Pocket K No. 57
Impact of GM Crops on Soil Health

A healthy agricultural production system cannot exist without healthy soils. Aside from being the habitat of diverse organisms that contribute to carbon sequestration, the soil plays a vital role in food production as well as in climate change mitigation.

Majority of the carbon dioxide present in the atmosphere are contributed by various biological processes that take place in the soil. Carbon sequestration happens when carbon from the atmosphere is absorbed and stored in the soil. This process is vital because the more carbon is stored in the soil, the less carbon dioxide would be present in the atmosphere that contributes to climate change. Thus, restoring degraded soils and adopting soil conservation practices are important to decrease greenhouse gases emitted by agriculture. [1]

With biotech products such as herbicide tolerant crops, conservation practices have been used not just to the farmers' advantage, but also to preserve soil health.

Effect of GM crops on soil health

Soil health is evaluated based on how soil performs its capacity to promote plant growth and productivity. This growth-promoting role should be preserved for future use. Several parameters are used as indications of soil health (soil organic matter, fertility, erosion, nutrient retention, etc.); physical (infiltration, soil structure, bulk density, etc.); chemical (pH, reactive carbon, soil nitrate, etc.); and biological properties (soil enzymes, microorganisms and their activities, etc.).[2] The effect of genetically modified (GM) crops with herbicide tolerance and insect resistance traits on some of these indicators have been explored to elucidate the impact of GM crops on soil health.

Soil erosion

Mechanical weeding is one of the causes of top-soil erosion. Weeds rob nutrients from crops. In one year, weeds would rob enough nutrients to have fed one billion people globally.[3] One of the common soil practices used in farming to get rid of weeds is tilling or plowing. However, this practice is very laborious, time consuming, and not very effective in controlling weeds. It also causes erosion and runoff, affecting soil biodiversity and allows greenhouse gasses to escape from the soil. According to World Wildlife Fund, half the world's soil has been lost in the recent 150 years.[4] These concerns have led scientists to develop crops that would not need tilling, which are now known as herbicide tolerant crops.[5]

Herbicide tolerant (HT) crops tolerate exposure to broad-spectrum herbicides like glyphosate and glufosinate, which are also among the safest kinds used in farms. These herbicides target specific enzymes in the plant metabolic pathway, which affects plant food production and in extreme cases kill the plants. When the HT crops are exposed to these herbicides, they do not die, unlike the weeds surrounding them. Thus, HT crops promote no-till or conservation tillage. After herbicide application, the weeds die and work as a blanket that protects the soil from wash off. With less or no tilling, there would be less soil erosion. This would mean more water retention and fewer greenhouse gas emissions.

This is a win-win solution for the farmers and the environment because there is less labor for farmers, and they don't need to purchase fossil fuel for tractors that plow the soil. The current types of herbicides used with herbicide tolerant crops are also far less toxic than those types used last century.[3]

The herbicide tolerance technology has helped millions of farmers all over the world. In 2018, 88.7 million hectares were planted with HT crops, the largest area planted to a biotech trait.[6]

Decomposition

Decomposition, the process of recycling nutrients back to the soil from organisms, involves the action of soil organisms (including microorganisms) that break down the large pieces of organic matter into smaller ones.

A field experiment was conducted to investigate the decomposition of leaf residues from Bt and non-Bt maize hybrids. To show the mechanisms that may cause variations in decomposition, structural plant components (C:N ratio, lignin, cellulose, hemicellulose) were evaluated. Bt protein concentrations were also monitored during all the stages of growth and development. Results showed that leaf residues were similar in Bt and non-Bt plants, while differences among non-Bt plants were more prominent. This was also observed in plant components, wherein more variations were found among the non-Bt plants than in between Bt and non-Bt plants. Bt protein was also found to have fast degradation, indicating shorter persistence in plant residues. No adverse effects was found to be contributed by Bt plants on the activity of the soil decomposer community.[7]

Soil enzymes

Soil enzymes are key in the ecosystem processes due to their role in accelerating several reactions in soils. Insect resistant Bt plants contain Cry proteins from soil bacterium *Bacillus thuringiensis* in all parts of the plant which has been questioned to change microbial dynamics, biodiversity, and essential ecosystem functions in soil. Researchers from New York University conducted a meta-analysis to define the fate and effects of Bt crops in soil ecosystems and found that the response ratios of soil enzymes involved in nitrogen cycling tend to increase and those involved in phosphorus cycling often decreased. They also noted that the responses of enzymatic activities were generally stronger in Bt crop cultivations with Bt residues than those without Bt residues. These findings imply that Bt proteins and the quality or quantity of Bt crops biomass could both influence the response ratios of soil enzymes, but more studies are needed to clearly define the cause and effect.[8]

Soil organisms

Several reviews on the impact of GM crops on biodiversity, particularly on soil organisms, have been published. One comprehensive review covering 70 scientific articles on the effects of Bt crops on soil ecosystem found that there were few or no toxic effects of Cry proteins on non-target soil organisms including woodlice, collembolans, mites, earthworms, nematodes, protozoa, as well as the activity of different enzymes in soil. The minor effects reported were mostly results of differences in geography, temperature, plant variety, and soil type, and were not linked to Cry protein presence.[9]

Another extensive review published in *GM Crops* also showed the impacts of GM crops on soil organisms and reached similar conclusion. Some of the studies included in the review are summarized in Table 1.[10]

Table 1. Studies on Impact of Bt crops on soil organisms

Organism	Crop Event	Comparison	Effect
enchytraeids	corn: Bt11 (Cry1Ab), MON88017 (Cry3Bb1)	Bt and non-Bt	no significant differences for Cry3Bb1; significantly higher survival and significantly lower reproduction for Cry1Ab, likely to be caused by differences in plant components
soil microbes	corn: MON863 (Cry3Bb1)	Bt and non-Bt	no adverse effects on saprophytic microbial communities of soil and decaying roots or on decomposition
soil microbes	corn: Event 176 (Cry1Ab), MON810 (Cry1Ab)	Bt and non-Bt	the presence of Bt maize did not cause changes in the microbial populations of the soil or in the activity of the microbial community
earthworms	corn: Bt11 (Cry1Ab), MON810 (Cry1Ab), MON863	Bt and non-Bt	no significant differences in biomass of juveniles and adults
earthworms	cotton: GK19 (Cry1Ac)	Bt and non-Bt	No significant acute toxicity; average weight, numbers of cocoons and new offspring not significantly different

snails	Cry1Ab	purified protein alone in soil	No negative effect during the observed stages

Based on the studies discussed, GM crops do not pose a significant risk to soil health. Other environmental factors such as weather changes usually contribute more to the differences in the soil health indicators. Instead, the cited studies provide evidence that GM crops help keep agricultural soils healthy and productive by promoting conservation tillage. With these advancements, it is expected that more GM crops engineered for conservation agriculture will be developed to keep our soil healthy and our food secure.

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