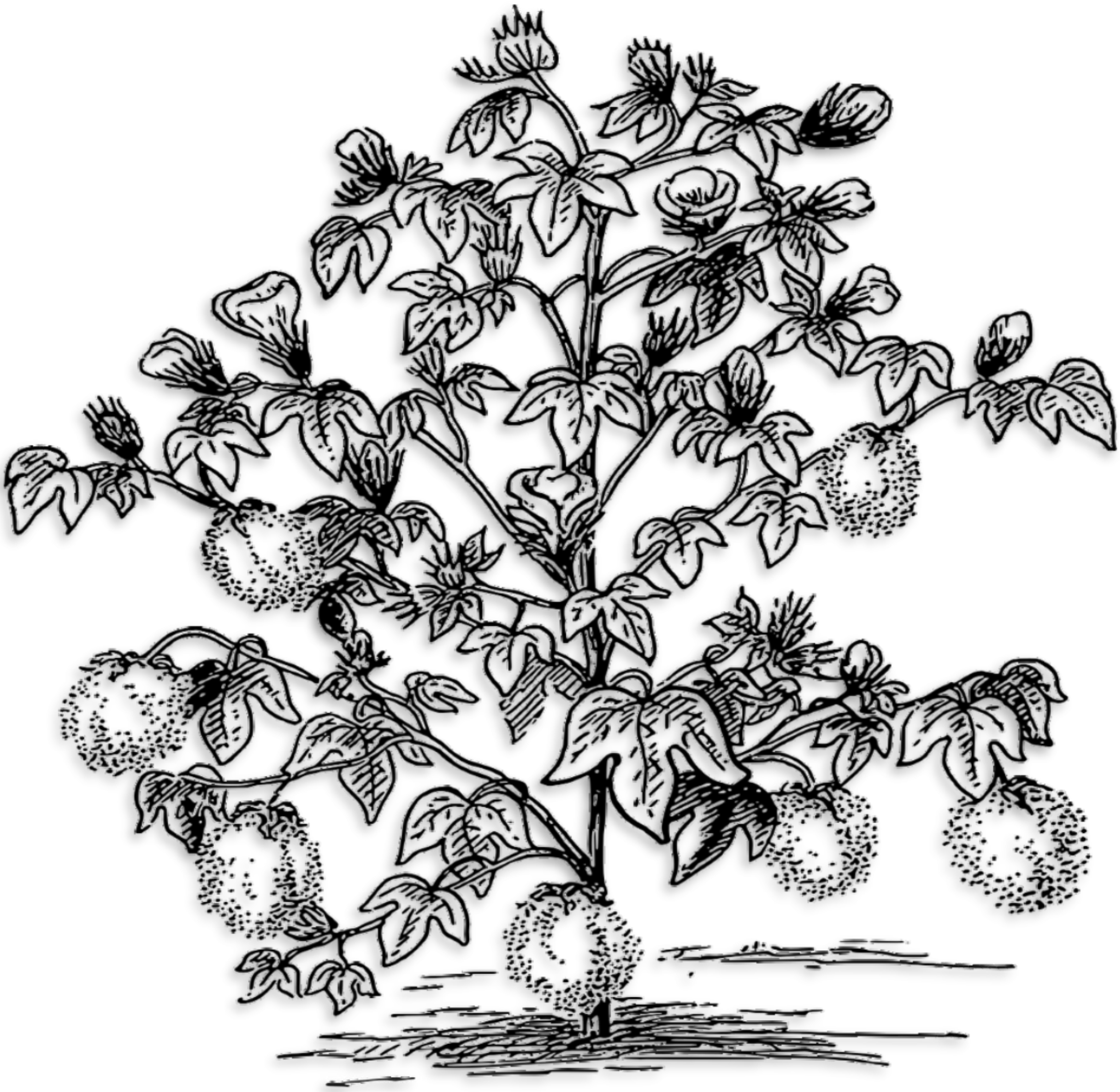
# BT-Cotton

## Is it worthwhile to grow BT-Cotton instead of conventional cotton?

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## Preface

Because the majority of the class has decided to investigate a technology that is part of dietary production, we thought we liked to pick a theme in a different area. Therefore, we have been investigating BT cotton. We cover a plant technology that forms part of the modern textile production. Since the media recently is discussing the use of BT-Maize and its environmental impact, we have come up with the idea of dealing with BT cotton and investigated if the use of BT-Cotton in agriculture is similarly discussed in the public as BT maize

# 1. Introduction

## 1.1 Background

### 1.1.1 Cotton

Cotton is one of the most important fibre plants of global production. It is cultivated in tropical and subtropical regions in more than eighty countries of the world and occupies nearly 33 million ha annually. China, USA, India, Pakistan, Uzbekistan, Australia, Brazil, Greece, Argentina, and Egypt are the main cotton producing countries. These countries contribute almost 85% to the world cotton production. The textile industry, which uses cotton, offers employment to about 16% of the total workforce. Cotton in its various forms also serves as a raw material for more than 25 industries.

### 1.1.2 Transgenic cotton

Transgenic cotton means that a gene or genetic material has been transferred by genetic engineering techniques from another organism to the cotton genome. It is mainly used for improving the yield, but only to a very limited extent for changing the fibre quality. To facilitate cultivation, there are modifications on the one hand to increase the resistance to insects by transferring genes of the soil bacterium *Bacillus thuringiensis* to the plant genome (BT-Cotton) and on the other hand to enhance the herbicidal tolerance, in particular to glyphosate.

### 1.1.3 Bacillus thuringiensis (BT)

The first scientist who discovered the BT bacterium was a Japanese biologist called Shigetane Ishiwatari. He investigated the cause of Sotto disease (sudden collapse disease), which killed large populations of silkworms. He isolated the bacterium *Bacillus thuringiensis* (BT) in 1901 as the cause of the disease.

Bacillus thuringiensis is a bacterium found mainly in the soil, but also on plants and in insect cadavers. The BT toxins produced by the bacterium are used for biological pest control in agriculture and forestry as well as for the control of pathogenic mosquitoes. The various subspecies of *Bacillus thuringiensis* produce over 200 different so-called BT toxins that are specifically lethal to certain insects. The spectrum of action of *Bacillus thuringiensis* is limited to three groups of insects, namely butterflies, leaf beetles and two-winged insects such as mosquitoes and flies.

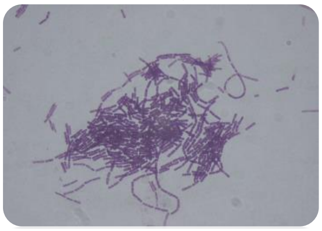

*Figure 1 – Bacillus thuringiensis bacteria*

### 1.1.4 BT-Toxin

*Bacillus thuringiensis* produces crystalline proteins that are specifically toxic to various insect species. However, humans are unaffected, and BT is completely biodegradable.

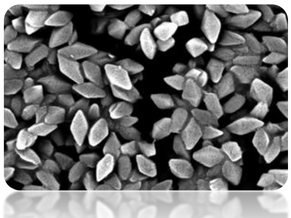

*Figure 2 – BT-Toxin Crystals*

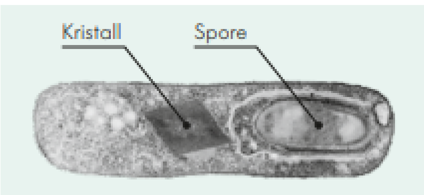


*Figure 3 – Electron microscope image of a sporulation Bacillus thuringiensis cell*

In 1989, the proteins were subdivided into five main classes according to their host range, the correspondence of their gene sequences and their molecular size (Cry standing for crystal):

Cry I: works specifically against butterflies

Cry II: butterflies and diptera

Cry III: Beetle

Cry IV: two-winged

Cry V: beetles and butterflies

## 1.2 Leading questions

During the report we addressed the following questions regarding BT-Cotton:

- How does the mechanism of action work and what are general aspects of BT-technology?
- Is there any resistance in connection with BT-Cotton and, if so, to what extent?
- Is there any transmission of the transgenic trait to wild species?
- Does BT-Cotton have an effect on non-target organisms?
- Is the use of BT-Cotton more environmentally friendly overall than conventional methods with pesticides?

## 1.3 Recent events

### 1.3.1 Genetically modified seeds dominate cotton production

The first approval of a BT-Cotton crop, which was developed by the Monsanto Group, took place in 1996 in the USA. In 2010, 64% of the global cotton acreage was transgenic. Transgenic cotton was grown in 2009 in the 12 countries Argentina, Australia, Brazil, Burkina Faso, China, India, Colombia, Mexico, South Africa, USA, Indonesia, and Costa Rica; Pakistan and Myanmar joined in 2010.

In Brazil, unlicensed BT seed from neighbouring Argentina was sown for more than seven years until the Brazilian government granted approval in 2005. In Pakistan, in 2007/08, an estimated 40% of cotton was sown with not officially authorized BT-Seeds, mainly from India, China and Australia. In order to regulate this high black-market share and due to the good experience in India, Pakistan announced in July 2009 that it would officially allow cultivation in the following year.

Applications for authorization have also been submitted in the EU recently, but the approval has not yet been granted. Currently, there is hardly any use of conventional cotton all over the world.

### 1.3.2 Cotton pollution in Pakistan

The genetically modification (GM-)free cotton varieties in Pakistan are genetically contaminated by BT-Cotton. This was reported by the Pakistani newspaper "The News". It argues that the contamination is the cause for the increasing resistance to pests. Since 2010, genetically modified cotton that produces BT toxins to repel pests is commercially viable in Pakistan. According to the industry-related organization ISAAA, BT-Cotton is now growing on 97% of the Pakistani acreage. It has now also contaminated the GM-free Pakistani cotton varieties, as the Pakistan Central Cotton Committee now acknowledged. All 15 GM-free crops developed by private breeders or governmental organizations have been found to be contaminated.

### 1.3.3 Burkina Faso as a pioneer for India?

Monsanto has lost the market in Burkina Faso in a public dispute over preferring the conventional plant again and thus heightens the scepticism of many countries regarding Monsanto's genetically engineered cotton. The dispute over the poor quality of Monsanto's cotton has also reached India. India is the second largest cotton exporter in the world. 95% of its cotton is genetically engineered.

While in the United States, Australia and Brazil cotton is grown on large farms and harvested by large-scale machines, it is grown on small areas of land in India and harvested by hand. In India, the farmers are forced to grow the American BT-Cotton instead of the native varieties.

For a decade, cotton plants have been using the gene of a bacterium, *Bacillus thuringiensis*, which is said to fight a pest, the cotton bollworm. BT-Cotton seed is expensive and has to be bought every year from patent-protected seed companies, which increases the expenses and thus the risks and dependence of the farmers. India made sad headlines about high suicide rates among small farmers, who were indebted because of the expensive genetically modified seeds. Burkina Faso in Africa has recognized that its own cotton, without genetic engineering, is better than American goods and much cheaper. If this realization now also reaches India, Monsanto loses a core business.

## 1.4 Where the technique is used

Transgenic cotton and with it the BT technique is used all over the world where cotton is grown. The largest cotton producing countries are India, China, the United States and Pakistan.

India extends cotton farming from 50,000 hectares in 2002 to about 9.6 million hectares today, which is about 35 % of the world cotton area. China is the world leader in cotton production after India. Due to the large population, more farmers are engaged in the agricultural industry. China is not only the second largest producer of cotton, it is also the largest cotton consumer.

The USA is the largest country which uses modern ways of production and cultivation on milions of hectares. Farmers of America are cultivating almost all the crops in a modern manner with machinery. In Pakistan, the production of cotton is done by small farmers; over more than 1.4 million farmers are depending on cotton as their regular income.

## 1.5 Alternative treatments

### 1.5.1 HR-Cotton.

As an alternative to BT-Cotton, there is herbicide resistant (HR) cotton, short HR-Cotton.

HR systems consist of an herbicide-resistant plant and the associated herbicide. By applying the complementary herbicide, weeds are killed on the field, while the resistant crop survives the application. Certain herbicide resistance is also present in some conventionally grown crops, but this property is predominantly achieved by genetic engineering methods.

The transgenic HR plants grown today are predominantly resistant to glyphosate or glufosinate. Both are so-called total herbicides that are toxic to most plants. Because field weeds have become resistant to glyphosate over time, companies have been developing and combining transgenic plants with resistance to other total herbicides such as ALS inhibitors, dicamba, 2,4-D or isoxaflutole for some time now. Thus, genetically modified organisms with triple herbicide resistance have been developed, mostly against glyphosate, glufosinate and another total herbicide. According to experts, glyphosate will remain the world's most widely used herbicide in the future.

### 1.5.2 RNA interference

An entirely different approach to circumvent the development of resistance to Bt toxins is to combat the pest by RNA interference by stably introducing short pieces of DNA from insect pest genes. Since the RNA interference requires a sequence similarity between the introduced piece of DNA and the gene in the target organism, a high specificity is possible with a suitable choice of the sequence

## 2. Engineering technique

The protein crystals are dissolved in the basic intestinal environment and bind to specific receptors in the midgut of the insects. There, they cause a bowel perforation, in addition to an intestinal paralysis and associated eating stop, which eventually leads to the death of the pests. The spores also multiply and lead to new infections. The toxins of different subspecies act specifically on certain insect families and therefore has no side effects on the user, the farmer.

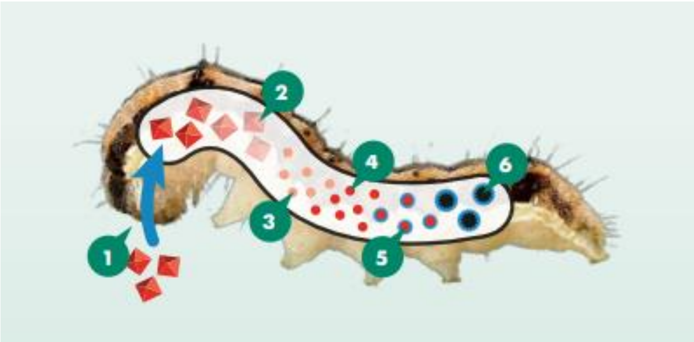

*Figure 4 Effect of BT in insects*

1. The larvae eat toxins (protein crystals) and spores
2. The protein crystals are dissolved
3. The protoxins are released in the intestine
4. The protoxins are activated by digestive enzymes
5. The activated endotoxins bind to intestinal receptors
6. The toxins destroy the cell wall of the intestine

A single trait or stacked traits of the soil bacterium *Bacillus thuringiensis* get transferred to the DNA of the cotton, depending on the subspecies code proteins, which get converted to toxins in the intestinal tract of many insects. The resulting plant contains the corresponding toxins in every cell. Depending on the used BT gene the formed toxins are deadly for certain beetles, butterflies and other specific insects like the cotton bollworm (*Helicoverpa armigera*).


*Figure 5 - Helicoverpa armigera*

## 3. Interview

Our interview partner, Dr. Juan Gonzales Valero, is Senior Executive Leader at Syngenta. He is heading the public policy, sustainability and partnership function at Syngenta.

Questions to Dr. Juan Gonzalez Valero, Head Sustainable and Responsible Business, Syngenta

-How can you transfer a gene from one species to another? (e.g. BT tox gene to Cotton)

Biotechnology is the use of living organisms to develop products with enhanced features and includes the use of genetic modification, also known as "gene technology" or "genetic engineering". This refers to the process of adding a specific gene (or genes) to an organism or removing one to produce a desirable, and often novel, characteristic. In agriculture, it allows the production of food and feed crops with improved characteristics such as higher yield, improved nutritional qualities, or resistance against insects and diseases. Traditional breeding practices have sought to combine crops that display useful characteristics to increase resistance to threats over an extended period of time. Since the start of crop cultivation thousands of years ago, farmers have looked for desirable traits to incorporate them into the following generation of plants. Originally, they created new varieties by cross-breeding. This shuffled the plant's genes, leading to random variation, and the better plants were selected for replanting while the less interesting ones were discarded. By contrast, GM involves defining the desired characteristic in advance and then carefully selecting the gene that confers it. Developments in plant sciences have made it possible to identify desired 'traits' on a genetic level and to breed those desired traits safely and efficiently.

-How much does a BT-Crop cost compared to an unmodified Crop?

Like with any new crop breeding, be it conventional or using biotechnology, the seeds will be sold at market price considering the additional agronomic and economic benefits to the farmer. The price deferential that can be achieved reflects the value add to the farm operation. This will vary by region and crop.

-Can the benefit of the BT-Crop cancel out the extra cost?

The main benefits to farmers are a) reduced labor costs, b) savings for conventional crop protection products, and c) in particular for larger farm operations, the savings in machinery fuel costs. Typically, GM crops are the more efficient crops, and that means their price and costs as ingredients are less than non-GMOs.

-May the GMO pose a threat to human health if we eat an animal that was fed with the GMO?

Yes. All genetically modified (GM) crops are subject to stringent regulations and testing of allergenic or toxic properties for humans and animals. People around the world have safely consumed GM foods on a daily basis for nearly 20 years. Leading scientific bodies, regulatory agencies and international organizations have concluded that GM crops are as safe as or safer than similar crops developed using more conventional breeding methods.

When it comes to feed, it's important to understand that almost all the food that we (or animals) eat contains DNA and proteins. The DNA and proteins found in food, GMO and non-GMO, are processed by the digestive system in our gastrointestinal tract. During digestion, GMO and non-GMO DNA is broken down into the four nucleotides that make up all DNA, and/or into small nucleotide fragments. Similarly, proteins, again GMO and non-GMO, are broken down into one or a few of the 21 amino acids that exist in nature. Many studies have been conducted on the potential for GMO DNA or proteins to be transferred into animal tissue. No intact or immunologically reactive protein or DNA has been detected in animal tissue.

<u>-Does BT-cotton pose a threat to wild populations of cotton? - Does it pose a threat to the environment in general?</u>

Biotechnology delivers biodiversity benefits in numerous ways with minimal impacts on non-target organisms. By building in an ability to fight particular pests, insect-resistant genetically modified (GM) crops avoid the need for pesticides with minimal impacts on non-target species. Bt corn, for example, uses protein derived from the soil micro-organism Bacillus thuringiensis (Bt), also used as a pesticide in organic farming. BT proteins target specific pests and degrade rapidly so they have a low impact on the broader environment.

There is no credible evidence that existing GM crops are or could be any more difficult to manage than conventionally-bred crops. Both conventionally-bred and GM crops are developed to have certain traits that are beneficial for agricultural purposes. These traits do not make them – or any hybrids created through cross-pollination with other plants – any more fit for survival in the wild. In fact, such crops are unable to compete with wild plants and do not survive long without continued cultivation.

<u>-Is the use of BT-Cotton more environmentally friendly overall than conventional cotton which is protected with pesticides?</u>

GMOs can lead to fewer pesticide applications. Overall GM crops, including crops with the "Bt" (Bacillus thuringiensis) trait for insect resistance, have contributed to a 37 percent* decrease in pesticide applications.

# 4. Discussion

## 4.1 Positive and negative progress made in relation with BT-Cotton

Through the use of BT-Cotton, the application of pesticides was reduced greatly. This was beneficial for farm workers, since the exposure to pesticides is much lower. Further benefits are the lower environmental pollution, since the only species affected by the BT-Cotton are the pests because of the specificity of the mode of action implemented on the gene level. All other species are not impacted.

*Bacillus thuringiensis* increases the cotton yield by about 25% over the average yield of conventional cotton growing areas. Combined with the money saved by not having to purchase pesticides, it causes up to 50% more profit. For example, in India cotton is grown mainly by smallholders with a holding size of less than 15 acres and a cotton holding averaging 3 to 4 acres. These farmers and the areas of cotton production can take great advantage of the 50% more profit and develop faster. Because cotton is often produced in poorer regions, this financial benefit is very valuable for the people of the cotton cultivating regions.

There is, however, a downside of the BT-Cotton technology, since bollworms are currently becoming more resistant to the BT-Cotton. Resistance was found to the Cry I and Cry II genes in the BT-Cotton. This means that the use of pesticides is again increasing because of the growing resistance. Especially on older BT-Cotton product generations like Bollgard, Bollgard II and Widestrike, insecticides have to be applied. There is mixed feedback for newer generations like Bollgard III and Widestrike 3. For some, pesticides are not needed for the protection, but for others, pesticides have to be used.

## 4.2 Future Research

There is not much to discuss about the future research on BT-Cotton, because it is a finished product. The only thing that can be done is to search for a completely new product on the basis of a new bacterium with new genes that the pests do not have a resistance to and use those in the next product generations.

## 4.3 Leading questions

### 4.3.1 How does the mechanism of action work and what are general aspects of BT-Technology?

In order to kill pests, genes from the bacterium *Bacillus thuringiensis* are added to a plant. When an insect eats this plant, the BT gene releases toxins into the stomach of the insect, causing it to die.

### 4.3.2 Is there any resistance in connection with BT-Cotton and, if so, to what extent?

Bollworms are currently becoming more resistant to BT-Cotton. There is resistance to the Cry I and Cry II genes present in BT-Cotton.

### 4.3.3 Is there any transmission of the transgenic trait to wild species?

In gene flow studies in wild cotton plants of the *Gossypium hirsutum* species in Mexico, transgenes of genetically modified plants were found in wild populations.

### 4.3.4 Does BT-Cotton have an effect on non-target organisms?

Non-target organisms are easily spared, because they do not eat from the plant or the toxin is ineffective.

### 4.3.5 Is the use of BT-Cotton more environmentally friendly overall than conventional methods with pesticides?

Non-target organisms are more common on BT-Cotton fields than on conventional insecticide-treated fields. The ecosystem is therefore less burdened and only the target organisms are killed.

### 4.3.6 Alternatives against resistance

The emergence of pests that are resistant to the BT proteins of genetically modified crops has increased significantly in recent years. This is the conclusion of a study published in October 2017 in the journal "Nature Biotechnology". Preventive measures as well as the use of new BT-Proteins can delay the development of resistance.

The fact that the development of resistances would only be a matter of time, was already known to scientists in the late 1990s. A suitable strategy to delay the development of resistance is the high dose / refuge strategy. When insects that have become resistant mate with non-resistant insects, the offspring usually has poor resistance. The genetically modified plants must produce a sufficient amount of BT protein in order to kill even these weakly resistant insects (high dose). For the non-resistant insects to find enough habitat and thus also incipient resistances are "thinned out" again, conventional plants of the same species must be cultivated in close proximity to the fields on which BT plants are cultivated.

### 4.3.7 Arguments for the use of BT-Cotton

The constant expression of the toxin in BT-Cotton in the field results in a constant exposure of the pest insects and thus in a suitable control and protection of the cotton plants. The periodic use of biological or chemical insecticides, when the pressure of the pest increases to a certain level, results in periods with high and periods with low or no exposure of pest organisms to pesticides. Another important difference for using BT-Cotton instead of BT toxins in form of suspensions is that pests ingest the toxin directly in their diet. The oral exposure of the pest insects is very specific and has less environmental and human side effects. This technology leads to a high precision in pest control and protection of the cotton than the conventional cotton sprayed with pesticides. Pests can be better controlled and non-target organisms can be spared more safely, because they do not feed from the plant and thus the toxin is ineffective.

A meta-analysis published in 2007 evaluated 42 field experiments with invertebrates. This study demonstrated that non-target organisms are generally more abundant in BT-Cotton fields than in conventional fields treated with insecticides. The ecosystem is being less strained and only the target organisms are killed.

### 4.3.8 Arguments against the use of BT-Cotton

In studies on gene flow in wild cotton plants of the species Gossypium hirsute in Mexico, transgenes of genetically modified plants were found in wild populations. In about a quarter of the 270 wild cotton seeds tested, transgenes of insect-resistant, antibiotic-resistant or herbicide-resistant cotton were found. One seed came from a population located 755 kilometres to the nearest GM cotton plantation. This means that pests can build up resistance faster because the BT-Cotton is redundant in the wild.

## 5. Summary

Genetically modified cotton, which uses the bacterial BT toxin to defend itself against a major pest, dramatically increases yields – say the manufacturers. BT-Cotton has no substantial impact and drives the indebted farmers in India to suicide – say environmentalists. The truth lies in the middle. In any case, technology does not solve the real problems.

In our opinion, the problem has now slipped into a completely different area. Farmers no longer have the opportunity to adapt to new technologies, to develop optimal handling and the best form of application for their field. The change between new varieties and technologies is too fast. The profits to be generated in the short term would quickly be eroded by a lack of management.

## 6. References

During writing the term-paper we used the following information sources:


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