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

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Herbicide Tolerant Lettuce

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7. LETTUCE

Herbicide Tolerant

Production

California produces approximately 70% of the head lettuce and 90% of the leaf lettuce grown in the U.S. [6]. In 1999, lettuce acreage in California totaled 214,000 with an annual production of 7.2 billion pounds and a value of $1.1 billion [6].

Weed Control

Several broadleaf weeds occur in California lettuce fields, including pigweed, purslane, common groundsel, annual sowthistle, shepherds-purse, mustard, burning nettle, nightshades and common lambsquarters. Some of the grassy weeds are annual bluegrass, barnyardgrass, canarygrass and volunteer cereals [3].

The majority of lettuce plantings are direct seeded, using coated seed. Control of weeds during seedling emergence and the early stage of lettuce development are essential to reduce competition and increase crop vigor. Weeds that emerge within two weeks of lettuce emergence must be removed to prevent yield reductions. Once a lettuce plant has developed eight to ten leaves, weed competition losses are less likely to affect development of lettuce quality [3]. Weed control is also necessary to reduce thinning costs and crop injury associated with thinning under weedy conditions [3]. A second flush of weeds may occur following thinning and cultivation and lead to weeds at harvest time, which can interfere with harvest quality and efficiency. Burning nettle makes hand harvest difficult because it has stinging hairs on the plant surface [3].

Before the development of effective herbicides, severe weed infestation sometimes resulted in complete lettuce crop losses in California [1]. The current weed management system used in California lettuce production includes a combination of herbicide use, cultivation and hand hoeing (long handled hoes). The herbicides used in California have changed little in more than 30 years. Sethoxydim was registered for postemergence grass control in the 1980's although preemergence applications of pronamide, benefin and bensulide have been the principal

herbicides used in lettuce production since the 1960's [2]. Because of limited availability and the relatively short growing season, the application of postemergence herbicides is not a general practice with lettuce.

Lettuce herbicides have relatively long soil persistence. Pronamide and benefin will persist past the normal crop growing season [3]. As a result, crops that are tolerant to these chemicals are selected for planting in rotation with lettuce. Pronamide and bensulide are applied mainly to dry soil after lettuce planting and incorporated with sprinkler irrigation [2]. Benefin must be preplant incorporated [3]. With lettuce herbicides, an irrigation of one inch of water is considered adequate for herbicide movement into the zone of weed seed germination [3]. Pronamide, benefin, and bensulide can cause injury to lettuce under environmental conditions where lettuce emergence is slowed.

The extreme diversity of weed species results in many problems for maintaining acceptable control during the production season. No individual herbicide or any combination of herbicides will control all weed species under all production conditions and soil types [7]. Common groundsel and annual sowthistle are in the same botanical family as lettuce, and therefore, difficult to control with herbicides that are registered for use in lettuce [3].

Following seedling emergence, the lettuce crop is cultivated two or three times for weed control. Handweeding is performed in conjunction with thinning and once again later in the season. Hoeing of lettuce fields with long, handled hoes must be supervised closely to avoid crop loss, as the damage or elimination of one lettuce plant per six bed feet row results in the potential loss of 181 cartons of lettuce per acre at harvest [3]. Growers apply nearly all lettuce herbicides as banded applications down the row of plants. Cultivation is practiced between the rows of plants.

Because of the combination of herbicides, cultivation and handweeding, lettuce fields are largely free of weeds. Lettuce yield losses because of uncontrolled weeds in California are minor – estimated at 2% of potential yield [14]. Lettuce in the Salinas Valley is for the most part grown on land that has very low weed pressure. This is due to effective weed management (cultivation,

hand weeding, and herbicides) for a long period of time. Growers keep the perimeters of fields very clean and seldom allow weeds to go to seed [12].
Table 7.1 presents weed control ratings for benefin, bensulide, pronamide, sethoxydim and glyphosate. As can be seen, pronamide controls eight of the twelve troublesome/common weed species in California lettuce. (Bensulide controls six; benefin controls four and sethoxydim controls two.) Glyphosate is registered for use in lettuce at preplant for removal of emerged weeds. As can be seen in Table 7.1, glyphosate provides control of 11 of the 12 species.

Table 7.2 presents information on the use amounts of herbicides currently used in California lettuce. As can be seen, approximately 193,000 pounds of active ingredient are used annually. A University of California budget for production of lettuce in Monterey County was prepared for 2000-2001. Weed control costs total $166 per acre out of an estimated $4,500 per acre to produce lettuce (see Table 7.3). The Budget assumes that the typical lettuce field is cultivated twice, and eight hours of handweeding are required.

Transgenic Lettuce

Lettuce has been transformed with genetic material from a soil bacterium that enables the plant to tolerate direct applications of glyphosate (Roundup), an herbicide used to kill emerged weeds. Researchers at the University of California have released results of field studies with glyphosate tolerant (Roundup Ready) lettuce cultivars in 2000 in the Salinas Valley [10, 11]. The 2000 trials showed that a single application of glyphosate at the two true leaf stage of lettuce provided excellent weed control and this has been confirmed with trials in 2001[13].

Overall, the glyphosate treatments provided better control of pigweeds, nightshade, shepherds-purse and groundsel than the standard pronamide or bensulide [11]. The labor required for handweeding and thinning for all glyphosate treatments was significantly lower than that required with bensulide or pronamide (67% lower). There was no evidence that glyphosate resulted in any crop injury to lettuce. The most effective glyphosate treatment included two applications (at 1.0 Lbs. AI/A): one at the two-leaf stage of lettuce growth, and another two weeks later. Lettuce yields were significantly higher in the glyphosate plots than in the bensulide or pronamide plots [11].

Although no lettuce crop injury due to glyphosate applications was noted in the 2000 trials, further tests are needed using different cultivars, different types of coated seed, and testing under different planting/weather conditions in different production regions. [13].

It is not possible to extrapolate from this trial to grower fields since weed pressure in the trial was so much higher than typical grower fields. High populations were worked with in order to clearly define the correct stage to apply glyphosate to lettuce. [12] The use of extremely heavy weed populations put the available herbicides at a disadvantage. The amount of labor required for handweeding and thinning was not typical of a commercial operation.

The UC trial results suggest that reduced hand weeding costs may be possible in glyphosate tolerant lettuce compared to standard practices. However, standard grower practices were not simulated in the trial: weeds were not removed at the time of thinning to determine if glyphosate could be used to remove them more cheaply than hand weeding. This is not a typical practice. If glyphosate is applied at the 2 to 3 leaf stage, approximately seven days before thinning, then the thinning crew would have fewer weeds to remove by hand and in theory could move more quickly and save labor costs. [12]. Thus although lettuce yields were higher in the 2000 trials, this may be the result of the way in which the trials were handweeded and thinned. Glyphosate is not expected to provide a yield advantage over existing commercial weed control practices.

UC researchers believe that glyphosate tolerant lettuce has the potential to reduce handweeding inputs [12] Crews generally walk through a field twice, once to thin and remove some weeds and a second time after thinning to remove weeds. The use of glyphosate tolerant lettuce may eliminate the need for the second weeding trip [12]. There are two reasons for this: 1. Glyphosate applied at the 2-3 leaf stage will miss fewer weeds that thinning crews and early cultivations do now; and 2. if there are many weeds after thinning, it may be cheaper to spray the field a second time with glyphosate than to send a hoeing crew through the field a second time. There is one caveat, and that is due to the presence of burning nettle, a common weed of lettuce. Glyphosate has little activity on this species, therefore pronamide and or bensulide will continue to be used in fields with nettle populations, and weed management practices on those fields will remain the

same as they are now. It is estimated that the use of glyphosate could result in a reduction of .5-1.0 hour/acre savings in the time for final hand hoeing [13]

Estimated Impacts

For the following calculations, the 1999 California lettuce acreage total of 214,000 is used. If growers switch from the currently used herbicides (193,000 lbAI/y) to using one application of Roundup (.25 Lbs AI/A) with Roundup Ready lettuce, overall herbicide usage amounts would decrease by 140,000 pounds of active ingredient. Growers currently apply nearly all lettuce herbicides as band applications and it is likely that they would continue this practice with glyphosate, [12] Two 5-inch bands on a 40-inch bed means that 25% of the field is treated. One quart of Roundup Ultra is1.0 lb./a, which implies .25 lb./a if, applied as a band treatment or 53500 lbs. AI of glyphosate on the entire California lettuce acreage. Less than 25% of the growers would require two applications [12].

Roundup 4EC has been priced at approximately $46 per gallon in recent years, implying a cost of $11.50 per pound of active ingredient. Applying .25 pounds of active ingredient per acre would mean a materials cost of $3 per acre. One application cost of $8/a is assumed for the Roundup Ready system. There is no expectation that growers would cultivate less in the Roundup Ready system although an hour less of handweeding per acre may result [12] [13].

There is likely to be a “technology fee” for use of the Roundup Ready lettuce seed as well as a premium price for the seed. For this calculation, the technology fee and increased seed cost is assumed to be $50 per acre. Table 7.4 compares the per acre costs of the Roundup Ready system with the current system. As can be seen, the two systems are essentially equivalent in per acre costs ($166 current vs. $168 Roundup Ready).

A potential future problem for lettuce growers has been a failure to identify alternative herbicides that can be safely used with lettuce that will control problem weeds. For example, twenty registered herbicides were screened in lettuce 1998-2000. No viable lettuce herbicides were found [10].

It is the opinion of California Lettuce Research Board members that Roundup could play an important role in managing weeds in lettuce [13]. One primary factor that could significantly increase the potential value of the Roundup Ready system would be if the currently-used herbicides were cancelled for use in lettuce. For example the primary herbicide used in California lettuce is pronamide, which was first registered in 1972. Although pronamide was re-registered by EPA in 1994, it now requires a reassessment under the Food Quality Protection Act of 1996.

TABLE 7.1: Susceptibility of Weeds to Herbicides (Lettuce)

Weed Species	Herbicide				
	Benefin	Bensulide	Pronamide	Sethoxydim	Glyphosate
Barnyardgrass	C	C	P	C	C
Canarygrass	P	C	C	C	C
Groundsel	N	N	N	N	C
Lambsquarters	C	C	C	N	C
Mustards	N	N	C	N	C
Nettle, Burning	P	C	C	N	N
Nightshade, Hairy	N	N	C	N	C
Pigweeds	C	C	P	N	C
Purslane	C	C	C	N	C
Shepherds-purse	N	N	C	N	C
Sowthistle	N	N	N	N	C
Volunteer Cereals	N	N	C	P	C

C = Control; P = Partial Control; N = No Control
Source: [4]

TABLE 7.2: Herbicide Use: California Lettuce (1999)

Active Ingredient	%* Treated	Lbs. AI Applied/A/ Yr.	Total Lbs. AI/Yr.
Paraquat	1	.81	2179
Benefin	8	.76	13,039
Bensulide	12	2.91	75,760
Pronamide	65	.68	95,377
Sethoxydim	<1	.22	150
Glyphosate	1	2.28	6572
Total			193,077

*calculated by dividing acres treated [5] by acreage planted in 1999 of 214,000 [6]

TABLE 7.3: Cost to Produce Lettuce in Monterey County (2000/2001)

Weed Control	$/A
Herbicide Application Cost (IX)	8
Herbicide Material Cost	40
Cultivation (2X)	27
Weeding (8.0 hours/A)	91
Subtotal	166
TOTAL: ALL COSTS	4,500

Source: [9] Weeding costs include 3 hrs of the thinning hrs/acre. Cultivation costs excludes cost of fertilizer.

TABLE 7.4: Comparative Weed Control Costs: California Lettuce ($/ A)

	Current	Roundup Ready
Herbicide Application Cost (1X)	8	8
Herbicide Material Cost	40	3
Cultivation (2X)	27	27
Hand Weeding	91 (8 hrs)	80 (7 hrs)
Technology Fee/ Seed Premium	-	50
Total	166	168

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