
Herbicide Tolerant Alfalfa

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Financial Support for this study was provided by the Rockefeller Foundation, Monsanto, The Biotechnology Industry Organization, The Council for Biotechnology Information, The Grocery Manufacturers of America and CropLife America.
California ranks first in the production of alfalfa hay producing 7.1 million tons on one million harvested acres in 2000 [3]. California alfalfa yields of 7.0 tons/A are twice the national average for all states. The value of alfalfa hay production was $621 million or $87/Ton in California in 2000 [2]. Alfalfa is the second most important revenue producing field crop in California behind cotton and the third most important crop overall behind grapes and cotton. Alfalfa is the major feedstock for the state’s $3.6 billion/year dairy industry. California is the nation’s leading state in the production of milk and cream producing 25 billion lbs./yr.

The principal users of alfalfa hay remain the dairy industry consuming approximately 70% of California’s production. The remaining 30% is shared by the horse, cattle and sheep industry [31].

Alfalfa hay has certain attributes that make it an excellent forage for dairy cows. It is lower in fiber and higher in protein than any other single forage. As an ingredient in a ration for high producing cows, no single forage can contribute in more ways than alfalfa hay. Eighteen pounds of alfalfa provides one third of the fiber, over a third of the crude protein, a fourth of the energy and half of the calcium required for a high level of milk production [20]. High-quality alfalfa hay is also very palatable which is important for maintaining high levels of consumption to support high milk yields. In California, alfalfa has been the predominate forage of choice for high producing dairy cows because of its high intake and its rapid rate of digestion; both of which support high-energy intake to meet energy requirements for milk production during peak production [21].

Alfalfa is a perennial legume crop, usually grown for a three-to-five-year period. Each year new growth rises from the crown and it can be cut several times during a growing season. Alfalfa is grown in nearly every county in California under many different soil and climatic conditions from the low desert where 9-10 cuttings per season are made to the mountain valleys where 3-4
cuts are more common. Fall planting is generally recommended and is the most prevalent practice in California [19]. The entire California alfalfa acreage is irrigated.

Weed Problems

Alfalfa is a perennial herbaceous plant that is propagated from seed. Once established as a perennial, alfalfa grows rapidly and is extremely vigorous. Consequently, it competes effectively with many weeds. In contrast to the vigor of the established plant, seedlings of alfalfa are small, grow slowly, and are extremely susceptible to competitive suppression by various weeds that germinate with the crop. Thus the weed problems associated with alfalfa production are separated into two distinct groups: those of the year of seedling and those of established stands [7].

In new seedlings of alfalfa, competitive suppression is the major harmful effect of weeds. Many annual weeds and perennials overtop the slow-growing alfalfa seedlings soon after they emerge. Competition for light, nutrients, and water can retard alfalfa seedlings severely and even kill them. Weeds that grow uncontrolled during the establishment of a fall-seeded alfalfa crop can result in total stand loss before the first cutting [24].

In California, alfalfa has two distinct weed populations: the winter annual weeds which germinate with winter rains, and the summer annual weeds (usually grasses) which germinate in early spring and exist through summer [1]. Certain perennial weeds are able to encroach and proliferate in alfalfa fields. Also in areas of mild winters, winter annual weeds become established and grow when alfalfa is dormant.

The weeds present in the first three cuttings of the season are the winter weeds. When effective herbicides are not used, weeds represent up to 76% of the first cutting yields [8] [30]. In established stands, winter annuals start to germinate in September and October. If left unchecked, they become highly competitive before crop growth starts in late winter or early spring.

Many alfalfa fields can be infested with summer grasses. By August, if not controlled, the level of infestation can get very heavy; it is not unusual for the grass to be 50 to 70% of the forage
Annual grasses, especially yellow foxtail and barnyardgrass, cause the major summer weed problems in alfalfa. Yellow foxtail is one of the most serious summer weed problems. It can surpass the growth of a stand of alfalfa that is ageing or not growing vigorously.

Grasses reduce production and stand vigor by competing with alfalfa for nutrients, water and light. In the case of yellow foxtail, the sharp spikes or awns on the flower head irritate or ulcerate the inside of the mouths of livestock [22]. Most weeds reduce the quality of alfalfa. Because weeds are usually less palatable and less nutritious than alfalfa, their presence reduces the feed value and palatability of the total forage and reduces the forage intake compared with that of alfalfa alone. Milk production is reduced because the grass contains less protein and is digested more slowly than alfalfa. Milk production is further reduced because the cattle simply eat less of the alfalfa-weed mixture than they do of pure alfalfa. Hay quality is substantially reduced; the grasses typically have only 8 to 10% protein compared to 22% for good alfalfa and they can be very fibrous. Infestations of grass as high as 75% of the tonnage harvested from commercial fields have been observed [12]. Quality can be reduced from US no.1 hay to US no.3 or sample grades. This reduction in quality can translate into a $25 to $40 per ton loss to the grower [22]. [18]

The ten most common weeds in California alfalfa fields are: yellow foxtail, barnyardgrass, shepherd’s purse, common groundsel, coast fiddleneck, london rocket, common chickweed, common sowthistle, dodder and annual bluegrass.

In California the most common toxic weed problems are caused by groundsel and fiddleneck which may create pyrrolizidine alkaloid poisoning (PA poisoning). PA’s can damage the liver of animals and maintain their toxicity even in dried plant material and hay. The PA content of these plants ranges from less than .5% up to 1.2 % dry weight [27]. Most animals find PA plants unpalatable and will not eat them. Animals cannot select PA plants out of cubes or pellets and sometimes hay containing pelletized PA plants are made into a pelleted feed which causes losses of animals in feedlots [23].

Rarely do either fiddleneck or common groundsel occur as the only weed problem but normally they will be associated with other winter annuals consisting of london rocket, shepherd’s purse,
annual bluegrass and chickweed [35]. Common groundsel competes aggressively with alfalfa and can infest newly planted as well as older established fields.

With effective weed control, an alfalfa grower can expect to gain one half to one pound of alfalfa for each pound of weeds that are controlled.

**Herbicide Use**

Current herbicide use patterns on California alfalfa acreage are delineated in Table 35.1. As can be seen, California growers used 1.3 million pounds of active ingredients on alfalfa. Table 35.1 also shows estimates of the costs of the herbicides used in California alfalfa which totals approximately $16.6 million per year. The major herbicides used on California alfalfa acreage are trifluralin, imazethapyr, diuron, hexazinone, paraquat, bromoxynil, and 2,4-DB.

One herbicide active ingredient is rarely enough to control the full spectrum of weeds present in alfalfa fields at either the seedling stage or in established fields [15]. Generally combinations of herbicides need to be used in sequence for control of summer and winter weeds. Research has demonstrated that properly timed sequential applications of herbicide combinations can result in weed-free alfalfa hay in California. [17][32]

While pre-emergence herbicides are available for use in seedling alfalfa, most growers opt for post-emergence control programs. The most commonly used postemergence herbicides on seedling alfalfa in California include imazethapyr, bromoxynil, sethoxydim, and 2,4-DB. Imazethapyr controls many broadleaf weeds and some grasses. Bromoxynil or 2,4-DB is needed when fiddleneck, sowthistle, prickly lettuce, or lambsquarters are present [25]. Under heavy grass populations, sethoxydim has to be added.

Standard weed management practices in established alfalfa typically involve the use of a soil active herbicide (hexazinone, diuron) or, in the case of far northern California, metribuzin applied alone or in combinations. Summer annual grasses are typically controlled with a pre-emergence application of trifluralin and/or EPTC or with post-emergence applications of selective grass herbicides (sethoxydim or clethodim) [5].
It is estimated that approximately 20% of California’s alfalfa hay acreage does not receive adequate herbicide treatments currently and, as a result, weedy bales are produced during one half of the cuttings annually on 200,000 acres.[9] It is estimated that a $30/ton discount occurs due to weediness on half of the annual production (3.5 tons) on these acres[9],[14]. The total discount due to weediness is estimated at $21 million/year. Weedy bales result when herbicides are not used or when they are applied and do not perform effectively. [10]

Weed control in seedling alfalfa is often unattainable with available herbicides [29]. Preemergence herbicides can be safely used with seedling alfalfa only when the plants developed roots below the top soil layers where the herbicides are incorporated. Since the preemergence herbicides must be applied before weed seeds have germinated and after alfalfa roots have grown deep enough to avoid injury, proper timing is difficult. Because the post-emergence herbicides can only be safely used on alfalfa with a minimum of 2 or 3 trifoliate leaves, ideal timing of postemergence herbicide application for effective control may not be possible. Applications need to be made when the weeds are young seedlings—less than three inches tall. When the weed seedlings are taller than three inches, control can become erratic and unsuccessful[33]. Many times fiddleneck and groundsel will be beyond the three-inch stage before the alfalfa is mature enough to be treated [35]. Excellent weed control is the exception rather than the rule for seedling alfalfa [4]. More weed control failures in seedling alfalfa are related to treating too late for effective control [5]. The limiting factor is that by the time the alfalfa reaches the tolerant stage of its growth, the weeds are beyond their susceptible stage.

Some herbicides used in alfalfa perform erratically even when applied at the right growth stages of alfalfa and weeds. For example, 2,4-DB is very erratic under cold, foggy conditions [17]. When irrigation water is poorly drained, trifluralin will break down anaerobically and be ineffective [6]. Preemergence herbicides do not perform well if they are leached below the weed seed germination soil layer or if the soil is too cold.

Many alfalfa growers limit herbicide use in alfalfa during the last year of a stand because of anticipated planting of the land in the following year with a crop other than alfalfa. All of the preemergence herbicides used in alfalfa have plantback restrictions of 1-4 years due to their persistence in soil and potential for damage to sensitive rotation crops. The plantback restrictions
for commonly-used alfalfa herbicides are shown in Table 35.2. Thus, many growers limit their last year herbicide use to nonresidual postemergence grass herbicides –such as sethoxydim or clethodim- and/or the contact herbicide paraquat which can only be used in the winter when alfalfa is dormant. When paraquat is sprayed before alfalfa regrowth begins, broadleaf and grass weeds can be eliminated. However, broadleaf weeds cannot be further treated later in the year because of the absence of a postemergence nonresidual broadleaf herbicide. In the low desert valley and in other areas where non-dormant varieties of alfalfa grow throughout the year, winter dormant herbicides, such as paraquat, cannot be used because plants are still growing. Diuron is often used in combination with paraquat but it has a one-year plant back restriction. A grower’s choice for rotation is limited to cotton if diuron or hexazinone is used in the previous year. Weeds can contribute up to 30% by weight of the total forage yield during the last cuttings in the final year of a stand [18].

Transgenic Alfalfa

Glyphosate is a broad spectrum non residual herbicide which effectively controls most of the common annual broadleaf and grass weed species that are problems in California alfalfa fields [34]. Through genetic engineering, researchers have transformed alfalfa varieties through the insertion of a gene from a soil bacterium. This transformation confers glyphosate tolerance to the alfalfa. Research has demonstrated that the glyphosate tolerant alfalfa (Roundup Ready alfalfa) has excellent tolerance to glyphosate at all stages of plant development [11]. Preliminary research shows no negative effects of the Roundup Ready transgene on forage yield or other important agronomic traits. [11] [13]

Field tests with the glyphosate tolerant alfalfa are underway in California and several other states.

Estimated Impacts

It is estimated that two applications of glyphosate at .75lb ai/a each would provide effective season-long control of the troublesome weeds in California alfalfa fields. It is estimated that the glyphosate cost would be $15/a and that a seed premium of $5/a would be charged. The total annual cost of the Roundup Ready alfalfa program, if adopted on all one million California
alfalfa acres would be $20 million/year which represents an increase of $3.4 million in comparison to current weed control expenditures (see Table 35.1). The use of glyphosate would average 1.5 lb/a/yr which is .2lb/a higher than current herbicide application (see table 35.1). Thus, total herbicide use would be 200,000 pounds greater.

It is assumed that the glyphosate treatments would prevent the current loss of $21 million/year due to weediness in California alfalfa sales.
Table 35.1  California Alfalfa Herbicide Use: 2000

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Acre Treatments(^1) (000)</th>
<th>LB AI/ACTRT (000)</th>
<th>LB AI(^1) (000)</th>
<th>$/LB(^2) AI</th>
<th>Cost/yr (000 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2, 4-DB</td>
<td>46</td>
<td>.78</td>
<td>36</td>
<td>20</td>
<td>720</td>
</tr>
<tr>
<td>Benefin</td>
<td>7</td>
<td>1.29</td>
<td>9</td>
<td>16</td>
<td>144</td>
</tr>
<tr>
<td>Bromoxynil</td>
<td>42</td>
<td>.24</td>
<td>13</td>
<td>29</td>
<td>377</td>
</tr>
<tr>
<td>Clethodim</td>
<td>73</td>
<td>.15</td>
<td>11</td>
<td>95</td>
<td>1,045</td>
</tr>
<tr>
<td>Diuron</td>
<td>173</td>
<td>1.38</td>
<td>238</td>
<td>6</td>
<td>1,428</td>
</tr>
<tr>
<td>EPTC</td>
<td>43</td>
<td>2.63</td>
<td>113</td>
<td>5</td>
<td>565</td>
</tr>
<tr>
<td>Hexazinone</td>
<td>137</td>
<td>.47</td>
<td>65</td>
<td>31</td>
<td>2,015</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>100</td>
<td>.07</td>
<td>7</td>
<td>224</td>
<td>1,568</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>9</td>
<td>.44</td>
<td>4</td>
<td>27</td>
<td>108</td>
</tr>
<tr>
<td>Norflurazon</td>
<td>55</td>
<td>1.14</td>
<td>63</td>
<td>17</td>
<td>1,071</td>
</tr>
<tr>
<td>Parquat</td>
<td>174</td>
<td>.60</td>
<td>105</td>
<td>14</td>
<td>1,470</td>
</tr>
<tr>
<td>Pendimethalin</td>
<td>12</td>
<td>3.42</td>
<td>41</td>
<td>8</td>
<td>328</td>
</tr>
<tr>
<td>Sethoxydim</td>
<td>50</td>
<td>.32</td>
<td>16</td>
<td>52</td>
<td>832</td>
</tr>
<tr>
<td>Trifluralin</td>
<td>306</td>
<td>2.02</td>
<td>617</td>
<td>8</td>
<td>4,936</td>
</tr>
</tbody>
</table>

Total 1,227 1,338 16,607

\(^1\) Source: [16]

\(^2\) Source: [28], [26]
<table>
<thead>
<tr>
<th></th>
<th>Alfalfa Must Be</th>
<th>Weeds Must Be</th>
<th>Rotation Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromoxynil</td>
<td>&gt;2 leaves</td>
<td>&lt;3”</td>
<td></td>
</tr>
<tr>
<td>Hexazinone</td>
<td>&gt;6” root</td>
<td>&lt;2”</td>
<td>2 years</td>
</tr>
<tr>
<td>2, 4-DB</td>
<td>1-4 leaves</td>
<td>&lt;3”</td>
<td></td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>&gt;2 leaves</td>
<td>&lt;3”</td>
<td>1-4 years</td>
</tr>
<tr>
<td>Diuron</td>
<td>Dormant</td>
<td></td>
<td>1 year</td>
</tr>
<tr>
<td>Paraquat</td>
<td>Dormant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References:

9. Canevari, Mick, University of California, Personal Communication.

34. “Alfalfa Susceptibility of Weeds to Herbicide Control”, UC Pest Management Guidelines, University of California, 7/01.