December 14, 2000

Monica Alvarez
Chemical Review Manager
Office of Pesticide Programs (7508C)
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Washington, D.C. 20460

Dear Monica:

The enclosed document is a benefits statement for acephate and, particularly, for the higher rates of this product that are required in Arizona for *Lygus* control on cotton. This document was cooperatively prepared by staff of the National Cotton Council, the Arizona Cotton Growers Association, and Dr. Peter Ellsworth, IPM Specialist, University of Arizona.

I believe this document is complete and should provide sufficient data to conduct an adequate benefit/risk analysis. Please feel free to call me, however, if you need any further clarification or if we can provide additional data. Thank you for the opportunity to submit this document and we look forward to working with you on this important matter.

Sincerely,

E. Keith Menchey
Manager, Science and Environmental Issues

Enclosure (1)

Cc: Daniel Helfgott

Benefits of Acephate for *Lygus* Control in Arizona Cotton Production

Summary

Widespread availability of insect growth regulators for whitefly control and the general adoption of Bt cotton for pink bollworm control in Arizona has resulted in significant reductions in insecticide applications, which previously inadvertently suppressed *Lygus* populations and has essentially opened a window of opportunity for *Lygus* to cause damage promoting this pest to major status. Another factor for this increase in this pest is the significant increase in alfalfa acreage in Arizona; alfalfa is also a preferred host for *Lygus*.

Management strategies for *Lygus* control are limited. There are currently no commercially available biological control strategies for *Lygus*. Additionally, no host plant resistance has been identified from either traditional breeding efforts or genetic engineering. Insecticides are the primary means for *Lygus* management and no current products have a narrow spectrum for this pest.

Orthene®, Vydate®C-LV, and Monitor® demonstrated the most effective knockdown and residual control of *Lygus* nymphs. The highest labeled rates (1.0 lb.a.i./A) provided the longest residual activity on *Lygus* nymphs and the highest seed cotton yields.

A 0.5 lb. a.i./A rate for Orthene® is not commercially viable. Orthene® at the lower rate is less than 50% effective compared to the full rate of 1 lb. a.i./A. Much of the residual effect of Orthene® is due to its partial systemic activity; with the climate of Arizona, this systemic activity is very rate sensitive. Furthermore, the impact on beneficial insect populations is less severe with a reduced frequency of insecticide applications. Frequency of acephate applications can only be decreased at the higher rates where residual effects are more active.

The majority of Orthene® (97%) is aerially applied in Arizona. Because of the high mobility of this pest, chemical treatment must be applied rapidly to a large area. Furthermore, much of Arizona cotton in irrigated. Irrigation equipment, furrows, and wet field conditions make ground application impractical.

A comparative application rate study showed, at the 0.5 lb. a.i./A for Orthene®, Arizona cotton farmers would have lost $15.4 million in lint using 1994 data.

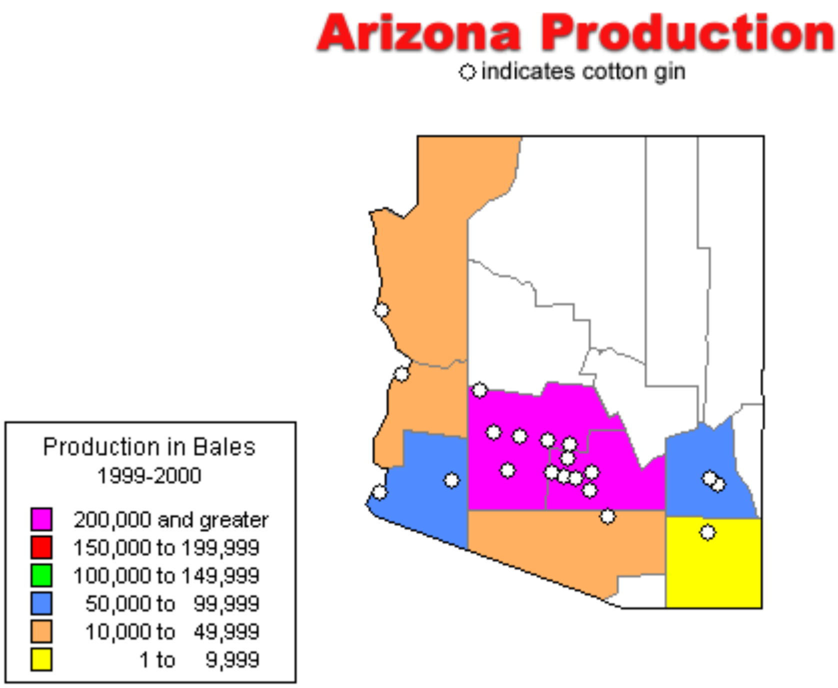
The effective alternatives for Orthene® are few - in decreasing order of preference, Vydate®, endosulfan, and Monitor®. In 1999, Arizona cotton farmers would have incurred total additional costs of $669,731, $206,249, and $2,039,321 per application, respectively, by using these alternative products.

Evidence shows that *Lygus* has a propensity to develop resistance to chemical pesticides. Because of the limited number of efficacious products available for *Lygus* control, it is imperative that the greatest range of product choices be maintained at effective rate levels, so that resistance can be more readily managed.

Arizona Cotton Production

Cotton is Arizona's most widely planted and most valuable field crop. Arizona farmers cultivate both upland (*Gossypium hirsutum*) and Pima or extra-long staple (*Gossypium barbadense*) cottons. Arizona cotton production is located in the western and southern counties of the state with the largest concentration of production (71.5% in 1997) in Maricopa and Pinal counties followed by Yuma and Graham counties (Figure 1).

Figure 1: Arizona Cotton Production by County.



From 1990 to 1999, Arizona upland cotton production averaged 318,400 planted acres with an average yield of 1,175 pounds/harvested acre and total production of 775,000 bales (Table 1). During the same time period, Arizona Pima cotton production averaged 72,100 planted acres with an average yield of 806 pounds/harvested acre and total average production of 91,400 bales (Table 2).

Table 1: Arizona – Upland Cotton Production, 1990-99

Year	Planted Acres (Thousands)	Harvested Acres (Thousands)	Yield lbs./ Harvested Acre	Production (Thousand Bales)
90	350	348	1,119	811
91	360	359	1,201	898
92	325	323	1,077	725
93	316	315	1,204	790
94	313	312	1,203	782
95	365	364	1,046	793
96	315	314	1,189	778
97	320	324	1,255	847
98	250	248	1,177	608
99	270	269	1,278	716

Table 2: Arizona Pima Cotton Production, 1990-99.

Year	Planted Acres (Thousands)	Harvested Acres (Thousands)	Yield lbs./ Harvested Acre	Production (Thousand Bales)
90	125	124	751	194
91	106	103	860	184
92	103	102	649	138
93	57	57	734	87
94	48	48	806	80
95	49	49	713	72
96	42	42	848	74
97	22	22	916	42
98	16	16	830	27
99	9	9	853	16

For the years 1994 through 1998, all cotton lint and cottonseed averaged total cash receipts of $314.4 million in Arizona (Table 3). For three of these five years, cotton lint and cottonseed ranked first in Arizona crop production cash receipts competing only with head lettuce for first place among all other crops.

Table 3: Arizona Cash Receipts, All Cotton, 1994-1998.[1]

	1994	1995	1996	1997	1998
	------------------------------ $1,000 ------------------------------				
Cotton lint	308,085	265,130	298,277	253,469	269,834
Cottonseed	34,359	32,835	40,566	34,342	35,229
Total	342,444	297,965	338,843	287,811	305,063

1 *1999 Arizona Agricultural Statistics*. July, 2000. USDA-NASS/University of Arizona, pg. 1.

Cotton Insect Pests

Cotton is attacked by a myriad of insect pests including boll weevil, bollworm/budworm, pink bollworm, cotton fleahopper, *Lygus*, cotton leaf perforator, spider mites, thrips, beet armyworm, fall armyworm, European corn borer, stink bugs, grasshoppers, saltmarsh caterpillars, aphids, whiteflies, loopers, and cutworms. These pests, of course, vary by region and season. However, their damage to the U.S. cotton crop is substantial. In 1999, insect pests reduced overall U.S. yield by 7.66%. Total cost of management and loss to insects to the 1999 crop was $1.269 billion or $93.34 per acre (M.R. Williams, 2000b).

In 1999, *Lygus* infested 6.89 million acres of cotton or 51% of the U.S. crop. That year, it ranked as the fourth most damaging insect pest and accounted for 0.9% of U.S. cotton pest loss (Williams, 2000a). These numbers were down from 1998 when *Lygus* infested 57% of U.S. cotton acreage and was ranked third (Williams, 1999).

Lygus and Arizona Cotton

Though *Lygus* populations in Arizona consist of a complex of four different species, by far, the most common species (95%) found in the cotton growing areas of central and western Arizona is *Lygus hesperus* Knight (Dennehey and Russell, 1996; Pacheco, 1998). Until recently, *Lygus* has not been a visibly major pest of cotton. However, due to a series of factors, it has pushed itself to the forefront of importance in Arizona cotton production.

One reason for this change in prominence is a drastic reduction in the number of *Lygus*-active insecticides sprayed on Arizona cotton fields. These reductions have come about because of widespread availability of insect growth regulators (IGR) for whitefly control and the general adoption of Bt cotton for pink bollworm control. In 1995, an average of 12.5 foliar insecticide sprays for all insects (1.26 directed at *Lygus*) were made in Arizona cotton, many of which had some degree of *Lygus* activity. In 1997, this frequency was reduced to 5.33 applications (2.1 directed at *Lygus*), and about 0.5 of these sprays were IGRs which have no *Lygus* activity. These reductions in insecticide applications, which previously inadvertently suppressed *Lygus* populations, have essentially opened a window of opportunity for *Lygus* to cause damage and has promoted this pest to major status (Ellsworth, 1998). Another factor for this increase in this pest is the significant increase in alfalfa acreage in Arizona (Sossaman, 2000); alfalfa is also a host to *Lygus*. Alfalfa is not normally treated for *Lygus* (Ellsworth, 2000b).

Lygus Damage

Lygus can cause direct losses to cotton production in two ways. First, experimental evidence confirms that *Lygus* has the capacity to cause damage to cotton from emergence through the early lint development stage of the last harvestable bolls. However, it is during the period between first square and peak bloom that cotton is most susceptible to economic damage from *Lygus*. High populations of *Lygus* during the first 6 weeks of squaring have the capacity to significantly reduce yield or delay maturity. Damage is caused by feeding on small squares which usually results in “blasted squares” that abort within a few days. Square shed is by far the most important and devastating type of damage.

Feeding on larger squares may result in abortion of the squares, but more commonly, they remain on the plant. The effect of this type of damage is related to the amount of anther damage. When less than 30% of the anthers are damaged, there is little or no effect. As the level of damage increases, there is an increase in the percentage of malformed bolls and in the number of aborted bolls.

The most common damage, with the greatest yield impact, is to small squares. *Lygus* will feed directly on small bolls resulting on a dull, dark colored, slightly sunken lesion on the outer boll wall. Small to medium sized bolls that have been heavily damaged may eventually abscise or fail to open. On larger bolls with more developed lint, *Lygus* feeding rarely destroys the entire boll but may result in damaged seed, discolored lint, and reduced weight of the harvestable lint.

The second type of direct loss occurs from excessive loss of fruit and of apical growing points. This type of damage often results in secondary vegetative growth causing a multiple branched plant with little fruit. Loss of fruit can also stimulate vegetative growth that may result in tall, whip-like plants. Excessive plant height can lead to inefficient defoliation which increases the amount of leaf trash in the harvested cotton and which can affect ginning properties. Increased leaf trash is an expensive and often hidden cost to growers (Ellsworth, 2000a).

Lygus may also cause indirect consequences. *Lygus* is a key pest in Arizona and, as such, it often requires treatment during the early part of the growing season when insecticides might not otherwise be used. Applications at this time may destroy important beneficial insects that would otherwise aid in suppressing populations of other pests and reduce the likelihood of having to treat for them, at least until later in the season. Potential damage caused by these pests and the cost of their control indirectly add to losses attributable to *Lygus* (O'Leary, 1998).

In Arizona cotton, the severity of *Lygus* infestations has varied widely over recent years. Economic losses from *Lygus* range from $287,000 to $19.3 million in a ten-year period (Table 4).

Lygus are particularly difficult to manage not only because of their mobility but also because it is difficult to predict the damage they will cause. In some cases, large numbers may move through a cotton field and feed only minimally on squares. Other times, fewer numbers, coming from drying weeds, can cause considerable damage. The severity of *Lygus* damage seems to depend on three factors: whether the population is migrating through or resident in the cotton crop, the stage of fruiting, and the rate of fruiting (USDA-OPMP/PIAP, 1999). Other factors include the number of host plants available, cotton variety, stage of cotton development, soil type, seedling disease, fertilization, planting patterns, planting date, and presence of other early season pests may impact population densities and the severity of damage caused by *Lygus* (Gilliland, 1981; Oakman, 1981).

Table 4: Arizona Statewide *Lygus* Infestations, Control and Costs, and Economic Losses (1990-99)[1]

Year	% Acres Infested	% Acres Treated	Sprays (No./A)	Control Cost ($/A)	% Total Control Cost	Yield Loss (%)	% Total Insect Losses	Lint Price $	Economic Loss $1000
1990	87	63	1.90	17.10	15.0	0.95	15.8	0.759	3,465
1991	93	82	3.30	33.00	31.4	1.64	51.6	0.667	5,696
1992	98	24	0.50	5.00	4.1	0.12	1.2	0.569	287
1993	90	5	0.20	2.60	3.7	0.50	11.3	0.614	1,295
1994	100	80	1.20	14.40	10.4	4.81	45.5	0.706	12,730
1995	100	90	2.30	27.60	12.8	6.08	70.1	0.767	19,344
1996	100	50	1.26	25.25	22.7	6.24	47.5	0.697	16,253
1997	100	91	2.10	37.67	35.0	3.16	41.4	0.647	8,302
1998	100	93	2.76	55.20	53.4	9.22	78.3	0.547	14,717
1999	100	51	1.02	19.98	53.7	3.98	72.8	0.457	5,936

1 Ellsworth and Jones, 2000; AZ Cotton Insect Losses Summary, www.ag.arizona.edu/cotton/cil.

Lygus Control

Lygus control frequency and costs have increased in recent years in Arizona due to a complex of factors. Broad spectrum insecticides that were once used against pink bollworm and whiteflies have now been replaced on the majority of acres by the highly effective Bt cottons and insect growth regulators, respectively. These two sets of pest control technologies have helped to reduce the number of foliar insecticides since 1996 – down from 11.5 sprays in 1990 to 1.9 sprays in 1999 (Ellsworth and Jones, 2000) – and contributed to a decade-low spray requirement and costs in 1999. The decision for use of in-season insecticides primarily depends on the presence of *Lygus*.

Adult *Lygus* are highly mobile and, although cotton is not their preferred host, cotton fields can be invaded by this pest between May and September when great numbers migrate from nearby crops such as alfalfa and safflower. During the growing season, it is possible for a cotton field to experience a migration event that causes population densities to rapidly shift from non-economic to economic levels within days.

There are currently no commercially available biological control strategies for *Lygus*. Additionally, no host plant resistance has been identified from either traditional breeding efforts or genetic engineering. Insecticides are the primary means for *Lygus* management and no current products have a narrow spectrum for this pest.

Pest managers must be vigilant in monitoring for *Lygus* and they routinely are faced with making decisions as to whether insecticide treatments are economically warranted for this pest. Unnecessary application is not only costly but increases the possibility of secondary pest outbreaks. On the other hand, inadequate scouting or delays in required treatments for *Lygus* can result in severe yield loss.

The current threshold recommendations for *Lygus* control in are:

1) 15 total *Lygus* per 100 sweeps, and/or
2) 25% of the squares with signs of damage, and,

3) at least four *Lygus* nymphs are present (Ellsworth, 2000a).

The third criterion is particularly important because *Lygus* adults can be transitory especially adjacent to alfalfa that is periodically cut. Also, *Lygus* eggs take approximately seven days to hatch under Arizona conditions and most insecticides fail to control eggs. Waiting for the appearance of nymphs ensures the spray will be most effective (Ellsworth, 1998).

Effective chemical use is one of the three keys to cotton IPM in Arizona. The lack of effective biological control or host plant resistance to this pest dictates that insecticides are a primary tool for *Lygus* management. Part of the key depends on selection of the proper insecticide. The following are recommendations for chemical control (Ellsworth, 2000a): 1) use one of four possible insecticides – acephate (Orthene®), methamidiphos (Monitor®), oxamyl (Vydate®), and endosulfan (Thiodan®) at appropriate rates, 2) avoid the use of synthetic pyrethroids which remain ineffective, 3) observe action thresholds, and 4) practice resistance management. Ample evidence exists to suggest that *Lygus* do become locally resistant to overused insecticides (Dennehy and Russell, 1996; Dennehey et al., 1998).

In efficacy studies, Ellsworth reported that acephate (Orthene®), oxamyl (Vydate®), and methamidiphos (Monitor®) provided the best *Lygus* control (Ellsworth, 1998). Methidathion (Supracide®), endosulfan, and dimethoate provided some level of suppression but were considered second tier compounds, most useful when trying to address some other primary problem. Later studies have shown that Supracide and dimethoate are not viable options for *Lygus* control. Pyrethroids failed to provide control. Orthene or Vydate used alone performed and yielded as well and usually better than all of the combination materials tested, even Orthene + Vydate. For efficacy and resistance management, growers should opt for the appropriate single insecticide at the optimal rate which is usually the higher rate.

Tables 5 and 6 present insecticide usage for control of *Lygus* both for *Lygus* alone and *Lygus* in combination with other pests. The preeminence of acephate use, alone and in combination with other insecticides, shows grower preference for the effectiveness of acephate control. Acephate was the product of choice in 2000 and second only to endosulfan in 1999.

Pacheco (1998) found that Orthene®, Vydate®C-LV, and Monitor® demonstrated the most effective knockdown and residual control of *Lygus* nymphs. The highest labeled rates (1.0 lb.a.i./A) provided the longest residual activity on *Lygus* nymphs and the highest seed cotton yields. According to Dr. Peter Ellsworth, IPM Specialist, University of Arizona, the 0.5 lb./A rate for Orthene® is not even commercially viable. Orthene® at the lower rate is less than 50% effective compared to the full rate of 1 lb./A. Much of the residual effect of Orthene® is due to its partial systemic activity; with the climate of Arizona, this systemic activity is very rate sensitive. Furthermore, the impact on beneficial insect populations is less severe with a reduced frequency of insecticide applications. The frequency of acephate applications can only be decreased at the higher rates where residual effects are more active.

Table 7 shows acephate application rates in Arizona from 1995 to 2000. It is obvious that the percentage of uses (reports) at these rates has increased dramatically, by more than 7 fold, during this period. The percentage of acreage treated with higher rates has also increased with around two-thirds of all acreage treated at more than 0.875 lbs. a.i. per acre in 1998-2000.

Table 5: Pesticide usage in Arizona for *Lygus* control – alone or in combination with other insect control – 1999[1].

Any *Lygus* 1999		Only *Lygus* 1999	
Active ingredient	**Acres**	**Active ingredient**	**Acres**
Endosulfan	58,154	Endosulfan	48,178
Acephate	46,788	Acephate	40,809
Acephate/Endosulfan	42,615	Acephate/Endosulfan	28,036
Oxamyl	20,737	Oxamyl	17,033
Acephate/Chlorpyrifos	20,125	Acephate/Chlorpyrifos	10,902
Acephate/Lambdacyhalothrin	14,615	Chlorpyrifos	4,430
Endosulfan/Lambdacyhalothrin	9,174	Dimethoate/Endosulfan	3,654
Acephate/Fenpropathrin	7,306	Acephate/Cyfluthrin	3,387
Acephate/Pyriproxyfen	6,603	Acephate/Dimethoate	3,180
Dimethoate/Endosulfan	5,917	Acephate/Lambdacyhalothrin	2,809
Chlorpyrifos/Endosulfan	5,502	Dimethoate	2,680
Acephate/Chlorpyrifos/Lambdacyhalothrin	4,824	Endosulfan/Lambdacyhalothrin	2,075
Chlorpyrifos	4,769	Lambdacyhalothrin/Methomyl	1,449
Endosulfan/Methomyl	4,382	Lambdacyhalothrin	1,325
Endosulfan/Pyriproxyfen	4,329	Endosulfan/Methomyl	1,325
Acephate/Cyfluthrin	4,201	Aldicarb	1,305
Acephate/Dimethoate	4,055	Acephate/Gossyplure	862
Dimethoate	3,843	Acephate/Methamidiphos	834
Chlorpyrifos/Cypermethrin	2,997	Other	733
Lambdacyhalothrin/Methomyl	2,751	Methamidiphos	725

Table 6: Pesticide usage in Arizona for *Lygus* control – alone or in combination with other insect control – 2000.

Any *Lygus* 2000		Only *Lygus* 2000	
Active ingredient	**Acres**	**Active ingredient**	**Acres**
Acephate	42,452	Acephate	29,971
Endosulfan	22,170	Oxamyl	7,104
Acephate/Endosulfan	17,728	Endosulfan	6,817
Acephate/Fenpropathrin	13,205	Acephate/Endosulfan	2,379
Oxamyl	10,257	Chlorpyrifos	1,918
Acephate/Lambdacyhalothrin	8,303	Acephate/Dimethoate	1,508
Acephate/Oxamyl	5,167	Acephate/Oxamyl	1,299
Endosulfan/Zetacypermethrin	4,519	Endosulfan/Zetacypermethrin	1,178
Amitraz/Endosulfan	4,511	Acephate/Lambdacyhalothrin	1,083
Acephate/Cyfluthrin	4,226	Chlorpyrifos/Oxamyl	827
Acephate/Chlorpyrifos	4,152	Dimethoate/Endosulfan	711
Acephate/Cypermethrin	3,950	Dimethoate	704
Endosulfan/Lambdacyhalothrin	3,803	Methamidiphos	637
Acephate/Endosulfan/Gossyplure	3,290	Aldicarb	561
Acephate/Pyriproxyfen	3,232	Acephate/Fenpropathrin	344
Chlorpyrifos/Endosulfan	2,978	Chlorpyrifos/Lambdacyhalothrin	311
Lambdacyhalothrin	2,924	Acephate/Chlorpyrifos	307
Chlorpyrifos/Lambdacyhalothrin	2,394	Chlorpyrifos/Endosulfan	267
Chlorpyrifos	2,356	Amitraz/Endosulfan	260

1 Agnew and Baker, 2000.

Table 7: Application rates of acephate greater than 0.875 lb.a.i. per acre in Arizona, 1995-2000.[1]

Year	Acephate Applications with rates greater than 0.875 lbs. a.i. per acre	
	Reports	Acres
1995	7.0%	6.6%
1996	25.0%	27.8%
1997	48.4%	54.2%
1998	61.2%	66.8%
1999	58.5%	67.5%
2000	54.5%	63.7%

1 Agnew and Baker, 2000.

Because Orthene® is not effective at the 0.5 lb./A rate for *Lygus* control in Arizona, most efficacy studies are conducted at the higher rate of 1.0 lb./A. However, Pacheco (1998) compared a range of compounds at varying rates for *Lygus* control in Arizona. Orthene® was applied at 0.5 and 0.9 lbs. a.i./A in 1994. He reported a difference in yield of 219 lbs. seed cotton/A in favor of the higher rate. Using 1994 data, Arizona farmers harvested 360,000 acres of upland and Pima cotton (Table 1 and 2). That year, 100% of cotton fields in Arizona were infested with *Lygus* and 80% or 288,000 acres were treated (Table 4). At the lower rate of Orthene® application, 63.072 million pounds of seed cotton would have been lost to ineffective insect control. Assuming a 34.5% turnout, this poundage translates into 21,759,840 lbs. lint. The price of lint in 1994 was $0.706 for an economic loss of $15.4 million. This number is an underestimate since it does not account for the higher price for Pima cotton and does not include the loss from reduced cottonseed production. Cottonseed production averaged 303,800 tons valued at $42.2 million (USDA-OPMP/PIAP, 1999).

Table 8: Orthene Treatments for *Lygus* in Arizona Cotton, 1995-2000

		Orthene Alone	Orthene in Combination
1995	**Acres**	54,110	799,492
	Rate	0.64	0.56
	% Application	13	193
1996	**Acres**	26,146	376,628
	Rate	0.84	0.66
	% Application	7	105
1997	**Acres**	46,568	310,321
	Rate	0.83	0.77
	% Application	13	89
1998	**Acres**	65,825	190,210
	Rate	0.84	0.79
	% Application	25	72
1999	**Acres**	54,820	176,921
	Rate	0.81	0.79
	% Application	20	63
2000	**Acres**	44,732	132,323
	Rate	0.84	0.78
	% Application	16	46

Table 8 presents Orthene usage data for *Lygus* control on Arizona cotton fields over six years. This data again shows that there is a clear trend towards higher rates and that tank mixes are decreasing in use while Orthene used alone is increasing.

The majority of Orthene (97%) is aerially applied in Arizona. Because of the high mobility of this pest, chemical treatment must be applied rapidly to a large area. Furthermore, much of Arizona cotton in irrigated. Irrigation equipment, furrows, and wet field conditions make ground application impractical.

If maximum application rate for Orthene was reduced to 0.5 lb. a.i./A, the product would be ineffective in Arizona for *Lygus* control and cotton farmers would have to turn to the few available products. According to Dr. Ellsworth, the effective alternatives for Orthene are few - in decreasing order of preference, Vydate®, endosulfan, and Monitor®. At the recommended maximum label rates, the additional cost per acre per application is $2.89, $0.89, and $8.80, respectively, based on average 2000 Arizona retail prices. The 2000 growing season in Arizona had relatively low insect pressure from *Lygus*. The 1999 season was more typical of *Lygus* pressure in this area. Therefore, using the 1999 data from Table 8, the cotton acreage treated with Orthene for *Lygus* control was 231,741 acres. By using the above alternatives, Arizona cotton farmers would have incurred total additional costs of $669,731, $206,249, and $2,039,321 per application, respectively.

Finally, as stated earlier, evidence shows that *Lygus* has a propensity to develop resistance to chemical pesticides. Because of the limited number of efficacious products available for *Lygus* control, it is imperative that the greatest range of product choices be maintained at effective rate levels, so that resistance can be more readily managed.

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