Plant Biotechnology: Current and Potential Impact For Improving Pest Management In U.S. Agriculture An Analysis of 40 Case Studies

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Fungal Resistant Sunflower

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23. SUNFLOWER

Fungal Resistant

Production

In 2000, there were 2.8 million acres of sunflowers planted in the U.S. [1]. North Dakota is the number one sunflower producing state. Forty eight percent of the nation's sunflower acreage is in North Dakota, with a production value of $125 million [2]. Kansas, Minnesota, and South Dakota combined account for approximately 38% of the nation's sunflower acreage. Table 23.1 delineates sunflower acreage, production, and value for these four states.

Approximately 80% of sunflower acreage is planted to oilseed varieties, with the remaining planted to non-oilseed, or confectionery. Sunflower oilseed is a major source of vegetable oil nationally and internationally. Confectionery seed is used in snacks, baking, and birdseed mixes.

Sclerotinia Diseases

Throughout the 1990's, sunflower growers in North Dakota, Kansas, Minnesota, and South Dakota ranked Sclerotinia as their number one disease problem [4]. In a 2000 North Dakota field survey, incidence of Sclerotinia (wilt and head rot) ranged from 0 to 20.6%, with a state average of 8.1% [6]. Since both Sclerotinia wilt or head rot can destroy the plant, yield losses may be similar to the percent of infected plants, approximately 8%. In a 1997 survey, it was determined that a considerable number of sunflower fields had incidence of Sclerotinia head rot that exceeded 10% of the plants: Kansas (36%), Minnesota (34%), North Dakota (19%), and South Dakota (27%) [4]. In 1999, Sclerotinia reached epidemic proportions, affecting more than 80% of the sunflower fields in eastern North Dakota [5]. The National Sunflower Association estimated this loss at over $70 million to sunflower producers.

Sclerotinia sclerotiorum is the fungus that causes Sclerotinia wilt and Sclerotinia stalk and head rot. The fungus is often called 'white mold'. It is soil-borne, surviving as sclerotia (resting bodies) in the soil for up to five or six years [7, 8]. When sunflower

roots come in contact with sclerotia in the soil, the sclerotia germinate and infect the roots, causing Sclerotinia wilt. The fungus decays root tissue and grows up into the stem and decays stem tissue. The plant becomes girdled and quickly wilts and dies. Weakened stems also make plants susceptible to lodging in high winds.

Sclerotinia wilt infection spreads to neighboring plants by contact between the roots. Spread is therefore usually limited to within rows, seldom reaching across rows. When infected plants die, however, sclerotia are returned to the soil, increasing inoculum levels for infection of the next crop. Sclerotia are spread from field to field by natural or human-assisted soil movement.

If weather conditions are right, with high soil moisture for ten to fourteen days, sclerotia in the soil will germinate to form mushroom-like structures, *apothecia*, which sprout above the soil surface and produce and release millions of ascospores. The spores are carried by air currents to susceptible plant hosts, such as sunflower, where they can germinate and infect the stems or head. Ascospores require a film of water to germinate and infect. Stalk rot appears as a water-soaked lesion which eventually girdles and decays the stalk, causing it to bend over at the point of infection. In wet weather, a cottony growth develops on the rotting stalk. The tissue above the point of infection dies. Head rot first appears as water-soaked spots or bleached areas on the back of flower heads. The entire head may decay and the entire seed layer falls away, or seeds will remain but the majority will be empty.

Low levels of sclerotia in the soil will cause substantial losses in sunflower [7]. Plants infected with Sclerotinia wilt usually die quickly. Plants that survive may or may not produce seed. Their heads are usually smaller and their seed weights lower, yielding about half what a healthy plant would yield.

Sclerotinia stalk and head rot occur more sporadically than wilt does, but can cause significant losses in addition to increasing levels of sclerotia in the soil for future infections. Plants suffering from Sclerotinia head rot may yield up to 33% less than a

healthy plant, but more yield is lost due to difficulty in harvesting seed from heads made brittle from infection. Head rot also decreases seed oil content of oil seed sunflower and quality of confection sunflower.

Sclerotinia Management

There are no sunflower hybrids available with Sclerotinia resistance, and there are no fungicides registered for its control. The key to Sclerotinia control is reducing levels of sclerotia in the soil [7, 8]. This is done by avoiding planting in infested fields, avoiding solid seeding and high plant populations, avoiding planting next to infested fields, and by crop rotation with non-susceptible crops such as small grains, corn or sorghum. Recommended rotation length will vary with disease level in the soil. Low incidence may require a three to five year rotation, while a high level of incidence may require as many as six to eight years. Growers are advised to not rotate with other highly susceptible crops, including dry beans, mustard, crambe, and canola. Monitoring throughout crop development also is needed to assess Sclerotinia disease presence and incidence.

Sclerotinia Resistant Sunflower

Resistance to Sclerotinia has been a goal of sunflower breeders for decades [10]. Some varieties have more tolerance than others, although none will stand up to a heavy infection. While natural tolerance has been incorporated into a limited number of commercial hybrids, it fails to provide complete protection when the crop is subjected to environmental conditions conducive to disease development [11, 12]. Often useful traits such as disease resistance are closely linked with undesirable traits, so capturing the desirable without the undesirable can be difficult. Resistance to Sclerotinia is particularly complicated because it causes two types of disease, the wilt infection that originates at the roots from sclerotia, and the head and stalk rot infections that originate from airborne spores. Breeders are now looking toward genetic engineering to develop Sclerotinia resistant sunflowers.

Oxalate is a toxin secreted by Sclerotinia. It weakens plant tissue and plays a key role in the pathogenicity of Sclerotinia [13]. Crops with natural resistance to Sclerotinia, such as wheat and barley, produce an enzyme, oxalate oxidase, that breaks down and detoxifies the toxin oxalate. Researchers at Pioneer Hi-Bred International, in collaboration with researchers at Advanta Seeds and Syngenta, have isolated an oxalate oxidase gene from wheat and inserted it into sunflower via *Agrobacterium*-mediated transformation [14]. Transgenic lines were produced that constitutively express oxalate oxidase and that show good resistance to wilt, stalk and head rot [3]. In one experiment detached sunflower leaves were inoculated with Sclerotinia. After 10 days Sclerotinia lesions had grown much larger on the non-transformed leaves (8cm) than on the transformed leaves (1cm) [15]. Researchers are also investigating the effects of different promoters in enhancing oxalate oxidase expression [15]. Field tests of inbred and hybrid lines showed that oxalate oxidase gene expression enhanced resistance to head rot even in lines with some background level of natural tolerance [16]. This suggests higher levels of resistance may be achieved by combining transgenic resistance with natural tolerance.

Estimated Impacts

Because Sclerotinia is currently not being treated with fungicides, hybrids engineered to be resistant to the disease will not impact pesticide use. Transgenic varieties, however, are expected to prevent the yield losses to Sclerotinia currently estimated at 8% annually ($17.2 million) in North Dakota, Minnesota, Kansas, and South Dakota. Table 23.2 delineates these yield loss estimates by state. It is assumed that a price premium of $2/acre would be charged for the transgenic sunflower seed with Sclerotinia resistance, which implies an increase in production costs of $4.8 million per year assuming all acreage in the four states are planted with the transgenic. Transgenic sunflower with Sclerotinia resistance may also facilitate an increase in annual sunflower acreage by making it possible to shorten crop rotations and thereby plant sunflower more frequently in a given period of time [9]. Farmers' flexibility in crop choice may also increase as crops like canola or dry beans, which are currently avoided in rotations for fear of exacerbating Sclerotinia in sunflower, may be judiciously included with the resistant sunflower [9].

TABLE 23.1: Sunflower Production: Major States (2000)

	Acres[1] (000)	Production (Million lbs.)	Value (Million $)
North Dakota	1340	1760	125
Kansas	220	252	14
Minnesota	90	126	10
South Dakota	740	1132	64

Source [1],[2]

TABLE 23.2: Losses of Sunflower Production to Sclerotinia Diseases[1]

	Production (million lbs.)	Value (million $)
North Dakota	140	10.0
Kansas	20	1.2
Minnesota	10	0.8
South Dakota	90	5.2
Total	260	17.2

[1]Calculated at 8% of the value and production estimates. See Table 23.1

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