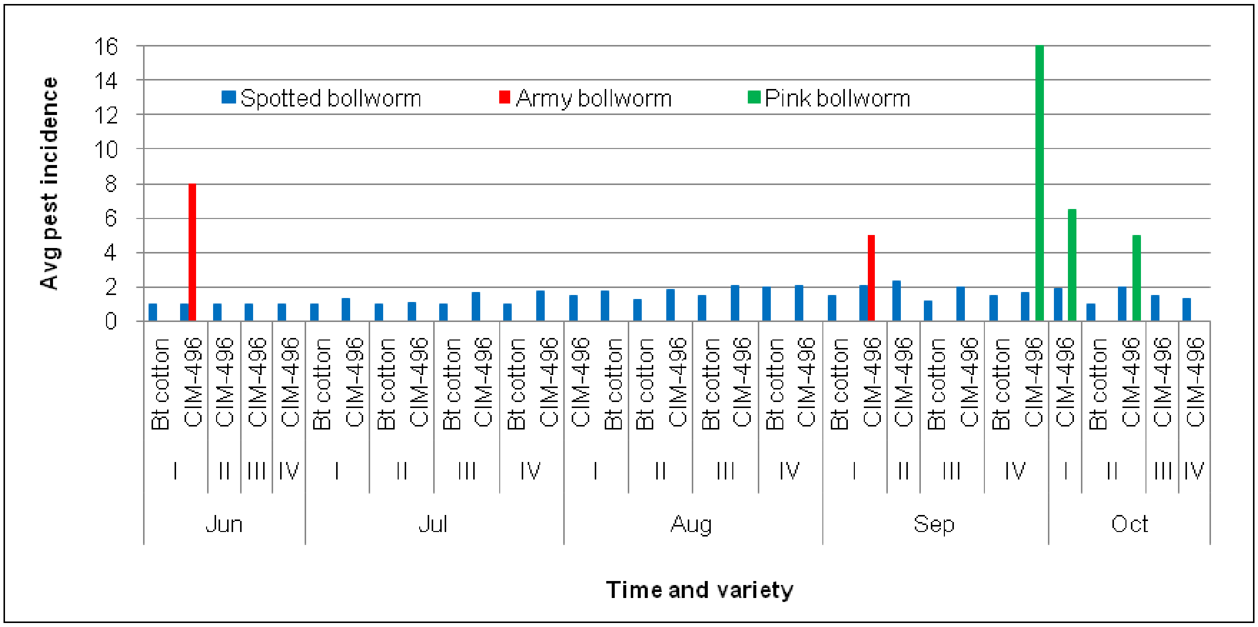

Figure 14. Chewing-pest incidence on Bt cotton and the CIM-496 in District Multan in 2006.

groups, and in extreme cases, uprooting the plants—as was observed during the author's field visits. Although some pesticides suppress the MB population on targeted patches, they cannot eliminate the entire population due to the MB's defense mechanism and also because, at times, the pesticide is unable to cover every part of the plant. Consequently, the MB again starts spreading either in the same field or in the adjoining field through a rapid increase in population.

Figure 13 shows that Multan suffered the most from the MB, as compared to Lodhran and RYK; in Multan, more than 60 MB incidents were recorded on Bt cotton, while 300 MB incidents were reported on the CIM-496 variety. The reason for such high incidence levels could be due to the extensive cultivation of the host plant, i.e., mango. The location of the agriculture management headquarters and of the Central Cotton Research Institute (CCRI) in Multan could be another reason for the high MB incidence, as the personnel of these organizations could have made vigilant observation and timely recordings of the incidence. On the other hand, Lodhran has the minimum rate of MB incidence on Bt cotton; this could be due to lesser number of plots sown, as proliferation of Bt cotton was gradual in the neighboring districts of Multan.

Observe that although the ratio of Bt to CIM-496 cultivation in Multan is 1:5.8, the ratio of MB incidence is lower (i.e., 1:4.5), which indicates relatively higher MB incidence on Bt or relatively lower MB incidence on CIM-496. A detailed study of MB incidence using ADSS is discussed in Abdullah (2009).

Chewing-pests Incidence

In this section, a comparative analysis will be done of the attack of army bollworm (ABW), pink bollworm (PBW), and spotted bollworm (SBW) on Bt cotton and CIM-496 from June to October for Multan.

From the pest-scouting records of 2006, the SBW population remained consistent throughout the season without any significant change in District Multan (Figure 14), and its average number did not exceed above 2 on either of the varieties. However, the CIM-496 variety was vulnerable to the pests' attack in the first week of June 2006. In September and October, cotton generally shows a vulnerability to bollworm attacks. In the first and fourth weeks of September, the CIM-496 variety was attacked by the ABW and the PBW, respectively. In the first and second weeks of October, this variety was also attacked by the PBW with an average number between 4 and 16.

Pest-scouting data shows that in the three districts of Multan, RYK, and Lodhran, Bt cotton was cultivated in the year 2006; however, due to the lack of pest-incidence records, it is difficult to draw any significant conclusions from it. The absence of any record of the chewing-pest occurrence on Bt cotton in District RYK might be due to the Bt cotton's unique characteristic of showing resistance towards these pests. Figure 15 shows the weak negative correlation between usage of typical cotton pesticides on Bt cotton and incidence of chewing pests (bollworms). This suggests that Bt cotton has indeed controlled the chewing pests for which it was engineered.

Conclusions and Future Work

The popularity of Bt cotton is growing at an exponential rate in Punjab, Pakistan. In the area under study, the number of sowings of CIM-496 increased by 60% from 2005 to 2006, but during the same time period, Bt cotton sowings increased by a staggering 1,700%. The high level of sowings in Tehsil Multan during the year 2006 depicts the progressive approach of the local farmers towards the adoption of transgenic cotton varieties (Figure 4). Multan is the core Bt-cotton-growing zone where Bt cotton is cultivated mostly on plot sizes of less than 25 acres (Figure 4).

The view that Bt cotton is not susceptible to the bollworm complex was found to be true (Figures 14 and 15); however, the incidence of SBW remained consistent on Bt cotton throughout the season without any significant change (Figure 8). Bt cotton was not found to be resistant against sucking pests, especially the newly emerged MB pest (Figure 9). However, growth regulator was found to be a good choice for controlling the jassids and whitefly populations on Bt cotton.

A dramatic reduction in use of pesticides has been experienced in the countries where Bt cotton was adopted. With the commercial cultivation of Bt cotton allowed in Pakistan, similar results are expected here; however, this may have some negative impacts, too. These include decreased business and sales for pesticide and chemical resellers, as well as diminished market size for agrochemical companies. The pesticide companies may have to respond to the challenge posed by Bt cotton by adopting different strategies, such as lowering prices for integrated-pest-management-compatible pesticides, assuming that conventional cotton growers will contribute to the pesticide sales. Bt cotton has also been associated with increases in yield (for example, in 2001, adoption of Bt cotton in China and the United States increased world cotton production by 0.7% and reduced the world cotton price by $0.014 per pound [Frisvold, Reeves, & Tronstad, 2006]). Since Pakistan is one of the major cotton producers of the world, the new ability to cultivate Bt cotton coupled with the availability of genuine Bt cotton seed may increase the yield and affect cotton prices.

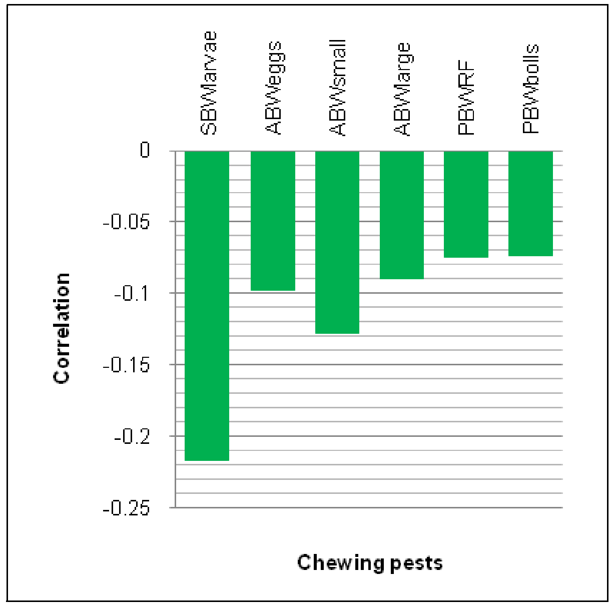

Figure 15. Correlation between chewing pests population and pesticide usage in Multan 2006.

The study can be further strengthened by extending the study period beyond 2006 for a year-to-year variability impact for general conclusions. As part of future work, empirical experiments can be designed to further corroborate some of the findings observed in this article, such as relationship with CLCV incidence, effect of weather, comparison with varieties other than CIM-496, etc. It would be interesting to do a cross-section study with reference to area, education, yield, pesticide usage, household income, and poverty of thousands of farmers of Punjab, Pakistan who have/have not adopted Bt cotton. Finally, conclusive statements about Bt cotton's sustainability require long-term monitoring of possible secondary effects.

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