

Is cotton conquering its chemical addiction?



**PESTICIDE
ACTION
NETWORK UK**

A REVIEW OF PESTICIDE USE IN
GLOBAL COTTON PRODUCTION

October 2017

Foreword

Pesticides in cotton have been a topic of debate for many decades now. The difference between cotton growers who are agronomically well educated and farming on a large mechanised scale, and smallholder farmers who lack extension support and technical know-how, is often at the heart of these debates. Interest groups, often in more regulated and advanced economies, claim that pesticide use in cotton is no longer a problem. They argue that the advancement in technologies, like genetically modified varieties (*Bt* cotton), have helped reduce the application of pesticides. We know that this is not the complete picture.

Cotton is still the fourth largest consumer of agricultural chemicals. Excessive use of pesticides, especially by smallholder farmers in underregulated countries, can have huge impacts on human health and the environment. Pesticide poisoning of farm workers, contamination of rivers and ground water, reuse of empty toxic containers, and loss of biodiversity are all very real effects of chemical use. We also have good reason to believe that the extent of the problem is significantly under-reported, and that the use of banned pesticides continues in many developing countries. It is indeed regretful that we continue to take cover under the pretext of outdated studies and lack of data.

We are thankful to Pesticide Action Network UK for undertaking this study to provide current data on global patterns of pesticide use in cotton and documenting the associated problems. The study clearly shows that reductions in pesticide use are possible, but that the adoption of IPM and other agro-ecological practices must be central to these efforts if reductions are to be maintained.

C&A Foundation has supported the study, as it will certainly help fill an important knowledge gap and help stakeholders make informed decisions. Our endeavor at C&A Foundation is to work with farmers to produce cotton sustainably and get off the 'pesticide treadmill'. This will only be possible if in addition to IPM methods that lead to more responsible use of pesticides, the industry as a whole also steps up both research and investments on biological control, and adopts more agroecological approaches to pest management.

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Executive Summary

- ◆ Pesticide use patterns have changed over the past few years as many of the older, more toxic pesticides – such as endosulfan – have been banned and replaced by newer, more selective chemicals.
- ◆ The coverage of sustainability standards such as the Better Cotton Initiative, Cotton made in Africa, Fairtrade and Organic has dramatically increased. These standards, which restrict the use of some highly hazardous pesticides and promote farming practices to reduce reliance on pesticides now reach over 1.7 million farmers and cover 3.7 million hectares.
- ◆ Nevertheless, many highly hazardous pesticides are still used in cotton production and, in some regions, the conditions under which pesticides are used continue to give rise to pesticide exposure and poisoning incidents. This is particularly true in smallholder cotton production.
- ◆ The introduction of *Bt* cotton – cotton genetically modified to be toxic to certain cotton pests – in the early part of the century was followed by a dip in insecticide use, but this reduction has not been sustained in many of the countries examined.
- ◆ This renewed increase in insecticide use has been driven by a surge in “secondary” pests like aphids, thrips and jassids. These pests, which had previously caused relatively low levels of damage, have now become a serious threat to cotton productivity.
- ◆ Poor resistance management, particularly in mixed smallholder cropping systems with minimal coordination and regulation, is leading some species of bollworm to develop resistance to certain varieties of *Bt* cotton and to an increase in insecticide use.
- ◆ Herbicide use in cotton has not substantially declined. In fact, in some countries, the introduction of varieties of cotton that have been genetically-engineered to be tolerant to some herbicides has been accompanied by an increase in herbicide use.
- ◆ Herbicide resistance in weeds, driven by a lack of effective resistance management, is becoming a problem and increasing herbicide use in some countries. This resistance is caused by both the transfer of herbicide-tolerant genes to weeds and, more commonly, by weeds “naturally” developing resistance as a result of excessive herbicide use.
- ◆ Australia is notable for its success in delivering and maintaining dramatic reductions in insecticide use. However, despite insecticide use declining by 89% over the past two decades, herbicide use has not dropped. Australian farmers regularly deliver the highest cotton yields in the world.
- ◆ The Australian cotton sector is unique in its ability to manage resistance on a “landscape-scale” via rigorous enforcement of requirements across a relatively small number of farmers with dedicated strong scientific support. However, these conditions can rarely be replicated elsewhere.
- ◆ Australian farmers have also embraced Integrated Pest Management (IPM). Not only has this helped in resistance management, but IPM has been a significant factor in helping them to control secondary pests without resorting to higher insecticide use.
- ◆ Turkey has diverged from other major cotton producing countries by rejecting GM cotton and focussing on IPM. Turkish yields have doubled since the 1980s to some 1700 kg/ha – approximately double the global average – yet pesticide use remains low.
- ◆ Numerous studies have been published relating serious health impacts to pesticide exposure among cotton communities. Symptoms recorded include impairment of the nervous system, lower neurobehavioral performance, delayed puberty, breast milk contamination, blood abnormalities as well as many acute symptoms such as nausea, respiratory problems, dizziness and convulsions.

- ◆ Case studies presented in this report clearly show that poor practices continue to exist in cotton production. Personal protective equipment is not widely used and, in some instances, children apply pesticides. Re-use of empty pesticide containers is a major route of exposure. Occupational poisoning levels are high with as many as 42% of farmers reporting signs and symptoms of pesticide poisoning.

Photo: harvesting cotton in a cotton field, Amravati, Maharashtra, India



Acronyms

ABRAPA	Brazilian Cotton Producer's Association
ABR	Responsible Brazilian Cotton
BCI	Better Cotton Initiative
BMP	Best Management Practice
<i>Bt</i>	<i>Bacillus Thuringiensis</i>
CICR	Central Institute of Cotton Research (India)
CMDT	Compagnie Malienne de Développement des Textiles
CmiA	Coton made in Africa
EFSA	The European Food Safety Authority
Embrapa	Brazilian Agricultural Research Corporation
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
GM/GM	Genetically Modified/Genetically Modified Organism
HHP	Highly Hazardous Pesticide
IARC	International Agency for Research on Cancer
ICAC	International Cotton Advisory Committee
ICAR	Indian Council of Agricultural research
IPM	Integrated Pest Management
IPPM	Integrated Pest and Production Management
IRM	Insecticide Resistance Management
LEC	Lutte Étagée Ciblée
NASS	National Agricultural Statistics Service
PAN	Pesticide Action Network
SEEP	Social, Environmental and Economic Panel of the International Cotton Advisory Committee
USDA	United States Department of Agriculture
WHO	World Health Organization

Introduction

Cotton supports around 100 million rural families across the globe; it provides employment and income, and is the mainstay of the economies of some of the poorest countries in the world. But cotton has its problems: it has been associated with everything from forced and child labour to pesticide poisoning of farmers and their families and environmental pollution. A number of high profile initiatives have been launched to tackle these problems and they are making inroads, many of the most egregious practices harming human health and the environment have been – or are being – addressed. But it is a work in progress and data on the level of change is sketchy.

The question of pesticide use in cotton production has long been contentious, with critics arguing that it is damaging to the environment and farmers' health. Supporters meanwhile respond that insecticide use in particular is falling, that any damage stems from isolated instances of misuse, and that many of the most problematic pesticides have been banned or otherwise eliminated.

The debate in recent years has been severely distorted by the use of figures that are out of date and inaccurate. This report aims to shine a light on the current rate of pesticide use in cotton, and examine trends and patterns of use. We take a detailed look at six countries and regions who between them account for around four-fifths of the world's cotton production: Africa, Australia, Brazil, China, India and the United States.

The task has not been easy. Reliable data on global pesticide use in cotton is not readily available and is spread across multiple sources with different approaches to data collection. In this report, we have drawn on figures from the Agricultural Outlook 2016-2017 database compiled by the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO) of the United Nations. Where possible, these data sets have been compared with information made publicly available from other official and/or scientific literature sources (e.g. International Cotton Advisory Council, US Department of Agriculture and other national data sources).

There is little doubt that total pesticide use in cotton has fallen from the previous highs reported in the late 1980s; insecticide use in particular has declined, though this decline is not as substantial as some have claimed and insecticide figures appear to be on the rise again in some areas. While herbicide use has also declined, the falls have not been as significant and use also appears to be rising in some places (see section 2).

The pest complex in many cotton growing regions has changed, sometimes as a result of the use of genetically modified cotton (or more precisely, due to poor management of resistance to the technology). Pest adaptation to the new transgenic environment is also changing the ways pests are controlled, and in some cases requiring the pattern of insecticide use to be adapted accordingly.

What is clear is that progress is not uniform: some countries have achieved and sustained significant reductions in pesticide use, while others have seen use rise. It is worthwhile noting that those countries who have been most successful at cutting pesticide use – and in keeping it low – have been those who have embraced IPM. The lesson is clear: if it is serious about reducing pesticide use, the sector must make more use of tools like Integrated Pest Management (IPM) and other agro-ecological approaches such as botanical and biological control.



1. Global cotton production

The major cotton growing countries are Australia, Brazil, China, India, Pakistan and US. Together, they account for around 80% of cotton produced globally. Cotton is heterogeneous: there is no single profile for cotton production, be it scale or the agro-ecosystem in which it takes place. There are countries growing cotton on a very large mechanised scale (US, Brazil, Australia), while others have many more smallholders and are less technologically advanced or have a mix of production scales (India, Pakistan, China). Many countries allow genetically modified (GM) cotton, while others (such as Turkey) have a well-developed system of smallholders, achieving high yields without GM. Uzbekistan and Central Asia have inherited the large scale Soviet system, with some movement towards smallholders rather than large estates. Major regions like West Africa are yet another story. Cotton is grown from temperate to tropical zones, with the majority in tropical and sub-tropical areas.

Some countries farm cotton mainly for export (US and Australia), whereas others see much more consumed domestically. About a third of annual world production is exported and around half of global production receives some form of state support. Imports are dominated by Bangladesh (1,546,000 metric tonnes), Vietnam (1,350,000), China (1,089,000), Turkey (740,000) and Indonesia (697,000), followed by Pakistan (435,000) and India (381,000).

Cotton markets are increasingly driven by what happens in other sectors, as cotton prices often react to polyester prices, which affects demand. Cotton has changed a lot in the past decade, according to data published in Agricultural Outlook 2016-2017.¹ India is now the largest cotton producer ahead of China and the US, and Brazil is now the 5th largest producer, ahead of Australia, and grows on a par with all of the African countries combined (table 1).

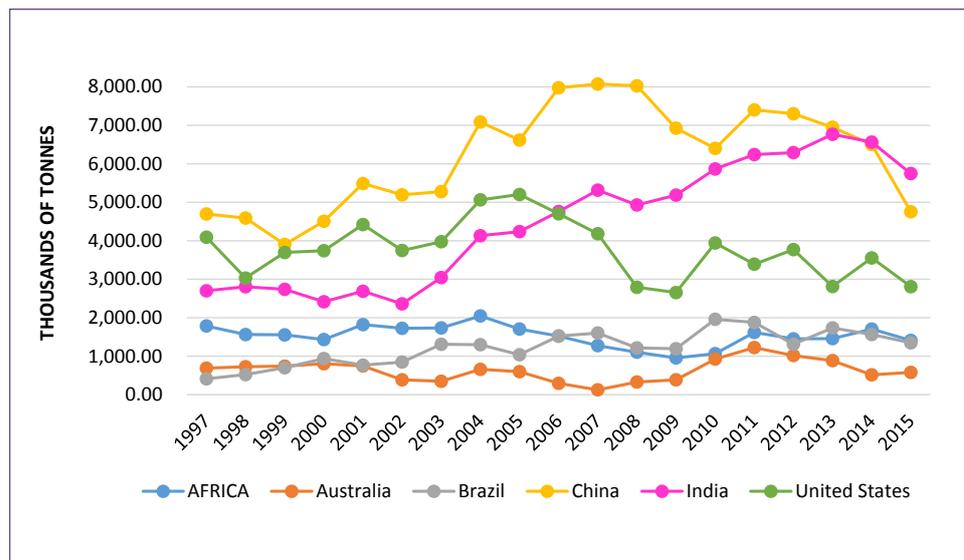
TABLE 1 GLOBAL COTTON PRODUCTION AND CONSUMPTION UPDATE TO 2016/17 (USDA FAS); IN THOUSANDS OF METRIC TONNES

	DATA 2016/17	2017/18 (ESTIMATE)
World cotton closing stocks	19451	19096
World cotton production	23076	24978
Major cotton producing countries	India 5770 China 4953 US 3738 Pakistan 1676 Brazil 1481 Australia 958 Turkey 697 Uzbekistan 185	India 6096 China 5225 US 4180 Pakistan 2025 Brazil 1524 Australia 1045 Turkey 806 Uzbekistan 806 Burkina Faso 305 Mali 283 Tajikistan 103
World cotton consumption	24727	25368
World cotton exports	8012	8022

Source: United States Department of Agriculture Foreign Agricultural Service June 2017 Cotton: World Markets and Trade

In India, for instance, production started growing in 2002, coinciding with the approval (but not widespread uptake) of *Bt* cotton. Since 2002, the adoption of *Bt* cotton has increased from 50,000 to 11.6 million hectares in 2014, and the percentage of area under *Bt* cotton also increased from 1 per cent to 95 per cent over the same period.² At the same time, the Better Cotton Initiative (BCI) reported an increase from 2011 in the yields of BCI project participants compared to the yields of producers operating in the same area, but not receiving BCI training.³ There is a question of when Indian yields started rising, with some noting that it began before *Bt* became widespread.⁴

FIGURE 1 COTTON PRODUCTION



Source: *Agricultural Outlook 2017-2016 database* (<http://stats.oecd.org>)

Cotton is grown in a range of diverse contexts. Many modern practices – like Integrated Pest Management (IPM) – are shared, but the level of organisation and infrastructure affects capacity to implement measures to manage cotton production more responsibly. Practices like IPM and the increased use of non-mineral, soil fertility management strategies (crop rotation, green manuring, compost, etc.) are accepted to enhance productivity, and can be found in both conventional and organic production. Their application has the potential to drive a reduction in insecticide use across all cotton production models.

However, context can aggravate the hazards of pesticide use. It is, therefore, important to recognise that cotton production takes places on farms of different sizes, by farmers with different equipment and levels of training, and on different soils and climates. Cotton is grown in around 80 countries, from tropical to temperate climates, wetlands to drylands, from conflict zones to stable, rich countries. There are mega-farms and micro-plots, almost entirely mechanised farms and farms worked by large family and kinship groups using the humble hand hoe. Globally, many cotton growers (out of perhaps 100 million farmers in total) are smallholders in rain-fed agriculture. But much land is under irrigation which sees higher yields and is more often comprised of large, mechanised farms. Although most cotton is what is known as medium staple (28-32mm long), there is also short and long staple cotton. This complex ecology of production is also changing under pressure from population growth, climate change, rising costs of labour, and competition from other fibres, with cotton’s share of textile demand declining even as production is stable. One common feature of cotton growing is its unpredictability: a long growing season, pests, weather, and price volatility.

Context can have a big impact on which pesticides are used, and how well. While large, mechanised farms can use more pesticides by dint of more spending power, they may be constrained by legislation, as well as health and safety regulations. On the other hand, pesticides use in smallholder contexts in developing countries is harder to regulate, it is harder to train farmers, and there are additional risks of black market, obsolete or fake pesticides being used.

More intensive systems pose additional threats to the diversity of the farm system and environment because of reduced crop or landscape diversity; while smallholder systems see increased problems from poor disposal of empty containers or unused products, or their use on the wrong crops or pests. Overall, pesticides are hard to use safely in smallholder contexts as a rule (even where volumes used are lower), although good support systems can make a difference, as is the case in sustainability standards or with programmes such as FAOs IPPM programmes.

In developing countries, notably in Africa, *'a very high proportion of the products used are acutely toxic to humans, classified by WHO as extremely, highly and moderately hazardous, and the conditions of use are highly unsuitable. Most African farmers and farmworkers do not use adequate, if any, protective clothing or equipment and their exposure to pesticides is therefore higher than in countries with sophisticated application equipment and strict regulations on pesticide handling.'*⁵

Photo: cotton harvester



CONVENTIONAL, IPM, ORGANIC AND GM TRENDS

Efforts to increase sustainability of pest management in cotton production, including the reduction of pesticide use,⁶ are largely based on the application of some form of IPM, which the FAO defines as:

'Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.'^{7,8}

Today, IPM features, in some form or other, in most verified and/or certified cotton labels, standards (organic, Fairtrade, CmiA and BCI) and programmes (such as MyBMP in Australia or ABR in Brazil). It is found from the US to Burkina Faso, Australia to Benin. In theory, IPM works with a toolbox approach. In regards to pesticides, tools include the concept of rational use: that is, they should be used for specific purpose and on a needs basis (costs of economic damage) only. Pesticides should be the last choice, and deployed only when use of alternatives like biological and cultural control, or resistant varieties, have proved unsuccessful.⁹ IPM has to be about more than substituting some pesticides for others, it needs an approach that focuses on the whole production system. Sadly, much of the IPM adopted so far only cherry picks elements of IPM theory, rather than adopts it wholesale.

Photo: Cotton



How does IPM differ from ‘conventional cotton’? There is no formal definition of conventional cotton. People might sometimes call this traditional, normal or mainstream. Conventional cotton might mean cotton grown with a goal of maximising the production of good quality fibre in the most profitable way possible and using inputs and technology towards this goal. However, in many countries conventional cotton is subject to regulations reducing or limiting pesticides or selected chemicals, or even require the use of IPM or Better Management Practices. While not formal sustainability programmes, such approaches can have a significant effect on cotton production and its environmental and/or social impacts. Conventional cotton is thus a treacherous word if applied to mean cotton that is not grown with attention to its environmental impacts.

There are a variety of certified or verified schemes for sustainable cotton as well as national and international programmes. Data for the main standards is summarized in table 2.

TABLE 2

ORGANIC COTTON	Most recent data shows that the volume of organic cotton lint produced in 2014/15 was 112,488 MT. Organic cotton was produced in 19 countries. Five of them represent 92% of cultivation: India (67%) China (12%), Turkey (6%), Kyrgyzstan (5%) and US (2%). In 2014/15 193,840 farmers cultivated organic cotton on 350,033 hectares of land.
CmiA COTTON	In 2016, a total volume of 320,100 MT of CmiA cotton lint was produced in ten African countries by 780,000 farmers on 1,182,000 hectares of land, which was a slight decline on the previous year.
FAIRTRADE COTTON	The cultivation of Fairtrade cotton lint was around 16,640 MT in 2015/16. The cotton was produced by 32,430 farmers on 34,876 hectares in seven different countries. A large percentage of Fairtrade cotton is also certified organic. In 2015, 73% of Fairtrade cotton producers also held organic certification – marking an increase of 8% over the previous year.
BETTER COTTON	Better Cotton represents the largest share of more sustainable cotton. In the 2015/16 season, 2.5 million MT of Better Cotton lint was produced in 23 countries on five continents, including cotton produced under benchmarked standards: 52,000 MT myBMP in Australia, 832,000 MT ABR in Brazil, and 320,100 MT CmiA. Better Cotton was produced by 1.5 million farmers on 3.5 million hectares of land.

Source: Sustainable Cotton Ranking 2017

The Better Cotton Initiative (BCI) is now the largest source of verified cotton, although organic cotton still achieves a higher percentage of cotton traded according to its standards in the market.¹⁰ Sustainable cotton programmes also include national programmes like MyBMP (Australia), ABRAPA in Brazil and partnerships such as Cotton Leads between the US and Australia, which is not a standard but a promotion programme making sustainability claims based on the national regulations in place in both countries.

Organic cotton, the oldest sustainable cotton, has very strict criteria on the use of chemicals, banning the use of so-called synthetic pesticides, although many plant-derived extracts or other chemical preparations are used that are deemed natural and non- or low-toxic. It is regulated by law (agricultural and environmental aspects only) in most countries with voluntary and more comprehensive standards (including social and economic issues) offered by the International Federation of Organic Agriculture Movements (IFOAM). Organic cotton production saw several years of production declines but returned to growth (slowly) from 2014 before a slight drop again in 2014/15. Table 3 shows recent figures.

TABLE 3 REPORTED PRODUCTION AND RETAIL SALES OF ORGANIC COTTON AND TEXTILES

YEAR	PRODUCTION (METRIC TONNES OF COTTON LINT)
2005/6	31,017 (2005/6) later adjusted to 37,799
2006/7	57,931
2007/8	145,872
2008/9	209,598
2009/10	241,698
2010/11	151,079
2011/12	138,819
2012/13	109,826
2013/14	116,974
2014/15	112,488

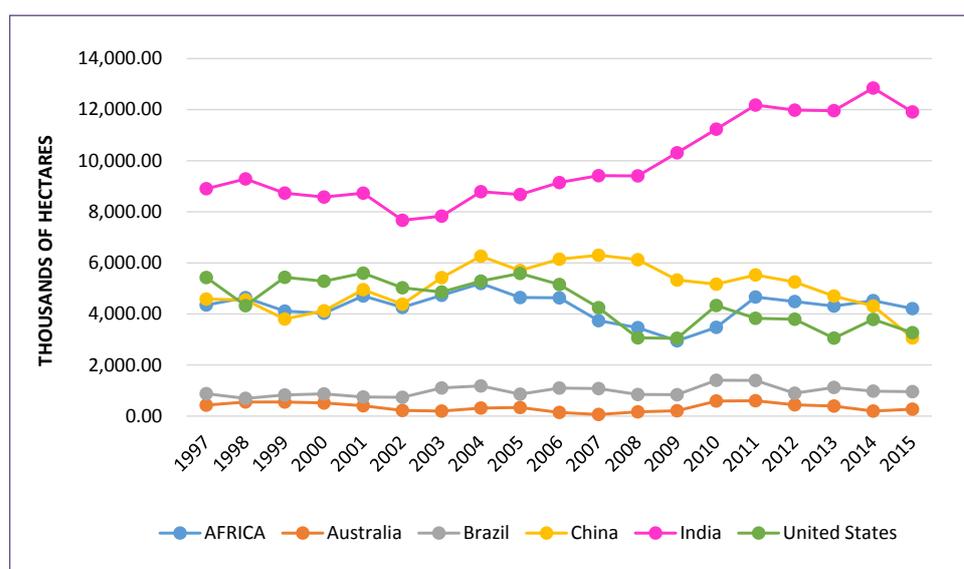
Source: compiled from various Textile Exchange reports. Originally produced for Cotton Horizons (2014) and updated for Solidaridad, WWF and PAN UK (2016)

Fairtrade cotton has also seen decline in recent years, but a new sourcing programme suggests it may turn a corner. Fairtrade cotton standards have environmental requirements including prohibitions on some pesticides and restrictions on others. In 2011/12, production was 50,600 tonnes of seed cotton, and 45,500 tonnes in 2013/14.

Better Cotton is rapidly increasing production, grown in 23 countries it covered some 1.5 million farmers, 3.5 million hectares and produced 2.5 million tonnes of lint (12% of world production), including benchmarked programmes (e.g., Brazil and Australia).¹¹

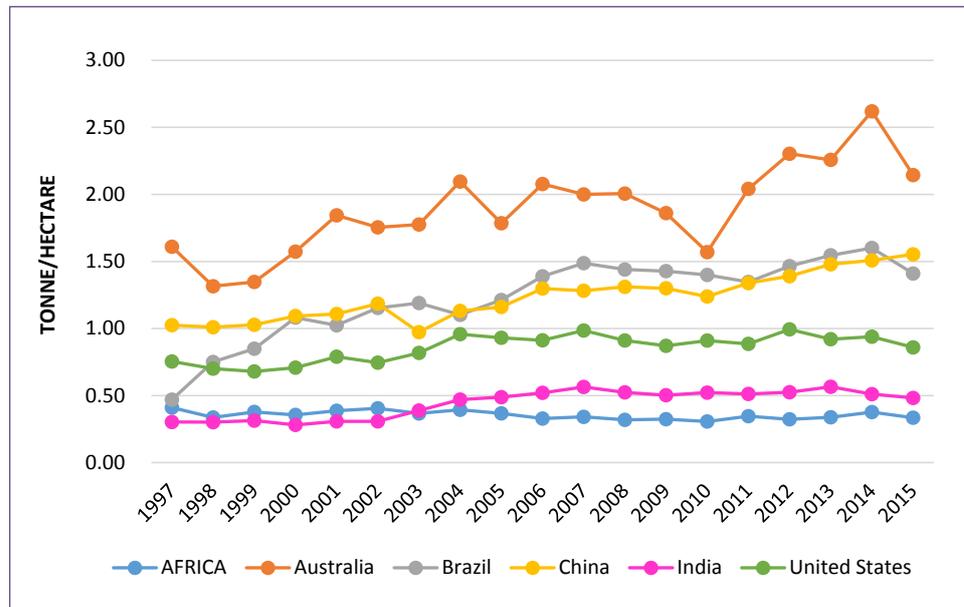
Cotton made in Africa (CmiA) is grown specifically on the continent, by smallholders, and without irrigation only in rain-fed conditions. CmiA production reached 320,100 tonnes in 15/16, from 10 producing countries.¹⁰ Fairtrade, BCI and CmiA all prohibit certain pesticides, including those featured on the Stockholm and Rotterdam Convention lists,¹² and certain others – often the most acutely toxic to humans (WHO classes 1a and 1b).

FIGURE 2 AREA HARVESTED



Source Agricultural Outlook 2017-2016 database (<http://stats.oecd.org>)

FIGURE 3 YIELD



Source Agricultural Outlook 2017-2016 database (<http://stats.oecd.org>)

Bayer's e3 programme, which is available in the US only, is the first standard based, verified, sustainable cotton offered by a pesticide manufacturer. It is a voluntary system, but farmers do sign a 'sustainability agreement' where they commit to optimise soil management and water use as well as the application of pesticides. Worker Health & Safety is also part of the agreement. Bayer offers support, seed and access to information on pesticides (farmers are not obliged to use Bayer's products); however, pesticide use depends on local laws. Some non-chemical approaches are promoted, such as cover crops, trap crops and no-till practices, alongside the use of economic thresholds to support decisions to spray, but compliance with US laws remains the norm.

Another initiative emerging from the US is Cotton Leads. This programme has no criteria, and relies instead on data collected from different programmes and compliance with legislation to make sustainability claims for US and Australian cotton. It is not possible to call this a sustainability mark as such, although it does reflect the regulation and legislation that farmers have to comply with, including pesticides use.

The Social, Environmental and Economic Panel (SEEP) of the International Cotton Advisory Committee (ICAC), has come up with a list of metrics that can be adapted to the many locally specific conditions under which cotton is grown. These are being tested in several countries. The proposed metrics build on tools such as the FAO/WHO Code of Conduct on Pesticide Management, but add ways to measure change. The UN Conventions (Rotterdam and Stockholm) also feed into these metrics, with specific indicators monitoring the implementation and the use of HHPs. Implementation of these metrics on a serious basis could seriously influence the future use and reduction of use of pesticides.

Due diligence guidelines from the OECD on agriculture and textiles may also lead to more pressure on brands to seek out more sustainable cotton, certified, verified or otherwise.



2. Pesticides used in cotton

MARKET TRENDS IN PESTICIDES USE

Globally, the market for all pesticides (not just cotton) grew 9.8% per annum between 2007-2012 (33 million tonnes of active ingredient), the largest share being herbicides (to which many GM crops are now bred to be resistant, including cotton). Next in importance are insecticides, then fungicides. According to the latest figures from the International Cotton Advisory Committee (ICAC) published in 2012, in total, around 5% of pesticides sold are destined for use on cotton, and 14% of insecticides. This data reflects a decline in pesticide use in India, and elsewhere, during the first decade of the 21st century which has not been sustained (see below for more detail). ICAC have provided more up-to-date figures for this study (see box) which points to a levelling off in some pesticide use, notably insecticides, but potentially increases in areas such as herbicides.

Information supplied to this study¹³ by ICAC suggests that pesticides sales worldwide were US\$ US\$58.5 billion in 2014. Cotton was 5.7% of this (by value) in 2014, with insecticides the largest (16.1% of all insecticide sales), far ahead of herbicides (3.9%), growth regulators/ desiccants/defoliants (4%) and fungicides (1%). The peak use of pesticides was in the 1980s, and this is where many commonly used (but wrong or outdated) 'statistics' come from. Back then, figures were cotton accounting for 11% of pesticides use and 22.5% of insecticides.¹⁴

Terry Townsend of ICAC lists reasons for reduction as:

- ◆ Researchers and farmers being better informed
- ◆ The cost of pesticides
- ◆ Better technology for applying pesticides
- ◆ Biotechnology

While the overall use of insecticides declined from 19% in 2000 to 14.8% in 2010, it has increased in India and Pakistan due to pressures from mealybugs and pink bollworm. This has driven an increase in insecticides to 16.1% in 2014.

According to Townsend, cotton typically sees an application of 1 kg/ha of active ingredients, but of course there are variations. He stresses that the amount of pesticides is not an automatic indicator of 'hazard, exposure and risk', as these depend on conditions of use.

ICACs regular surveys of the costs of production of cotton also point to overall reductions in insecticide use: the 2016 survey shows (based on 2015/16 data) that the cost of insecticides per kilo of cotton lint fell from 17 US\$ cents in 2000/1 and 16 in 2012/13 to just 12 in 2015/16. This is explained by a rise in average world yields, but also an overall decline in use (the overall cost of insecticides has risen). While total cotton production costs have risen to US\$1.16/kg in 2015/16, insect control costs are down.

Brazil is also mentioned as distorting global figures, as its climate and pest complex (including the Boll Weevil) leads to a large number of sprays (15 to 40 per year). Without Brazil, cotton is said to account for 4% of global use of pesticides and 10% of insecticides. Brazil has recently claimed that there have been large reductions in pesticides used for cotton, albeit we have not received any evidence backing up this claim in time for this study.¹⁵

In some countries, pesticide use reduction can also be achieved using only Integrated Production and Pest Management (IPPM) and other approaches, as in the cases of Turkey and Mali, with IPPM in Mali leading to a 92% reduction in pesticide use.¹⁶

The decline in insecticides has coincided with the introduction of Genetically-Modified (GM) cotton varieties for insect control. Many of the cotton varieties planted in many cotton growing countries contain a *Bacillus thuringiensis* (*Bt*) gene that encodes the Cry1Ac and Cry2Ab toxins which are toxic to cotton bollworm species on ingestion. Other GM cotton varieties have been modified to be tolerant to over the top (OTT) applications of certain herbicides such as glyphosate. Their cultivation has been associated with a rise, not a decline, in herbicide use.

There is little doubt that the introduction of *Bt* cotton did result in a reduction of insecticide use for the control of cotton bollworms – at least at first – the assertion that it has driven an overall decline in pesticide use is less clear cut. The reason being that populations of sucking pests such as mirids, silverleaf whiteflies, stinkbugs, aphids that are not affected by the toxin in the transgenic cotton crops have increased and farmers have resorted to the use of synthetic insecticides to control these pests. There have been peaks and troughs in pesticide use as the technology has become more widespread, and a global rise in insecticides use in cotton did occur in 2009, followed by a plateau in 2011 and 2012 (the original decline in cotton was from 22.5% in the 1990s, to 16-18% in 2000). There have been big rises in insecticide use in Brazil where GM is in widespread use, while Turkey, which does not allow GM cotton, has low and falling usage.

Recent bollworm development of resistance to *Bt* cotton, as well as the use of herbicide tolerant seeds, have led to renewed insecticide use and increased herbicide use respectively. Secondary pests especially sucking pests are also a problem in most countries using GM cotton (see section 2.2.5). In countries with smallholder production and limited ability for institutions to support resistance management (refugia – providing habitats for non-resistant populations of pests – seed quality control, etc.) the problems will be larger. Concerns exist over resistance management in countries like India, where problems with pink bollworm are occurring. Resistance in *Bt* cotton is much harder to manage in a developing economy where cotton is grown by large numbers of small farmers, and where problems are compounded by fake or illegal seed, re-use of GM seeds and input supply. Here, the risk of a repeat of the old ‘pesticides treadmill’ (where problems with one product are resolved by launching a replacement, with the periods of effectiveness standing still or getting shorter) is great. If the structural causes of rapidly increasing resistance frequencies of bollworms to GM crops are not addressed (farmer capacity, seed and input supply mechanisms, GM resistance training programmes which include GM resistance management refuge system, adoption of integrated pest management (IPM) programmes) then more insecticides can end up being used against bollworms on GM crops.

In 2016, examples from Israel were presented to the Bremen Cotton Conference¹⁷ explaining how up to 16 sprays in the 1980s were reduced with IPM and IRM (Integrated Resistance Management), which also involved avoiding monocropping with cotton. This approach, which was described as the ‘agronomic violation of ecologic balance’, saw sprays reduced to just seven per season between 1986 and 1992.

In some countries surveyed by ICAC, insecticide use is rising again. To counter further rises, suggestions are to reduce pesticide use, hazard, and exposure. For this, continued use of Farmer Field Schools is required along with IPM, on a scale that is large enough to be effective (i.e., where better managed fields do not become refuges for pests from poorly managed ones). However, many still see pesticides as a needed tool, to be managed, rather than an instrument of last resort.

It must also be noted that around 75% of cotton insecticide use is reported to be in just 5 countries¹⁸ (Brazil, India, China, USA, Pakistan), while cotton is still the fourth largest market for agricultural chemicals overall.

In a recent article, Dr Kranthi, Head of ICACs technical section and previously director of the Indian Central Institute for Cotton Research (CICR) notes that these five countries are also seeing pest problems 'brewing up'. The problems are '*boll weevil, cotton bollworm, pink bollworm, whitefly and leaf curl virus*'. With yields stagnating and pesticide use increasing, he warns of a potential serious threat to cotton, not just from pest resistance but also from new pests, herbicide resistance, and disease.

While some countries have the capacity to act quickly, others do not. Even those with capacity have not responded quickly enough to the declining effectiveness of *Bt* cotton, or to the fact that technological responses to pest problems do not last forever: ecosystems respond to change with new pests filling the voids left by those successfully controlled. There is a continued race for technology to stay ahead of nature's speed of adaptation, a race on a knife edge. To be successful, new tools will need to be broader, selective and IPM compatible rather than more GM or more broad-spectrum chemicals, and embrace cottons with different, shorter seasons or other characteristics such as physical and physiologically adaption for pest survival, biological control, and agro-ecological approaches.

The concentration of power among a few companies in the agricultural chemicals and input sector remains a concern, in terms of the supply of inputs such as seeds and pesticides, and increasingly, technology to make use of data. A series of three mega-mergers, (the latest of which is between Monsanto and Bayer, following those of Dow Chemicals and DuPont and ChemChina's purchase of Syngenta) means even greater influence¹⁹ and global monopoly of the chemical market supply and distribution, hence higher cost of pesticides.

Photo: cotton bollworm



PESTICIDE USE BY REGION AND COUNTRY

Africa

Recent data on pesticides use in Africa is not easy to come by, and data may be incomplete as records are likely to be less accurate than in other regions. Africa accounts for 8-9% of the world cotton market, with most growers being smallholders (this is backed by other studies²⁰). Pesticides use in is relatively low on Africa cotton, but even so, cotton is the third major user of pesticides on the continent, after maize and cereals; the pesticides market in Africa breaks down as 65.4% insecticides; herbicides 32.4%; 2.2% fungicides. West Africa – the main cotton-producing region on the continent – makes up 55% of the pesticides market in Africa. The African market for pesticides on crops is worth US\$ 2.1 billion, of which 82% is insecticides and herbicides in 2015. The market prediction is for \$7.5 Billion in 2030, with growth expected to be 8.5% on average for the next 15 years.

In Burkina Faso, 90% of pesticides are used in cotton, with the pesticides market dominated by insecticides (organophosphates: profenophos, chlorpyrifos and pyrethroids: cyfluthrin, cypermethrin, lambda-cyhalothrin) and herbicides (triazines, glyphosate, paraquat). Meanwhile, in Mali, cotton accounts for 44.5% of pesticides sold; again insecticides (52.8%) are most widely used, followed by herbicides (31.7%), then fungicides (10.8%).

Three countries however dominate the market in Africa (by shipment): South Africa, Nigeria and Egypt, with the leading pesticides companies in the market being Syngenta, Bayer, BASF, Dow-Dupont, Adama, Arysta, UPL, Sumitomo, Wynca Chemical.

In Egypt, one of the leading destinations for pesticides shipments, the following products are used (88% of Egypt's use is insecticides).

TABLE 4 EGYPT: HERBICIDES (10%); INSECTICIDE (88%), VALUE 10.6 MILLION US\$ (HIGHLY HAZARDOUS PESTICIDES IN BOLD)

COMPOUND	HERBICIDES	INSECTICIDES	FUNGICIDES	OTHER	TOTAL
Sulphur			1146		1146
Mancozeb			1141		1141
Chlorpyrifos		1089			1089
Thiobencarb	912				912
Malathion		872			872
Glyphosate	526				526
Mineral Oil		463			463
Dimethoate		329			329
Coppers			279		279
Methomyl		229			229
Metalaxyl			140		140
Thiophanate-m			99		99
Methyl Bromide				81	81
Carbendazim			72		72
Aluminum phosphide				69	69
Subtotal	1438	2982	2877	150	7447
Market share (value)	26%	30.3%	39.9%	3.8%	100%

From table 4.3 p33 Agrow leading crop protection compounds in Egypt 2015

There are some 10 million cotton farmers in West Africa, the largest cotton growing region.²¹ Yields in Africa are low compared to the world average, and have been in decline for reasons including the lack of know-how in cotton crop management, extension services, and problems with pest, disease and weed management – in spite of heavy and growing use of pesticides. Stakeholders also report problems including input supply and weak input management infrastructure (e.g., illegal, contaminated and obsolete pesticides, poor regulation). Farmers also struggle to apply pesticides at the correct time and safely.²¹ Attempts to improve and reduce the use of pesticides with many illiterate farmers, such as LEC (Lutte Etagée Ciblée), a threshold spraying technique, have caused their own problems. Growers are not trained in decision making protocols that incorporate pests and beneficial insects (predator to beneficial insect ratios) and the appropriate tools to use to minimize negative impact on beneficial arthropods.

Cotton pesticides are technically regulated and granted approval, sometimes through state bodies, with West African countries often calling for tenders to supply estimated cotton needs each year (this system can be problematic, and could break down in some countries as private suppliers can supply quicker and cheaper generic and ineffective pesticides). Pesticides are commonly distributed by cotton companies and ginners as packages with seeds and fertilisers, on credit against the sale of the crop. In some cases producers' associations are involved in both identifying farmer needs and in selecting pesticides to be imported (e.g., Burkina Faso).²¹

Mali is a case where the national cotton company, CMDT, supply inputs, whereas in Burkina Faso's zoned system the three privatised cotton companies do so, working in coordination with the farmers' union, UNPCB. In East Africa, private cotton companies usually supply inputs, but the governance structure is much weaker than in West Africa, where government regulations underpin pesticide imports and trade, and the cotton sector has governance bodies including cotton companies, farmers, research and government. In these cases and many other countries cotton pesticides are often supplied as a package on credit with seeds and fertilisers.

Cotton also sees a large volume of illegal, counterfeit or obsolete pesticides while the use of cotton pesticides on food crops is common as farmers struggle to get inputs for other crops. The use of cotton pesticides on food crops means doses are incorrect in both cases, while there is little attention to worker or family member safety.

With IPM trained extension services thin on the ground, there is little to help farmers use pesticides more rationally, and the programmes that do exist are small or geographically limited. In general, data is lacking on the impacts of pesticides in Africa, especially from large scale studies.²² However, it is widely accepted that serious problems exist: inappropriate sales, cross-border smuggling, foreign language labels, lack of controls, sold for wrong crops, expired products, wrong dosage recommendations, and ineffective economic thresholds are all widespread. The difficulties of using pesticides in Africa often render the safety measures needed impractical, and have led observers to call for withdrawal of many pesticides²³ and the placing of more emphasis on the adoption of agro-ecological and non-chemical control methods. Settle et al., have shown that it is possible to virtually eliminate insecticide use with the use of IPPM.¹⁶

Historically, pesticides – especially insecticides – used in Africa have been non-selective, with high impacts on non-target species providing essential ecosystem services (bees and natural enemies of pests). Organophosphates were one such group, with acute toxicity to vertebrates and non-vertebrates, suspected carcinogenicity and potential to be endocrine disruptors. Even though Africa has a relatively low use by volume, use of Highly Hazardous Pesticides including WHO classes Ia and Ib – the most acutely toxic – is frequent.

Products widely used in earlier years include alpha-cypermethrin, chlorpyrifos, cypermethrin, deltamethrin, dimethoate, endosulfan, and lambda-cyhalothrin.²⁴ In common with the rest of the global cotton sector, there has been a shift towards more selective, and lower toxicity pesticides, often driven by global bans or demands of sustainability standards. CmiA's prohibited list, for example, removes most Class Ia and Ib not already under PIC and POPs.

In the past seven years there has been some replacement of pesticides, with the introduction of products such as the following due in or after 2011:²¹

- ◆ Thunder 145 O-TEQ (betacyfluthrin + imidacloprid)
- ◆ Sherphos 370 EC (cypermethrin + triazophos10)
- ◆ Tihan 175 O-Teq (flubendiamide + spirotetramate)
- ◆ Emamectin

In Cameroon in 2011, cypermethrin was already being used, along with profenofos and triazophos, while alternatives to endosulfan being introduced there included indoxacarb and emamectin benzoate, also to manage resistance to pyrethroids.²¹

More modern chemicals introduced in LEC programmes, including spinosine, indoxacarb, and acetamiprid.

While a shift to less hazardous pesticides is welcome, it does not address the conditions of use of pesticides on cotton, or their use on other crops. However, there is some evidence to suggest that LEC and other programmes may have improved the handling of pesticides in some situations, but their reach is very limited.²¹

Many problem pesticides – including endosulfan – continue to be used, though in much lower volumes.²⁵ Cypermethrin and acetamiprid remain in use in cotton, according to CmiA, along with other products like Emamectin Benzoate, profenofos, indoxacarb, chlorpyrifos, deltamethrin, dimethoate, 2,4 D, atrazine, paraquat and glyphosate.²⁶ Cypermethrin has also been shown to cause problems along with profenofos and deltamethrin.⁵

Africa has seen a rapid growth in pesticide imports (19% p.a. in the 1990s), faster than agricultural production growth (2.5%), and official figures significantly underestimate use as there is a parallel market in repackaged obsolete or illegal pesticides. Growth is expected to continue, but not at the rapid rates seen so far; one study²⁷ predicts that pesticide use in Sub-Saharan Africa will increase by a factor of between '1.24 to 2.32' (depending on income growth), but will remain low by world standards. However, there is uncertainty between data reported and data the survey found in a household analysis, and exposure risks are high. Better educated farmers however are able to make better decisions about pesticide use. The paper reports that the '*average pesticide application rate in 2015 is approximately 0.11 kgs/ha*' and would reach up to 0.26 in the highest growth scenario by 2040. In cases like Mali, cotton input subsidies also drive increased use (doubled between 1995 and 2001).

West Africa's pesticide registration system (the Comité Sahe'lien des Pesticides (CSP): <http://www.cilss.bf/spip.php?article227>) has improved things somewhat, but it has limited capacity and problems can be increased in countries with the weakest agricultural systems and services. There is little testing of chemicals used.

Australia

The use of insecticides in Australia in terms of grams of active ingredient applied per hectare has shown a downward trend in the last two decades. Despite three peaks in insecticide use during the seasons of 1999, 2005 and 2008 (see graph below), a decrease in use was recorded in six consecutive cotton seasons between 2009 and 2013. Comparing the five year averages for the periods 2008-2013 and 1998-2003, the cotton industry has achieved an 89% reduction in insecticide use.²⁸

The need to reduce pesticide became increasingly apparent following years of overuse of organophosphorus compounds which ultimately resulted in contamination of the north-eastern rivers.²⁹ In the early 1990s, chemical pesticides were the main source of pest control in Australian cotton production and 15 insecticide applications per season using broad spectrum chemicals – including endosulfan and synthetic pyrethroids

– were not uncommon. As a result, bollworm and spider mites developed widespread resistance and overuse was driving outbreaks of secondary pests like whiteflies, mirid bugs and aphids.

Efforts to promote Integrated Pest Management (IPM) in Australian cotton had been underway since the mid-1970s, but uptake was low. The crisis of the 1990s, provided extra momentum and Australian researchers particularly Dr Robert Mensah began to develop new IPM techniques based of supplementary food sprays, beneficial insect refuges within cotton crops, beneficial insect to pest ratio threshold, petroleum spray oils and roll them out among receptive farmers. By 1999, when the sector’s first national IPM guidelines were published, nearly a third of cotton farmers had adopted some form of IPM strategy.

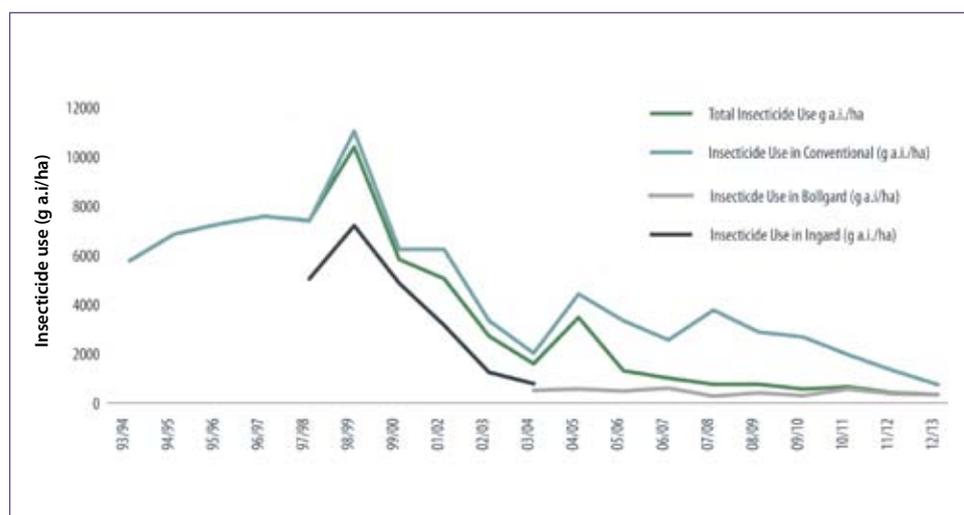
This first flush of enthusiasm for IPM also coincided with the introduction of *Bt* cotton to Australia and has been one of the key factors in Australian cotton growers’ relative success at managing resistance. A key feature of the Australian approach has been rigorous and demanding resistance management strategies. Between 1996 and 2003, *Bt* cotton (Ingard which expressed Cry1Ac toxin) was only allowed to be grown on 30% of cotton to provide a “refuge” for non-resistant bollworms. Compared with 96% permitted in the US.³⁰ In 2004-2005, the Ingard cotton was replaced with Bollgard II cotton, which expresses Cry1Ac and Cry 2Ab toxins for season-long control of *Helicoverpa* spp. The refuge area to be used to manage non-resistant bollworms was reduced to 5% requiring farmers to actively plant and manage pigeon pea or conventional cotton refuges for both non-resistant bollworms and beneficial insects. The Australian attention to Best Management Practices (BMP) allowed it to rigorously enforce refuge requirements and other resistance management practices – and to promote IPM. This was assisted by the unique character of the Australian cotton sector which is made up of a relatively small number of well-educated, agronomically-literate and disciplined growers and agronomists and managers of corporate farms who farm very large areas – often thousands of hectares. In contrast, farmer compliance with resistance management plans is much patchier in other parts of the world.

What is more, effective communication within the Australian Cotton Industry by dedicated researchers, cotton consultants and co-ordination by Cotton Australia’s Cotton Information Team (Extension Officers), allowed the development of a pre-emptive “area-wide” approach to pest and resistance management. Recent research from Australia indicates that co-ordinated action over an area of 10-20km is needed to manage bollworms in transgenic landscapes.³¹ The prevalence of large farms in Australia means that this can often be achieved by co-ordinating with farm agronomists, cotton consultants, researchers and a handful of farmers. Such co-ordination in the smallholder dominated cropping systems that prevail in India, China, and Africa where farms can be smaller than 1 hectare, would require organising many hundreds of farmers – something that would be impossible under current conditions. Having said this, it will be possible to establish an area wide management IPM strategies in countries such as India, China, Pakistan and Africa through continuous training of farmers particularly “lead farmers”.

Prior to the adoption of IPM and transgenic (*Bt*) cotton in Australia, resistance to pyrethroids by cotton bollworms increased to 90 per cent³² while other insecticides like fipronil used to control sucking pests were reported as problematic especially for bees.^{33,34} Synthetic insecticides used in controlling *Helicoverpa* spp. prior to the introduction of transgenic cotton crops inadvertently suppressed green mirid populations in conventional (non-transgenic) cotton crops. But because sucking pests such as mirids, green vegetable bugs and whiteflies are unaffected by *Bt* toxins, the introduction and adoption of transgenic cotton has increased the sizes of populations of sucking pests and driven an increased use of insecticides such as Fipronil and pyriproxyfen. Though not on the scale seen in other regions. The adoption of IPM has helped to prevent secondary pests from becoming a major problem in Australia and cotton growers have managed to keep insecticide use comparatively low, nevertheless, alternative strategies such as biopesticides are needed and are beginning to be rolled out.^{35,36}

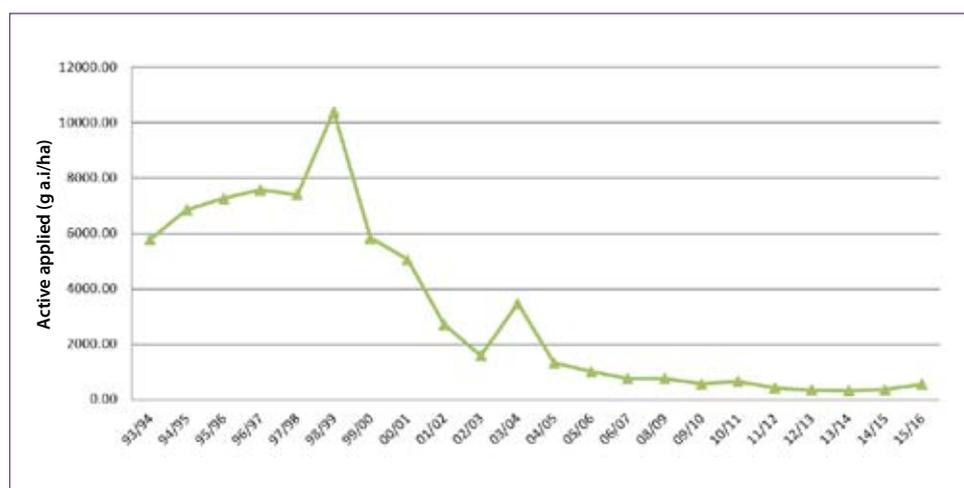
A detailed figure of different insecticides used until 2013 is shown in figure 4 while figure 5 shows the global use of insecticides up to 2016.

FIGURE 4 INSECTICIDE USE UP TO 2013



Source: CCA 2013 – reported in the Australian Grown Cotton Sustainability Report 2014

FIGURE 5 HISTORICAL INSECTICIDE USAGE ON COTTON

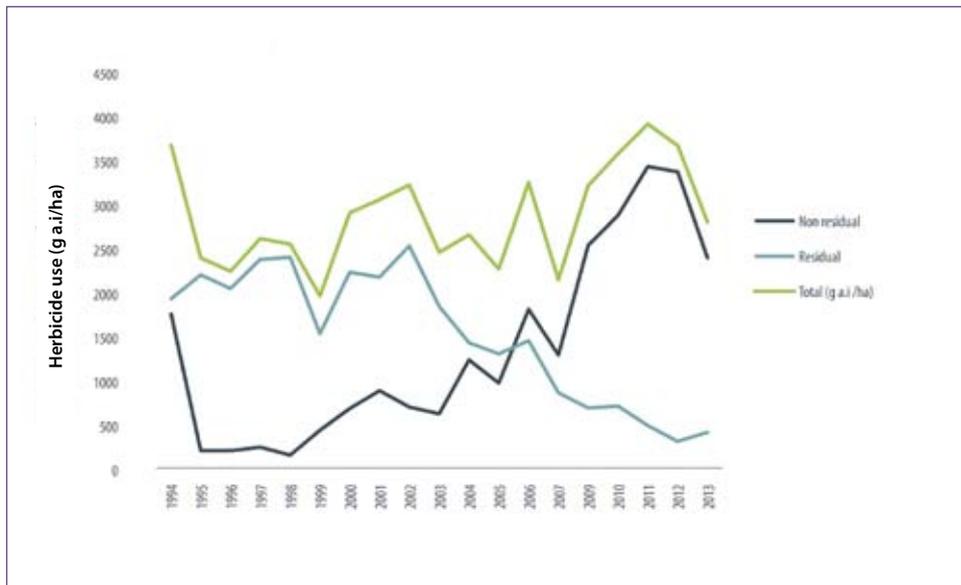


Source: CCA survey

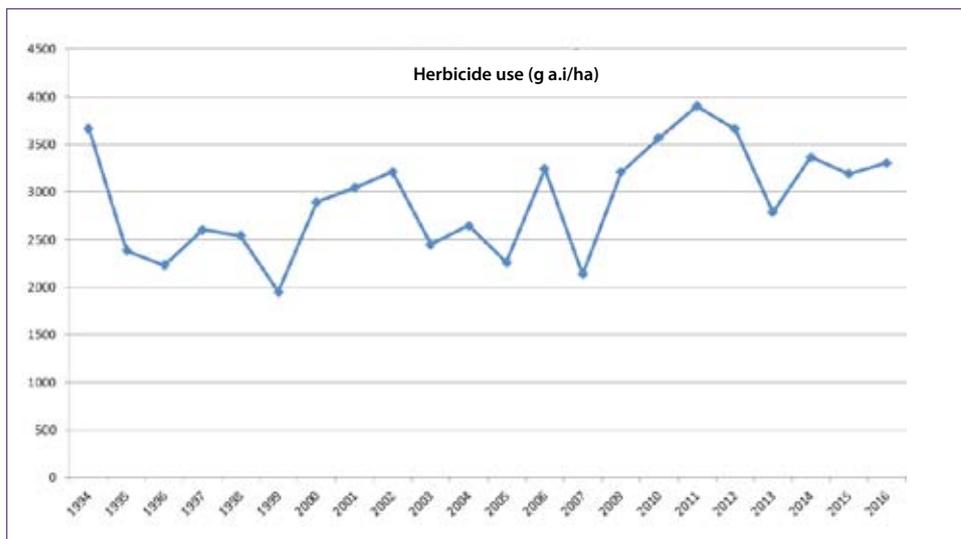
Although this strategy has been successful in the reduction of insecticides, the same cannot be claimed for herbicide use. The quantity of herbicides used in Australian cotton has fluctuated over the two decades, but there has been no dramatic decrease. Cotton Australia claims that the use of very persistent “residual” herbicides such as trifluralin, diuron, fluometuron and prometryn has dropped significantly, as farmers have switched to less persistent “non-residual” herbicides – usually based on glyphosate. This switch corresponds with the introduction of glyphosate-tolerant traits in cotton varieties.

However, defining glyphosate-based herbicides as “non-residual” is contentious. The European Food Safety Authority (EFSA)³⁷ notes that glyphosate persistence in soil ranges from low to very high, and that of its metabolite AMPA as being moderate to very high. Its half-life varies from less than a week to more than a year and a half, depending on the extent of soil binding and microbial breakdown. In addition, because glyphosate has high water solubility, and both it and its metabolite AMPA, are increasingly found in the aquatic environment, effects on aquatic organisms are of growing concern.³⁸

The use of residual and non-residual herbicides up to 2013 is shown in figure 6 and the global use of herbicides up to 2016 in figure 7.

FIGURE 6 USE OF RESIDUAL AND NON-RESIDUAL HERBICIDES UP TO 2013

Source: CCA 2013 – reported in the Australian Grown Cotton Sustainability Report 2014

FIGURE 7 TOTAL USE OF HERBICIDES UP TO 2016

Source: CCA survey

Cotton production in Australia is especially reliant on glyphosate for weed control, with over 90% of the area planted with cotton each year carrying a glyphosate-tolerant trait.³⁹ The chance of weeds developing resistance to this herbicide – either through gene transfer, or simply due to overuse of glyphosate – is a very real risk and the Australian Grains Research and Development Corporation (GRDC) reported that the farming systems with highest risk were summer fallow and both glyphosate-tolerant and conventional non-irrigated cotton.⁴⁰ As a result, Cotton Australia is placing increasing attention on weed management in an attempt to avoid the situation in the US and elsewhere where massive overuse of glyphosate has driven the emergence of herbicide-resistant weeds (see section 2.2.6). A toolkit has already been published by Cottoninfo,⁴¹ but the problem of pesticide use in Australian cotton is not yet solved.

Brazil

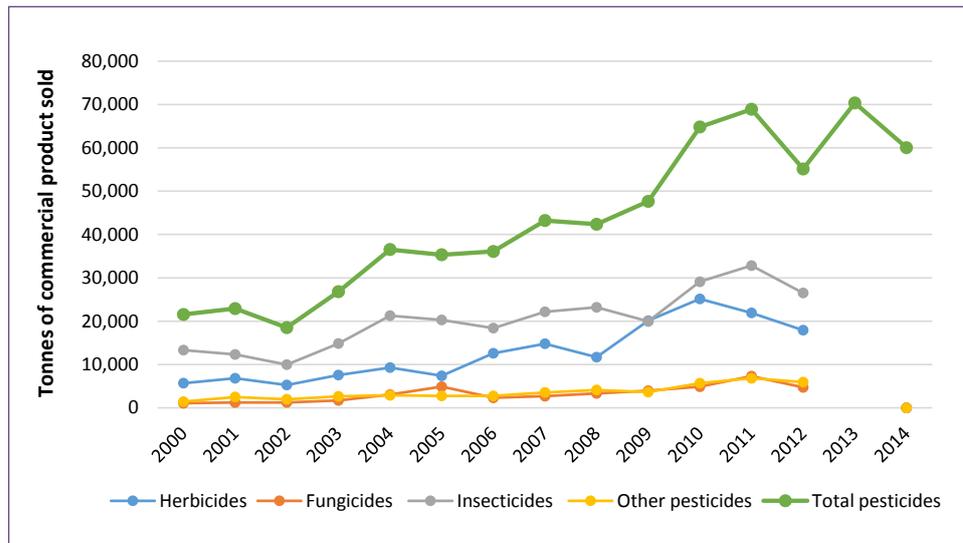
Official data on the use of pesticides on cotton in Brazil is not readily available and, even where data is published, they are not in a format that is easy to analyse (eg in PDF). However, the Group of Engineering of Knowledge (Greco) at the Federal University of Rio de Janeiro (UFRJ) has developed the Open Data Portal on Agrochemicals⁴² to collect and share information on pesticide use to assist researchers and public policy-makers. It compiles data from different institutions including the Ministries of Agriculture, Environment and Health and the Sindiveg (Sindicato Nacional da Indústria de Produtos para Defesa Vegetal).

Thanks to this initiative, data by class of pesticides is available from 2000 to 2012, and on total volume of pesticide sales from 2000 to 2014. Figure 8 shows that the volume of insecticides sold doubled between 2000 and 2012 while the volume of herbicides has tripled. In total, the volume of all pesticides sold for use on cotton crops almost tripled between 2000 and 2014.

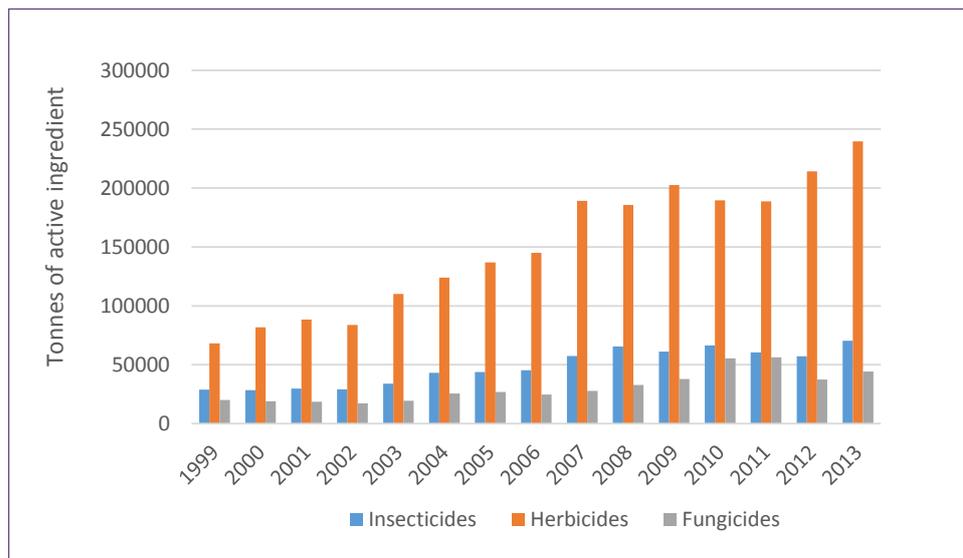
This data reflects a national trend for spiralling pesticide use in Brazil. Between 2001 and 2008, the sales of agrochemicals in Brazil jumped from US \$2 billion to over US \$7 billion, reaching record levels of US \$8.5 billion in 2011. Thus, by 2009, Brazil became the world's largest consumer of agrochemicals, exceeding 1 million tons, or 5.2 kg of agricultural pesticides per inhabitant.

Photo: manual cotton harvesting on a plantation in the municipality of Leme, Sao Paulo, Brazil



FIGURE 8 PESTICIDES IN COTTON - SALES IN BRAZIL

Source: <http://dados.contraosagrototoxicos.org/dataset/comercializacao-sindag> Elaboration by PAN UK

FIGURE 9 TOTAL USE OF PESTICIDES IN BRAZIL

Source <http://www.fao.org/faostat/en/#data> Elaboration PAN UK

And cotton is one of the heaviest users: a study in 2014 measuring the average consumption of pesticides per hectare per crop in the Brazilian state of Mato Grosso during 2012, found that farmers were using 12 litres of pesticides for soy; 6 litres for corn; 4.8 litres for sugarcane; and 24 litres for cotton.⁴³ Data from the most productive municipalities gathered from official sources shows that cotton is the crop with the highest pesticides use with a minimum of 17,5 l/hectare and a maximum of 44,9 l/hectare.

One of the drivers behind cotton's heavy use of pesticides is that most Brazilian cotton areas are tropical zones with heavy pest pressure. Over the years, pesticides have emerged as the first control option. Insecticides are often applied early in the season, killing beneficial insects and disrupting natural control mechanisms. This allows pests like boll weevil and aphids to flourish. The heavy and indiscriminate use of pyrethroids in particular has driven pesticide resistance, encouraging farmers to make more and more applications throughout the season.

The overuse of broad-spectrum insecticides like pyrethroids, has been identified as a problem by the cotton sector itself. Sebastião Barbosa, Director General of Embrapa Cotton-Brazil, has blamed this overload in the tropics for suppressing the “friends of the farmer” beneficial predators and parasites, leading to pest resurgence and secondary pest outbreaks. The financial costs of insecticide strategy used in Brazil are high – agrochemicals account for around 80% of the cost of cultivation in Brazil, some \$2,500 per hectare.

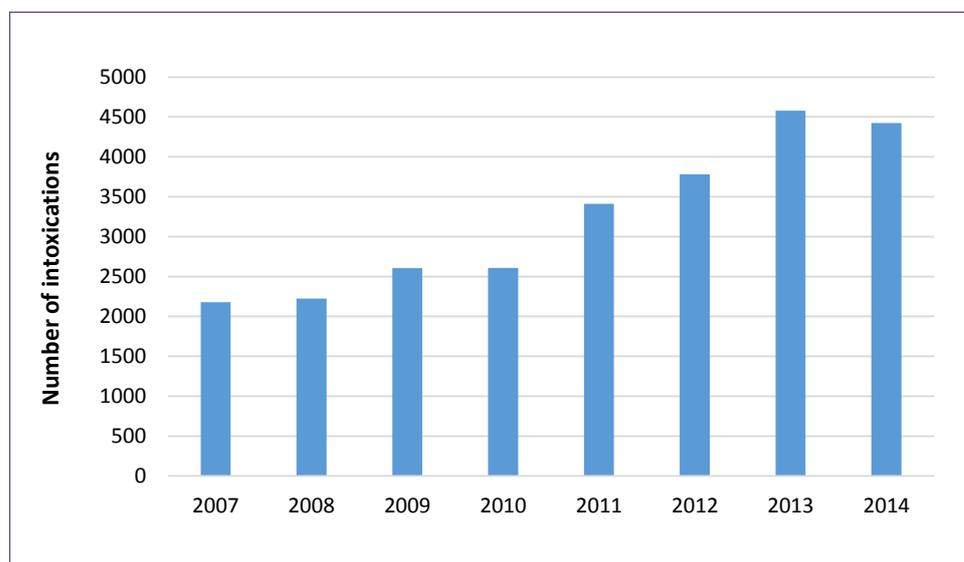
Even though the awareness is rising, there are no signs that the pesticide use in Brazil is likely to fall any time soon. In fact, the opposite is true as problems of resistance have been recorded for pyrethroids, which have been the main tool used to control the boll weevil in cotton growing regions of Brazil, but whose indiscriminate use has led to resistance in other pests.⁴⁴ Also, the emergence of *Helicoverpa armigera* in Brazil will further increase insecticide use because *H. armigera* in Australia has developed resistance to many synthetic insecticides particularly pyrethroids. The pest is highly mobile and has increased resistance frequencies to *Bt* cotton toxins in Australia. Similarly, herbicide resistance is becoming more and more problematic,⁴⁵ so much so that herbicide use now accounts for 45% of the pesticide volumes consumed, followed by fungicides (14%) and insecticides (12 %).

The excessive use of pesticides has prompted the Brazilian National Institute of Cancer (INCA) to raise concerns over the threats this poses to human health.⁴⁶ INCA has blamed the introduction of genetically modified seeds and their diffusion in the agricultural areas as being behind the increase in pesticide use.

A study by scientists of the Centre of health science of the Federal University of Ceará, (Centro de Ciências da Saúde, Universidade Federal do Ceará, Fortaleza, Brasil) concluded that agrochemicals are now an important public health problem in Brazil. They report that between 2007 and 2011, there was a growth of 67.4% in new cases of non-fatal work accidents due to agrochemicals.⁴⁷

The Ministry of Health in Brazil provides data on poisoning incidents through the SINAN (Sistema de Informação de Agravos de Notificação) portal.⁴⁸ However, data on pesticide poisoning in agriculture are only available from 2007 to 2014 and are displayed in figure 10.

FIGURE 10 PESTICIDE POISONING - AGRICULTURAL USE



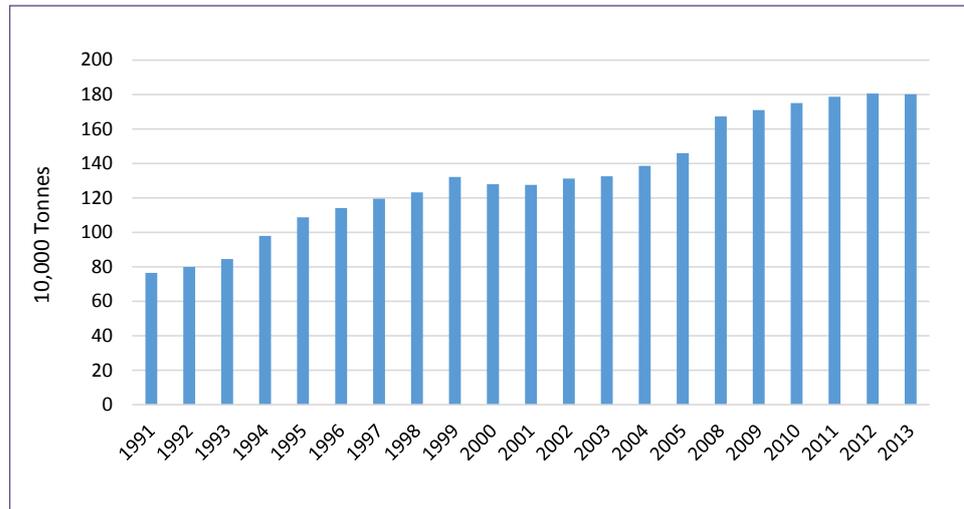
Source: Brazilian Ministry of Health – Sinan portal <http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sinanet/cnv/Intoxbr.def>. Elaboration PAN UK

Even though the intoxications reported are not limited to cotton alone, it is clear that as the volume of pesticides sold rises, the number of pesticide poisoning incidents reported also rises. This suggests that the increased use of pesticides is not accompanied by an increased management capacity and risk awareness.

China

The Ministry of Agriculture of the People's Republic of China conducts regular surveys of pesticide use and publishes the results. However, the data is not disaggregated by class, nor by crop, nevertheless, it is possible to see that between 1991 and 2013 the total use of agrochemicals in China for crop protection has more than doubled.

FIGURE 11 PESTICIDES USED IN CHINA



Source: China Agricultural Yearbook 2014 <http://english.agri.gov.cn/service/ayb/index.htm>. Elaboration PAN UK

Numerous studies point to the misuse of pesticides as a problem in the country.^{49,50} Poor farmer training is often singled out as a significant driver of misuse and farmers commonly exceed the suggested pesticide dosage just “to make sure”, while others underuse pesticides.⁵¹ Overuse and underuse are two faces of the same coin: both can result in insecticide resistance. This is the result of a lack of knowledge and information, and poor agricultural extension services. Ineffective control of pests such as bollworms and sucking pests can cause pests with high resistance frequencies to spread and move across farm field boundaries, pushing neighbouring farmers to increase their pesticide use to achieve effective control, which also increases resistance levels of these pests. Increased use of insecticides even low doses of pesticides can be sufficient to kill beneficial organisms and natural enemies and can promote pest resistance.

Bt Cotton was introduced in China in the late 1990s and, in common with the experience in India and elsewhere, the initial results were positive. Yields initially increased and insecticide applications decreased, but within a few years these gains had been reversed. One study in four Chinese counties found that insecticide use dropped dramatically in the first few years after farmers started to grow *Bt* cotton and delivered greater profits.⁵² But within two to three few years, farmers were spraying just as much as their conventional neighbours to control secondary pests. Within seven years, populations of secondary pests had increased to such an extent that farmers were spraying as many as 20 times in a season. With *Bt* seed costing three times the price of conventional seeds, these farmers were worse off than before and so re-use *Bt* cotton seeds exposing the technology to high levels of resistance to the *Bt* toxins.

A survey of 1,000 randomly selected farm households, in five Chinese provinces, revealed the perception among farmers of a substantial increase in secondary pests after the introduction of *Bt* cotton.⁵³ In all five provinces, the number of pesticide applications was higher on GM cotton than in conventional cotton. In general, farmers stated that *Bt* cotton brought bollworm under control, but the majority of those surveyed reported that secondary pests had increased since the start of *Bt* cotton cultivation, leading them to use an increased amount of pesticides.

Another more recent study, claims that despite the widespread adoption of *Bt* cotton, Chinese farmers still spray excessive amounts of pesticide on their cotton fields. The authors blame the high use on poor quality seeds with low expression of *Bt* toxin which does not offer adequate control of bollworms and prompts an overuse of pesticides.⁵⁴ The re-use of *Bt* cotton seeds, coupled with poor resistance management strategies means that bollworm and pink bollworm are less and less susceptible to the *Bt* toxin expressed by GM cotton. This overuse of pesticides in cotton and the resulting resistance in pests has been reported in several scientific papers.^{55,56,57,58,59}

Secondary pests are also a problem: Field trials conducted over 10 years in northern China show that mirid bugs (Heteroptera: Miridae) have progressively increased population sizes and acquired pest status in cotton and multiple other crops, in association with a regional increase in *Bt* cotton adoption.⁶⁰ Aphids are also a problem, which has driven a rise in neonicotinoid use threatening animals beneficial to agroecosystems such as arthropods, bees, and birds.⁶¹

Photo: cotton picking cotton planting base, Jiangxi, China



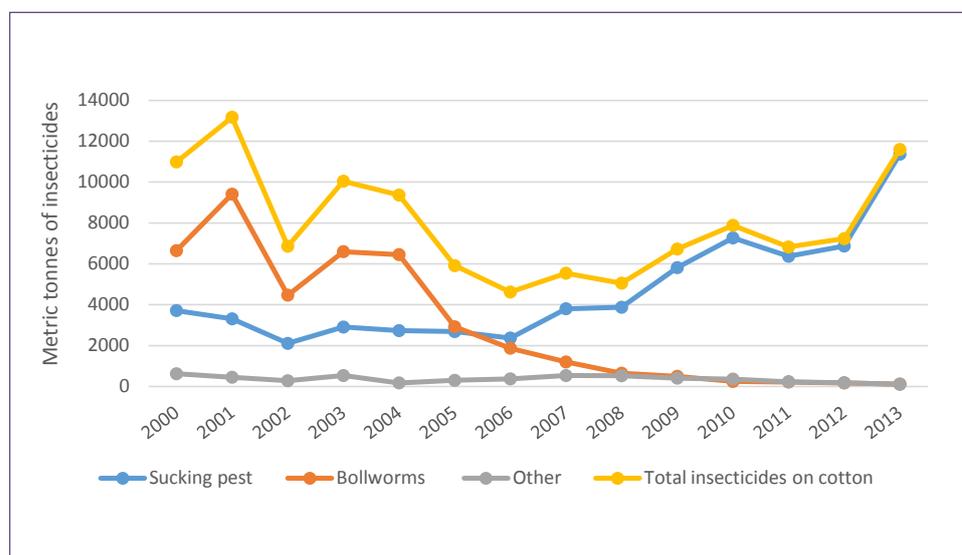
India

In 2002, India introduced *Bt* cotton. At the time of introduction, bollworms were the main cotton pests and accounted for over 90% of insecticide use. Between 2000 and 2006, insecticide use fell from 1.0-1.2 kg/ha to 0.5 kg/ha.

However, this decline was short-lived. Many of the hybrid (GM) varieties proved particularly vulnerable to sucking insects, like whiteflies, thrips and leaf hoppers. These pests, which had caused minimal damage prior to 2002, began to cause significant problems and insecticide usage on sucking pests rose steeply between 2006 and 2013 as the area under sucking pest-susceptible hybrids grew.

More than 1,000 new cotton hybrids were introduced after 2006 and the area cultivated with *Bt* cotton increased from about 45% in 2006 to 95% in 2013. Infestation by sap-sucking insect pests advanced unchecked and, by 2013, insecticide usage had bloomed to 11,598 M tonnes (0.9 kg/ha).⁶²

FIGURE 12 INSECTICIDES IN COTTON - INDIA



Source "Cotton Production Systems - Need for a Change in India" Dr. K.R. Kranthi Cotton statistic and news. No. 38 16th December, 2014 Cotton Association of India. Elaboration PAN UK

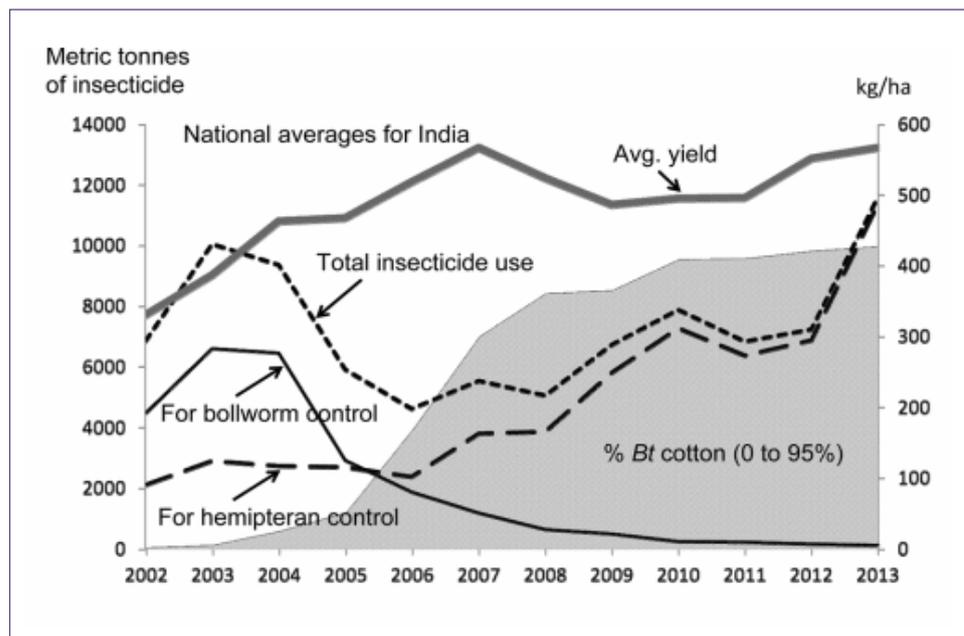
Far from solving the problem of sucking pest infestation, the indiscriminate and uncontrolled use of insecticides only made the situation worse. Studies conducted by ICAR-CICR suggest that almost all of these insect pests have developed resistance to the insecticides that were approved over a decade ago and some to the newer neonicotinoid group of pesticides. This has driven farmers to use more and more insecticides to try and keep on top of the problem.

Indian cotton farmers are now using nearly 1.0 kg per hectare of insecticides solely for the control of sap-sucking insect pests in *Bt* cotton. This is almost the same amount as was being used prior to the introduction of *Bt* cotton in 2002, when more than 90% of insecticide usage was for bollworm control.

Resistance is also a growing problem in the pests that *Bt* cotton was designed to control. Until 2015, *Bt* cotton appeared to be largely effective in keeping cotton bollworms in check, but in the past few years, the insects have become increasingly resistant and farmers have resorted to pyrethroid sprays to control them.⁶³ A second generation of hybrid *Bt* cotton – Bollgard II – was introduced to address this problem, but Pink Bollworm *Pectinophora gossypiella* has now developed resistance to this variety.

This has led some to predict that insecticides in cotton may reach an unprecedented 2.0 kg per hectare with the next few years. The Indian Agrochemical Industry, is also banking on a growth in use: ‘*The Indian crop protection market is dominated by Insecticides, which form almost 60% of domestic crop protection chemicals market. The major applications are found in rice and cotton crops. In order to increase yield and ensure food security for its enormous population agrochemicals penetration in India is bound to go up.*’⁶⁴

FIGURE 13 TRENDS FOR COTTON YIELD, PESTICIDE USE AND PERCENTAGE OF TOTAL COTTON-GROWING AREA PLANTED WITH *Bt* COTTON.



Source: K. Kranthi elaboration Gutierrez et al.^{65,66,67}

What is more, it’s not just insecticide use that is on the up in Indian cotton. A report commissioned in 2016 by the Indian Ministry of Agriculture, Department of Agriculture and Cooperation (Crop Division) concludes that “usage of fungicide and herbicide in cotton has also shown increasing trend since 2002-03 and one of the reasons for this increase may be due to area expansion under *Bt* Cotton”.⁶⁸ The authors of the study complain about a lack of data on crop specific pesticides.

The greatest irony is that *Bt* cotton has had little impact on cotton productivity in India (see figure 13), perhaps because many of the currently cultivated hybrids are designed to perform best under high input conditions of fertilizers and pesticides. To complicate the problem, poor quality seed and counterfeit (mostly generic) pesticides have also affected yields. Manufactured illicitly and given names that sometimes resemble the original products, counterfeits account for up to 30 percent of the \$4 billion pesticide market, according to a government-endorsed study.⁶⁹ The reliance on chemical control is proving ineffective and yields have stagnated and are likely to decline further due to sucking pests.⁷⁰

This situation has placed a heavy economic burden on resource-poor cotton growing farmers.⁷¹ *Bt* cotton seed is more expensive than the non-*Bt* varieties it replaced, but this cost is no longer offset by reductions in pesticide costs. A recent study has linked the growing use of insecticides on *Bt* cotton to an increase of farmer suicides and economic distress has been identified as leading cause of suicide. The study points to increasing insecticide use, and expensive *Bt* seed as driving up farmer costs and links yield losses to ecological disruption by induced pests and ill adapted and possibly ineffective *Bt* varieties.⁷²

Currently, a total of 65 chemicals have been approved as pesticides for use on cotton in India by the Central Insecticide Board (CIB). Among them 18 are linked to human cancer as listed by many global authorities such as the WHO (World Health Organization), IARC (International Agency for Research on Cancer) and US-EPA (United States Environmental Protection Agency) and at least seven belong to the WHO Class-1a or 1b category of extremely or highly hazardous pesticides. In small scale cotton production systems, it is very common for farmers to use the cheapest of available insecticides for pest control. Many of the cheaper insecticides either belong to WHO Class 1 (extremely or highly hazardous) or are linked to carcinogenicity.⁷³ India still permits the use of monocrotophos, a pesticide blamed for the death of 23 children in Bihar in 2013 after they ate contaminated free school lunches. That tragedy prompted the Food and Agriculture Organization (FAO) of the United Nations to advise developing countries to phase out such chemicals.⁷⁶

Turkey

Cotton growing in Turkey supports around 300,000 farmers, many of whom are smallholders, on farms of five hectares or less, but there are some larger farms. According to FAO and USDA FAS, cotton's share of GDP is around 4%.⁷⁴

In the current season (2017/18) Turkey is forecast to produce 820,000 tonnes of cotton on 460,000 hectares of land. Turkey also grows organic and BCI cotton, with organic cotton at 12,000 tonnes of lint in 2016/17 and 15,000 in 2017/18. The country produced 23,000 tonnes of Better Cotton in 2015, and is expected to produce some 32,500 tonnes in 2016/17, and perhaps 40,000 in 2017/18.⁷⁵

Turkish production in recent years has rebounded from a low of 440,000 tonnes in 2008/9, which was caused by low cotton prices, attractive alternative crop markets and global conditions. Organic cotton has mirrored the sector here.

Turkey has diverged from other major cotton producers in rejecting GM cotton and focussing its attention on IPM. In that time, its yields have soared to some 1,700 kg/ha (yields have doubled since the 1980s), and grown faster than the world average. Turkish yields are now more or less double the world average and comparable to the best global producers.

Turkish cotton production has modernised in recent years, but still has a mix of small and larger farmers. Production has shifted from the Aegean region towards south-eastern Anatolia. This is due to a rise in production costs as well as to the opportunities farmers have in other crops. There is strong control on seed quality.

Exact volumes of pesticides used in cotton in recent years are not known, but total pesticide use for the country remains quite stable, albeit insecticides are increasing as a share of the total. Total use hovered around 39,000 tonnes a year between 2013 and 2015, with insecticides growing from 8,500 (2013) through 9,000 (2014) to 9,600 (2015) (FAOStat). Pesticide use is broken down as 47% Insecticides, 24% herbicides, 16% fungicides, and 13% for others. In 2003 a total of 33,000 tonnes of pesticides were used. In cotton, in the same period, pesticides use was 5-6,000 tonnes, or 15-18% of the total, with insecticides the largest group. A more recent total pesticide use figures from a different source (the Turkish Ministry of Food, Agriculture and Livestock) show a total pesticide usage of 50,000 tonnes in 2016, of which 10,000 were insecticides, 10,000 herbicides and 20,000 fungicides. Total pesticide use in Turkey in agriculture amounts to 1.2 kg/ha, but in cotton in 2009 it was only 0.6 kg/ha on average.⁷⁶

Insecticide use in Turkey is low while productivity is high, and insecticide costs are proportionately low. Insecticides cost an average \$134 per hectare. Turkey supports training on reduced production cost techniques as well as on IPM and optimal use of inputs (Yucer & Sarsu 2010). When ICACs SEEP panel commissioned a study on pesticides, Turkey had the lowest use of extremely hazardous pesticides in the SEEP study (de Blecourt et al., 2010).

The development of varieties resistant to disease and the push for certified seed have helped reduce pesticide use, including a 17% lower insecticide use rate.

In 2005, the most commonly applied pesticides in Turkey were diafenthiuron (Polo 50, II), carbosulfan (Marshall 25 EC, II), lambda cyhalothrin (Karate, II), chlorfluazuron (Atabron, U), thiodicarb (Larvin, II), nissorin, (n.l.), acetamiprid (Mosphilan, n.l.), Endosulfan (Thiodon, II), and imidacloprid (Gaucho, II). Popular herbicides are linuron (Match, U), trifluralin, (U), fluzafob butyl, (n.l.), and prometryne (U) (ICAC, 2005). In general no defoliant are used. There are no Class I pesticides.

The trade in pesticides involves of cooperatives, private sellers, and government agencies. The principal organisation in the sector is the Ministry of Food, Agriculture and Livestock, which coordinates research and sets national strategy through its General Directorate of Agricultural Research and Policy, (GDARP). The Turkish Scientific and Technical Research Council, the Scientific Research Project Coordination Department of Universities, and the private sector are also all heavily involved in cotton research. There are also research institutes, notably the Cotton Research Station at Nazilli. There is also a Seed Certification and Approving Center where varieties are trialled.

Fertilisers and pesticides are supplied from a variety of sources including private sellers, producer unions and cooperatives. Private companies include giants such as Bayer, Dow and Sumitomo as well as Turkish companies.

Extension advice can come via leaflets, demonstrations, field days, the internet, TV and trade fairs. The Directorate of Agriculture (in provinces) organises this under the control of the Ministry of Agriculture, but universities also do extension through farmer meetings, trainings and media. They also organise demonstration plots. The Ministry of Agriculture also organises research and training on different topics related to agronomy, including input use, and IPM.

Photo: ripening cotton boll

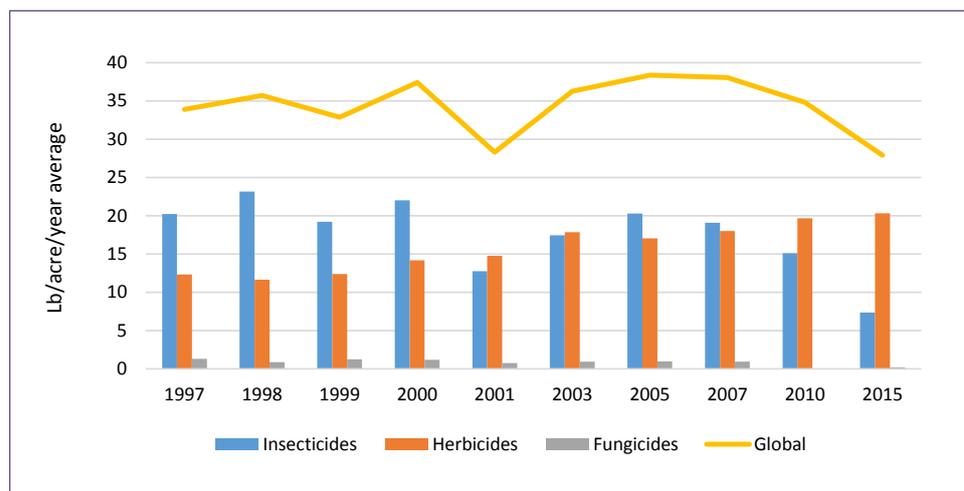


United States

The U.S. Department of Agriculture (USDA), through the National Agricultural Statistics Service (NASS), has collected comprehensive pesticide use data for major crops since 1990. The NASS surveys collect data in states that collectively account for at least 85 % of the area planted nationally. It is worth noting that the NASS estimates of total pesticide use on surveyed acres of a given crop typically underestimate total national crop use by about 15 %, because the national area planted always exceeds the NASS area surveyed. Another consideration is that in the last three surveys (2007 – 2010 and 2015) in some instances, data for single pesticides has been “Withheld to avoid disclosing data for individual operations”(code (D)). Prior to 2007, data were reported for every single pesticide listed, but since then information is only available for some active ingredients only. In NASS reports pesticide use for Upland cotton only not including Pima cotton.⁷⁷

According to Cotton Inc., growers in the United States make 50% fewer pesticide applications than the generation before them.⁷⁸ We have been unable to derive independent data for the frequency of treatment, but data from the USDA for the total quantity of pesticide used by acre shows that while insecticide use has fallen by 64% and fungicide use by 84%, herbicide use has increased by 65%. As a result total pesticide use has shown a modest decline of 18% in almost two decades, with a fluctuating trend showing unpredictable positive and negative peaks (figure 14). The reduction of insecticide use and the growth of herbicide use are backed up by other studies.^{79,80}

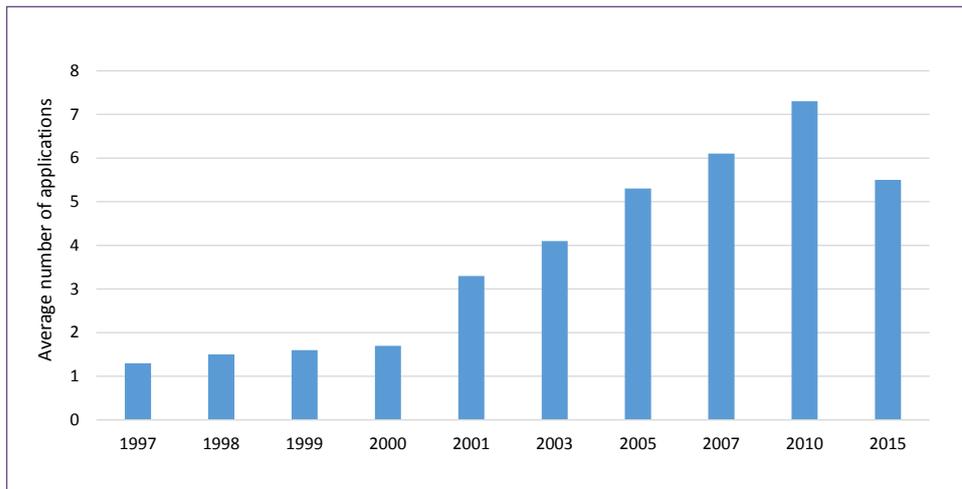
FIGURE 14 US COTTON - PESTICIDE APPLICATIONS LB/ACRE



Source: USDA National Agriculture Statistical Service (NASS) <https://quickstats.nass.usda.gov>
Elaboration PAN UK

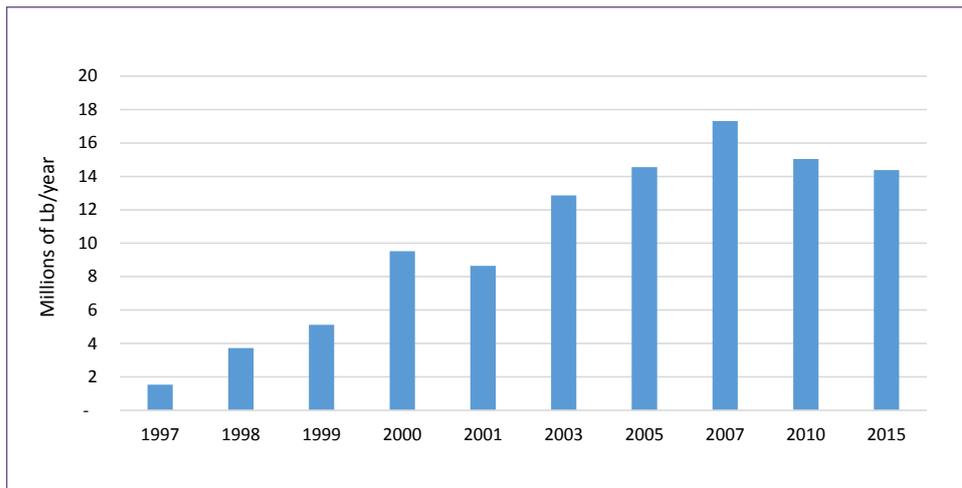
In particular, glyphosate applications and quantity/acre have steeply increased. The NASS collects data on the total number of applications or quantity of five different types of glyphosate⁸¹ and the data reported here are the sum across the five forms of glyphosate. The Agricultural Chemical Usage 2007 Field Crops Summary⁸² reports that herbicides were applied to 97 % of the Program States' cotton planted acreage in 2007 and that, glyphosate isopropylamine salt was the most commonly applied herbicide being used on 85% of the planted acreage.

FIGURE 15 US COTTON - AVERAGE NUMBER OF GLYPHOSATE APPLICATIONS PER YEAR



Source: USDA National Agriculture Statistical Service (NASS) <https://quickstats.nass.usda.gov>
Elaboration PAN UK

FIGURE 16 US COTTON - AVERAGE AMOUNT GLYPHOSATE APPLICATIONS PER YEAR LB/ACRE



Source: USDA National Agriculture Statistical Service (NASS) <https://quickstats.nass.usda.gov>
Elaboration PAN UK

This trend contradicts the often-repeated claims that today's genetically-engineered crops have significantly reduced – and still are reducing – pesticide use. Looking at data we can see that in 1997 the total amount of pesticides used was around 34 lb/acre and had decreased to around 29 lb/acre in 2015 (18%). Again, the decrease hasn't been linear and shows a fluctuating trend making future forecasts difficult. As reported by Benbrook⁸³ in 2012, the spread of glyphosate-resistant weeds in herbicide-tolerant weed management systems has driven an increase in the number and volume of herbicides applied. The consistency of growth in herbicide use on herbicide-tolerant crops debunks the asserted reduction in pesticide use on GM crops over the past 16 years, and the common forecast is that it will continue for the future.⁸⁴

The substantial increase in glyphosate use, which represents the 54% of all herbicides applied on cotton,⁸⁷ is linked to the uptake of herbicide tolerant GM cotton. For a few years after the introduction of GM herbicide-tolerant crops a limited number of glyphosate applications were effective at controlling weeds and were economic. As a result, the area treated with glyphosate rose rapidly, but over time, this triggered the emergence of weeds less sensitive or resistant to glyphosate.⁸⁵ Since the initial report of a glyphosate-resistant weed (rigid ryegrass in Australia) in 1996, a total of 24 glyphosate-resistant species have been reported around the world, and 14 of these are present in the United States.⁸⁶

The problem of resistance is not restricted to weeds, but also involves insects. GM crops expressing insecticidal toxins *Bt* appear to have contributed to pest and insecticide reduction.⁸⁷ However, the build-up of resistance in pests undermines their long-term prospects for insect control.⁸⁸ Resistance has long been recognised as an issue and the US Environmental Protection Agency (EPA) has included resistance management requirements in *Bt* cotton registration since 1996.⁸⁹ But these requirements will only delay, not prevent, resistance and in future, the *Bt* toxin on its own will not be enough to control pests, despite the ongoing research to insert multiple genes with different modes of action into cotton varieties. In addition an impending resistance issue to neonicotinoids has been recently reported⁹⁰ and it is likely that insecticide use will soon be on the rise unless comprehensive IPM systems, based on agroecological principles, are adopted.

Photo: cotton flower



WIDELY USED PESTICIDES

Chemical Families and Pesticide Groups

The FAO/WHO International Code of Conduct on Pesticides Management, defines a pesticide as ‘any substance of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth.’ A tailored chemical or biological compound is produced aiming to control a particular type of pest from a particular environment. Pesticides are designed to kill or harm certain unwanted organisms (e.g. by disturbing their reproduction) and, unlike other industrial chemicals, are deliberately released into the environment for this purpose. Such is the variety of pests, diseases, weeds and cropping environments, that over one thousand different chemicals, belonging to numerous different chemical families, have been deployed as pesticides. The agrochemical industry continues to search for new and more effective pesticides to deal with the rising problem of specific pests and diseases, or weeds developing resistance to some frequently used compounds and to market products with less harmful human or environmental health profiles.

TABLE 5 EXAMPLES OF DIFFERENT CHEMICAL FAMILIES AMONG INSECTICIDE AND FUNGICIDE GROUPS (PESTICIDES QUALIFYING AS PAN HHPs SHOWN IN RED)

CHEMICAL NAME	CHEMICAL FAMILY	PESTICIDE GROUP
DDT	Organochlorine (OC)	Insecticide
Endosulfan		
Chlorpyrifos	Organophosphate (OP)	Insecticide
Monocrotophos		
Profenofos		
Fenobucarb	Carbamate	Insecticide
Carbosulfan		
Imidacloprid	Neonicotinoid	Insecticide
Thiametoxam		
Cypermethrin	Pyrethroids	Insecticide
Deltamethrin		
λ -Cyhalothrin		
Epoxiconazole	Triazole	Fungicide
Azoxystrobin	Strobilurin	

There are three main primary pesticide groups: insecticides (targeting insect and other arthropod pests); fungicides (substances that target fungal diseases of crop plants) and herbicides (targeting unwanted plants, i.e. weeds).

Broad- and Narrow-Spectrum pesticides

Ideally, a pesticide would act only on the specific target, unwanted organism, without risk or harm to non-target animals (including humans), microbes or plants. Most pesticides, however, can affect a fairly broad range of organisms, i.e. they are non-selective in their action. Most of the older generation insecticides can kill or harm a broad spectrum of insects and arthropods, including beneficial ones such as honey bees. Organophosphate and carbamate insecticides are very broad-spectrum

Pesticides can be classified as systemic or non-systemic: **systemic pesticides** are taken up by the plant's system, absorbed and transported to the roots, stem, leaves, flowers, fruits, and possibly surviving into the developing seeds. Glyphosate is an example of a broad-spectrum and a systemic herbicide. **Non-systemic pesticides** remain on the plant parts targeted by the application (e.g. foliar spray, root drench) and can, in theory, be 'washed off/away' at any time, as well as being more vulnerable to breakdown by UV light, water, heat and microbial action than compounds protected within plant tissue.

Pesticides used in cotton

Although many pesticides are still used on cotton, we focused on the most used active ingredients. The list is the result of a recent survey conducted by the ICAC Technical Information Section. The survey covered the 30 major cotton growing countries.

The most used active ingredients are mainly insecticides, and cover several pesticides groups (see table 6, white columns are insecticides, grey column are herbicides). The pesticides in bold pesticides are not included in the PAN list of Highly Hazardous Pesticides (HHPs).

TABLE 6 WIDELY USED PESTICIDES IN COTTON

INSECTICIDES				HERBICIDES
ORGANOPHOSPHATE	PYRETHROIDS	NEONICOTINOIDS	ORGANOCHLORINE	
Acephate	Cypermethrin	Imidacloprid	NOT WIDELY, BUT STILL USED	Glyphosate
Chlorpyrifos	Deltamethrin	Thiamethoxam		2,4 D
Monocrotophos	λ-Cyhalothrin	Acetamiprid	Endosulfan	
Profenofos				

Source: personal communication with ICAC

Photo: mixing pesticides



WHAT ARE HIGHLY HAZARDOUS PESTICIDES (HHPs)?

The FAO defines HHPs as ‘pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or GHS or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous’. It encourages countries to adopt measures – including progressive banning of HHPs – to control these pesticides.⁹¹

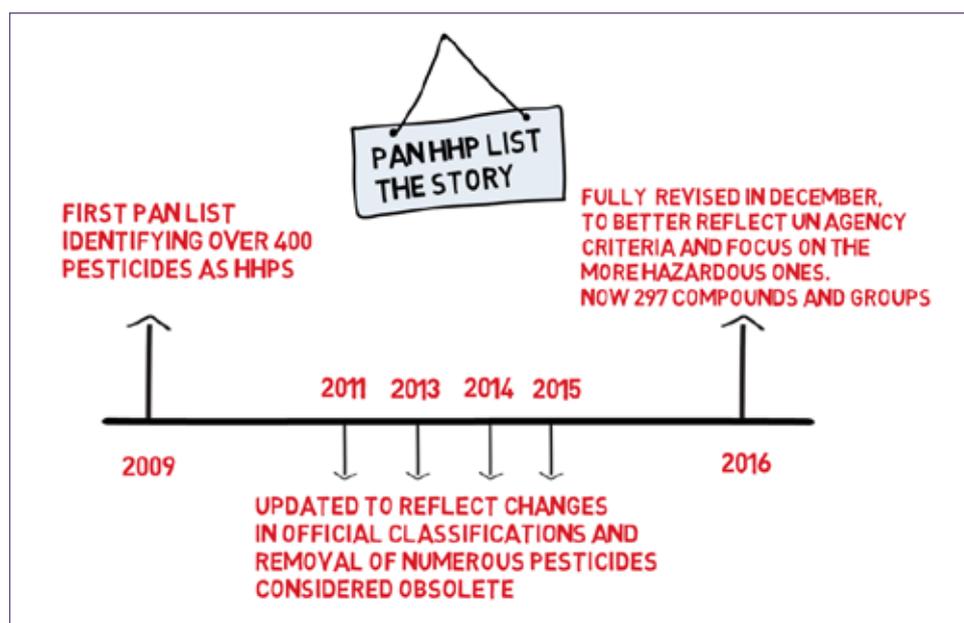
In October 2007, the FAO/WHO Joint Meeting on Pesticide Management (JMPM) outlined criteria to identify highly hazardous pesticides (HHPs) as follows:

- ◆ classes Ia or Ib of the WHO Recommended Classification of Pesticides by Hazard;⁹²
- ◆ carcinogenicity Categories 1A and 1B of the GHS;⁹³
- ◆ mutagenicity Categories 1A and 1B of the GHS;
- ◆ reproductive toxicity Categories 1A and 1B of GHS;
- ◆ pesticides and formulations listed by the Stockholm Convention (POP list);⁹⁴
- ◆ pesticides and formulations listed by the Rotterdam Convention (PIC list);⁹⁵
- ◆ pesticides listed under the Montreal Protocol;⁹⁶
- ◆ pesticides and formulations that have shown a high incidence of severe or irreversible adverse effects on human health or the environment.

PAN International strongly welcomed the approach, but felt that the agreed HHP criteria had some important shortcomings: in particular, pesticides with endocrine disrupting properties, eco-toxicological properties, or inhalation toxicity have not been taken into account.

PAN International in 2009 decided to independently develop a definition of HHPs with a more comprehensive set of hazard criteria, used by recognised authorities, such as the EU and the US Environmental Protection Agency (EPA), and to develop a list of HHP⁹⁷ pesticide active ingredients based on these criteria.

FIGURE 17 BIRTH AND EVOLUTION OF THE PAN INTERNATIONAL HHPs LIST



HHP profile of widely used pesticides

Table 7 matches the profile of some of the pesticides that are widely used in cotton against the PAN HHPs list criteria. All of them are insecticides, except from glyphosate, which is an herbicide.

TABLE 7 CHARACTERIZATION OF THE WIDELY USED PESTICIDES IN COTTON

PESTICIDE	INTERNATIONAL CONVENTIONS		ACUTE TOXICITY		LONG TERM EFFECTS		ENVIRONMENTAL TOXICITY
	PIC*	POP**	WHO 1b Highly hazardous	H330 Fatal if inhaled	IARC probably carcinogenic	Endocrine disruptor	Highly toxic bees
Acephate							✓
Chlorpyrifos							✓
Cypermethrin							✓
Deltamethrin						✓	✓
Endosulfan	✓	✓		✓			
Glyphosate					✓		
Imidacloprid							✓
Lambda-cyhalothrin				✓		✓	✓
Monocrotophos	✓		✓	✓			✓
Profenofos							✓
Thiamethoxam							✓

The profile of each widely used pesticide is listed here below.

💧 **Acephate**

Type of pesticide: organophosphate insecticide

Mode of action: Broad-spectrum, contact and ingestion systemic action. When insects ingest acephate, they can turn it into methamidophos.

Target pests: used normally as a foliar spray to control chewing and sucking insects. Effective against: Aphids; Leaf miners; Lepidopterous larvae; Sawflies; Thrips

Chemical/physical properties: is volatile and highly soluble in water and most organic solvents. It is not expected to leach to groundwater. Whilst it is mobile, it tends not to be persistent in soil or aquatic systems.⁹⁸

Harmful effects: Acephate can cause cholinesterase inhibition in humans; it means that it can overstimulate the nervous system causing nausea, dizziness, confusion, and at very high exposures (e.g., accidents or major spills) respiratory paralysis and death.⁹⁹ People exposed to acephate report also diarrhoea, abdominal cramps, shaking, sweating and rapid heart rate, and it's also a recognised irritant. Symptoms usually begin quickly after exposure (minutes to hours).

Environmental impacts: It has a low potential for bioaccumulation. It has a moderate to low toxicity to birds, earthworms and most aquatic organisms. Being a broad-spectrum insecticide it is highly toxic to bees and other beneficial insects.¹⁰⁰

💧 Acetamiprid

Type of pesticide: Neonicotinoid insecticide

Mode of action: Systemic (the active ingredient is taken up by plant roots and transported to the growing points, where it can affect plant-feeding pests) with translaminar activity (the insecticide can penetrate leaf tissues and form a reservoir of active ingredient within the leaf) having both contact and stomach action.¹⁰¹ The insecticidal action is due to activation of nicotinic acetylcholine receptors, which means that it can interfere with the normal nervous system stimulation.

Target pests: Ground and aerial application against Aphids; Thrips; Mirids; Spider mites; Whiteflies¹⁰²

Chemical/physical properties: It is highly soluble in water and is volatile. It is not expected to leach to groundwater. It is not persistent in soil systems but could be very persistent in aquatic systems under certain conditions.

Harmful effects: It has a moderate mammalian toxicity and it has a high potential for bioaccumulation. Mild to moderate poisoning can cause eye irritation, nausea, vomiting, diarrhoea, abdominal pain, dizziness, headache, and mild sedation.¹⁰³ Acetamiprid may adversely affect the development of neurons and brain structures associated with learning and memory functions.¹⁰⁴

Environmental impacts: It is highly toxic to birds and earthworms and moderately toxic to most aquatic organisms. It is toxic for bees, even if less toxic compared to other neonicotinoids.¹⁰⁵

💧 Chlorpyrifos

Type of pesticide: organophosphate insecticide and acaricide

Mode of action: It is a Cholinesterase Inhibitor; it works blocking an enzyme which controls messages that travel between nerve cells. Depending on the length of time and amount exposed to, can cause severe nervous system damage.¹⁰⁶

Target pests: used to control soil and foliage pests, such as Scale; Woolly aphid; Leaf roller; Caterpillars; Flies

Chemical/physical properties: It has a low aqueous solubility, is quite volatile and is non-mobile. There is a low risk of leaching to groundwater based on its chemical properties. It can be moderately persistent in soil systems but is not usually persistent in water systems.¹⁰⁷

Harmful effects: It is highly toxic to mammals, a skin and eye irritant, is classified as a reproduction toxicant, an acetyl cholinesterase inhibitor and a neurotoxicant.¹⁰⁸ Inhalation or ingestion of chlorpyrifos will affect the nervous system and cause, depending on the dose and length of exposure, a broad range of effects from headaches to unconsciousness.¹⁰⁹

Environmental impacts: Chlorpyrifos enters the environment through direct application on crops and clings to soil. It is highly toxic to birds, fish, aquatic invertebrates and honey bees, and moderately toxic to aquatic plants, albae and earthworms.

💧 Cypermethrin

Type of pesticide: synthetic pyrethroid insecticide

Mode of action: it has contact and ingestion non-systemic action. It works by altering nerve function, which causes paralysis in target insect pests, eventually resulting in death.¹¹⁰

Target pests: used to control a broad spectrum of pests: Aphid vectors of BYDV; Summer aphids; Weevils; Caterpillars¹¹¹

Chemical/physical properties: It has a low aqueous solubility and is volatile. It has been detected in groundwater and it is considered a serious marine pollutant. It is moderately persistent in soils but is likely to degrade moderately fast in water systems under daylight conditions.

Harmful effects: it is an eye, skin and respiratory tract irritant. The US EPA has classified it as a possible human carcinogen¹¹²

Environmental impacts: It is highly toxic to most aquatic species and honeybees. It is moderately toxic to earthworms but there is little risk to birds.

◆ Deltamethrin

Type of pesticide: pyrethroid insecticide and veterinary treatment

Mode of action: it has contact and ingestion non-systemic action. It works by altering nerve function, which causes paralysis in target insect pests, eventually resulting in death

Target pests: used against Cockroaches; Spiders; Ants; Fleas; Silverfish; Bed bugs; Bird mites; Mosquitoes; House flies; beetles

Chemical/physical properties: It has a low aqueous solubility, is semi-volatile and has a low potential to leach to groundwater. It is not persistent in soil and is non-mobile.¹¹³

Harmful effects: highly toxic to humans and other mammals. It is a neurotoxin. It can be mildly irritating to the eyes.¹¹⁴ The acute effects of deltamethrin exposure on humans include convulsions, ataxia, dermatitis, diarrhoea, tremors, and vomiting. Allergic reactions to the compound through skin exposure are also common among agricultural workers.¹¹⁵ Potential endocrine disruptor.¹¹⁶

Environmental impacts: It is relatively non-toxic to birds and earthworms although it presents a high risk to most aquatic organisms and honeybees..

◆ Endosulfan

Type of pesticide: organochlorine insecticide and acaricide

Mode of action: endosulfan is a central nervous system stimulant. It antagonizes the action of the neurotransmitter (GABA), which leads to a state of uncontrolled neuronal excitation. Insects are exposed on contact or through stomach action, and hyper-excitation and paralysis lead to death.¹¹⁷

Target pests: Whiteflies; Aphids; Leafhoppers; Colorado beetle; Ticks; Mites¹¹⁸

Chemical/physical properties: According to the risk profile on endosulfan, adopted by the POPRC, endosulfan is persistent in the atmosphere, sediments and water. Endosulfan bioaccumulates and has the potential for long-range transport. It has been detected in air, sediments, water and in living organisms in remote areas, such as the Arctic, that are distant from areas of intensive use.¹¹⁹

Harmful effects: Because of its toxicity endosulfan has been listed under the Rotterdam Convention¹²⁰ and under the Stockholm Convention.¹⁰³ Endosulfan, classified as fatal if inhaled by the GHS, can be absorbed following ingestion, inhalation, skin contact or via the transplacental route. The clinical symptoms of poisoning include: vomiting, agitation, convulsions, cyanosis, dyspnoea, foaming at the mouth and noisy breathing.¹²¹ In severe causes poisoning may lead to coma, respiratory depression and even to death. Long term exposure has been linked with damage to kidneys, liver and the developing foetus.¹²² All over the world dozens of poisoning cases have been reported, including deaths.¹²³

Environmental impacts: It is moderately toxic to birds, honeybees and earthworms. It is known to be harmful to fish and other aquatic organisms.

◆ Glyphosate

Type of pesticide: broad spectrum, non-selective herbicide

Mode of action: The herbicidal action of glyphosate is primarily due to its capacity to block the production of essential amino acids in plants and some micro-organisms through a pathway called “shikimate”, which is present only in plants.

Target pests: Annual and perennial weeds, Broad-leaved weeds, Grasses.¹²⁴ It is sprayed on numerous crops and plantations, including about 80% of genetically modified (GM) crops (canola, corn, cotton, soybean, sugar beet)

Chemical/physical properties: glyphosate has high water solubility, and both it and its metabolite AMPA are increasingly found in the aquatic environment. Glyphosate persistence in soil can be low to very high, and that of its metabolite AMPA can be moderate to very high, depending on the extent of soil binding and microbial breakdown.¹²⁵

Harmful effects: Acute effects of glyphosate observed in laboratory include breathing difficulties, ataxia, and convulsions. It’s an eye and skin irritant. Long term exposure can lead to kidney and liver damage and it has been classified by IARC as probably carcinogenic to humans.¹²⁶ Genotoxic effects and interaction with hormones have been reported, as well as reproductive, developmental, immune and neurological effects.¹²⁷

Environmental impacts: because of its high water solubility effects on aquatic organisms are of growing concern. It has a big impact on natural aquatic communities, microorganisms and invertebrates. Developmental effects have been reported in amphibians and molluscs as long as detrimental effects on fish. It can affect soil micro-organisms, earthworms, birds, bees and plants.

Photo: spraying young cotton plants



💧 Imidacloprid

Type of pesticide: Neonicotinoid insecticide

Mode of action: It is a systemic insecticide that translocates rapidly through plant tissues following application. It is effective by contact or ingestion. The insecticidal action is due to activation of nicotinic acetylcholine receptors, which means that it can interfere with the normal nervous system stimulation.¹²⁸

Target pests: sucking insects, chewing insects. Plant hoppers, Aphids, Termites, Colorado beetle, Fleas, White grubs¹²⁹

Chemical/physical properties: highly soluble, non-volatile, persistent in soil. It is moderately mobile.

Harmful effects: Farm workers reported skin or eye irritation, dizziness, breathlessness, confusion, or vomiting after exposure.¹³⁰ No chronic effects for humans have been reported.

Environmental impacts: It is highly toxic to birds and honeybees. Moderately toxic to mammals and earthworms. It is non-toxic to fish.

💧 Lambda cyhalothrin

Type of pesticide: synthetic pyrethroid insecticide

Mode of action: it has a non-systemic, contact and stomach action. By disrupting the nervous system of insects, it may cause paralysis or death. Temperature influences insect paralysis and the toxicity of lambda cyhalothrin.¹³¹

Target pests: Aphids; Thrips; Colorado beetles; Caterpillars; Mosquitoes; Ticks; Flies

Chemical/physical properties: It has a low aqueous solubility, is relatively volatile, is non mobile and, based on chemical properties, there is a low risk of it leaching to ground water. It is persistent in soil.¹³²

Harmful effects: it has high acute mammalian toxicity. It is a respiratory and eye irritant, and a skin sensitiser. It can disrupt nervous system function. Lambda-cyhalothrin has significant adverse effects on blood parameters and on liver, lungs, kidneys and heart. Classified as endocrine disruptor and can present reproductive toxicity. In vivo and in vitro studies reported induction of oxidative stress.¹³³ Evidence of neurological detrimental effects have been reported.¹³⁴

Environmental impacts: it presents potential risks to beneficial insects, mammals, amphibians, aquatic invertebrates and freshwater and marine fish.¹³⁵ Highly toxic to honeybees and moderately toxic to earthworms.

💧 Monocrotophos

Type of pesticide: organophosphate insecticide

Mode of action: Broad spectrum, systemic with stomach and contact action. It is a Cholinesterase Inhibitor; it works blocking an enzyme which controls messages that travel between nerve cells.

Target pests: sucking and chewing pests typically on cotton, citrus and other crops. Aphids; Common mites; Ticks; Spiders; Caterpillars.¹³⁶

Chemical/physical properties: High solubility in water, low volatility. Moderately persistent in soil, persistent in water.

Harmful effects: because of its acute hazard classification and concern as to its impact on human health under conditions of use in developing countries it has been listed under the Rotterdam Convention.¹³⁷ It is classified as WHO 1b (highly hazardous) and fatal if inhaled (GHS H330). Symptoms of poisoning include excess salivation and lachrymation, tremors, convulsions, and miosis. In vitro tests showed that monocrotophos and its formulations had weak mutagenic potential.

Environmental impacts: highly toxic to birds and mammals, moderately toxic to fish, slightly toxic to aquatic invertebrate and earthworms, very toxic to bees.

💧 Profenofos

Type of pesticide: organophosphate insecticide and acaricide

Mode of action: Broad spectrum, systemic with stomach and contact action. It is a Cholinesterase Inhibitor; it works blocking an enzyme which controls messages that travel between nerve cells.¹³⁸

Target pests: used to control Aphids; Lygus bugs; Cotton bollworm; Tobacco bud worm; Leaf webber; Cotton leaf-perforator; Beet armyworm; Whitefly (suppression); Spidermites; Caterpillars

Chemical/physical properties: It has a low aqueous solubility, is relatively volatile, slightly mobile and presents low risk of it leaching to ground water. Not persistent in soil.

Harmful effects: Profenofos can cause cholinesterase inhibition in humans; it means that it can stimulate the nervous system causing nausea, dizziness, confusion, and at very high exposures (e.g., accidents or major spills), respiratory paralysis and death. Chronic effects in humans have not been reported.¹³⁹

Environmental impacts: moderately toxic for mammals, highly toxic for birds, fish and crustaceans. Moderately toxic for aquatic invertebrates. Very highly toxic for bees.¹⁴⁰

💧 Thiamethoxam

Type of pesticide: broad range neonicotinoid insecticide

Mode of action: It is a systemic insecticide effective by contact or ingestion. The insecticidal action is due to activation of nicotinic acetylcholine receptors, which means that it can interfere with the normal nervous system stimulation.

Target pests: Aphids; Whiteflies; Thrips; Lacewings; Leafhoppers; Mealybugs; Wireworms; Ground beetles¹⁴¹

Chemical/physical properties: High solubility in water, low volatility. It can leach in soil and it is moderately persistent.

Harmful effects: Occupational exposure to thiamethoxam may occur through inhalation and dermal contact. Mild to moderate poisoning can cause eye irritation, nausea, vomiting, diarrhea, abdominal pain, dizziness, headache, and mild sedation.¹⁴²

Environmental impacts: It presents moderate toxicity for mammals and birds and low toxicity for fish, aquatic invertebrates, aquatic plants and earthworms. Highly toxic for bees.¹⁴³

💧 2,4-D

Type of pesticide: selective systemic herbicide

Mode of action: 2,4-D kills plants changing plant cells characteristics. The effect of these changes is to cause cells to divide and the plant to grow uncontrollably. The end result is that the tissues of the plant are damaged and death occurs. 2,4-D is known from its use as a compound (together with 2,4,5-T) of Agent Orange in the Vietnam War.

Target pests: Broad-leaved weeds, Evasive weeds in aquatic situations. It's applied on GM herbicide tolerant crops¹⁴⁴

Chemical/physical properties: It is highly soluble in water, volatile and has a low potential to leach to groundwater. It's weakly absorbed by soil particles and it can therefore contaminate surface and groundwater. It is non-persistent in soil but may persist in aquatic systems under certain conditions.

Harmful effects: poisoning incidents describe the most common symptoms as irritation, inflammation, and itching of eyes and skin, nausea, vomiting, throat irritation, headache, dizziness, coughing, and difficulty breathing.¹⁴⁵ It is not classifiable as a human carcinogen, but it presents some evidences of mutagenicity. In 2000, the European Union classified 2,4-D as a potential endocrine disruptor based on results derived from in vitro experiments.¹⁴⁶ It can affect the central nervous system, liver and kidneys. It may have negative effects on reproduction, development and is considered to be a neurotoxin.¹⁴⁷

Environmental impacts: It is moderately toxic to birds and most aquatic species as well as honeybees and earthworms.

Photo: cotton harvester dumps the product from a truck on a farm, Sao Paulo, Brazil





3. Health impacts of Pesticides

The FAO/WHO International Code of Conduct on Pesticide Management defines a pesticide as ‘any substance or mixture of substances of chemical or biological ingredients, intended for repelling, destroying or controlling any pest, or regulating plant growth.’¹⁴⁸

When we talk about ‘pesticides’ we refer to more than 1,000 active ingredients. The properties that make them efficient killers of pests can make them hazardous for humans too, because many pests have biological systems similar to ours.

This phenomenon is particularly associated with insecticides, many of which are designed to interfere with biological systems common throughout much of the animal kingdom, such as the nervous and reproductive systems. Indeed, of the over 300 agrochemicals classified by the WHO as being either ‘Extremely’, ‘Highly’ or ‘Moderately’ hazardous, around 50% of them are insecticides.¹⁴⁹

Many organisms cannot break down, or metabolise, pesticides into less harmful substances. Instead, some of these chemicals can remain present in organisms, water and soils for many years.

TOXICITY AND EXPOSURE

Pesticides can be absorbed by ingestion, inhalation and through the skin. Exposure to pesticides can occur at any stage from manufacture and packaging of the pesticide to distribution, storage, use and disposal.

The toxicity of a pesticide is its capacity to cause injury or illness. The toxicity of a particular pesticide is measured by subjecting test animals to varying dosages of the active ingredient and its formulated products. In some cases, other chemicals mixed with the active ingredient for formulating the pesticide product may affect the toxicity.

Acute toxicity occurs over a short time period. It refers to an incident where exposure to a substance causes harmful or lethal effects following oral or dermal exposure to a single dose, or to a multiple dose in a short space of time (24 hours), or an inhalation exposure of 4 hours. Acute effects can be delayed by up to four weeks and can include cramping in the lower limbs that leads to lack of coordination and paralysis. Improvement may occur over months or years, but some residual impairment may remain.

Symptoms of poisoning develop in close relation to the exposure. The extent of acute poisoning symptoms depends both on the toxicity of the product and on the quantity absorbed. Acute toxicity can result in a range of health impacts, ranging from headaches, dizziness, rashes, gastrointestinal disturbance, lesions, neurological symptoms, convulsions, loss of consciousness and, in extreme cases, can result in death.

Long term (or chronic) toxicity occurs when a substance causes harmful effects over an extended period, usually following repeated or continuous exposure. This is commonly associated with occupational exposure or living / working in close proximity to areas where pesticides are used.

Assessing the chronic toxicity of pesticides is more difficult, the effects may only be discovered years after the exposure. And difficult to trace back to a specific incident or groups of incidents. Victims can gradually become ill over a period of months or years. Over time, the poison can accumulate in the body, or cumulative damage can become significant enough to cause clinical symptoms. They can include impaired memory and concentration, disorientation, severe depressions, severe, irreversible or even lethal harm such as cancers, foetal abnormality, infertility, developmental effects, endocrine disruption. Some symptoms may only appear later in life, or even in the next generation. These include learning difficulties, behavioural and reproductive defects (e.g. accelerated puberty, infertility), and increased susceptibility to cancer. Other long-term effects include teratogenesis (inducing embryo malformation) and DNA mutations (inducing genetic or chromosomal mutations).

Long term toxicity has been considered by US, EU and other international bodies and many of these factors are included in the globally harmonised system of classification.¹⁵⁰

HOW BIG A PROBLEM IS PESTICIDES POISONING?

According to the World Health Organisation 'Poisoning is a significant global public health problem.' In 2012, WHO estimated that 193,460 people died worldwide from unintentional chemical (including pesticide) poisoning and that most of these exposures were preventable. Of these deaths, 84% occurred in low and middle-income countries. WHO estimates that in the same year, unintentional poisoning caused the loss of over 10.7 million years of healthy life (disability adjusted life years, DALYs).¹⁵¹ Unfortunately, the proportion of incidents attributable to pesticides is not known. However, WHO report that the estimated annual illness costs of acute poisonings in Nepalese farmers due to pesticide use was nearly one third of total annual healthcare costs. In Parana, Brazil, for each dollar spent on pesticides, approximately US\$1.28 may be spent on healthcare and sick leave due to occupational poisoning.

These figures, however alarming, do not capture the full extent of the problem. Many studies have shown that pesticide poisoning is significantly under-reported. In Central America, for example, the Pan American Health Organization (PAHO) undertook a study in six Central American countries which found that only between 1% and 20% of the cases of acute pesticide poisoning are officially reported.¹⁵² Recent studies in Eastern Europe and the Caucasus also indicated that few incidents reach health services or other authorities.¹⁵³ PAN UK's own surveys of cotton farming communities in Africa and Central Asia (Mali, Mali, Senegal, Tanzania, Benin, Ethiopia and Kyrgyzstan) have found pesticide poisoning rates among cotton farmers of 25-57%.

Photo: farmer spraying cotton field in Greece



SYSTEMATIC REVIEW OF SCIENTIFIC STUDIES ON THE EFFECTS ON HUMAN HEALTH RELATED TO PESTICIDES USED IN COTTON

Aims and Objectives

With the help of researchers at Barts and The London School of Medicine, Queen Mary, University of London, we conducted a systematic review of the scientific literature to evaluate and compare findings on the association between pesticide use cotton production and health effects. The review examined all papers published in peer-reviewed scientific journals from 31st December 1999 to 1st June 2017.

Inclusion/ exclusion criteria

Inclusion criteria

Studies that investigate the association between cotton crops and health outcomes included:

- ◆ Can address both conventional and GM farming methods
- ◆ Study reporting use of at least one pesticide (or pesticides in general) and at least one health-related outcome
- ◆ Articles in English
- ◆ Articles published after 31st December 1999

Exclusion criteria

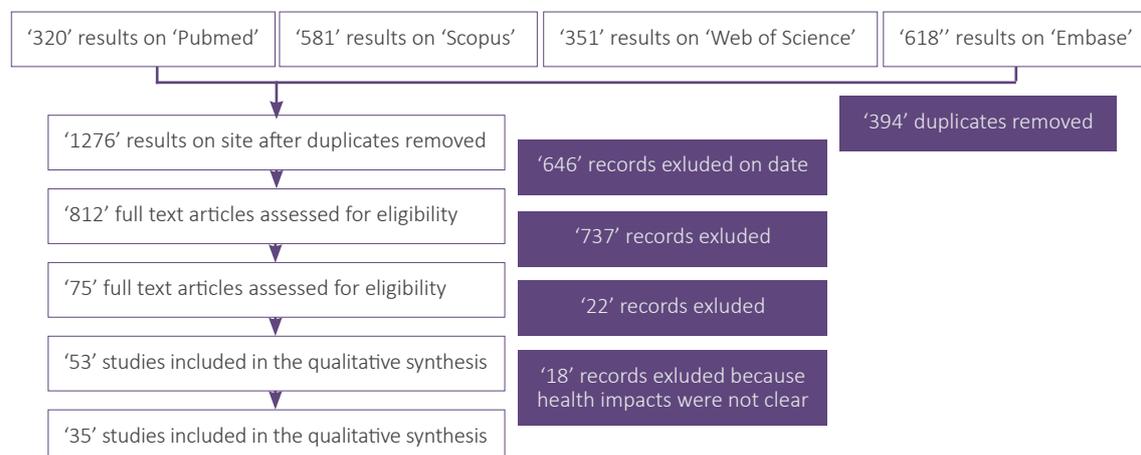
Studies were excluded if:

- ◆ Articles don't look at a health outcome in relation to the pesticide/herbicide/insecticide/fungicide used on the crops
- ◆ Studies not able to distinguish between cotton and other crops
- ◆ Studies that are not carried out in humans (wild life health effects)
- ◆ Articles published on or before 31st December 1999

Sources

PubMed, Web of Science, Embase, Scopus

Result



The review found that, in the new millennium, just 35 studies have investigated the relationship between pesticides used in cotton and human health effects. But they clearly show that health impacts continue to be found.

Out of the final 35 studies included in the review, 11.5% examined children and adolescents, 17.5% women, 40% focused on farmers and 31% examined general health issues related to exposure to the pesticides used in cotton. Tables summarising the findings of the studies for key groups (children, women and farmers) can be found below.

An analysis of the studies on children's health showed that the main problem – reported in the 75% of the considered articles – is an impairment of the nervous system related to the low level of acetyl cholinesterase (AChE) and butyryl cholinesterase (BChE) activity. Both are enzymes needed for a proper functioning of the nervous system which are inhibited by exposure to pesticides. Problems reported include lower neurobehavioral performance, neuromuscular signs, knee reflexes and coordination abnormalities.

The main problems reported in the papers that studies the health effects on women were linked to the reproductive system and include delayed puberty, menstrual problems and breast milk contamination. Contaminated milk can induce long term issues for babies. Short term health problems reported include headache, skin and eye irritation, weakness and respiratory problems which can lead to the loss of working days. Chronic problems reported included DNA damage and blood abnormalities.

Photo: pesticide equipment in Georgia



The articles included in the review have been split by category: children, women, farmers and general. The aim and main findings of the studies considering vulnerable groups (children, women and farmers) are summarized in the tables below.

Studies about women's health issues

REFERENCE	AIM	HEALTH OUTCOMES
Ahmad, R. et al. 2004 Evaluation of toxicity due to commercial pesticides in female workers Pak J Med Sci Vol. 20 No. 4 www.pjms.com.pk	The study measures the agricultural spray hazards in female cotton production workers in Multan	Currently used pesticides have the potential to influence the reproductive system in the sensitive farm workers. Health outcomes include delayed puberty, early menopause, menstrual cycle impairment and miscarriage.
Bakhsh et al. 2016 Occupational hazards and health cost of women cotton pickers in Pakistani Punjab BMC Public Health 16:961 DOI 10.1186/s12889-016-3635-3	The objectives of the study are to identify health hazards due to pesticide exposure and health cost of cotton pickers.	Health impacts include skin problems, headache, cough, flu/fever, eye irritation and sleeplessness. The study also shows an extra economic burden on women cotton pickers through health costs.
G. Bapayeva et al. 2016 Organochlorine pesticides and female puberty in South Kazakhstan . Reproductive Toxic 65; 67–75. http://dx.doi.org/10.1016/j.reprotox.2016.06.017	The study aims to investigate reproductive system issues in female adolescents living in cotton-growing regions that use organochlorine pesticides.	Increased concentrations of pesticides in the blood of women and girls living in cotton-growing regions is associated with delayed physical and sexual development, relatively late puberty, and reduced level of two specific hormones (estradiol and IGF1).
Rekhadevi P.V. et al. 2016. Assessment of genotoxicity in female agricultural workers exposed to pesticides . Biomarkers, DOI: 10.1080/1354750X.2016.1252954	The study aimed at assessment of the various genotoxicity, biochemical and hematological profiles and oxidative stress parameters in female workers employed in cotton fields, who are active till harvest season.	The results indicated that cotton workers are at a greater risk of genotoxic damage, imbalance of antioxidant enzymes and hematological abnormalities. However data on female cotton workers is lacking.
Yasmeen H. et al 2017 Risk profile and health vulnerability of female workers who pick cotton by organochlorine pesticides from southern Punjab, Pakistan Environ Toxicol Chem, Vol. 36, No. 5, pp. 1193–1201 DOI: 10.1002/etc.3633	The aim of the study is to highlight the level of organochlorine pesticides in maternal blood and milk samples from women working in cotton-growing areas of Pakistan.	Higher levels of organochlorine pesticides were found from blood serum compared with milk samples, and dermal exposure was identified as a source of contamination in blood serum of female workers who pick cotton. The levels of pesticides in milk samples was not considered hazardous however, long exposure may lead to severe health complications for the babies.
Yasin T. et al 2013 Pesticide risk reduction methodologies for women cotton pickers through women open school participatory approach . Advanced Science Letters, Volume 19, Number 12, pp. 3496–3502(7) https://doi.org/10.1166/asl.2013.5198	The main objective of the paper is to assess the training approach and the methodologies to minimize pesticide exposure, which causes health issues reported by women.	The women participating in the training regularly monitored themselves regarding acute pesticide poisoning during exposure in sprayed fields and observed mild to severe signs and symptoms of headache, skin irritation, excessive sweating, hand irritation and exhaustion due to organophosphates and pyrethroids. The training enhanced their health awareness.

Studies about children's health issues

REFERENCE	AIM	HEALTH OUTCOMES
Abdel Rasoul, G. et al (2008). Effects of occupational pesticide exposure on children applying pesticides. <i>NeuroToxicology</i> , 29(5), pp.833-838. doi:10.1016/j.neuro.2008.06.009	This study examined neurobehavioral performance in children seasonally exposed to organophosphate pesticides to test the hypothesis that increasing exposure is associated with progressively larger neurobehavioral deficits.	This study showed that children and adolescents who apply pesticides in the cotton fields have significantly lower neurobehavioral performance and report more symptoms compared to non-exposed children. The neurobehavioral deficits demonstrated a dose-response relationship between days and years of exposure the problems reported.
Almberg, K. S. (2014) A study of adverse birth outcomes and agricultural land use practices in Missouri. <i>Environmental Research</i> 134; 420–426 http://dx.doi.org/10.1016/j.envres.2014.06.016	The primary aim of the study is to evaluate the relationship between county-level measures of agricultural crop production and low birth weight and pre-term birth in the state of Missouri in 2004–2006.	Positive associations between cotton and low birth weight and preterm births were found. The results of this study do not provide evidence with respect to the seasonality of adverse birth outcomes in the context of agricultural production.
Ismail, A. et al (2010) Clinical and biochemical parameters of children and adolescents applying pesticides. <i>Int J Occup Environ Med.</i> Jul;1(3):132-43. PMID:23022799	The aim of the study was to examine relationship between and neuromuscular signs, AChE levels and farmer work experience.	Children applying pesticides had more health impacts such as neuromuscular signs, knee reflexes and coordination abnormalities and lower AChE levels than the control children. Low AChE levels impair the functioning of nervous system.
Ismail AA, et al. (2017) Comparison of neurological health outcomes between two adolescent cohorts exposed to pesticides in Egypt. <i>PLoS ONE</i> 12(2): e0172696. doi:10.1371/journal.pone.0172696	The goal of the study was to examine the impact of pesticide exposure on health outcomes among two groups of participants examined in 2005 and 2009.	Pesticide applicators in both groups reported more neurological symptoms and signs than the non-applicators, especially in the 2005 group. The BChE helps the nervous system work properly, but pesticide exposure reduces its activity. This is more evident in the 2005 group than in the 2009 group. In addition, participants with low BChE activity showed more symptoms and signs than others.

Photo: children near a cotton plantation, Benin



Studies about farmers' health issues

REFERENCE	AIM	HEALTH OUTCOMES
Baratova, M. R. (2010) Features of clinical picture allergodermatosis at cotton workers and cattle breeders. European Journal of Pediatric Dermatology https://www.ejpd.com/journal/index.php/EJPD/article/view/695/694 - p65	The aim of the study is to investigate which allergic dermatosis affects cotton workers and cattle breeders.	Eczema is the most the allergic dermatosis affecting cotton workers. The diagnosis of eczema in cotton workers was confirmed by anamnesis, clinic, allergic and immunological researches.
Bennett, R. et al. (2003) Bt cotton, pesticides, labour and health. A case study of smallholder farmers in the Makhathini Flats, Republic of South Africa. Outlook on AGRICULTURE Vol 32, No 2, pp 123–128 https://doi.org/10.5367/000000003101294361	The aim of the research was to test if <i>Bt</i> cotton presents benefits in terms of pesticide and labour saving. It also included an attempt to gauge possible benefits to human health.	This survey of just 32 farmers found found insecticide use and accidental insecticide poisonings reduced as adoption of <i>Bt</i> cotton increased.
Damalas, C.A. (2010) Pesticide risk perception and use of personal protective equipment among young and old cotton growers in Northern Greece. Agrocienca 44: 363–371.	The objective of the study was to evaluate the levels of pesticide risk perception and the use of personal protective equipment among cotton growers from rural areas in northern Greece.	Young growers showed higher levels of risk perception about possible adverse effects of pesticides while old growers seem to perceive a lower risk and higher benefit from pesticide use, and to be less risk averse. A substantial percentage of cotton growers, irrespective of age, did not recognize the need to wear personal protective equipment on a regular basis.
Damalas, C. A. (2016) Farmers' use of personal protective equipment during handling of plant protection products: Determinants of implementation. Science of the Total Environment 571 ; 730–736 http://dx.doi.org/10.1016/j.scitotenv.2016.07.042	The objective of the project was to study the current levels of personal protective equipment (PPE) use and the factors related to PPE use among cotton farmers from rural areas in northern Greece.	A substantial percentage of farmers in this study did not recognize the need to wear protective equipment on a regular basis even if the pesticide label lists the minimum PPE for handling or early-entry activities. Changing farmers' behaviour with respect to PPE use might require considerable effort.
Elhalwagy, M.E.A. et al. (2010) Risk assessment induced by knapsack or conventional motor sprayer on pesticides applicators and farm workers in cotton season Environmental Toxicology and Pharmacology 30; 110–115. doi:10.1016/j.etap.2010.04.004	The purpose of the research was to assess dermal exposure to pesticides induced by two types of spraying equipment on applicators and farmers. The potential health risks associated with pesticides exposure were estimated.	Contamination on applicators was detected on head, body (thorax/abdomen) and legs at different percentages according to the spraying tools, with conventional motor sprayers inducing a higher contamination compared to knapsack motor sprayers. The study shows changes in enzyme activities that have been linked to adverse health effects from chronic pesticide toxicity that may lead to pathophysiological diseases, cancer or neurodegenerative disorders.
Farahat, T.M. (2003) Neurobehavioural effects among workers occupationally exposed to organophosphorous pesticides. Occup Environ Med;60:279–286	The aim of the study was to assess possible neurobehavioural deficits in workers employed for several years to apply organophosphorous pesticides to Egypt's cotton crop.	The exposed workers showed a consistent, statistically significant pattern of lower neurobehavioural functioning compared to controls. The deficits were seen in several neurobehavioural functions, including verbal abstraction, visuomotor speed, visual attention, auditory attention, memory and visual memory. The longer the period of agricultural work, and thus exposure to pesticides, the greater the performance deficits of the exposed participants relative to controls.

continued overleaf ->

REFERENCE	AIM	HEALTH OUTCOMES
Fenske, R. A. et al (2012) Contributions of inhalation and dermal exposure to chlorpyrifos dose in Egyptian cotton field workers. Int J Occup Environ Health. Jul-Sep; 18(3):198-209. doi:10.1179/1077352512Z.00000000030	The objectives of the study were to determine the relative contributions of dermal and inhalation exposure to internal dose in Egyptian cotton workers applying chlorpyrifos and to document the distribution of exposure across worker body regions.	Chlorpyrifos exposure was evaluated in three categories of workers: engineers, technicians and applicators. All workers' doses exceeded the acceptable operator exposure level of 1.5 mg/kg/day. An estimated 94–96% of the dose was attributed to dermal exposure. The most exposed category were applicators.
Hossain, F. et al (2004) Genetically modified cotton and farmers' health in China. Int J Occup Environ Health. Jul-Sep;10(3):296-303. DOI: 10.1179/oeh.2004.10.3.296	The main objective of the study was to measure the relationship between pesticide poisonings and the use of <i>Bt</i> cotton.	The calculated estimates showed that <i>Bt</i> cotton use reduced the quantity of pesticide applied and therefore estimated that it had a positive impact on poisoning. Nonetheless the authors state that integrated pest management (IPM) is clearly needed in China, because even with <i>Bt</i> cotton varieties, farmers spray far more pesticide than they need for good pest control.
Jonnalagadda, P.R. et al (2010) Biochemical alterations of certain health parameters in cotton growing farmers exposed to organophosphorous and pyrethroid insecticides. African Journal of Biotechnology Vol. 9(49), pp. 8369-8377. DOI: 10.5897/AJB10.784	This study focused on various signs and symptoms among 300 agricultural cotton growing farmers in Andra Pradesh exposed to organophosphate pesticides. The farmers were occupationally involved in pesticide spraying activities on an average of six hours per day for a period of about four months in a year ranging from 11-20 years or more.	The exposed subjects reported several symptoms immediately after pesticide spraying. Among the major symptoms reported are: chest pain, eyes and skin irritation, weakness, muscle twitching and paralysis. Other symptoms reported are salivation, nausea, vomiting, abdominal pain, diarrhoea, running nose, fainting, blurred vision and central nervous system symptoms such as headache, dizziness, confusion, convulsions, coma, difficulty in breathing and sleepiness.
Jonnalagadda, P.R. et al (2012) Genotoxicity in agricultural farmers from Guntur district of South India-A case study Human and Experimental Toxicology 31(7) 741–747 DOI: 10.1177/0960327111408151	The objective of the present study was to biomonitor the genotoxic effects in agricultural farmers cultivating cotton. Blood samples were collected for assessing the genetic damage by chromosomal aberrations (CAs) test and micronucleus test (MNT).	Genotoxicity has been observed in the agricultural farmers of the present study but since they are frequently exposed to mixture of pesticides, it is difficult to attribute the genotoxic damage to any particular chemical compound. The genotoxicity revealed by exposure to pesticides may be taken as an early warning signal for future development of diseases such as cancer and congenital malformations.
Khan, D.A. (2013) Pesticide exposure and endocrine dysfunction in the cotton crop agricultural workers of southern Punjab, Pakistan Asia Pac J Public Health. Mar;25(2):181-91. doi: 10.1177/1010539511417422	This study evaluated pesticide effects on reproductive and thyroid hormones of 88 cotton farmers of southern Punjab, Pakistan. The farmers (42 spray applicators and 46 cotton pickers) were randomly included with an equal number of age- and sex-matched controls.	Among the symptoms reported muscular weakness, skin burns, breathing difficulty, coughing, nausea, and vomiting were more common among spray applicators whereas headache and muscular weakness were quite high among cotton pickers. According to the data exposed in the study pesticide exposure is associated with disturbance in the thyroid and reproductive hormone levels in agricultural workers.
Kuye, R. et al (2007) Pesticide handling and exposures among cotton farmers in the Gambia. J Agromedicine. 12(3):57-69. PMID: 19042671	The aim of this study was to investigate how cotton farmers are exposed to pesticides in The Gambia, quantify their pesticide exposures and provide information for the formulation of a policy on pesticide safety for the country.	The study revealed that Callisulfan (endosulfan), is frequently sprayed on cotton plants by the farmers. Laboratory analysis of the mixed formulation showed a wide range in the concentration of the pesticide solution among the farmer/pesticide applicators and dermal patch samples showed very high residues of endosulfan analytes on their body surfaces.

<p>Mancini, F. et al (2005) Acute Pesticide Poisoning among Female and Male Cotton Growers in India, International Journal of Occupational and Environmental Health, 11:3, 221-232 http://dx.doi.org/10.1179/107735205800246064</p>	<p>This study was engendered by the need to document the serious human health consequences of the indiscriminate use of pesticides on cotton in India. The intent was to focus on less visible, but much exposed, subjects: women and marginal farmers.</p>	<p>Of the 323 reported events, 16.4% were asymptomatic, 39% led to mild poisoning, 38 % to moderate poisoning, and 6% to severe poisoning. Tremor was associated with organophosphate exposure in 83% of the cases, excessive tearing in 62%, and excessive salivation in 60%. No association between the three symptoms and the use of pyrethroids or botanical or inorganic components was reported.</p>
<p>More, P. R. et al (2003) Health monitoring of farm labourers engaged in MIPC 50 WP field sprays. J Environ Biol. 2003 Apr;24(2):205-9.</p>	<p>The aim of the study was to monitor the health status of farm labourers engaged in field sprays of a carbamate insecticide on cotton crop, as per the protocol approved by the Central Insecticide Board.</p>	<p>The spray personnel (mixers, loaders and sprayers) with protective clothing did not reveal any alteration in clinical, hematological and blood bio-chemical profile during exposure and post exposure periods. The spray personnel without protective clothing showed only a marginal reduction in their blood cholinesterase activity during the exposure period.</p>
<p>S.T. Singleton et al. 2015 Longitudinal assessment of occupational exposures to the organophosphorous insecticides chlorpyrifos and profenofos in Egyptian cotton field workers. International Journal of Hygiene and Environmental Health 218; 203–211</p>	<p>The aim of the study is to characterize the comprehensive exposure to multiple organophosphate pesticides to better assess human risk over the duration of the insecticide application period.</p>	<p>Levels of pesticides metabolite were detected in urine and blood of applicators, technicians and engineers working in cotton fields not only during the application period, but even after it. The most exposed are the applicators.</p>

Photo: cotton





4. Case studies

The following case studies aim to illustrate the conditions of use of pesticides by smallholder cotton producers. They draw on recent surveys of cotton farmers and their families by PAN UK and its partners in Benin, Ethiopia, and Senegal. A fourth case study reports on the experience of promoting IPM, and especially biological control, in Tajikistan. These case studies, are necessarily small scale and local in nature, but we believe that the conditions described are common in smallholder farming communities in other cotton-growing regions.

BENIN

At 4%, Africa's share of the global pesticides trade is small, but a large rural population, limited regulatory capacity, and lack of training combine to exacerbate the problems of pesticide use. Pesticide problems are common in the smallholder farming systems that characterise Africa's cotton growing sector. Extension services are often poor and farmers rely on pesticide retailers for advice on which pesticides to use and how to use them. Widespread illiteracy compounds this lack of information and many farmers are unable to understand the instruction labels on the pesticide containers they buy. Personal protective equipment (PPE) meeting international standards, is expensive and difficult to obtain, let alone to use in hot, humid and tropical climates. Pesticide exposure is common, but often unreported. This case study from the West African Country of Benin gives an insight into the reality of cotton production and pesticide use on the ground.

Introduction

In the small West African country of Benin, agriculture is the most important sector in the economy. It employs two thirds of the active population and contributes to 40% of the GDP. Cotton is the major cash crop grown in the country, and it accounts for up to 75% of export revenues. Around 2 million of Benin's citizens rely on cotton as their main source of income.

PAN UK has been active in Benin for over two decades, supporting our local partner OBEPAB to train thousands of smallholder farmers in organic and Integrated Pest Management (IPM) techniques. During this time we have collected data on pesticide use and farming practices.

This case study summarises the findings of a survey conducted by OBEPAB in 2016 with nearly 500 cotton farmers – a mix of organic and conventional growers – in four locations; two in the North of Benin (Kandi and Sinendé) and two further South (Glazoue and Djidja). Although this study considered many parameters related to production methods and yield, this case study focuses on the aspects relating to pesticide use and its impact on human health.

TABLE 8 NUMBER OF PARTICIPANTS IN THE BASELINE SURVEY

	NORTH (SHEA GROWING AREAS)		CENTRAL/ SOUTHERN (CASHEW GROWING AREAS)		TOTAL
	Men	Women	Men	Women	
Organic	114	60	79	40	293
Conventional	76	49	50	30	205
Total	190	109	129	70	498

Use of pesticides

The following products were associated with the signs or symptoms of pesticide poisoning in the previous 12 months. There are some highly hazardous pesticides on the list including methyl parathion, lindane and endosulfan.

TABLE 9 MOST USED PESTICIDES

TRADE NAME	ACTIVE INGREDIENT	HAZARD CLASSIFICATION	HHPS LIST
Cotonex	Fluometuron	Irritant – reproduction developments effects	
Emastar	Acetamiprid	Highly toxic for bees	
Endosulfan	Endosulfan	Listed under the Rotterdam and the Stockholm Conventions - Fatal if inhaled (GHS H330)	✓
Faria permefos	Chlorpyrifos + cypermethrin	Highly toxic for bees	✓ ✓
Gama	Lindane	Listed under the Rotterdam and the Stockholm Conventions – Endocrine disruptor - Highly toxic for bees	✓
Kalach	Glyphosate	Probably carcinogenic - IARC	✓
Metafos	Methyl parathion	Listed under the Rotterdam Convention – Acute toxicity (WHO Ia) – Fatal if inhaled (GHS H330)	✓
Napico	Acetamiprid + emamectin	Highly toxic for bees	

Photo: food spray trials in Benin



Pesticides problems

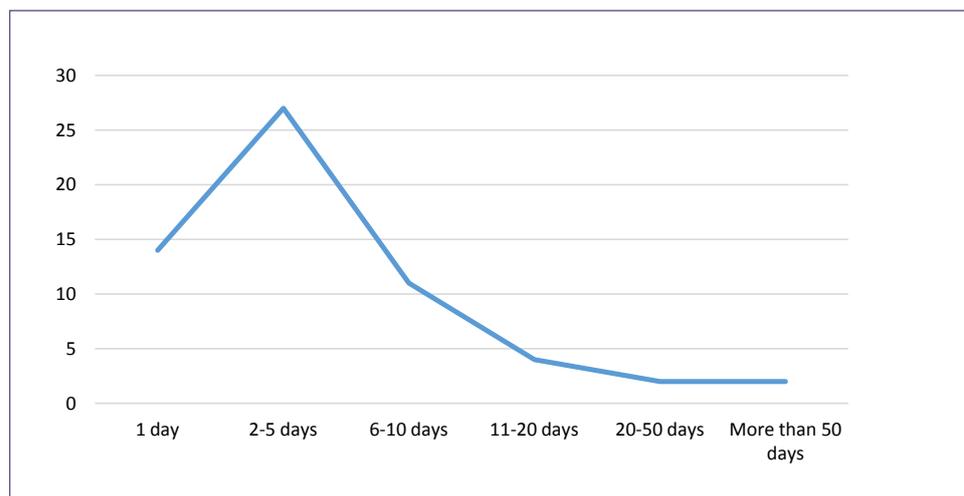
42% of conventional farmers said they had experienced signs and symptoms of acute pesticide poisoning in the previous year; 50 of these farmers (17%) said they had experienced signs and symptoms of pesticide poisoning more than six times in the previous year.

47% of the farmers experiencing symptoms of acute pesticide poisoning said that they had been unable to work as a result; 21% of the farmers lost 2-5 days' work. Four farmers said that they lost more than 20 days' work.

48% of the farmers affected by symptoms of pesticide poisoning bought medication. The average amount spent was FCFA 21,848.64 (£28) over the year. This is a significant expense, given that the average annual farm income from cotton is only £575.

Eight farmers reported that a child usually applies pesticides on their farm. This is particularly worrying as children tend to be more vulnerable to the impacts of pesticide exposure due to their smaller body mass and limited ability to process toxins.

FIGURE 18 DAYS' WORK LOST BY FARMERS DUE TO THE ACUTE EFFECTS OF PESTICIDES ON THEIR HEALTH



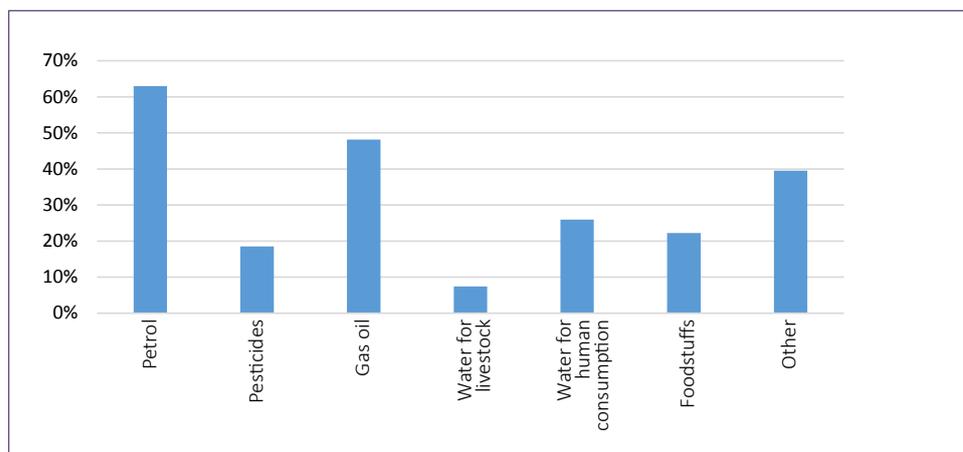
The types of symptoms reported by farmers included localised reactions such as eye (93%) and skin (91%) irritation, but a high proportion of farmers also experienced systemic reactions such as blurred vision (51%), general weakness (46%), tremors (34%), insomnia (34%), vomiting (9%), memory loss (3%) and convulsions (2%).

When organic farmers were asked why they ceased using pesticides, 52% said that their reason was because of the dangers pesticides pose to their health.

Empty pesticide containers are classed as toxic waste. Using them for drinks or foodstuffs can lead to fatalities – previous studies in Benin have revealed that re-use of pesticide containers is implicated in poisoning incidents and nearly nine out of ten fatal incidents. In spite of this, the survey revealed that over 20% people use them for drinks (26%) or foodstuffs (22%).

Around half (51%) of conventional farmers said they stored their pesticides in their homes. Most of them (96%) kept the pesticides locked, but 6% stored them alongside foodstuffs, with the potential for spills and contamination.

FIGURE 19 USES REPORTED FOR EMPTY PESTICIDE CONTAINERS



Acute poisoning by pesticides can be fatal. A range of other serious, permanent health effects from acute poisoning by pesticides include malignancy, teratogenicity (foetal abnormality) and organ damage. At lower doses, symptoms may be less severe in the short term, but chronic exposure is associated with serious impacts such as cancer, nervous system damage, reproductive disorders, developmental problems and disruption of the immune system.

The findings from the survey in Benin on the impacts of pesticides on farmers' health were extremely concerning. The nature and frequency of poisoning incidents were alarming, with systemic effects on the nervous system, heart rate, and respiratory system being reported and a high proportion of farmers experiencing multiple episodes per year. These factors are not only having a serious impact on health, but also on incomes and productivity.

A separate study, conducted by researchers from Abomey-Calavi University in Benin during the same year, examined cholinesterase levels in the blood of 264 cotton farmers in the centre of the country (Glazoué and Savè).¹⁵⁴

Researchers conducted erythrocyte acetylcholinesterase (AChE) tests before and after the spray season (farmers applied pesticides an average of five times over the season). Cholinesterase is one of many important enzymes needed for the proper functioning of the nervous systems of humans and insects. Organophosphate and carbamate pesticides are known to suppress cholinesterase and adversely affect the functioning of the nervous system. Comparing AChE levels in a person before and after the spray season gives an indication of whether their nervous function might be adversely affected.

The study confirmed PAN UK's survey findings that risky practices are commonplace and only a minority of farmers use protective equipment. Farmers reported that moderate signs or symptoms of acute pesticide poisoning (such as tremors, nausea) are relatively common. Some 60% of farmers recorded a drop in cholinesterase levels, with nearly 12% showing a drop of more than 20% indicating moderate to severe poisoning. Two farmers recorded AChE inhibition in excess of 50%.

This case study clearly shows that pesticides are still heavily used in cotton and that they pose a real threat to human health. In spite of many years of awareness-raising and training, poor practices are widespread. Even when farmers are aware of the negative impact of pesticides on their health, they often lack the training and support required to adopt safer alternatives. In addition, the costs and benefits of conventional versus organic systems are not clear to farmers. It is easy to compare yields but to overlook the range of costs associated with pesticides, including impacts on health and natural resources such as pollination services and soil quality.

ETHIOPIA

Introduction

This case study summarises the findings of a four-year project conducted by PAN UK in partnership with PAN Ethiopia in the Arba Minch, Mirab Abaya and Humbo Districts of the Ethiopian Rift Valley. It has trained nearly 2,000 smallholder farmers in Integrated Pest Management and new pest control techniques through Farmer Field Schools (FFS) and ongoing extension support.

Background

When the project was being developed in 2011-12, common scenarios included:

- ◆ Use of highly hazardous pesticides, including endosulfan
- ◆ Hazardous practices including lack of use of protective equipment; poor quality spray equipment; storage of pesticides in the home
- ◆ Use of agricultural pesticides to kill ectoparasites on humans
- ◆ Many people complained about the effects of aerial spraying of pesticides (which used to be conducted by commercial farms in the area)
- ◆ Suicide from drinking pesticides also seems to have been relatively common, particularly among adolescent men / boys

Several surveys have been conducted throughout the project to monitor awareness and behaviour of the participating farmers. The project focused on smallholder farmers but also included two large commercial cotton farms which joined the project in 2014. Both of these farms use significant quantities of hazardous pesticides and safety procedures and equipment are lacking.

Use of pesticides

Heavy pesticide use in cotton in Ethiopia has had serious health and environmental consequences.¹⁵⁵ Weak enforcement of pesticide legislation combined with an aggressive marketing of hazardous pesticides has allowed bad practice to become widespread. A recent article reported that pesticide retailers in the country '*focus mainly on facilitating sales and gaining profits, while safety, quality and environmental sustainability play hardly any role*'.¹⁵⁶

Endosulfan 25% ULV was used by the participating commercial farms for all pest control. In 2015, it was applied between two and four times per season. A total of 3.75Kg per hectare of endosulfan active ingredient was used in the 2015 production season. In the 2014 production season the farms used 10.27Kg per hectare of active ingredient from five different pesticides.

A survey of cotton farmers in the project area in 2013, soon after the project began, found that 36% of the farmers use synthetic pesticides on their cotton and other crops, among them some very hazardous pesticides, such as endosulfan, carbosulfan, dimethoate, lambda cyhalothrin and malathion. The majority of the farmers (92%) wear only normal clothes during pesticide application, without protective equipment.

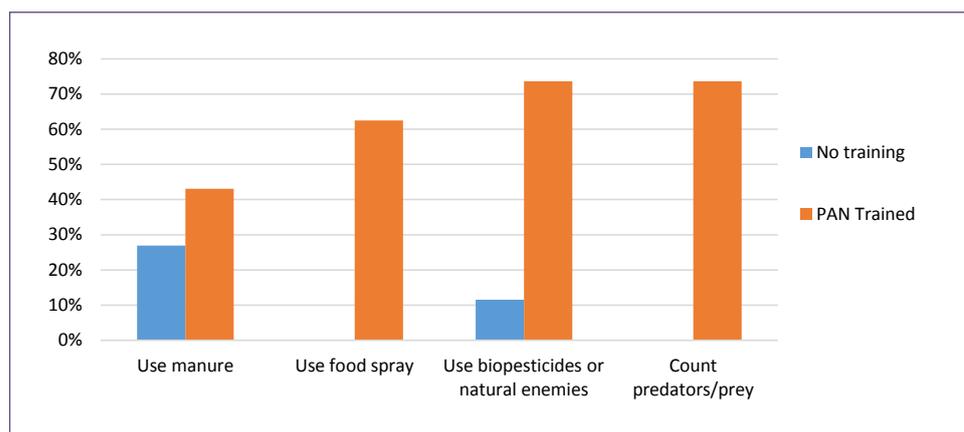
Health problems related to pesticides

The respondents of the 2013 survey reported that they experience feelings of discomfort and illness after pesticide application. When questioned about pesticide poisoning incidents in the previous 12 months; 31.8% of the farmers reported impacts on their health. Signs and symptoms included: headache

(56.4%), skin irritation (48.7%), weakness (30.8%), eye irritation (23.7%), loss of appetite (17.9%) and nausea (10.3%), excessive salivation and vomiting (5.1%), difficulty breathing and weeping (2.6%).

A second survey of farmers conducted in February 2016 clearly shows that the training provided by the project is having a positive impact on farmers' practices, such as use of manure to improve soil quality; use of biopesticides and inspecting the crop to determine the balance between pests and beneficial insects (figure 20).

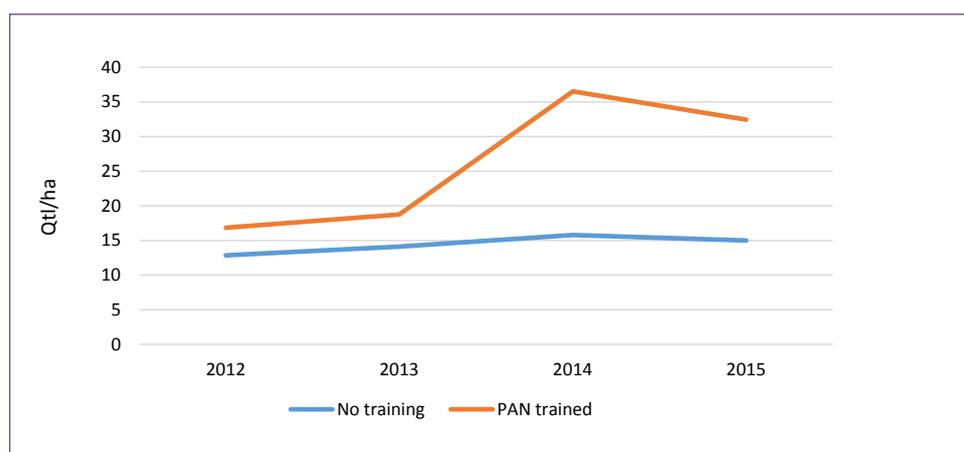
FIGURE 20 SHOWING THE % RESPONDENTS USING IPM TECHNIQUES WITH AND WITHOUT PAN TRAINING.



Testing IPM techniques against conventional practices

Figure 22 illustrates the results of several surveys showing the average yields of trained farmers versus untrained farmers in Gamo Gofa. It clearly shows that the IPM training provided by the project is enabling farmers to achieve higher yields.

FIGURE 21 SHOWING THE AVERAGE YIELDS OF FARMERS TRAINED IN IPM TECHNIQUES VERSUS UNTRAINED FARMERS.



However, farmers are not only interested in yields. Cotton is a critical source of income for smallholder farmers. They are at least as interested in profit as yield.

Data was collected from conventional smallholders (using pesticides) in the same villages as the trained IPM farmers (not using pesticides), to compare yields, costs and net revenue of different methods used by project farmers. It showed clearly that IPM approaches delivered higher yields than chemical control and profits were also higher. What is more, cotton quality was better among trained farmers allowing them to secure a much higher price.

Care should be taken in interpreting these results as the conventional smallholders had not received training in good agronomic practices and they used lower quality seed. Nevertheless the results of these and several other field trials all lead to the same conclusion; that conventional practices in the area, including pesticide use, do not result in good yields or revenue for farmers compared to an IPM approach.

Discussion

We know that highly hazardous pesticides continue to be bought and used by farmers in Ethiopia. Unfortunately, in the circumstances, we can be sure that these farmers, and their families, are at high risk of pesticide exposure and pesticide poisoning. Endosulfan remains in widespread use in the country in spite of a global ban through the Stockholm Convention in 2011. Ethiopia has signed and ratified both the Rotterdam and Stockholm Conventions, but it remains one of the few countries still openly formulating and selling endosulfan. The pesticide is registered for cotton only, but surveys by PAN Ethiopia indicate that it is misused and sprayed on food crops. This risk has been eliminated among trained farmers who have ceased using pesticides and their whole community benefits from a less polluted environment.

Knowledge has been the primary driver of improved health and welfare. Trained farmers feel confident to reduce or eliminate the use of pesticides. This create a healthier environment but also it leads to better and more sustainable yields, which means that the overall conditions of farmers and their families can be improved.

Photo: food spray trials in Ethiopia



SENEGAL

Farmers in the cotton producing regions of Senegal overwhelmingly rely on pesticides for crop protection, but do not have adequate knowledge or equipment to manage the high risks of the products available. The unacceptable rate of poisoning and deaths caused by endosulfan in West African cotton systems is well documented and eventually led to a regional (14 CILSS countries in 2008) then global ban under the Stockholm Convention in 2011.

This case study draws on a community monitoring project carried out by PAN Africa in 2011 in Velingara, a major cotton-producing area in Eastern Senegal. Between February and May 2011, 27 monitors from local cotton farming communities interviewed 1,195 farmers in 174 villages on pesticide use and impacts, and 119 women on community level impacts.

The findings confirm that poor practices are the norm, and far removed from recommended or label instructions, including use of endosulfan by 22% of farmers, re-use of pesticide containers.

Use of pesticides and practices

The cotton production sector is relatively well structured, with the cotton company (SODEFITEX) buying production and supplying inputs, including pesticides. Producers obtain their pesticides in approximately equal proportions from Sodefitex, local markets, and agrochemical dealers. The products used include WHO Class Ib and II which are moderately to highly hazardous; and endosulfan products (even though it has been banned in the region since 2008). This latter highly hazardous pesticide was being used by 22% of farmers, and must originate in obsolete stockpiles since it has not been supplied since 2007 – indicating that stockpiles are not secured and continue to expose rural populations.

Photo: cotton in baskets



Internationally recommended Personal Protective Equipment (PPE) is virtually absent, although many users do try to use locally available alternatives.

Store pesticides in the home	71%
Spraying into the wind	38%
Long sleeves or trousers as PPE	47%
Gloves (not international standard)	13%
Overalls (international standard PPE)	2%

The poor handling practices are compounded by poor equipment, and spills of pesticide coming into contact with unprotected skin or through inhalation are common. 61% of these spills occur during spraying.

Containers

Empty pesticide containers still contain toxic residues, and should be triple rinsed, punctured and recycled or disposed of. However not a single farmer questioned did this.

Return containers to source	4%
Throw containers into the field	23%
Burn containers in the field	57%
Domestic reuse	10%

The reuse of 'empty' containers regularly causes mass poisoning incidents, often involving children and leading to multiple deaths.

Health impacts of pesticides

A separate survey involving 119 women was conducted to investigate exposure incidents and health impacts. This sought to identify cases of exposure of other household members who may be exposed via take-home pathways including contaminated equipment or clothes, storage of pesticides in homes, or domestic reuse of empty containers.

Women experiencing health incident (12 months)	7%
% treated by doctor	66%
Top three symptoms - producers	
Headache	22%
Blurred vision	15%
Dizziness	8%

The study found that pesticide exposures are high due to poor practices. While farmers seem to understand that pesticides are dangerous in a general sense, they do not know or apply even basic precautions to minimise exposure, such as spraying with the wind. While basic measures would undoubtedly reduce risks and should be required as a minimum measure e.g. training by suppliers of pesticides, more important gains are possible by shifting to alternative pest management methods such as IPM and organic.

TAJIKISTAN

Introduction

This case study reports on the achievements of a project to train Tajik cotton farmers in IPM. The project was run by Cooperative Sarob, a private company that provides advice and support to farmers, helping them to improve production and expand market opportunities. The IPM training was part of a scheme to support farmers to achieve verification to the Better Cotton Initiative (BCI) standard which began in 2013.

Use of pesticides

Tajikistan no longer has any domestic agrochemical companies, and all pesticides are imported. Up until the late 1980s, the supply of pesticides was managed centrally through a network of state organizations and a central government organization had full responsibility for ensuring proper storage of pesticides, their effective use and reliable accounting. This system disappeared after the demise of the Soviet Union, and individual entrepreneurs or private companies have stepped in to fill the gap, importing pesticides and selling them to farmers.

The Tajik approach to pesticide regulation remains based on the old Soviet system and has not kept pace with the changing pesticide market. For example, the registration system has not been adapted and updated, and the standardization system of quality indicators for pesticides used is not developed. There is a lack of normative and technical documents about pesticides and the control system for the import and consumption of pesticides is not clear. The country also lacks toxicology laboratories able to perform tests to determine the residue level of pesticides, especially POPs, in environmental and agricultural products, and to control the quality of imported pesticides.

In 2011, a local environmental NGO (FSCI, Dastgiri-Center) estimated that, on average, 0.84 kg/ha of insecticides, and 0.25 kg/ha of herbicides were used in cotton production in the country.

Health problems related to pesticides

Problems related to bad pesticides management in the past are a heavy heritage in Tajikistan. Western parts of the country experienced intensive organochlorine use and storage to support large scale production of cotton and other crops. A study published in 1993 reported high levels of contamination with DDT, DDE, DDD and endosulfan in breast milk samples, but no recent studies have been conducted to determine whether this is still the case. A recent analysis of soils and raw food found heterogeneous contamination in soils, and relatively limited contamination in raw foods from local villages in proximity to soviet era pesticide dumps, fortunately indicating minimal transfer of legacy organochlorine pesticides into local food chains. The application of organochlorine has decreased over the years, but other pesticides are still used.

Co-operative Sarob monitored pesticides used by farmers in the project area in 2016 (see table 10), nine of the 11 active ingredients are listed in the PAN HHPs list.

Discussion

A key feature of the project was to increase farmers' access to biological plant protection and making use of beneficial insects, and the Cooperative set up a biological laboratory to breed beneficial insects such as the *Trichogramma* and *Habrabrakon* and Lacewings. It provided over 5kg of *Trichogramma* wasps and 2,000 cans of *Habrabrakon* wasps to farmers to treat 3,500 Ha. This was complemented by dedicated extension teams providing training on biological methods of control. This has helped farmers on the

project to cut their pesticide use, and they use around 73% less pesticides than other cotton farmers in the region (table 11).

The number of farmers involved has gradually increased, as has the area of cotton cultivated and the yields. In the first two years of the project (2013 – 2014), project farmers achieved on average a 53% higher yield than non-project farmers.

As the project has progressed, the average yield has increased from 2,74 ton/ha in 2013 to 2,9 ton/ha in 2016 (table 12).

The experience of Cooperative Sarob clearly shows that pesticide use can successfully be reduced decreasing health risks while delivering better yields and higher profits.

TABLE 10 PESTICIDES USED BY FARMERS IN THE PROJECT AREA IN 2016

PESTICIDE	ACUTE TOXICITY	CHRONIC TOXICITY		ENVIRONMENTAL TOXICITY		
	H330 FATAL IF INHALED	PROBABLY CARCINOGENIC	ENDOCRINE DISRUPTOR	VERY BIO ACCUMULATIVE	VERY TOXIC TO AQUATIC ORGANISMS	HIGHLY TOXIC TO BEES
Abamectin	✓					✓
Acetamidiprid						
Bromopropylate						
Chlorpyrifos						✓
Cypermethrin						✓
Diafenthiuron						✓
Dimethoate						✓
Lambda-cyhalothrin	✓		✓			✓
Profenofos						✓
Propargite		✓		✓	✓	
Thiamethoxam						✓

TABLE 11 PESTICIDES USE: COMPARISON BETWEEN TRAINED AND UNTRAINED FARMERS

SEASON	TOTAL ACTIVE INGREDIENT (AI) (KG/HA)		INSECTICIDE AI (KG/HA)		HERBICIDE AI (KG/HA)		FUNGICIDE AI (KG/HA)	
	PROJECT FARMERS	UNTRAINED FARMERS	PROJECT FARMERS	UNTRAINED FARMERS	PROJECT FARMERS	UNTRAINED FARMERS	PROJECT FARMERS	UNTRAINED FARMERS
2013-14	0.1218	0.3275						
2014-15	0.0604	0.2261	0.0589	0.2261	0	0	0.0015	0
2015-16	0.5658	0.7381	0.4021	0.5241	0.0014	0.0037	0.1623	0.2104
2016-17	0.0697	0.1899	0.0651	0.1776	0.0043	0.0118	0.0002	0.0005

TABLE 12 AVERAGE YIELD OBTAINED BY PROJECT FARMERS

YEAR	TOTAL AREA	TOTAL SEED COTTON PRODUCED	YIELD TON/HA
2013	11,299	31,000	2.74
2014	7,894	21,705	2.74
2015	11,688	33,788	2.89
2016	13,050	37,845	2.9

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Is cotton conquering its chemical addiction?

A review of pesticide use in global cotton production

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Pesticide Action Network UK

PAN UK is based in Brighton. We are the only UK charity focused solely on addressing the harm caused by chemical pesticides.

We work tirelessly to apply pressure to governments, regulators, policy makers, industry and retailers to reduce the impact of harmful pesticides.

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