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A Life-Threatening Review on Genetic Engineering of Crop Plants: Insect Resistance

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ABSTRACT: To fulfill the needs of sustainable agriculture in the twenty-first century, genetically engineering inherent insect pest resistance in crops has the potential to be a user-friendly, environmentally friendly, and consumer-friendly crop protection technique. Until far, the focus has been on introducing genes that allow customized Bacillus thuringiensis toxins to be expressed. Plant-derived insect control genes are a popular alternate method. Transgenic plants expressing various protease inhibitors, lectins, and other proteins have shown improved resistance to a wide range of pests in laboratory trials. Both classes of compounds have drawbacks: BT cotton has had serious failures in pest resistance; most plant-derived resistance considerations produce chronic instead than acute elects; but many significant pests are simply invulnerable to known resistance factors. The significance of a shift in this sector toward a more socially responsible mindset, as well as the need for a much better presentation of the advantages and responsible deployment of genetically modified crops, is underlined.

KEYWORDS: Crop Plants, Engineering, Genetics, Insects, Transgenic.

1. INTRODUCTION

If the needs of an increasing global population are to be fulfilled, there is a continuous, if not growing, need to boost global agricultural production. Improved harvest yields of main crops from current farmed land must be the foundation for this growth. One practical way to increase productivity is to save more of what is produced from pests, particularly insect pests, which are estimated to eat about 14% of total world agricultural production. Insects not only create enormous direct production losses as a consequence of their herbivory, but they also cause significant indirect losses as vectors for numerous plant diseases. Despite the widespread use of insecticides and fungicides, these losses occur. Crop losses would be considerably worse if such crop protection measures were not in place. The agrochemical solution is as follows: Crop protection is now based mainly on synthetic chemical pesticides. However, this chemical-based crop protection strategy is coming under greater scrutiny.

Although most of the criticism of the agrochemical business is based on emotion rather than science, the belief that such agricultural methods are unsustainable is now generally accepted. This viewpoint is based on their high nonrenewable resource costs; inefficiency in terms of the proportion of these resources that actually reach their intended target; the environmentally unacceptable consequences of the preceding criticisms, such as contamination of food chains and water sources; and growing consumer dissatisfaction with the publicly perceived consequences of.

Total pesticide use is declining globally, owing largely to significant reductions in use in the EU as a result of regulatory and public opinion pressure; the industries' preferred solutions to this situation tend to be risk reduction rather than use reduction, such as the development of more target-specific compounds with lower environmental persistence and the expansion of integrated cr programs. The enormous benefits that synthetic pesticides have brought to agriculture should not be overlooked, but there is a clear need to develop partial substitution technologies that would allow for a much lower use of synthetic pesticides while still providing adequate crop protection within a sustainable agricultural framework, such as IPM.

1.1 Agrochemical alternatives:

a. Pesticides made from plants:

Bio pesticides, which are made up of pest insect predators, parasitoids, and diseases, are becoming increasingly popular in integrated pest management (IPM) agricultural systems. However, they only make up a tiny portion of the pesticide industry. The difficulty of simultaneously managing three biological populations - predator, prey, and crop - is the main barrier to their wider use; they are particularly difficult to use in annual field crops, so they find their greatest application in glasshouses and forestry, where population dynamics are more easily regulated than in the field.

b. Inherent resistance:

The significance of inherent or partial host plant resistance as a crucial component in IPM is becoming more well acknowledged. The benefits of inherent resistance are widely recognized, and pest resistance is now often a major feature in traditional crop breeding programs. This contrasts with previous breeding program objectives, which resulted in relatively few farmed species maintaining the same level of resistance as their wild counterparts, forcing sprayed pesticides to replace them as crop protection agents. Recent research has emphasized the importance of managing this natural resistance[1]. Plants often produce defensive compounds in reaction to herbivorous insect damage, which may provide an advantage later in the plant's life. Aside from employing chemicals to improve the plant's response, it's also possible that permitting early season herbivores to eat would provide high resistance to later season pests, which are more economically destructive. The requirement for a source of resistance within the interbreeding gene pool limits traditional crop breeding programs, but there is still room for further success, particularly from broad crosses. This is one of the limitations that plant genetic engineering may alleviate by enabling resistance genes from any source to be incorporated into a breeding program[2].

c. Genetically modified crops:

Crop genetic engineering holds the promise of a variety of benefits, including the ability to introduce a number of distinct desired genes in a single event and a reduction in the time required to introgress new characters into an elite genetic background. Since the initial reports of transgenic plants, there has been a tremendous amount of work toward putting this novel technology to practical use in agricultural development. Plant genetic engineering was rapidly embraced as a means of protecting crops from insect pests[3]. A lot of commercial companies have been paying

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close attention to the potential size of this market, and the economic significance of this biotechnology industry is now being recognized. Plant genetic engineering requires the use of two equally essential technologies: cellular and molecular biology. Although a number of alternative genes that may be helpful for crop protection have been suggested, the list of suitable genes for introduction into transgenic crops has not increased at the same rate. In this review, we will focus mainly on genes that have been shown to have impacts in transgenic plants. The expression of Bacillus thuringiensis toxins in plants has received the most scientific attention in the development of pest-resistant transgenic crops[4].

d. Bt toxin

The insect pathogenic bacteria Bacillus thuringiensis-based formulations are the world's most popular bio pesticide, accounting for almost half of all bio pesticide sales. It has been used in the field for the treatment of lepidopteran pests for almost 40 years. Early researchers cloned genes producing insecticidal d-endotoxins, and transgenic tobacco and tomato production of modified toxin genes offered the first instances of genetically engineered insect resistance in plants. The BT d-endotoxins are a collection of similar proteins for which more than 140 genes have been identified and reclassified into 24 main categories. Although the sensitivity of various species within the &susceptible' order varies considerably, different poisons have distinct specificities for different orders of insects[5].

Although early transgenic plants carrying Bt genes showed some improved resistance to target pests, it became clear that native bacterial gene expression levels were too low to offer sufficient protection against key pest species in the field. The use of strong promoters and enhancers, as well as engineering the codon usage to bring much more in line with plant-preferred codon usage, rather than the A + T rich Bacillus preferred usage, and to eliminate undesirable mRNA secondary structure and polyadenylation signals, were all used to achieve significant increases in expression levels. Tobacco and tomato, cotton, rice, potato, and brinjal, maize and broccoli, oilseed rape, soybean, and walnut, larch and poplar, sugarcane and apple, peanut, chickpea, and alfalfa have all been brought and expressed with BT genes[6].

1.2 Specificity and long-term use:

Bts' high specificity is often mentioned as one of the advantages of using them over synthetic insecticides. Most crops, on the other hand, are attacked by a diverse group of pests rather than a single pest species. Cotton, for example, is susceptible to losses from a remarkably comparable pest complex globally, including heliothines, mirids, aphids, spider mites, and thrips, despite being cultivated in a variety of cropping methods. Many of these pests are not known to be resistant to Bts[7]. If chemical pesticides must still be used on a regular basis to control, for example, whitely, the utility of transgenics resistant against heliothines is likely to be greatly diminished. There is a need to find insect control genes for these pests that are presently resistant. Transgene products are inherently unique to those bugs that are vile enough to devour those plants since they are basically tricked inside the host plant[8]. So, although there is a tendency toward using very selective,

ISSN: 0374-8588

Volume 21 Issue 7, July 2019

narrow spectrum chemicals as chemical pesticides, it might be argued that with transgenics, a wider range of action is preferable, as long as it does not include beneficial insects[9].

1.3 Alternatives to Bt in genetic engineering:

With only a few counterexamples, the search for alternative ICPs to Bt has focused on those derived from plants. Plants have evolved some very effective countermeasures to predatory insects over the course of their ca.300 million years of co-evolution the plants' solutions to the plants' problems. In artificial diet or in vitro studies, many different classes of plant proteins have been shown to have some toxic or anti-metabolic effect on insects, and have been proposed as targets for crop genetic engineering. Only those examples of ICPs that have been shown to improve resistance in transgenic plants will be discussed. Many of these ICPs have chronic rather than acute toxic effects, so their perceived effects on pest populations are usually much less dramatic than synthetic chemical pesticides. In any realistic trial, they rarely kill insects, instead tending to increase mortality to a limited extent while significantly slowing insect growth and development. Some commentators have characterized this as a serious flaw.

1.4 Inhibitors of proteases:

Inhibition of protein digestion has been used to disrupt a pest's essential amino-acid metabolism. Many insects, especially Lepidoptera, rely on serine proteases as their primary protein digestive enzymes, and genes encoding members of various serine protease inhibitor families have been cloned and introduced into transgenic plants. Insects produce SPIs that act as inhibitors of their own digestive proteases and are thought to be involved in their regulation. It's been suggested that these inhibitors could be turned against insects by expressing them in transgenic plants, which is an intriguing idea given that these inhibitors have most likely evolved specifically to be effective against insect proteases. Other pests use thiol proteases as their primary digestive protease rather than serine proteases. Thiol protease inhibitors have been used to target these.

1.5 Inhibitors of alpha-amylase:

Pests' carbohydrate metabolism has been addressed using a-amylase inhibitors in the same manner as their protein metabolism has been targeted with genes producing protease inhibitors. The best described a-amylase inhibitors include those from wheat and common bean. According to early findings, expressing WAAI in transgenic tobacco enhanced the mortality of lepidopteran larvae fed. However, this has not been shown, and other labs have had difficulty getting even detectable expression of WAAI genes in transgenic plants. The gene encoding BAAI has been produced in transgenic pea seeds, where it was enhanced resistance to two species of bean weevil, which are significant storage pests of legume seeds, using the pha1 gene promoter to direct high levels of expression in seeds. The seeds of transgenic adzuki beans have shown similar increased resistance to bean weevils.

1.6 Lectins:

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Volume 21 Issue 7, July 2019

Plant lectins are a diverse collection of sugar-binding proteins that are thought to provide antimicrobial properties against a broad variety of organisms. In feeding experiments with pure proteins, lectins with different sugar-binding specificities were shown to have a long-term impact on the survival and/or growth of insect pests from diverse insect orders. The gene encoding the glucose/mannose-binding lectin from pea was utilized in the first evidence of increased resistance in transgenic plants expressing a foreign lectin. Transgenic tobacco expressing pea lectin performed substantially better in bioassays against H. virescens than controls. Unlike many insecticidal lectins such as wheat germ agglutinin and phaetohaemagluttinin, pea lectin has a low mammalian toxicity, which was a major factor in the choice to work with it. Unfortunately, it has a low insect toxicity level.

1.7 Microbiological chemicals:

The bulk screening of microbial culture supernatants against target pests is one method for discovering new insecticidal proteins. Vip1 and Vip2 are two proteins found in vegetative Bacillus cereus culture supernatants that exhibit acute toxic effects on maize rootworms when combined. A protein found in certain vegetative B. thuringiensis culture supernatants was highly poisonous to Agrotis and Spodoptera caterpillars. These proteins have action that is quite similar to Bt d-endotoxins, yet they are obviously different from them. There haven't been any reports of activity in transgenic plants yet.

1.8 Toxins produced by predators:

Spiders and scorpions, for example, generate peptides, which are potent insect neurotoxins. It's been proposed that they might be employed to safeguard transgenic plants, and genes encoding some of them have already been inserted into transgenic plants. The neuroendocrine system of the pest is the site of action of these neurotoxins, which is typically accessible by injection; simple ingestion may not be a suitable delivery method to these targets. However, it has been reported that transgenic plants expressing a scorpion poison cause harm in insects that eat them. Neurotoxins from predatory mites and scorpions have been inserted into recombinant baculoviruses, significantly increasing the death rate.

1.9 Resistance genes are stacked like a pyramid:

If transgenic crops are designed with multi-gene, multi-mechanistic resistance, the efficacy and longevity of resistance is expected to be higher. Sexual crossing of transgenic tobacco expressing the cowpea trypsin inhibitor with transgenic tobacco hemizygous for the pea lectin was the first example of &pyramiding' such varied resistance to be reported. There were F1 progeny that expressed none, one, or both of the alien genes. These plants were put to the test against H. virescens larvae in feeding tests. Both genes exhibited a protective impact on their own, and this effect was cumulative in the double-expressing plants. It is critical for pyramiding to be effective if the resistance mechanisms are compatible. The addition of an SPI and a snowdrop lectin to the same transgenic tobacco does not result in a protective effect that is additive. Because one of

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Volume 21 Issue 7, July 2019

GNA's actions is thought to be anti-feedant, it probably lowers the SPI's intake level below the threshold for the latter to have any impact[10].

1.10 Outstanding problems with transgenic crop protection:

In this article, we won't go through all of the difficulties with genetically modified organisms; instead, we'll focus on the ones that are particularly relevant to pest-resistant transgenics.

1. Acceptability by the general public: Recent farmer perceptions of insect resistant transgenic crops are largely positive, at least in the United States, with decreased pesticide exposure of farm workers and the environment seen as significant benefits of transgenic crops. However, many people are still concerned about transgenic crops in general, which includes pest-resistant crops that have been genetically modified. Some argue that this has resulted in excessive regulation as a consequence of bureaucrats' "self-defensive reactions." The public is concerned about the safety of genetically modified foods as well as the potential negative environmental effect of transgenic crops. The antibiotic marker genes used to select for gene transfer may lead to antibiotic resistance in human infections, as an example of the former worry.
2. Efficacy: Whether or not transgenic crops are effective depends a lot on whether they are seen through the lens of chemical pesticides or through the lens of no extra protective intervention. Even the most advanced transgenics are not as effective as chemicals. However, sufficient transgenic experiments in real IPM systems have yet to be conducted. Such studies are likely to show the actual, long-term advantages of transgenic crops, particularly if environmental harm and health concerns are included into the &costings'. Users may be more enthusiastic about transgenics as a consequence of these findings.
3. Activity spectrum: There are numerous insect pests that are just not sensitive to the present range of ICP genes. Corn rootworms and cotton boll weevils are the most well-known of them, owing to their great economic importance to agrochemical and seed firms in the United States. Many severe pests with local, crop-specific significance have received little or no attention from this technology, particularly if no effective Bt has been discovered. Plant transformation technology, on the other hand, has the potential to be very flexible. There is a need to increase the number of genes accessible to cover these presently untreatable pests.
4. Resistance management: No matter how successful a transgene is at first, pests will almost certainly acquire resistance to it, just as they do to chemical pesticides. With proper resistance management methods, the transgenic durability is expected to be prolonged. The greater the number of various kinds of genes accessible and the simpler it is to create alternatives, the easier it will be to successfully control resistance.

1.11 Transgenic technology:

After analyzing the present state of both chemical pesticide and transgenic crop methods to crop protection, we came up with a list of qualities that a "ideal" new pesticide would have.

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Volume 21 Issue 7, July 2019

We've recognized the following among them:

a) It should be reasonably inexpensive to manufacture.
b) It should be safe for the environment.
c) It should be simple to utilize in the field and specific to the target location.
d) It should have a broad range of action, but only against pests, not other beneficial insects or intended consumers.
e) It should be produced using a technique that is flexible enough to target any pest's susceptible locations; obviously, places that have already developed resistance to chemical pesticides should be avoided.
f) This technology should also be adaptable enough to target any specific pest species or order.
g) The technology should be flexible enough to allow for the rapid creation of substitutes if the pest develops resistance.
h) It should ideally have an acute rather than a chronic impact on the pest, but the latter's usefulness in an IPM approach should not be overlooked.

2. DISCUSSION

The agrochemical business is expected to follow the pharmaceutical sector in shifting from chemistry-based whole organism screening to biologically based target screening techniques for product development, albeit at a slower pace. The combination of biology, genomic techniques, and sequencing data with model insect and nematode systems like Drosophila and Caenorhabditis offers up a new method to pesticide development, replacing chemical modification and whole organism screening. This latter method has resulted in the discovery of few targets over time, and novel approaches, such as the bio insecticides discussed in this article, have their own set of constraints. The creation of a delivery route from transgenic plants to insect hemolymph would alleviate a major limitation of the transgenic crop protection strategy. The necessity for this research has become even more pressing in light of recent developments in the pharmaceutical sector.

3. CONCLUSION

Since the initial reports of transgenic plants surfaced, significant progress has been made toward applying this novel technology to the very real, practical goals of crop security. It is anticipated that the promising progress mentioned above will be maintained and expanded in order to make a major contribution to redressing the balance between global food production and global food demand in the twenty-first century. Scientists, industry and government officials, farmers, and the general public all have responsibilities to play in developing technology that is wider, longer-term, and more socially responsible than is now the case. Proteins have a tough time finding their way into the stomach as a target. It's also worth mentioning that none of the commonly used synthetic chemical pesticides are designed to attack the stomach. These are typically directed towards the pest's neuroendocrine system's most sensitive regions, which are accessible via the hemolymph.

ISSN: 0374-8588

Volume 21 Issue 7, July 2019

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