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

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Viral Resistant Wheat

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38. WHEAT

Viral Resistant

Production

Wheat acreage in the Pacific Northwest represents approximately 9% of national wheat acreage and 14% of national wheat production [1]. In 2000, 1.3 million acres of wheat were harvested in Idaho, 2.4 million acres harvested in Washington, and 0.9 million acres in Oregon. The vast majority (84% in Idaho, 92% in Washington, and 99% in Oregon) of wheat planted in the Pacific Northwest is white winter wheat, a low protein wheat used in pastries, cookies and other baked goods. The total value of soft winter wheat production in the Pacific Northwest in 2000 was $648 million with a total volume of 242 million bushels [1]. Winter wheat yields total 90 bu/A in Idaho, 73 bu/A in Washington and 62 bu/A in Oregon [1]. Winter wheat is planted in the fall and harvested during the following spring and summer.

Viruses in Wheat

Two of the most serious viruses affecting wheat in the Northwest and elsewhere are barley yellow dwarf virus (BYDV) and wheat streak mosaic virus (WSMV) [2, 3, 4, 5]. Barley yellow dwarf virus is a complex of closely related viruses that cause disease in small grains and grasses. The polyhedron-shaped virons occur only in the phloem tissue, the tissue responsible for nutrient transport throughout the plant. BYDV causes damage by partially plugging the flow of nutrients in infected plants.

Detection of BYDV in wheat can be difficult because its symptoms can be mistaken for those of water stress or nutrient deficiency. Leaves become stiff and inflexible, and discolor to yellow or red. Plants are also stunted with reduced root growth. Yield losses in wheat due to BYDV infection can vary widely from year to year, and depend on virus strain, plant cultivar, plant stage at time of infection and environmental conditions. Common estimates of regional losses to epidemics range from 5% to 25%, but may reach as high as 70% in an individual field [2, 6].

Barley yellow dwarf virus is transmitted only by aphids, which feed by inserting their mouthparts into plant phloem tissue and sucking out nutrients and sap. An aphid will have to feed on an infected host for at least thirty minutes and as long as several hours in order to become an infective carrier of BYDV [3]. There are several species of aphids that transmit BYDV in wheat in the Northwest, including the oat bird-cherry aphid, greenbug, corn leaf aphid, English grain aphid, and rose grass aphid [2]. Because aphid feeding is the only way BYDV is transmitted, aphid population parameters determine distribution of BYDV and may largely determine the severity of BYDV in a region.

Wheat streak mosaic virus particles are rod-shaped and flexuous [2]. The virus is spread by a tiny mite, the wheat curl mite, which feeds on wheat leaf margins and cannot be seen with the naked eye. The mite reproduces quickly and in high numbers, so much so that an early researcher estimated one mite could produce 180 quadrillion descendents in 50 days [3]. Mite feeding damage causes the leaves to curl upward and inward, enclosing and protecting the mites [2]. Mites may feed for as little as 15 minutes before picking up WSMV from an infected host or infecting a healthy host. WSMV survives only on green, living tissue and cannot propagate itself or be spread from dead plant material or stubble. All instars of the mite are capable of transmitting the virus, but adults can do so only if they acquire the virus as nymphs [14].

Symptoms of WSMV, are light green to yellow streaks on the leaves. In addition, plants are stunted. As with BYDV, severity of WSMV varies from year to year and depends on factors such as wheat cultivar, virus strain, plant age at time of infection, and environmental conditions. Distribution of WSMV, as with BYDV, is closely related to distribution of the vector [7]. The wheat curl mite is almost immobile and therefore is completely dependent on wind for distribution. As a result, an infected wheat field will often first show WSMV symptoms in plants along the borders. Yield losses in wheat infected with WSMV may be as high as 90% [3].

Virus Management

There are no pesticides that target viruses directly, and there are no commercial winter wheat cultivars with resistance to BYDV or WSMV or their vectors. So the best way to minimize the threat of these viruses is to minimize their sources and minimize exposure to their spreading agents [2, 3, 7].

For BYDV management, volunteer grains should be removed from fields and surrounding areas before planting winter wheat. Corn is a symptomless host for BYDV and is also a host for some of the aphid species that vector it, so winter wheat should be planted after corn has been harvested or dried. Because aphids must feed for an extended time period before BYDV is transmitted, use of insecticides to keep vector populations low help delay spread of BYDV. Some success has been achieved with systemic granules drilled in at fall seeding time for winter wheat. This practice helps to prevent aphid multiplication and spread of aphids that may vector barley yellow dwarf disease [12]. Approximately 2%of wheat acreage in the northwest is treated with an at-planting systemic insecticide for control of aphids [13] [4]. The insecticide is phorate, which is used at a rate of 0.9 lbs AI/A and a cost of $10/lb AI. It is estimated that 82,800 pounds of phorate are used annually in Northwest wheat to control aphids that spread viruses. Wheat growers in the northwest use a total of approximately 178,000 pounds of insecticides each year to control all pests.

There are no pesticides for use against the wheat curl mite, so care must be taken to plant when and where there are no sources for infestation. If mite infestation occurs and WSMV infection is severe in a field, the only solution is to destroy the crop and replant.

As with BYDV, destruction of volunteer wheat to remove virus sources and delayed planting to reduce exposure of young plants to vector populations are control measures for WSMV. Planting practices can also help manage wheat curl mite populations [8]. Leaving fields fallow in the summer creates a “brown period” between harvest of one crop and planting of the next during which there are no green hosts for the wheat curl mite and so its populations diminish. Since the mite and virus survive only on green tissue, they will die during this period. There is, however, an increasing trend in the Pacific Northwest of following winter wheat with a spring planting, which creates a "green bridge" for the mite to survive and continue infesting subsequent wheat plantings. The incidence and severity of WSMV in wheat is expected to increase along with increased plantings of "green bridges".

To minimize exposure of winter wheat to BYDV vectors, planting should be delayed until after vector populations have subsided, generally in late fall. A delay of two weeks after local cereal crops have matured is recommended before planting winter wheat. In some years the delay is short (1 week) while in other years the delay can be a month-long [11].

Although delayed planting is recommended as a practice for reducing risk of virus infection, other environmental conditions also affect decisions about planting date [7]. For example, soil moisture levels in dryland production influence wheat establishment in the fall and the crop's hardiness for winter survival, in addition to overall agronomic performance. Soil moisture levels are often highest in early fall, when risk of virus infection tends to be high. Planting winter wheat as early as possible can increase yields by 10% or more [3]. Growers must balance the risk of planting too late for optimal soil moisture and too early for virus management. It is estimated that 1.4 million acres of wheat (30% of the acreage) are planted on a delayed schedule in order to avoid the aphids that vector BYDV (see Table 38.1). It is estimated that the yield loss on this acreage due to delayed planting and the reduction of available soil moisture totals 4-10 bushels of wheat/A, which represents a loss of 6-13% on the acres planted late. The wheat plant gains stems and leaves first in the fall, then – cued by daylight hours and heat units – stops vegetative growth and starts forming and filling kernels. Kernel fill starts for all wheat, regardless of when it was planted, so harvest time ends up being the same for wheat planted early as for wheat planted late. How much fill is in the kernel depends on how many leaves and stems and tillers have been produced before kernel fill starts. So delayed planting cannot be made up for by delaying harvest [10].

Yield losses from BYDV and WSMV in wheat average approximately 1 to 3% which results in an annual loss of $6.6 million across the Pacific Northwest, [10] (see Table 38.2).

Transgenic Wheat

Researchers at the University of Idaho have transformed commercial soft winter wheat varieties with genes to protect the plants from viruses [6]. Three genes are being evaluated. Two are coat protein genes, one from each of the two viruses BYDV and WSMV. The pathogen-derived virus resistance induced by a coat protein gene would be specific for the virus it came from. The third gene is derived from yeast. The products of this third gene interfere with a key enzyme needed for viral replication, thus providing more general virus resistance than does pathogen-derived resistance. Researchers have developed resistant germplasm and have completed several years of field tests [14].

Estimated Impacts

Based on the 2000 crop value for Pacific Northwest winter wheat and an average annual loss of 2%, planting of winter wheat cultivars resistant to BYDV and WSMV could save an estimated $6.57 million by preventing current losses to these diseases (Table 38.2).

With virus resistant winter wheat, growers would no longer need to delay planting for virus management. They could therefore plant earlier, when soil moisture tends to be highest and most favorable for crop germination and establishment. Wheat production would increase by $39 million per year which is the amount currently lost to viruses and to the practice of late planting (see Tables 38.1 and 38.2). An additional impact would be the elimination of current insecticide use (82,800 lbs./yr) against aphids that vector BYDV. 15.2 million bushels would no longer be lost which is equivalent to 912 million pounds of wheat (60lbs./bu).

Table 38.1 Annual Losses to Delayed Planting in Winter Wheat

State	Affected Acreage[1]	Yield Loss (bu/acre)[1]	Total Yield Loss (bu)	Price ($/bu)	Lost Value ($)
Idaho	75,000	10	750,000	2.60	1,950,000
Oregon	225,000	4	900,000	2.70	2,430,000
Washington	1,110,000	10	11,100,000	2.70	27,945,000
TOTAL	1,410,000		12,750,000		**$32,325,000**

Based on 2000 acreage and prices.

[1] Sources [9, 10, 11]

Table 38.2. Annual Losses in Winter Wheat Due to BYDV and WSMV

		Estimated Average Annual Yield Loss			
STATE	**Bushels Harvested[1]**	**(%)[2]**	**(bushels)**	**Price ($/bu)**	**($)**
Idaho	65,700,000	2	1,314,000	2.60	3,416,400
Oregon	45,260,000	2	905,200	2.70	2,444,040
Washington	131,400,000	2	262,800	2.70	709,560
TOTAL	242,360,000		2,482,000	**TOTAL**	**$6,570,000**

[1] From [1]

[2] Source: [10]

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