Crop Profile for Cotton in Arizona

Prepared: August, 1999

General Production Information

- Among the cotton producing states, in 1998, Arizona ranked 8th in cotton lint and cottonseed production. Arizona ranked 3rd among the four Pima cotton producing states and 8th among the 17 Upland cotton producing states.
- Arizona accounted for 4.4% of 1998 U.S. cotton production on 2.5% of U.S. cotton harvested acreage. Arizona produced 4.3% of U.S. upland cotton production on 2.4% of the upland cotton harvested acres, and 5.6% of U.S. pima cotton on 6.6% of pima cotton harvested acres.
- For upland cotton, between 1994 and 1998, Arizona averaged 313,600 acres planted, 312,400 acres harvested with a yield per harvested acre of 1163.2 pounds, producing an average of 756,000 bales of cotton per year. Average cash value was $249,468,000.
- For pima cotton, between 1994 and 1998, an average of 35,300 acres were planted, 35,080 harvested, with yields of 806 pounds per acre, producing 58,560 bales. Average annual, statewide cash value was $29,965,400. There was a definite downward trend in Pima cotton production. 1998 acreage was 15,900 with a value of production of $11,278,000.
- Cottonseed production averaged 303,800 tons valued at 42,220,600 dollars.
- Production costs for Upland cotton ranged from a low in Maricopa county of $650 per acre up to $932 in Yuma county. (2) Pinal and La Paz were $736 and $892, respectively.
- Pima cotton production costs ranged from $555 per acre in Graham to $777 in Yuma county. Maricopa and Pinal were $698 and $756 per acre respectively.
- Crop primarily destined for international markets. (18)

Production Regions

In 1997, Pinal and Maricopa counties accounted for 71.5% of Arizona Upland cotton acreage. Other counties producing significant acreage of Upland cotton were La Paz, Yuma, Pima, Graham, Cochise and Mohave counties. For American Pima cotton, acreage was roughly equally spread across Maricopa, Graham, Pinal and Yuma counties.

Cultural Practices

Arizona's growing environment gives rise to a variety of different production strategies in cotton. Both Upland and Pima cotton are grown in Arizona. A traditional full season strategy aims for a maximum yield from the primary fruiting cycle and from the secondary fruiting cycle or "top crop". A short season strategy tries to maximize profits from the primary fruiting cycle by terminating irrigation early and minimizing costs. Choice of a full or short season strategy will effect planting windows, variety choice and other aspects of production. The recommended planting window is from 400 to 900 heat units accumulated since January 1. This can vary across regions and years from early March to mid May. Optimal plant populations are 25,000 to 50,000 plants per acre for row spacings between 30" and 40" for both Pima and Upland varieties. Presently there is very little no-till cotton produced in Arizona. Economics may dictate an increase of ultra narrow row cotton production.

Cotton is planted in two different ways in Arizona. A wet plant approach sows seeds into a pre-irrigated field. In a dry plant system, no irrigation takes place until after planting. Planting approach is generally determined by soil texture and salinity, with dry planting more likely in lighter texture and saltier soils. Dry plant becomes more common moving east to west across Arizona, except near the Colorado River.

Weed control is achieved by both chemical and mechanical means. To maintain the furrow for irrigation, mechanical tillage is usually done after every irrigation until the crop canopy closes over the furrow. Insect pest management varies across the state's different growing regions as well as different management strategies. One advantage of a short season strategy is avoidance of heavy late season insect pressure. Bt. Cotton was expected to comprise 80% of the upland cotton crop in Arizona in the 1998 season (3).

Insect Pests

Cotton Aphid (*Aphis gossypii*)

The most common aphid found in Arizona cotton is the cotton aphid. Early season infestations rarely harm the crop and provide food and attraction for beneficial insect populations. In general, populations are kept below the economic threshold by beneficial insect populations. Late season infestations, when boll is open, can result in harvest trouble. Honeydew produced by the aphids, and the resulting mold, can stain and contaminate lint.

Controls

Biological

Natural enemy populations can maintain aphid populations below levels of economic damage. Ladybird beetles and their larvae, syrphid fly larvae, lacewing larvae, and parasitic wasps are the primary natural enemies. Maintaining strong populations of these beneficials through sound IPM practices is the first line of defense against excessive aphid infestation.

Late season growth, encouraged by excessive or poorly scheduled nitrogen applications can bring on late season infestations.

Chemical

Chemical control of aphids should only be applied when aphids reach levels capable of causing problems with stickiness of cotton. Spot treatment is recommended.

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Beet Armyworm (*Spodoptera exigua)*

Beet armyworm can attack cotton plants throughout the growing season. Leaf damage is rarely problematic. Feeding on terminals, squares, blooms and bolls can lower yields particularly in shorter season areas where plants cannot compensate for early damage. Beet armyworm have a wide range of favored hosts including crops such as alfalfa, vegetables, sugarbeets and beans, and weeds like pigweed and nettleleaf goosefoot. In some years, viruses, parasitical wasps and predators commonly keep populations from causing economic damage.

Controls

Biological

Control measures need to take into consideration pest populations in surrounding fields, on weeds in the cotton field and the presence of natural enemies. Removal of infested weed populations can cause larvae to move to cotton seedlings causing serious infestation. Infestations commonly results from destruction of natural enemy populations by insecticide treatments to control other insects.

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Bollworm (*Helicoverpa zea*)and **Tobacco Budworm** (*Heliothus virescens*)
The bollworm and tobacco budworm are usually discussed together since they can only be distinguished by observing larvae under magnification or by immunoassay of eggs. Both of these species are only periodic pests in Arizona. The tobacco budworm is the greater concern in the central and western parts of Arizona, and is harder to control with insecticides. Cotton is not a preferred host so infestations are generally determined by surrounding crops.

Bollworm and budworm can do significant damage as older larvae feed on green bolls. Older larvae are more difficult to kill so control efforts are focussed on younger larvae. Predators usually keep populations below an economic threshold. Spraying for other insect pests, particularly pink bollworm and lygus bug destroys predators and parasites and creates conditions for damaging outbreaks. Summer rain can promote outbreaks.

Controls

Biological
A variety of predators feed on bollworm and budworm eggs and young larvae, and can successfully limit populations in untreated fields. Furthermore, there are parasitic wasps, particularly *Trichogramma*, which prey on eggs and larvae. Predator populations may reside in adjacent fields. Harvesting techniques and spraying regimes should take into consideration potential value of these beneficials to maintaining low pest populations in cotton.

Chemical
Management of bollworm and budworm focuses on the two periods in full-season cotton when squares and bolls are not yet mature but susceptible to damage.

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Cabbage Looper (*Trichoplusia ni*)
Cabbage Looper can cause extensive foliage damage in cotton but rarely causes economic damage. The cabbage looper provides food for a wide variety of beneficial insects and usually only reaches problematic populations when spraying for other pests has lowered beneficial insect populations. A naturally occurring virus also limits populations of cabbage loopers.

Controls

Biological
The natural complex of predators is usually sufficient to maintain populations of cabbage looper. Parasitic moths also feed on cabbage looper and could be introduced if not present in sufficient numbers.

Chemical

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Lygus Bug (*Lygus* spp.)
The lygus bug is an increasingly important insect pest in Arizona cotton. A decline in overall insecticide spraying of cotton, as a result of increased use of insect growth regulators and transgenic 'Bt' cotton, and an increase in alfalfa acreage both favor the presence of lygus bugs in cotton. Alfalfa is a preferred host, along with many broadleaf weed species, and presence of lygus bugs in cotton is commonly the result of migration from one of these other hosts.

Lygus bug damage depends on three factors: whether the population is migrating through or resident in the cotton crop, the stage of fruiting and the rate of fruiting. The presence of nymphs indicates a resident population capable of doing greater damage than adults alone. The most common damage, with the greatest yield impact, is to small squares. Overall damage depends on how much fruit is available and the yield potential of the field. Heavier fruiting cotton varieties are able to withstand more damage before incurring the economic damage.

Controls

Cultural
The best approach to lygus bug control is to keep them out of the cotton from the beginning. If cotton must be planted near crops like alfalfa and safflower, these hosts should be managed in a way to minimize migration into the cotton. Alfalfa crops can be strip-cut or neighboring blocks can be put on alternating harvest schedules. Either method maintains a host crop for the lygus bugs and also its natural predators. Similarly, safflower fields, and neighboring fields or right-of-ways with populations of broadleaf weeds, may need to be treated before the host loses its attractiveness to the lygus bugs.

As with most other cotton pests, minimizing wide-spectrum insecticide use in general will help maintain predator populations, making heavy lygus bug populations less likely.

Chemical
Recent tests have indicated that there is no advantage gained by using mixes compared to singular sprays of acephate or oxamyl.(14) Products with either of these active ingredients sprayed at full label rates are superior to a mix at reduced rates. Rotating from acephate and methamidophos to oxamyl may avoid resistance problems.

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Sweetpotato Whitefly, aka. Silverleaf Whitefly
(*Bemisia argentifolii,* a.k.a. *B. tabaci*)
Whitefly has became a serious pest in Arizona in the 1990s. Whiteflies feed on plant juices, excrete honeydew and are vectors for a virus that causes "crumple leaf" in cotton. Yield losses due to plant damage, and quality losses resulting from stained and sticky lint, are both causes of serious economic damage in cotton. (4)

Whiteflies frequently move into cotton from other hosts. Populations can increase dramatically through the growing season with successive generations. A general resistance building to pyrethroid chemicals in 1995 resulted in implementation of a resistance management program in Arizona. Use of insect growth regulators (IGR) have provided a new weapon against whiteflies but there is evidence that resistance is building to one of these new products, buprofezin.(11)

Controls

Cultural
Monitoring neighboring host crops for whitefly population development is an important part of a well-timed whitefly program. Whitefly chemical control practices in vegetable fields have been successful using imidacloprid (Admire). This success has meant lower populations of whiteflies in the spring when cotton is planted. For the sake of both cotton and vegetable growers, resistance to this important chemical is being monitored carefully.

Late season cotton production must be balanced with the risk of infestation and resulting stickiness and staining of the lint.

Biological
Two native whitefly parasitoids are present in Arizona cotton, *Eretmocerus eremicus* and *Encarsia meritoria*. There are also a variety of predators that attack whiteflies. In untreated plots, natural enemies alone are often unable to hold down late season whitefly populations. There is evidence however that they do have a dampening effect on populations in general and need to be considered when selecting insecticides.(13)

Chemical
Two insect growth regulators, buprofezin (applaud) and pyriproxyfen (knack), have become the cornerstone of successful whitefly control in Arizona. Use of one, or both in succession, often gives effective season-long whitefly control without resorting to pyrethroid sprays. Thresholds are well established for the first application of an IGR. The second application of the second IGR is less clearly delineated. One study showed substantial reductions in late season whitefly populations in test plot sprayed with the second IGR late in the season. IGR regimes compared favorably to pyrethroid/non-pyrethroid insecticide rotations. Just before defoliation, IGR regimes showed much lower populations of whiteflies than conventional pyrethroid/non-pyrethroid rotations. Late in the growing season, plant damage is not important but there is still sufficient time after defoliation for stickiness to develop that can lower the value of the crop. Researchers estimate less than 10% of growers used both IGRs in the same season (11)

Use of IGRs has had a positive impact on the efficacy of other insecticides. It has substantially reduced whitefly resistance to the synergized pyrethroids and increased susceptibility of whiteflies to certain non-pyrethroid insecticides. (10)

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Pink Bollworm (*Pectinophera gossypiella*)
From the 1960s through the 1980s pink bollworm was frequently the most damaging pest in desert cotton. (8) Pink bollworms survive the winter in diapause 4th instar larvae, emerging as adults the following spring. Eggs are laid on different parts of the cotton plant depending on time of emergence and plant development, and as many as five generations can develop in a single season. Adults emerging prior to square formation lay eggs on leaf buds and stems and rarely survive. Once squaring starts, eggs will be laid principally on squares. Small larvae developing in squares cause some damage, but serious damage by pink bollworm is done to bolls of upland 14 to 21 days after flowering.(8) Bolls of pima can still be punctured up to 30 days after flowering. In bolls, larvae feed on the seeds, damaging lint in the process. Yield reduction is in part dependent on levels of humidity. Higher humidity encourages rots and mold related to the pink bollworm damage, reducing yields. In low humidity some degree of infestation can be tolerated with almost no yield reduction.(8)

Because of the placement of eggs on, and the direct burrowing of neonate larvae into bolls, biological and chemical control measures are not highly effective against larvae.(8) A substantial proportion of pesticides sprayed on Arizona cotton was for the control the pink bollworm prior to the introduction transgenic cotton varieties utilizing genes from *Bacillus thuringiensis*. (3) The pink bollworm is presently being controlled with far fewer conventional insecticide treatments. Resistance to the Bt. toxins is an ongoing concern. Most research on resistance to Bt. toxins has focussed on other insects.(3) Arizona researchers are working to determine the potential for widespread resistance in the pink bollworm.

Controls

Cultural

Consideration of the full lifecycle of the pink bollworm reveals a number of cultural approaches to controlling populations. Managing over-wintering populations can have a large effect on spring and summer infestations, delaying needs for control. Cutting off irrigation early, to stop square production by September 15th, and harvesting early can deny pink bollworm their food source just as they prepare for diapause.(8) A variety of costs and benefits go into the decision of whether to pursue a shorter season strategy. Shredding and discing immediately after harvest kills larvae.(8) Delaying planting in the spring will limit the number of pink bollworm that find a suitable square for eggs. This depends on the planting window and degree days. Finally, rotation can have both positive and negative effects on pink bollworms. Winter crops can delay exit from the soil in the spring and thus increase the number of adults emerging when susceptible bolls are present.(8) Replacement of cotton by another crop for a year or more greatly reduces pink bollworm populations. Evidence from California indicates that winter irrigation can reduce over-wintering populations by 50-70%.(5)

Biological

Predators contribute to pink bollworm control, especially early in the season. They are not capable of suppressing infestations at critical periods of cotton growth.

Two parasitic nematodes, *Steinernema carpacoapsae* and *Steinernema riobravis* show promise in controlling larvae. Efficacy and ability to tolerate potential high surface soil temperatures have been established.(2,6)

Mating disruption using gossyplure (Nomate PBW) is an effective and widely used non-toxic control measure.

Chemical

Use of Bt. Cotton has drastically lowered the amount of conventional insecticides needed to control pink bollworm infestations.

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

<u>Cotton Leafperforator</u> (*Bucculatrix thurberiella*)

Cotton leafperforator is not a major cotton pest but under the right conditions can cause economic damage through excess boll drop, early boll opening and, infrequently, damage to cotton seedlings. The cotton leafperforator has an unusual lifecycle which makes it a challenge to control.(4) Larvae are only exposed to potential controls for approximately 3 and half days. Cotton leafperforators spend their first 3 to 4 days inside leaves feeding as leafminers. Then, after feeding on the surface for only a day, they move into an inactive "horseshoe stage" inside a shelter. Thereafter, two to three more days of exposed feeding and the leafperforator pupates.

Cotton leafperforator damage tends to be a late season problem. Damage is visible in the top third of plants. Timing of control measures is critical because of the unusual lifecycle. Stage of plant growth determines whether control is necessary. It is important to control leafperforators in crops that have not completely set the harvestable bolls. Control measures are best applied when the majority of larvae are in the horseshoe stage. This takes advantage of the relatively long period of exposure that comes after this state.

Controls

Cultural
The cotton leafperforator is another cotton pest that can be greatly suppressed by cultural practices. Timely plowdown and shredding after harvest will lower over wintering populations. Conservative pesticide use will allow predators and parasites to maintain population suppression longer during the growing season and under a wider range of conditions.

Biological
Conservation of naturally occurring predators and parasitoids is important for a basic level of control.

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Cutworms , various
Cutworms are the arthropod pest of greatest threat to cotton seedlings and stand establishment. Cutworms cut off seedlings at the ground level. Damage can warrant control measures. Cutworms damaging spring cotton usually stem from a previous alfalfa, grain or vegetable crop.

Controls

Cultural
Leaving a field free of other crops or weeds for at least three weeks can reduce the presence of cutworms in the field.

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Saltmarsh Caterpillar (*Estigmene acrea*)
The salt-marsh caterpillar is an occasional pest in Arizona cotton. Usually damage is done late enough in the season that no economic injury results. If infestation occurs before full crop set and maturation, controls may be necessary. Salt-marsh caterpillars create damage like that of the beet armyworm, skeletonizing or ragging leaves, depending on what level of development is present. Monitoring is most important when bolls are opening.

Controls

Biological
Predators are capable of maintaining saltmarsh caterpillar population below economic threshold. Judicious early season and wide spectrum spraying can help to maintain populations of beneficial insects.

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A.

Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Seedcorn Maggot (*Delia platura*)
Seedcorn maggot is only a problem under specific conditions and can be controlled with treated seed. Seed corn maggots can be a problem during wet, cool springs in poorly drained soil with high organic matter.

Mealybug (*Phenacoccus spp.*)
Mealybugs are aphid-like insects which can cause damage to cotton similar to that of whiteflies. Like whiteflies, they cause both direct damage to the plant and produce honeydew which causes stickiness in the lint. Predators usually keep populations below the economic threshold. Relatively little is known about mealybugs as pests of cotton because damage is very limited and sporadic.

Darkling Beetles (freq. *Blapstinus spp.*)
Darkling beetles are a seedling pest of cotton. Like cutworms, they will cut seedlings off at the ground level and be hidden during the heat of the day. A serious infestation can threaten stand establishment.

Controls

Cultural
Proper management of neighboring alfalfa and grain fields will reduce the likelihood of migration from these hosts into cotton. Barriers can be made with trenches.

Chemical
Carbaryl as a bait.

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Leafroller (*Platynota stultana*)
The omnivorous leafroller is seldom a serious problem in Arizona cotton. Larvae feed on leaves, small squares and the surface of green bolls and can cause early drop of bolls if damage is sufficient.(5) Populations are usually kept low by predators. When necessary, control can be difficult to achieve because of the webbed shelters within which leafrollers feed.

Controls

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Leafminers (*Liriomyza spp.*)
Leafminers are small flies with larvae that feed within leaves, between the upper and lower surfaces. Damage appears as a meandering track or mine, distinguishable from windows made by

leafperforators.(8) Damage rarely reaches economic thresholds on cotton. Infestations can be brought under control by parasitoids if insecticides are avoided.

Controls

Cultural
Vegetables and melons are common host plants for leafminers. Strategies for avoiding migration from these crops can be employed to limit damage in cotton.

Boll Weevil (*Anthonomus grandis*)
The boll weevil has been successfully eradicated in Arizona. Plowdown dates for cotton are mandated by the Arizona Department of Agriculture to maintain this success. Additionally, a network of pheromone traps is used to detect reinfestation, if it should occur.

Controls

Cultural
Early crop termination and shredding of stalks are essential. Crop debris should be buried to create a host-free period during the winter.(4)

Strawberry spider mite (*Tetranychus turkestani*)
Pacific spider mite (*Tetranychus pacificus*)
Twospotted spider mite (*Tetranychus urticae*)
Carmine spider mite (*Tetranychus cinnabarinus*)
All four species of mites can be found in Arizona cotton. Distinguishing between different species is important to detect and control early infestation by the strawberry mite. Early infestation of strawberry mites can be particularly problematic because the plant is young and small relative to the damage. Spider mites can cause defoliation resulting in lost fruit and lower yields. Usually generalist predatory arthropods maintain populations below economic thresholds. Damage is limited to lower leaves as the plant grows faster than the mites migrate.

At some point in mid-summer, depending on the area, populations will start to fall off as plants direct carbohydrates to fruit over foliage. Late season infestations need to be monitored, but once bolls have matured no damage can be done.

Controls

Biological
Spider mites management requires balancing the conservation of natural enemies and the use of chemical controls. Thrips are an effective early season predator of spider mites but are also capable of causing damage directly to cotton plants. In general, thrips in cotton are considered more valuable as a predator than damaging as a pest. Furthermore, mites are particularly prone to outbreaks following use of broad spectrum chemical treatments. Careful consideration of early treatments of cotton can maintain predator populations long enough to avoid any economically significant spider mite damage.

Organic
Sulfur, oils and insecticidal soaps are treatment options allowable under many organic certification standards.

Chemical
Organophosphate and pyrethroid chemicals not only have resistance problems with spider mites in some areas, they also stimulate mite reproduction and change plant physiology to make it a more suitable host.(8)

Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Stink Bugs

Consperse stink bug (*Euschistus conspersus*)
Say stink bug (*Chlorochroa sayi*)
Western brown stink bug (*Euschistus impictiventris*)
Several species of adult stink bugs will move into cotton from other host crops to feed on seeds in green bolls. Eggs are rarely found in cotton. Stink bugs feed on small grains, grain sorghums, alfalfa seed, safflower, and various weeds like Russian thistle. Migration from the crops can occur at maturation or harvest. Consequently, infestations are most likely to occur adjacent to these other crops. Damage from stink bugs includes staining of the lint. In young bolls, there is an increased possibility of boll rot and drop, while older bolls can harden to the point of being unharvestable.

Controls

Cultural
As with Lygus bugs, awareness of stink but development in surrounding crops can limit the potential for their movement to cotton. Cultural practices on neighboring fields can limit the migration of stinkbugs where this is an option. Where the grower does not have this option, closer monitoring is still possible.

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

Thrips (*Frankliniella occidentalis*)
Thrips are present in cotton throughout the year. They feed on the leaves, buds and flowers of cotton but also are a major predator of spider mites. Damage to seedlings is usually not severe enough to warrant control. Plants will grow out of even quite severe damage. The one circumstance under which thrips become a concern is during periods of slow, early-season cotton growth brought on by cool weather. If this happens damage can severely affect yields. The decision to control early season thrips depends on many variables: proximity to other host crops, field history, weather (including both germination and seedling conditions but also length of season) and cotton variety fruiting characteristics.(4)

Controls

Chemical
Arizona usage can be found in 1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 data table below. Information on Arizona pesticide use reporting is essential to interpreting use statistics.

1998 Reported Insecticide Use on Cotton in Arizona from A.D.A. Form 1080 Data

Active Ingredient	Reports	Acres	% of Planted Acres	Mean App. Rate	C A	B A W	B W	C L	L	S W F	P B W	C L P	S M C	M	S B	T
Acephate	2,687	254,470	95.7%	0.79	X		X	X	X	X	X				X	X
Aldicarb	161	22,267	8.4%	1.05					X			X				
Amitraz	72	6,319	2.4%	0.21	X		X			X	X			X		
Azinphos-methyl	35	3,420	1.3%	0.43							X					
Bifenthrin	82	7,142	2.7%	0.06		X	X	X		X	X	X	X	X		
Bt (Bacillus thur.)	1	35	0.0%				X	X					X			
Buprofezin	349	33,864	12.7%	0.35						X						
Carbaryl	6	275	0.1%	0.60							X		X		X	
Chlorpyrifos	2,310	240,836	90.6%	0.70	X	X				X	X		X			
Cyfluthrin	251	13,611	5.1%	0.04		X	X	X		X	X	X				
Cypermethrin	212	18,860	7.1%	0.05		X	X	X			X	X	X			
Deltamethrin	56	7,399	2.8%	0.03		X	X	X	X	X	X	X	X		X	X
Diazinon	3	321	0.1%	0.22												
Dicofol	65	5,614	2.1%	1.08										X		
Dimethoate	515	52,202	19.6%	0.46	X				X							
Disulfoton	23	2,152	0.8%	0.68	X											
Endosulfan	1,674	174,820	65.7%	1.02	X		X	X	X	X		X			X	
Esfenvalerate	40	4,422	1.7%	0.04		X	X	X		X	X	X	X			
Fenpropathrin	429	29,803	11.2%	0.20		X				X	X					
Gossyplure	668	59,382	22.3%	0.02							X					
Imidacloprid	36	1,888	0.7%	0.11	X					X						X
Lambda-cyhalothrin	1,008	100,016	37.6%	0.03		X	X	X		X	X	X	X			
Malathion	36	5,097	1.9%	1.32	X				X							
Methamidophos	65	9,213	3.5%	0.81	X	X		X	X	X				X		
Methidathion	33	2,175	0.8%	0.59					X		X					
Methomyl	150	16,940	6.4%	0.43	X	X	X		X	X		X				
Methyl parathion	270	21,773	8.2%	0.89			X			X	X		X		X	
Naled	7	625	0.2%	0.07												
Neem Oil	2	126	0.0%	0.13												
Oxamyl	589	63,429	23.9%	0.78	X				X	X	X	X				
Oxydemeton-methyl	30	4,208	1.6%	0.29	X									X		X
Permethrin	8	227	0.1%	0.16			X	X		X	X	X	X		X	
Phorate	57	5,089	1.9%	1.10						X				X		
Piperonyl butoxide	10	991	0.4%	0.12												
Profenofos	109	17,261	6.5%	0.93	X	X	X			X				X		

CA: Cotton aphid
BAW: Beet armyworm
BW: Bollworm and Tobacco budworm
CL: Cabbage Looper
L: Lygus bug
SWF: Sweetpotato whitefly
PBW: Pink bollworm
CLP: Cotton leafperforator
SMC: Saltmarsh caterpillar
M: Mites
SB: Stink bugs
T: Thrips

Diseases

Soreshin (*Rhizoctonia solani*)
R. solani is a soil fungus that attacks cotton seedlings. *R. solani* related damping off is associated with soil temperature well below ideal cotton germination conditions. Anything that delays germination or seedling growth can also be considered a factor. Phytotoxicity from herbicides, poor quality seed, planting depth, and crusting or other soil related problems all contribute to the possibility of damage.(7)

Controls

Cultural
High quality seed planted at proper depths, in well pulverized, weed-free, non-compacted soil that is over 65 degrees at 8 a.m. is a good start. Fallowing, rotation or double cropping has given positive results in some places. Herbicides must be handled carefully so as not to reduce seedling vigor.

Biological
Research in Arizona (9) in 1995 and1996 showed that an isolate from *Burkholderia cepacia* (D1) in a soil wash lowered incidence of damping off due to R. solani. D1 is not commercially available in this form at this time. Other forms of D1 did not show the same results.

Chemical
PCNB
Arizona usage can be found in 1998 Reported Fungicide, Nematicide and Fumigant Use on Cotton in Arizona from A.D.A. Form 1080 data table below.

Black Root Rot (Thielaviopsis basicola)
T. basicola is similar to R. solani in many respects. Upland and Pima cotton are equally susceptible. Difficult conditions for germination and seedling growth contribute to disease. T. basicola has historically been a problem at higher elevations.

Controls

Cultural
Same as R. solani

Chemical
Triadimenol There is anecdotal evidence of triadimenol use but none has been reported in the ADA 1080s use reports.

Arizona usage can be found in 1998 Reported Fungicide, Nematicide and Fumigant Use on Cotton in Arizona from A.D.A. Form 1080 data table below.

Texas Root Rot (Phymatotrichum)
Many areas of Arizona are infested with Texas root rot. It is a widespread rot affecting many different species of plants. Symptoms do not appear until well into the growing season during flowering or boll set.(7)

Controls

Cultural
Texas root rot is limited very localized patches and does not appear to spread regardless of cultural practices.

Biological
Some success has been had with heavy manure applications.

Chemical
None are recommended.

Verticillium Wilt (*Verticillium dahliae*)
Verticillium wilt is a serious disease of upland cotton across the U.S. Verticillium wilt is most active between 70 and 80 degrees. As a result, while it is infrequently seen in seedlings, it will more frequently occur in the early fall especially at higher altitudes. The disease can have a yield effect as it causes defoliation and boll shedding.

Controls

Cultural
Fallowing or rotation can reduce the presence of verticillium wilt. Managing for short season production can avoid many of the problems associated with this disease. Unlike Texas root rot, farm machinery does spread the sclerotia, the soil borne structures produced in residue. These sclerotia can persist in soil for many years.

Chemical
None

Southwestern Rust
An important foliage disease in Arizona, southwestern rust is caused by spores originating on certain species of grama grass. During the summer monsoon rains conditions can occur that support germination of spores on grama grass that can subsequently infect cotton. Spores can be carried as far as eight miles making control of the host grama grass impractical. A severe infection can reduce cotton yield by as much as 50%.

Controls

Chemical
Protective applications of mancozeb during July and August must start before cotton has been exposed to spores.

Mancozeb
Arizona usage can be found in 1998 Reported Fungicide, Nematicide and Fumigant Use on Cotton in Arizona from A.D.A. Form 1080 data table below.

Leaf Spot(*Alternaria*)
Alternaria Leaf Spot is caused by *Alternaria macrospora*, a fungus that infects the leaves, bracts and bolls. Pima cotton is very susceptible, while Upland cotton is fairly tolerant under normally dry weather conditions. *A. macrospora* survives in cotton debris and on weeds. Under high humidity or rainfall, spores are produced that are windblown or splashed on cotton plants. Red lesions appear where spores have germinated and grown into the host tissue. Infections late in the season are not considered a problem, but early infections during summer rains in July and August can cause severe defoliation.

Controls

Chemical
Mancozeb
Arizona usage can be found in 1998 Reported Fungicide, Nematicide and Fumigant Use on Cotton in Arizona from A.D.A. Form 1080 data table below.

Nematodes

Root-knot nematode(*Meloidogyne incognita*)
Root-knot nematodes occur widely throughout Arizona and are capable of causing severe yield reductions. In fields planted in continuous cotton, the problem will be worse. Above-ground indications of a nematode problem are not specific beyond general poor plant health. The roots will show small "knots" or galls indicating the presence of root-knot nematodes.

Controls

Cultural
Crop rotation with non-hosts such as alfalfa, winter small grains and other crops specifically resistant to the root-knot nematode. Summer rotations with sorghum or corn should be avoided. Root-knot nematodes will thrive on these crops. Deep tillage has been shown to increase yields in California. Nematode populations are not reduced but plants apparently are better able to uptake nutrients.

Chemical
Recent research in Arizona indicates that soil fumigation with Telone II (1,3-dichloropropene) improve both yields and economic return. Full label rates were effective while partial rates showed little improvement over untreated controls.

1,3-Dichloropropene
Arizona usage can be found in 1998 Reported Fungicide, Nematicide and Fumigant Use on Cotton in Arizona from A.D.A. Form 1080 data table below.

Aldicarb is primarily used as an insecticide but is registered for nematodes in Arizona. There is little evidence in the 1080 data of the high recommended application rates for nematodes during the planting window. Usage information is in the insecticide table above.

1998 Reported Fungicide, nematicide and Fumigant Use on Cotton in Arizona

Active Ingredient	Reports	Acres	% of Planted Acres	Mean Application Rate

Captan	5	206	0.1%	0.24
Copper oxychloride	6	834	0.3%	0.38
Dichloropropene	90	11,148	4.2%	48.13
Mancozeb	51	4,055	1.5%	1.14
PCNB	46	5,830	2.2%	0.69

Weeds

Weeds can be problematic in Arizona cotton at both the beginning and the end of the growing season. Weed competition during cotton germination and stand establishment, can cause reductions in plant populations, growth and yield. Weeds compete for water, nutrients and light and during the seedling stage, or the first 8 weeks of growth, cotton is particularly vulnerable to this competition. In addition, some species such as purple nutsedge that can occur at high population densities have allelopathic effects on cotton seedlings as well as competing for water, nutrients, and light. After the cotton canopy has closed, weed competition is not usually a problem with regard to cotton plant development although annual morningglory species can shade large cotton plants. Existing weed populations can reemerge as a problem after defoliation and cause difficulties with harvesting. For example, late season growth of purple and yellow nutsedge and grasses such as sprangletop can cause staining of the lint during harvest. Morningglory vines can impede harvesters in the field, requiring the manual labor to cut the vines, and can add trash to the lint during harvest. Staining of the lint or the presence of excessive weed trash in the lint can lower crop quality and price at the gin.

Weeds also play an indirect role in many other aspects of cotton management. Weeds in or near fields can play host to insect, fungus, disease and nematode populations. For example, purple nutsedge functions as a host for root-knot nematodes. Management of weeds needs to go beyond protecting crop development to maintaining good farmstead weed control and sanitation in order to provide a good growing environment for cotton and other crops. This includes ditch bank weed control by farmers and irrigation districts since water movement is a major avenue of weed seed movement.

The high light, high temperature environment in Arizona combined with frequent irrigation for crop production provides an ideal habitat for the growth of weeds that utilize the C_4 photosynthetic pathway. These plants are characterized by rapid growth rates and high temperature optimums for growth and include purple and yellow nutsedge, bermudagrass, Johnsongrass, barnyardgrass, junglerice, and Palmer Amaranth among others. These species were among the most commonly reported species in Arizona weed surveys conducted in 1995 and 1996. In order of relative abundance in 1995, the most common weed species were purple nutsedge (*Cyperus rotundus*), bermudagrass (*Cynodon dactylon*), annual morningglory (*Ipomoea* species), yellow nutsedge (*Cyperus esculentus*) Wright groundcherry (*Physalis wrightii*), Johnsongrass (*Sorghum halepense*), common purslane (*Portulaca oleracea*), Sprangletop (*Leptochloa* species), barnyardgrass (*Echinochloa crus-galli*), Palmer amaranth (*Amaranthus palmeri*), silverleaf nightshade (Solanum elaeagnifolium), desert thornapple (*Datura discolor*), junglerice (*Echinochloa colonum*), southwestern cupgrass (*Erichloa gracilis*), and field bindweed (*Convolvulus arvensis*). Although there were changes in relative abundance, similar results were found in 1996 with 13 species common to the two weed surveys. In 1996, desert thornapple and field bindweed were not found in surveyed fields and were replaced by horse purslane (*Trianthema portulacastrum*) and common sunflower (*Helianthus annuus*) in the list of the 15 most common weeds in Arizona (15).

Controls

Cultural and Mechanical

Proper long-term management at the field level is important for reducing weed infestations. Crop rotation can reduce specific weed population levels by exposing weeds to different cultural practices (e.g., planting dates, temperature environments, and irrigation regimes), different crop competition and different herbicides. Sanitation practices such as cleaning soil and weed propagules (e.g., purple nutsedge tubers and johnsongrass rhizomes) off of cultivators and laser leveling equipment before moving to another field, and cleaning and removing weed seeds from pickers decreases the spread of weeds from field to field.

A survey of 76 growers conducted by the Arizona Office of the NASS in 1996 (15) found that scouting is a commonly used practice in Arizona cotton production. Of the 76 reports summarized, 63 scouted for weeds, 68 for insects, and 63 for diseases. Most commonly, the operator or a family member did the scouting (24/63). Other methods of scouting were by crop consultants (18/63) and dealers (17/63). On the question of keeping records of the scouting results, 7 of 76 kept records of weed distribution, but 24 of 76 recorded insect findings. All 76 growers reported using cultivation to control weeds. Some form of mechanical cultivation is used by almost all producers because of the necessity of maintaining irrigation furrows. The earliest cultivation date reported was March 25 and the latest was August 27. Dates were asked for 3 cultivations. The average dates were May 1 (first cultivation), May 25 (second cultivation), and June 10 (third cultivation). Some 46 of 56 responding growers indicated that a moldboard plow was used on the selected field. A 1995 grower survey found that the average statewide cost for hand weeding was $27.87 per acre in addition to other weed control costs (15). Growers with severe annual morningglory infestations can spend up to $100 per acre or more for hand weeding.

Traditional cultivation techniques using field cultivators and rolling cultivators that leave about an 8 inch uncultivated band on the bed top along the crop seed line are most common. In recent years there has been significant adoption of precision tillage techniques utilizing articulated electro-hydraulic guidance systems. Articulated electro-hydraulic guidance systems actively steer the cultivation implement using a sensing device, typically a crop wand, to detect a crop row. The sensing device produces electrical signals that actuate a hydraulic steering system incorporated into a quick-attach hitch configuration. Articulated guidance systems move the cultivator relative to the tractor by pivoting the cultivator about a king pin, which is a part of the hitch mechanism. As the implement pivots, resistance on the soil engaging tools increases, which in turn causes the implement to move sideways. The most common precision cultivator configuration includes disk openers followed by beet hoes set with a 3 to 4 inch gap followed by torsion weeders or spring-hoe weeders to mechanically remove weed seedlings from within the seed row of large cotton. These latter devices are sets of spring steel rods which compress and crumble the soil around the base of cotton plants in such a way that small weed seedlings are uprooted. Precision cultivation places steel close to the crop row (within 1.5 inches) at the tractor speeds up to 5 to 6 mph. The combination of the early season herbicide sprays and precision guided cultivation with in-row weeding tools can make hand weeding of fields unnecessary by nearly eliminating annual morningglory from the fields. In addition to the substantial saving associated with the elimination of hand weeding costs, the greater tractor speeds attained with precision guidance also increase productivity and reduce cultivation costs and combined with the banding of herbicides can reduce cost and pesticide usage levels.

Chemical

Chemical control of weeds is in a state of flux in Arizona. The traditional cotton weed control approach usually involves the use of a preplant incorporated herbicide and cultivation, and possibly the application of a herbicide at layby. A survey of 76 growers conducted by the Arizona Office of the NASS in 1996 (15) found that preemergence herbicides were applied by 57 of the 76 reporting growers. The decision to apply the product was based primarily on experience from previous years (53/76). Some growers applied herbicide based on the recommendation of crop consultants (18/76) and a few (9/76) based on field mapping data. Only 31 of 76 growers reported applications of postemergence herbicides. Some (17/76) made the application as a routine treatment, others (18/76) applied the product based on the density of weeds, and a few (8/76) relied on the advice of crop consultants. Evidence from 1995 indicates that the majority of postemergence herbicides were broadcast applications indicating a layby application.

The recent development of herbicide resistant cotton varieties [resistant to bromoxynil (Buctril) or glyphosate (Roundup) herbicides] and the development of the postemergence herbicide pyrothiobac (Staple), provide the opportunity to pursue post-emergence weed control strategies that were not possible until quite recently. The developing or more modern weed control approach, particularly for broadleaf weeds, involves the application of a topical (over-the-top) herbicide (i.e., bromoxynil, glyphosate or pyrithiobac) at or prior to the 4 leaf growth stage. If necessary, topical applications are followed by post-directed herbicide applications and possibly by a layby herbicide application (particularly if annual morningglory is present). Early season herbicides combine with precision cultivation can keep fields weed free until layby, protect the cotton from weed competition during the critical early plant development period, eliminate hand weeding and may reduce or eliminate the use of some pre-plant, preemergence herbicides.

A survey of 76 growers conducted by the Arizona Office of the NASS in 1996 (15) found that only 1 of 76 fields was planted to a herbicide resistant variety (BXN57, BXN58). However, indications are that in recent years more growers are using herbicide resistant varieties and pyrithiobac herbicide. Recently, the most popular early-season postemergence herbicides have been pyrithiobac and glyphosate (Roundup Ultra), the latter being spraying on Roundup Ready cotton varieties. Recent research by U of A Agricultural Extension indicates that Staple and Buctril application regimes need to be combined with a banded or broadcast application of a dinitroaniline herbicide (pendimethalin, trifluralin) to be fully effective against Arizona’s weed spectrum (16). Roundup Ready cotton weed control regimes can be effective without the use of preplant-incorporated dinitroaniline herbicdes, however, this approach requires more management skill and entails greater production risks associated with weed control failures.

Generalized chemical weed control regimes for categories of weed species are briefly outlined below for the common weed categories. Mechanical cultivation as discussed above is an integral component of all weed control regimes.

Grass species

Application of a dinitroaniline herbicide (pendimethalin or trifluralin) preplant-incorporated is used to control seedlings of both perennial and annual grass weed species. The postemergence graminicides, clethodim, fluazifop-P-butyl, and sethoxydim are used to control escapes of annual species and to control perennial grasses such as bermudagrass and Johnsongrass. The postemergence applications are done as spot treatments if less than 10 to 15% of a field is infested or as broadcast applications if the infestation in a field is more widespread.

Nutsedge species

Norflurazon can be applied in wet planted cotton in conjunction with a preplant-incorporated dinitroaniline herbicide to provide short-term suppression of nutsedges. Postemergence control options in order of effectiveness include sequential glyphosate applications in Roundup Ready cotton varieties, sequential MSMA applications, and sequential EPTC applications as outlined in a section 24C special local needs label. Pyrithiobac applications have provided inconsistent suppression of nutsedges. Fallow ground treatments with EPTC (section 24C special local needs label) and crop rotation allowing the use of other herbicides are also used to prepare fields for cotton production (e.g., norflurazon in alfalfa, and halosulfuron in corn).

Broadleaf species

Application of a dinitroaniline herbicide (pendimethalin or trifluralin) preplant-incorporated is used to control small seeded broadleaf weed seedlings (e.g., Palmer amaranth, other pigweed species and common purslane). Band applications of postemergence herbicides such as pyrithiobac, glyphosate (Roundup Ready cotton varieties), and bromoxynil (BXN cotton varieties) are sprayed topically and post-directed early in the season as needed. Other older herbicides such as cyanazine, diuron, fluometuron, oxyfluorfen, and prometryn, alone or in combination with MSMA, are applied post-directed (i.e., "chemical hoe") in larger cotton (taller than 6 to 8 inches) and also as band applications. These latter applications can be made following a topical pyrithiobac application or early season bromoxynil applications. Precision cultivation and in-row weeding techniques are especially effective on broadleaf weeds. Particularly in fields with annual morningglory infestations, layby herbicides such as cyanazine, diuron, and prometryn are applied to protect the cotton crop after canopy closure.

1998 Reported Herbicide Use on Cotton in Arizona

Active Ingredient	Reports	Acres	% of Planted Acres	Mean Application Rate
Bromoxynil	52	3,904	1.5%	0.32
Clethodim	9	536	0.2%	0.20
Cyanazine	219	16,798	6.3%	0.99
Diuron	101	12,952	4.9%	0.68
EPTC	7	372	0.1%	2.00
Fluazifop-P-butyl	61	2,601	1.0%	0.30
Fluometuron	16	1,166	0.4%	0.52
Glyphosate	137	11,485	4.3%	0.60
MSMA	43	3,366	1.3%	1.37
Norflurazon	17	949	0.4%	0.38
Oxyfluorfen	27	1,378	0.5%	0.47
Pendimethalin	498	41,420	15.6%	0.91
Prometryn	457	42,074	15.8%	0.92
Pyrithiobac-sodium	100	6,422	2.4%	0.07
Sethoxydim	18	807	0.3%	0.34
Trifluralin	360	32,018	12.0%	0.63

Bold AIs are on the GWPL, see Arizona Pesticide Use Reporting for more information.

Defoliation

Defoliation facilitates harvest. Cotton will continue to grow through the end of the growing season. Cutting irrigation can start defoliation but defoliants are used to aid in leaf drop to minimize trash and staining in harvested lint.

1998 Reported Defoliant Use on Cotton in Arizona

Active Ingredient	Reports	Acres	% of Planted Acres	Mean Application Rate
Cacodylic acid	230	18,610	7.0%	0.64
Diuron	1,158	97,370	36.6%	0.04
Endothall	327	26,018	9.8%	0.07

Paraquat	518	46,529	17.5%	0.25
Sodium chlorate	1,270	103,418	38.9%	4.20
Thidiazuron	1,435	125,487	47.2%	0.08
Tribufos	510	47,187	17.7%	1.05

Bold AIs are on the GWPL, see Arizona Pesticide Use Reporting for more information.

Plant Growth Regulation

Plant growth regulators are used to manage fruit set and retention by controlling vegetative growth in the cotton plant.

1998 Reported Plant Growth Regulator Use on Cotton in Arizona

Active Ingredient	Reports	Acres	% of Planted Acres	Mean Application Rate
Cytokinins	60	5,499	2.1%	0.00
Ethephon	305	28,018	10.5%	0.86
Gibberellic acid	22	1,486	0.6%	0.00
IBA	35	3,215	1.2%	0.00
Mepiquat chloride	1,768	136,230	51.2%	0.04

Bold AIs are on the GWPL, see Arizona Pesticide Use Reporting for more information.

Arizona Pesticide Use Reporting

The state of Arizona mandates that records be kept on all pesticide applications. Submission to the Arizona Department of Agriculture (ADA) of these pesticide use reports is mandated for all commercially applied pesticides, pesticides included on the Department of Environmental Quality Groundwater Protection List (GWPL) and section 18 pesticides.

Commercial applicators licensed through the state must submit Arizona Department of Agriculture Form 1080 Pesticide Use Reports for all applications. The use of commercial applicators varies across crops. Aerial application is all done by commercial applicators.

The GWPL is a list of active ingredients determined by the Department of Environmental Quality to potentially threaten Arizona groundwater resources. Enforcement of this list is difficult. Strictly speaking, only specific types of soil application of GWPL active ingredients must be reported. Inclusion on the GWPL should indicate a higher level of reporting but without further research, no useful distinctions can be drawn.

Section 18 active ingredients should have 100% reporting. In cotton, buprofezin was a section 18 throughout the 1998 growing season. Pyriproxyfen was granted a section 3 late enough in the season that reporting should be essentially 100%.

Voluntary reporting does take place. Anecdotal evidence indicates some producers submit records of all applications

Reported pesticide usage provides a solid lower bound of acres treated and a mean application rate of reported applications. Relative magnitude of reported acres is useful for rough comparison but could reflect a bias among commercial applicators or differing reporting rates as a result of inclusion on the GWPL. Finally, while the quality of data from the ADA 1080 forms has improved dramatically in recent years, there is still the possibility of errors.

Contacts

Tim Dennehy, extension specialist, professor - entomology
(520)621-7124, e-mail tdennehy@ag.arizona.edu

Peter Ellsworth, Area IPM Associate Specialist
(520)568-2273, e-mail peterell@ag.arizona.edu

Bill McCloskey, Weed Specialist
(520)621-7613, e-mail wmcclosk@ag.arizona.edu

Michael A. McClure, Professor - Plant Pathology (nematodes)
(520)621-7161, e-mail mcclure@ag.arizona.edu

Mary Olsen, Plant pathology specialist (diseases)
(520)626-2681, e-mail molsen@ag.arizona.edu

Jeff Silvertooth, Agronomist - cotton
(520)621-7616, e-mail silver@ag.arizona.edu

Compiled by: Ken Agnew
Pesticide Information and Training Office
University of Arizona
Tucson, AZ 85719
(520) 621-4012

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