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PEST CONTROL STRATEGIES FOR NON-TRADITIONAL CROPS IN ARIZONA: CURRENT STATUS AND FUTURE NEEDS

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PEST CONTROL STRATEGIES FOR NON-TRADITIONAL CROPS IN ARIZONA: CURRENT STATUS AND FUTURE NEEDS

by

Dale Robert Cross

A Thesis Submitted to the Faculty of the

COMMITTEE ON PLANT PROTECTION (GRADUATE)

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ABSTRACT

Pests and pest control strategies on selected non-traditional crops (guar, guayule, jojoba, plantago and tepary beans) were examined to determine what pests had been identified on these crops and how they were being controlled. Additionally, selected traditional crops (carrots, cotton, grape, lettuce and pecan) were reviewed to learn their early pest control activities and how these might be applied in developing control programs on the current non-traditional crops. The study was carried out with the use of a literature search plus a DELPHI survey and personal interviews.

Although the results indicated a general lack of awareness of the pests on these non-traditional crops, weeds were recognized as the predominant problem. Other conclusions indicated that there was a discrepancy between the literature and the survey responses regarding pest controls and the research apparently addressing the topic. Finally, the lack of any easily usable source on the history of pests and their controls on the more traditional crops makes the development of guidelines and the correlation of pest problems and their controls to the non-traditional crops difficult at best.

CHAPTER 1

INTRODUCTION

People in Arizona agriculture generally agree that things are not as they used to be. Good agricultural land is being usurped by growing urban areas and used for housing developments, business parks or other non-agricultural purposes (e.g. the Salt River Valley region of Maricopa County). If prime land is not lost to urbanization, it is lost due to lowering of the water table or increased salinization of the soil only to be replaced by utilizing marginal virgin land or previously planted land that had been taken out of production. The whole matter is additionally complicated with the problem of water use (urban vs agriculture) and the new Arizona water laws (with new taxes and the establishment of water management areas). This has led to increased interest over the past few decades in the potential for domesticating and commercializing drought and salt tolerant plant species.

Several plant species have been examined and a number of papers have been published on the virtues of specific plants, describing the potential economic gains to be realized if only a native species can be domesticated or an introduced species commercialized. In this quest for new agricultural crops the economic market for the plants and their by-products has been studied, but a great deal of the basic agronomic research has been generally slighted. Literature in the area of potential pest problems and their controls has been markedly deficient.

This lack of information may justifiably be due to the limited experience with many of these plants on large scale plantings. It might equally be true that in our zeal to pursue the "economics" of commercializing a drought tolerant native crop we have generally ignored the pest problems; economics alone is a formidable obstacle and pest problems do not normally express themselves until large scale plantings of the crop have been grown for a few years.

It is not the intent of this paper to predict which plants will be successful in Arizona agriculture, and the exclusion of any plant from this study does not necessarily mean that its chances of success are not considerable. To borrow a phrase from G.L. Fisker (32): "Time only will tell whose estimates of supply and demand are most accurate. I do not care to be placed among those who attempt to forecast the future of a product which has had little market exposure to date...".

Obviously, economic considerations are involved in all aspects of plant production from when and what to plant to when and how to harvest. Considerations such as cost of seed, fertilizer, water and equipment as well as market value of the crop often dictate how much a grower is willing to expend for pest control during the life of a crop. This will, in turn, influence his decision on which control measure he can best afford. Aside from the influence of the market place, one must still confront the reality that not all plants are readily amenable to common agronomic practices. Additionally, pest problems can occur at such levels in certain locations that the amount of pest control required to achieve satisfactory yields can preclude any chance of profitably growing the crop.

This study was undertaken to determine 1) what information is available concerning pests and pest control strategies on some of these "new" crops, 2) to find out from the agricultural community what pest problems are viewed as important to the establishment of these crops, and 3) to review selected traditional crops for pest control measures that could be applicable to the non-traditional crops. Also, guidance might be provided for areas needing investigation and what types of problems a grower might expect to encounter when entering into an operation involving "new" crops.

CHAPTER 2

PEST CONTROL STRATEGIES

In evaluating pest control measures on crops, it is necessary to have an understanding of the practices employed and the methods under study for potential controls. The methods used can be divided into the following categories (listed in no particular order): 1) chemical, 2) biological, 3) cultural, 4) host plant resistance, 5) mechanical/ physical, 6) regulatory, and 7) integrated pest management. The following is a brief discussion of each strategy and its advantages and disadvantages.

Chemical Control

Of all the control measures available to a grower, the one which is most often and most easily used (and misused) is that of chemical control. The term chemical control is readily identifiable with the many pesticides available on the market for controlling a wide variety of pests, whether plants, vertebrates, invertebrates, or microorganisms. Basically these chemicals come in 12 types of packagings or formulations: sprays, dusts, aerosols, granulars, fumigants, impregnants, fertilizer mixtures, baits, timed release, repellents, attractants, and animal systemics (102). This variety of formulations is designed to improve effectiveness, ease of handling, and/or safety of the product. These products are readily available to growers (unless they are restricted class compounds and then certain criteria must be fulfilled to obtain them) and each one has its own unique advantages and disadvantages.

The requirements and regulations regarding the use of any of these compounds are found in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 with amendments. Application is strictly controlled according to the labeling associated with any such product. Some advantages of using chemical controls include rapid expression of results, both broad spectrum and selective activity, cost when compared to labor, application when and as needed, and ease of incorporation into most pest control programs. The disadvantages include environmental contamination, operator safety, cost for development, insufficiency of selective compounds, destruction of beneficial organisms, rapid development of resistance, and the rise of secondary pests to primary importance. Throughout this paper, chemicals are identified by their common names only. Appendix A has been provided to identify chemical names of the compounds mentioned should that information be desired. The mention of any compound in this paper is not to be considered as an endorsement of that compound, but simply a statement of the information gathered.

Biological Control

In a stable plant community, biological control is an everyday process normally unseen and taken for granted. Only when there is an alteration or change in the status quo of the environment (such as the introduction of a monoculture agricultural system or misapplication of a pesticide) do we become aware of the actual role that this control mechanism plays in checking pest problems. Essentially, biological control is the use of natural controlling organisms (insects, pathogens, vertebrates etc.) in such a way as to reduce pest populations to levels below what they would ordinarily be in the absence of those organisms (commonly referred to as beneficials). This method employs two principles. The first involves the manipulation of agronomic practices so as to minimize the disturbance to natural populations of beneficials. It can also include measures taken to enhance the environment to provide a reservoir of beneficials or make the environment amenable to large population growth. The second principle involves the direct influence of man on the pest populations (such as reuniting a displaced pest with its control or augmenting the beneficial populations already present by mass releases or genetic manipulations).

The advantages of biological control are safety, permanence, normally high degree of selectivity and, over the long run, economy. Disadvantages are that precise knowledge concerning the pest and the beneficial organism is essential (initial research must be thorough), biological controls are slow and therefore must be allowed time to operate so users must suppress the urge to resort to chemicals when pests are first encountered (particularly true with insects), and biological control programs can be easily disrupted or destroyed by the carelessness of ill-informed persons. While there are numerous cases to demonstrate the effectiveness of this method (e.g. the cottony cushion scale (*Icerya purchasi*) controlled by the vedalia beetle (*Rodolia cardinalis*), puncture vine (*Tribulus terrestris*) in Arizona controlled by a combination of seed and stem weevils), in practical application it has been more successful in controlling insects than other pests; and even there complete control is a rarity. With increased study this control method should prove more applicable for all agricultural pest types.

Cultural Control

One of the oldest methods of applied control is cultural control and, until the advent of the chemical era, it was practiced by virtually every concerned grower. Simply stated, this method is the use of normal crop production practices in such a manner as to make the environment unsuitable for the growth, reproduction or survival of a pest species (104). This category includes such routine practices as modifying planting, growing, or harvesting dates, rotating crops according to particularly effective schedules, cleaning up fields after harvesting, water management, and use of acclimated or competitive crop varieties. Disadvantages to this method include fuel costs for extra cultivations (above those required for basic soil preparation), prior planning is required as well as knowledge of the biology of the pest and its host plant, and there is little room for manipulation in the advent of an unusually large pest outbreak. In its favor, cultural control has none of the undesirable side effects of pesticide use, and no additional expenses are incurred above those of normal crop production (with the exception of additional cultivations directed towards pest control only).

Host Plant Resistance

Host-plant resistance or resistant varieties refers to the inherited ability of a plant to withstand or limit the damage resulting from pest encroachment. This can range from immunity, where a plant is never attacked by a specific pest, to varying degrees of susceptibility, where the plant might be attacked by a pest but can accommodate for the injury and continue to develop. The mechanisms of this method are antibiosis (the plant can prevent injury or destroy the offending organism), tolerance (the plant is able to withstand pest damage and continue to grow and develop in spite of sustaining injury that could destroy a susceptible variety), and preference or non-preference (which refers to characteristics of a plant or pest which would make one plant more preferred than another). The advantages of this control method are its specificity, low cost (both in development and use), compatibility with other control programs, safety to the environment and the user, and long term and cumulative effectiveness. The disadvantages include the long lead time required to develop resistant varieties, inconsistency of use by growers, rapid development of biotypes, races or strains which are capable of circumventing resistance mechanisms, and the occasional undesirable effect of developing resistance at the expense of other desirable plant characteristics. Although this topic is quickly reviewed here, it is by no means a minor pest control alternative since a great deal of research on disease and insect control is centered around this method.

Mechanical and Physical

Mechanical and physical control methods are ancient in use and refer to the removal of a pest by mechanical or physical means. In its simplest form, this method includes hand removal of weeds, insects, or diseased plants from a field. In its more technical applications are environmentally controlled storage facilities, the use of light and sound traps, and physical walls or barriers in or around fields. The chief advantages of this type of control are specificity, safety to the user and the environment, ease of application and compatibility with other methods. Disadvantages include the cost (generally high labor requirement and often very expensive permanent structures), the impracticality of some of the systems on large field applications, the need for a thorough understanding of the biology and ecology of the pest, and the inflexibility of an established system to cope with unexpected additional problems.

Regulatory Control

Containment, suppression, prevention, and/or eradication are the objectives of a regulatory control system and these are achieved through the use of quarantine, inspection stations and controlled spray programs. Southwestern programs which have been successful include the checking of the spread of major pecan (*Carya illinoensis*) pests and noxious and undesirable plant species into and out of Arizona, and controlling outbreaks of screworm (*Cochliomyia macellaria* (Fab)) along the U.S. and Mexican borders. A major advantage of this method is obvious: if a pest is not allowed to enter an area, no other control measures will have to be instituted against it. This can be of considerable importance when introducing a crop into new areas removed from the pressures of native pests. It is also quite effective in preventing a pest from spreading out of an area of infestation to other potentially more sensitive areas (control of the mediterranean fruit fly, *Ceratitis capitata* is an example of this). Disadvantages of this method include the difficulties in obtaining the regional, national and sometimes international cooperation necessary for the success of such a program, the sizeable cost of such an undertaking, and the argument that given sufficient time, a pest organism will establish itself, despite actions taken to prevent it.

Integrated Pest Management

Among researchers, industrial representatives, and growers alike, the ideal pest control strategy of the future is agreed to be Integrated Pest Management (IPM). Early on , IPM was considered to be synonymous with Insect Pest Management and thus, the majority of application was in the area of insect control. More recently, however, IPM has come to mean the control of all types of pests through the application of one or more of the above mentioned control strategies. As the term implies, IPM is the integration of control methods in such a manner as to have a mitigating effect on populations of pests. It does not eliminate the use of any one strategy nor does it preclude the possibility that only one method of control will be used. It simply means that by applying what is known concerning the biology and ecology of an economic plant and the numerous pests associated with it, a system can be developed incorporating the various control strategies to improve the quality and quantity of crops at a minimum cost to the grower and the environment.

The employment of IPM relies upon good sampling, the use of economic threshold (ET) and a knowledge of how ET relates to economic injury level (EIL). Historically, the ET has been considered to be the point in a pest infestation where some type of control measure must be implemented in order to prevent economic damage (before such damage becomes obvious). The ET is determined using criteria such as the cost of control measures, market value of the product, expected yield, and presence of beneficials, since these will dictate how much of an infestation can be tolerated before economic loss is incurred. Ideally this is not a fixed value but can fluctuate yearly in response to the biological and economic environment of that crop. Fields are sampled regularly to keep track of pest populations so that action may be taken when they reach the ET. When pest populations have reached levels high enough to cause economic crop loss, they have reached the EIL. The ET is normally placed sufficiently below the EIL so that corrective action may be taken well before a pest causes economic loss. The advantages of employing IPM include increased flexibility to the grower, (often at less cost since pests are not acted against unless they reach economic levels), reduced environmental problems and safety hazards, and increased awareness of the grower of the extremely complex relationship between the crop and its total environment.

Although there are very few disadvantages to the employment of full scale IPM, there is one considerable impediment to its success, and this is in the understanding of the biology and ecology of the pest/crop relationship. It is difficult enough to gain a modicum of understanding of the relationship between a single plant with a single pest under controlled conditions. Incorporating population thresholds which can change with the season, training and scheduling scouts so that fields are adequately monitored and working under natural rather than controlled conditions quickly complicates this simple picture. If one considers the influence of weather, competing insect species at fluctuating population levels, diseases of varying severity, the poorly understood relationship between economic and weed species (is there an ET for weed plants?), and the potential influence on a grower's field of what is being grown by his neighbor. It becomes easy to see how really difficult it can be to develop a full scale IPM program. This does not mean that IPM is not a viable pest control method or that it can be employed in only limited instances. It does mean that considerable study must be undertaken and that we must have all control strategies available so they can be employed in the most efficient mix possible. To be most effective, IPM must be practiced year-round with emphasis on the use of practical non-chemical alternatives (64). Other obstacles to the use of this strategy include the general lack of agreement as to its practicality, its effectiveness, the real cost and actual definition of what the term implies.

CHAPTER 3

THE CROPS

While much of the interest in non-traditional crops in Arizona is centered around their low water use, drought and salt tolerance, and adaptability to marginal lands; these crops may well be grown near or in rotations with some of the more traditional crops. Several traditional crops were included in this study to provide historical perspective on how problems were dealt with when these were the "new" crops and so that we might learn from those experiences.

To limit the scope of this paper it was decided that 5 traditional and 5 non-traditional crops be investigated, each group consisting of 3 annuals and 2 perennials. The following is a brief discussion of the pest problems and solutions used in Arizona agriculture on these crops. Since chemical control has been the strategy that pest control has centered around most recently, Table (1) highlights the chemicals registered for use on these crops. The same compound might be registered for use on several sites so there will normally be more entries recorded than actual compounds available.

Table 1. Numbers and Sites of Pesticides Registered For Use on Selected Crops.

CROP	# OF SITES*	# OF ENTRIES**
Carrot	26	2283
Cotton	52	3651
Grape	98	3227
Lettuce	44	3744
Pecan	26	814
Guar	3	36
Guayule	0	0
Jojoba	0	0
Plantago	0	0
Tepary Bean	0	0

Numbers were taken from the National Pesticide Information Retrieval Service (NPIRS) April, 1983.

* This term refers to the number of uses in which the crop name appears e.g. carrots foliar, carrots soil, carrots storage.

** This term refers to the number of different registrations on a crop.

The Traditional Crops

Carrot

Carrot, Umbellifera *Daucus carota* L., is a native of Europe and the adjoining portions of Asia. It is a cool weather plant, grown as an annual except when grown for seed. The seed is a tiny, dry, indehiscent, one-sided fruit which germinates very slowly and requires a fine friable seedbed and a uniform supply of moisture on soils which are deep, loose, slightly acidic, and well drained loams or sandy loams (103). Production occurs chiefly in the Salt River and Yuma Valley areas and the crops are grown to yield two annual crops, early winter and spring (71).

Exactly when carrots were introduced into Arizona agriculture has been difficult to ascertain, but references as early as 1909 (55) described carrots as growing well in the southern valleys of Arizona with planting date from August to March and apparently free of diseases or pests. Carrots are a fairly expensive crop to grow, originally requiring hand weeding and hoeing for weed control and hand thinning after stand establishment. In 1939 it required 289 man-hours to grow and harvest a single acre (103).

Perhaps the most serious pest affecting carrots is weeds since carrots are poor competitors. The recommended practice over the last few decades for weed control centered around avoiding known weedy areas and using a good preplant irrigation to leech any soluble salts and to germinate weed seeds for later mechanical destruction during the process of bed preparation and planting. (When possible, subsequent cultivation kept to a minimum during the season was also recommended) (7,71). In recent years this practice has been greatly modified with the widespread use of herbicides, but the importance of cultural controls remain significant.

Although carrots are not considered to be disease prone, they are susceptible to two field fungi, one physiological phenomenon and 9 different species of nematode (7). The USDA Index of Plant Diseases (5) lists 36 different disease organisms and 6 different viruses as affecting carrots. It is considered good practice to avoid areas of known root knot nematode (<u>Meloidogyne</u> sp.) infestation since carrots are highly susceptible to this pest in the sandy soils of Arizona (7, 71).

Carrots are fed on by at least 23 different insect species (7). In 1952, Roney (83) listed an aphid as the only serious pest requiring control and recommended that chemical applications be made once aphids appeared on the crowns of the carrots. Grasshoppers and cutworms were listed as general crop pests and again the preferred method of control was chemical application. By 1957, the major insect pests listed were the tulip bulb aphid *Dysaphis tulipae* and the vegetable weevil *Listroderes costirostris obliquus* with grasshoppers, crickets, yellow-striped armyworm *Spodoptera ornithogalli* and the green peach aphid *Myzus persicae* as occasionally serious pests (71). When available, chemicals were the preferred and recommended method of control of insects once they reached noticeable levels.

Cotton

Cotton, Malvaceae *Gossypium* sp., is a stiff growing herbaceous annual (outside the tropics) with fairly large, lobed leaves. Ripe fruits are dehiscent capsules containing up to 40 or 50 obovate, rounded or angular seeds to which the lint is attached (53).

The use of cotton is quite ancient with evidence of cotton textiles over 5000 years old found in Pakistan and dating back to 2500 B.C. in Peru. There is also evidence of its antiquity found in pre-historic ruins located in Arizona. However, the first cultivation and use of cotton was probably in India, which for over 3000 years was the major center of the world's cotton industry.

Although cotton use in Arizona and the American Southwest predates the rise of the cotton industry in the Southeastern U.S. by centuries, Arizona is a latecomer to the industry. Cotton was first introduced into Arizona in 1902 on an experimental farm near Mesa, by Dr. A.J. Chandler. In 1908 the "Yuma" variety was developed from plantings of Egyptian seed in Yuma by the U.S.D.A. and became the first commercial cotton grown in Arizona. Over the years the volume of cotton produced has varied with the going price of the product, reaching the point in 1963 where it accounted for 36% of the total agricultural income of the state (6).

Early on, the value of rotation with legumes and other crops was recognized in Arizona for not only maintaining soil productivity and improving water penetration, but also for assisting in the control of insects, diseases and weeds. The consistent climate also made it possible for growers to respond rapidly to price relationships and other constraints rather than following more standard rotations. Row spacing was critical to provide access for cultivation necessary for weed control, preventing surface crusting, facilitating irrigation (opening furrows), and forming the appropriate beds suitable for mechanical harvesting (6).

The early interest in Arizona cotton pests involved the insect populations on native or wild cotton in the vicinity of cotton fields. This was chiefly due to the fact that since the majority of serious cotton pests from the eastern US were not in Arizona it was deemed necessary to identify potential native pests. In a 1914 study, Pierce and Morrill (73) collected samples from several localities in Pima and Pinal counties and compiled a list of 83 different insect species representing 8 orders. Of this group, 25 species were classified as injurious to the native cotton plant. Of particular note were the boll weevil *Anthonomus grandis* var. *thurberiae*, the leaf worm *Alabama argillacea*, the thurberia boll worm (unidentified but felt to closely resemble the Trinidad pink boll worm <u>Acadodes pyralis</u> Dyar), the blister mite <u>Eriophyes</u> sp., a leaf galling midge (Cecidomyiidae), and a mealy bug <u>Pseudococcus</u> sp.

In 1917, Morrill (65) reviewed the cotton pests in Arizona and observed that if one used the nintyeighth meridian (running North to South passing thru eastern Texas just west of Ft. Worth) as a marker, there were at least 43 insect pests of cotton to the east and at least 23 possible pests to the west. Ranked by importance, he listed the pest orders as Hemiptera, Orthoptera, Lepidoptera, Coleoptera, Homoptera, Thysanoptera and Acarina. Mention is made that the Mexican boll weevil <u>Anthonomus grandis</u>, while found in some western areas of Texas had still not adapted itself to the arid environment encountered in Arizona and that the Arizona wild cotton boll weevil was still not considered to be a serious threat to Arizona cotton. In an effort to preclude the eventuality of the Arizona weevil adapting itself to cultivated cotton, the Tucson valley was designated as a cotton free area and an attempt was made to eradicate all wild cotton from the Tucson valley. Morrill noted that the pink bollworm <u>Gelechia (Pectinophora) gossypiella</u> had established itself in the Laguna district of Mexico (its first enclave on North America). Since this insect was feared above all insect pests of cotton, his wholehearted advice was that the most vigorous measures be taken to exterminate this insect for the sake of the U.S. cotton industry.

In 1918, Morrill (66) listed a total of 13 cotton pests and gave recommendations for control where possible. These control measures consisted of chemical sprays such as sulfur or arsenates, poisoned baits (for grasshoppers), mechanical removal (knocking cotton stainers Dysdercus sp. off plants and into a vessel containing water with a small amount of coal oil), and quarantine of seed cotton and cotton seed. A comprehensive quarantine program was instituted to prevent the introduction and establishment of the cotton boll weevil and the pink bollworm within the state of Arizona. Chemicals, however, were already the control method of preference.

In 1920, information developed in the Southeast, led to the use of trap crops for controlling cotton pests. Corn planted in and near cotton fields was proposed as a proven and likely crop to use for the trapping of the cotton bollworm (67). In 1921 the literature addressed containment of the Thurberia boll weevil by destroying its native food plant, the wild cotton (68). However, the optimism of eradication by the elimination of native food plant proved false and was replaced with the stark reality that the situation had intensified with the removal of the wild cotton. The fallacy of the program was that the weevil was capable of migrating over fairly large distances (8 to 16 km) in search of food and, in the absence of its native food plant it was quite adept at feeding on the available cultivated cotton. In fact, the absence of the Thurberia plant greatly facilitated the spread of the weevil over considerable distances. Also noteworthy is the fact that although the native thurberia plant was noted as having some 23 injurious insect species feeding upon it, only one was considered in beginning the eradication program. In 1926 the topic of the Thurberia eradication program was again in the literature (17). It was noted that an earlier, half hearted attempt at making the Tucson

Valley a cotton free zone in the effort to contain the native weevil had failed due to lack of support. In this instance, the most recent attempt to contain the pest through the use of a cotton free zone was overturned by the courts after the application of pressure by some of the growers. Considering the adaptability of this weevil, it was felt to be a far more serious menace than either the eastern (or Mexican) boll weevil or the pink bollworm.

By 1929 the pink bollworm had infested a rather large area in the eastern end of the Salt River Valley (57) and measures were instituted to eradicate it. Among the practices instituted were fastidious cleanup operations, establishment of non-cotton zones, delayed planting dates for restricted areas, and specific cultural measures to remove and destroy volunteer cotton and overwintering larvae. As time has progressed, insects have faded in and out of prominence in the cotton picture. From about the early 1940's members of the Heteroptera (64, 82) including Lygus bugs, the western cotton plant bug, stink bugs, superb plant bug and cotton flea hoppers were prominent pests. They remained so up through the 1950's and the early 1960's when the use of stub cotton and more exotic pesticides began to give rise to the complexes which we are now experiencing in Arizona (64). According to their most recent update on cotton pests (105), the cooperative extension service of the University of Arizona lists 8 major and 26 minor (local or infrequent) insect pests on Arizona cotton. Recent developments within the past year indicate that the heretofore innocuous pest (the boll weevil) might be rapidly rising to a position of prominence. Along with the changing pest complexes came changes in the methods of control which rapidly gravitated to the almost indiscriminate use of chemicals. This situation remained virtually the same up until the late 60's and early 70's when pest resistance to chemicals had become a serious problem. At that time, researchers started looking at other control measures and began to develop initial IPM programs.

The use of pesticides on cotton constitutes the single largest area of chemical use in Arizona. A 1982 national survey disclosed that the total usage of insecticides and herbicides in Arizona 1979 was 738,902 kg and 266,758 kg. active ingredient respectively (58, 77).

The USDA Index of Plant Diseases (5) lists over 90 different causal agents of disease to cotton (not all of which are active in Arizona). Control has been through a variety of measures including the use of chemicals, cultural methods (rotations, using resistant varieties), or avoidance of known areas of infestation.

As with all crops, weeds are a serious pest and have been from the outset. Avoiding land previously planted to cotton provided initial success in weed control; and if this was coupled with scheduled crop rotation, weed problems were often easily controlled. Additionally, preplant irrigations followed by cultivation to destroy emergent weeds, and followed again by several cultivations up to the stage where the cotton plant can effectively compete with weeds has been mostly successful.

Grape

Grapes, Vitaceae, _Vitis_ sp., are perennial, long-lived vines, grown using trellis supports or a system of wire supports for the vines of those plants utilizing short self supporting trunks. Varieties are of European or American origin and are grown in every state in the United States. Fruit are produced in bunches with skin which may be thin or thick and which may or may not adhere to the inside pulp (53). The earliest records indicate that grapes were introduced into Arizona around 1707 by the Jesuit priest Eusebio Kino, most likely for use in the official church sacraments. The influx of settlers during and after the gold rush days of the mid 1800's and the migration of Mormon settlers down from Utah contributed to the growth and spread of the grape industry in this state. By the time of the prohibition years (1913 - 1933) there was a small wine industry in Arizona with vineyards near Sedona, Flagstaff and Phoenix and a scattering of wineries in Sedona and Phoenix. Prohibition saw an end to the wine industry in Arizona and grape growing became restricted to the production of table varieties. Currently in Arizona there are approximately 1620 hectares devoted to the production of table grapes and another 101 hectares devoted to wine grapes. If present trends continue wine grape production will continue to expand (61).

One of the better guides available concerning grape production and pest management is a recent publication from the University of California, Berkley (8). Addressing the area of vitaculture and associated pest management problems, Grape Pest Management is a highly usable text describing the ecology of common California grape pests and their accepted controls. A total of 11 general grape diseases are described encompassing 16 different fungi or bacteria and 3 different viruses. Also included are 11 major and 25 minor insect pests, 10 species of nematode and 6 common vertebrate pests including rabbits, deer, gophers and several species of birds. For the most part, use of chemicals is the chief means of controlling these pests. The text addresses grape pest problems from the viewpoint of managing them at proper times and via several methods. When available, cultural, mechanical/physical, resistant varieties, and biological methods are advocated; and when chemicals are employed, monitoring, timely applications and chemical programs are recommended. Generally, the extent of the pest problem in Arizona is not as widespread or as serious as that found in California, but environmental conditions in the grape growing areas of the two states are similar enough to that the text should prove useful for Arizona grapes.

For grapes as well as other crops, weeds are a problem because they compete for water and nutrients, harbor insects and diseases, attract birds and interrupt normal cultural and harvesting practices. Under proper management weeds may be usefully employed in the vineyard by allowing selected species of plants to grow in order to improve erosion control and water penetration, provide humus to the soil, and help suppress dust in the rows. Recommendations are made in weed management based upon the type of irrigation system used, the age of the vineyard, and season of the year. The primary methods employed include mechanical removal with specialized equipment, hand removal, and a well planned herbicide program. Several herbicides are discussed, covering type (e.g. preemergence), application rates, and possible injury warnings.

Under normal conditions, a number of insect pests can be found on Arizona grape crops, only a few of which are serious enough to require any controls. In the early years of Arizona grapes, control recommendations were fairly scarce until the advent of the arsenical and sulfer dusts; in most cases it appears that pest problems were fairly insignificant and did not cause serious concern. Major insect pests include the grape flea beetle (Altica chalybea Illiger), the varigated leaf hopper, and the western grapeleaf skeletonizer (Harrisina brillians Barnes & McDunnough) (61). Historically, the most serious and consistent insect pests have been the grape leafhoppper (Erythroneura spp.) and the grape leaf skeletonizer, which is sometimes injurious but fairly easily controlled with chemicals (4). These insects were included in Roney's recommendations in 1952 (83) along with spider mites and three-lined sphinx worms as pests of grapes controlled through the use of various chemical dusts and sprays.

Some minor insect pests occurring on Arizona grapes include thrips, white flies, and aphids. Bees and wasps are also noted as being pests in the vineyard but more as a nuisance to workers involved in normal field operations and during harvest. Essentially, any control measures taken against these pests amount to chemical applications unless the beneficials are giving effective control as in the case of the skeletonizer. The current fear is that any problem existing in California vineyards has the potential of moving over into Arizona. This is especially true with the leaf hoppers which are beginning to show signs of resistance to chemical controls employed in the Yuma area. One recent pest which may warrant monitoring is the pearl scale, found in the area of Queen Creek, Arizona. It is a good example of the ever changing picture of pest control on all crops since it is a new pest, not yet controlled and spreading (61).

Due to the hot dry climate of Arizona, many of the disease problems of California are not found here or are found on a small scale. The chief problems occurring in Arizona include root rot (caused by *Phymatotrichum omnivorum*) and Powdery Mildew. Many of the other disease problems are minimized through the use of chemical control, resistant varieties, and cultural control methods, in addition to the fact that they just do not exist here (possibly the result of the quality of the care taken in the type of stock provided from nurseries).

Lettuce

Lettuce, (*Lactuca sativa*) belongs to the Compositae family. Lettuce thrives best at cool temperatures, hence it is an early spring, fall or winter crop in the south and southwest (102). Cultivated lettuce is thought to be native to the Near East and the Mediterranean and was introduced into North America by Christopher Columbus in 1494. First introduced on a commercial basis when Arizona was still a territory (pre 1912) the area planted to this crop has slowly increased over the years reaching 4050 ha. in 1935 (60) and averaging 20,250 ha. currently (72). The major production areas were and still are the Salt River and Yuma Valleys with two crops produced annually. The fall crop is planted in September for harvest in December and January, and the spring crop is seeded beginning in October with harvest set for March and April. Beds are generally placed at 102 to 107 cm centers; and bed height is relatively important in terms of warmth of the bed and the amount of water required to obtain the desired amount of moisture in the soil. Irrigation practices vary depending upon the season, soil type, and locality. Whenever possible, a preplant irrigation should be employed and the seed beds should be kept moist but not waterlogged during germination and seedling emergence.

Weed control was achieved culturally by applying a preplant irrigation allowing for weed seed germination. Once the surface of the soil dried sufficiently to be worked and weeds had emerged, the soil was disked to a depth of 15 to 20 cm to aerate the soil and destroy the weeds. Later in the season, prior to thinning and again after thinning, additional cultivation would control late weeds. It is more common now that chemical methods be employed to control weeds (72).

Of the insect pests affecting lettuce, the major one was the cabbage looper *Autographa brassicae* (Riley) (*Trichoplusia ni* Hubner) and it was a problem chiefly during the fall planting since the spring crop developed during the cooler winter months when there was considerably less looper activity. The controls for this pest included predators and parasites of all life stages, some cultural controls and chiefly chemical dusts which included paris green, sulfer, derris, cryolite, pyrethrum and calcium arsenate. These dusts were applied in various mixtures and at varying rates primarily just prior to thinning of the crop as the looper was normally most destructive in the period of growth after crop thinning (60). The most recent publication concerning Arizona lettuce (72) continues to list the looper as one of its most serious insect pests and goes on to list two armyworms, two aphids, cutworms, the corn earworm Heliothis zea, crickets, leaf miners and the salt marsh caterpillar Estigmene acrea. These are basically similar to the pests which were listed in an earlier publication by Roney (83). Controls are basically unchanged from the early days, except natural controls do not seem to be able to contain populations below economic levels and, therefore, insecticide applications are usually required (using the safer and more effective newer compounds). In the case of the salt marsh caterpillar it is necessary to use physical barriers (aluminum foil up to fifteen cm. high) to prevent infestations since chemicals appear relatively useless against this migratory pest.

Of the diseases of Lettuce, only 8 of the 31 causal agents listed in the USDA Index of Plant Diseases (5), are considered of importance in Arizona of which 5 are virus in origin, 2 are fungal and 1 is physiological (72). Which problems affected the early industry are not readily identifiable but it is probably safe to assume that the primary means of control consisted of avoiding areas known to harbor organisms injurious to lettuce, or to adopt cultural practices which minimized the crop exposure to these organisms at points when the plant was most susceptible.

Pecan

Pecan, Carya illinoensis Koch, is a member of the walnut family Juglandaceae, and is native to the southern United States and northern Mexico (62). The history of Pecan in Arizona is somewhat confused but there is evidence that pecan trees may have been growing in the area of Nogales, Arizona at the time of its founding in the 1700's. The first commercial recordings are from the Yuma, Arizona area in the early 1900's (61). Officially, pecan was commercially introduced into Arizona in about 1920 and by 1930 was being grown on approximately 1620 ha. in the lower valleys of Yuma and Maricopa counties. By 1965 this area had slowly declined to around 202.5 ha. chiefly due to the poor, long range adaptability of earlier varieties. As the result of varietal development in New Mexico and western Texas (mid 1950's to early 1960's) commercial plantings in Arizona began to be developed in Pima, Pinal and Maricopa counties at the 458 to 915 m. level and to a lesser extent at lower elevations in Yuma county. By 1978 there were over 4860 commercial hectares of pecan trees in Arizona (62), and by 1983, that figure was close to 8100 ha. (61).

Pecans grow well on a variety of soil types but perform best when planted on medium textured loams. Deep soils free of hard pan are preferred while high alkali soils and soils with high water tables (within 2 - 3 meters of the surface) are to be avoided. Depending upon age, a tree can require 102 - 198 cm. of water per year under flood irrigation and 25 - 135 cm. of water a year under drip irrigation. Drip irrigation allows for decreased weed control measures since the precise water application does not provide water for consumption by weeds except in the immediate vicinity of the trees (62).

Weed control is perhaps the major pest problem in pecan groves since weeds compete for water and nutrients, provide habitat for undesirable organisms and act as reservoirs for potential diseases.

Weed control is chiefly achieved via mechanical and chemical means and the degree to which these controls are employed can be affected by the use of drip irrigation since this will necessarily limit the amount of mechanical cultivation possible in a area. This also means that increased reliance upon chemicals for control of the weeds that do occur will be the end result.

There are several major insect pests of pecan in the eastern U.S. but fortunately these have been precluded from Arizona due chiefly to the desert barrier and an active pecan products inspection program. The major insect pest of importance here is the Black Margined Yellow Pecan Aphid (*Monellia costalis* (Fich.). The seriousness of this pest is somewhat limited since there appears to be some sort of conditioning mechanism operating in pecan trees such that early season feeding produces an apparent resistance to later season feeding. There also appears to be some varietal preference in operation, which is to say that some varieties appear to be preferred by this aphid over others. Research is currently being conducted to develop a chemical control program for this particular pest (61).

There are no serious diseases of pecans in Arizona; the most important is root rot (caused by *Phymatotrichum omnivorum*) but it appears that trees are only susceptible to this disease at an early age and as they mature they become less susceptible.

The Non-traditional Crops

Pest control on these crops has revolved around highly labor intensive programs in the lands of their origin (e.g. guar *Cyamopsis* *tetragonoloba* or plantago *Plantago* spp.) or cultural and mechanical/ physical practices in the United States. Obstacles to the development of control strategies are that, with the exception of the ever-present weed problem, pests of these "new" crops have not been determined and these crops have been grown only on limited areas. The most recent Arizona statistics list only guar and jojoba under Misc. Field Crops and the area devoted to these crops were; guar 3038 ha. (1981) and 8910 ha. (1982), and jojoba 3281 ha. (1981) and 6568 ha. (1982).

Chemicals, which have become the preferred pest control method in the United States, are limited; as is demonstrated by Table 1 (pg. 13). Note that guar is the only non-traditional crop holding federal registration for pesticide use. One alternative to this lack of chemicals is the use of section 24C (special local needs or SLN) registrations. These are available by state and their use is subject to approval by the EPA in addition to state regulatory bodies.

The established criteria for requesting an SLN are; 1) no other compound is available for use on the crop, 2) compounds approved are not available, 3) compounds available are not as effective as the one desired, and 4) the compound desired is safer than those already registered. Once an SLN is received, it is initially good for a period of 5 years unless revoked. After 5 years the SLN is reviewed and the registration may be renewed or discontinued due to the need no longer existing, (as that compound received federal registration, the pest problem has passed, or other effective compounds are now available). Table 2 lists Arizona SLN's available for the non-traditional crops.

Table 2. Compounds Holding Special Local Need (24C) Registration in Arizona on Selected Non-traditional Crops.

CROP	COMPOUND	PEST	REGISTRATION #
GUAR	METHYL PARATHION	MIDGE	AZ820018
		PALE STRIPED FLEA BEETLE	AZ820018
GUAYULE	METHYL PARTHION	LEPIDOPTEROUS INSECTS	AZ800013
		PLANT BUG	AZ800013
JOJOBA	METHYL PARATHION	ANT	AZ800013
		APHIDS	AZ800013
		GRASSHOPPER	AZ800013
		LEPIDOPTEROUS INSECTS	AZ800013
		MEALY BUG	AZ800013
		MIDGE	AZ800013
		PLANT BUG	AZ800013
		SCALE INSECT	AZ800013
	PENDIMETHALIN	BARNYARDGRASS	AZ820008
		JOHNSONGRASS	AZ820008
		JUNGLE RICE	AZ820008
		PIGWEED	AZ820008
	GLYPHOSATE	BERMUDAGRASS	AZ820009
		JOHNSONGRASS	AZ820009
	OXYFLURFEN	MALLOW	*
		LONDON ROCKET	*
		SHEPARD'S PURSE	*
		SOW THISTLE	*
PLANTAGO	-	-	-
TEPARY BEAN	-	-	-

NOTE: SLN registrations are available from the Office of the State Chemist or their counterpart in each of the states. Once the National Pesticide Information Retrieval Service (NPIRS) is fully operational one should be able to gain this information by calling this service. (24)

* approval has been given and registration numbers have been assigned to two formulations of this compound. #AZ8300012 for the 2E formulation and #AZ8300013 for the 1.6E formulation.

Guar

Guar, Luguminosae Cyamopsis tetragonoloba, is of questionable origin but evidence points towards northern Africa, western Asia or the Indian subcontinent where it has been grown for generations. Guar is a summer annual herb which has never been found in the wild. It has small purplish-pink flowers which are borne in axillary racemes and is completely self-fertilizing. It thrives best in sandy, sandy loam and coarse-textured alluvial soils which are well drained. Guar is salt-tolerant, prefers soils of pH 7.0 over acidic soils, and is intolerant of excess moisture or water logging during the growing season.

In 1797 the plant was introduced into the Botanical Garden at Calcutta and in 1903 Guar was introduced into the United States. Early on, Guar was sent to federal and state experiment stations in the Southwest since it was felt that the soil, climate and growing seasons there were best suited for the production of this plant. Originally, emphasis was placed on its suitability as a soil improving legume and as an emergency cattle forage (107). Since its performance in these two regards was unremarkable it soon fell into disuse. Research on guar in Arizona began in 1938 and rapidly expanded under the guidance of General Mills Inc. at the Arizona Agricultural Experiment Station which was investigating its use as feed stuff (54).

During World War II, when a Mediterranean starch source was cut off from the West, guar was discovered to be ideally suited as a source of galactomannan gums used in the production of paper. Guar has historically been used (Indo-Pakistan subcontinent) for human and cattle food stuffs, for pharmacological purposes and as crop and soil enhancers. Since its resurgence during World War II, guar has been finding more and more application in industry. In addition to the paper industry, it has found application in the petroleum industry, the explosives industry, the mining industry, the tobacco industry, in cosmetics and pharmaceuticals, and in the foods industry (107).

The interest in guar is the result of its apparent drought tolerance (consumptive use approximating 51-64 centimeters of applied water), its use in increasingly more products, and the need to have available a source of the plant in the event that there is a disruption in the supply from the highly volatile Middle East. It has been found that guar has difficulty establishing on both alkali and saline soils but exhibits salt tolerance after achieving 20-25 cm. of growth (30). Guar is currently being grown on a commercial basis in the Rolling Plains and the south-central areas of Texas, southwestern Oklahoma and in areas of Arizona generally below 915 m. in elevation (28). During the 1982 growing season, there were over 8200 ha. planted to guar in Arizona (33). Guar may be planted on the flat or in beds, however, bed plantings are generally preferred since this facilitates cultivation. Current data suggests that the more favorable time for planting the crop is mid-June to mid-July at elevations indicated above. Harvesting in Arizona is normally delayed until plants mature and defoliate naturally or until after the first frost (28, 30).

Guar is a poor competitor of weeds; therefore, it is preferable to avoid areas where weeds are expected to present a problem (30, 54, 107). In 1948, Matlock and Aepli (54) noted that yield was closely related to weed infestation, and they recommended a good preplant irrigation followed by thorough disking and harrowing in areas where weeds were known problems, being sure to space rows in such a manner to facilitate early cultivation. The most promising cultural methods available at present indicate that by planting in late June to moisture, closely managing water and using 1 to 2 cultivations (the first at 30 days and the second at 60), weeds should be generally controlled (33).

Over the years, as many as 23 different compounds have been studied and the findings published (107). Currently (Table 1), only a few have received registration for use on guar. Of these, four are herbicides: nitralin, paraquat, profluralin and trifluralin. As seen in Table 2, there are no current SLN's for weeds in guar in Arizona. In a 1982 article (56), a Yuma farmer is reported to have grown 97 ha. of guar in 1980 on 53 cm. centers to facilitate cultivation. He had used a preplant incorporation of profluralin and found that further cultivation during the season was unnecessary. No mention was made of the field history.

Although guar is commonly thought of as being relatively free of insect pests, Whistler and Hymowitz list 16 insects as pests on guar (Table 3). Of this number only two, Contarinia texana and Asphondylia sp., are considered of major importance and Asphondylia sp. is not believed to be a major pest due to its habit of late season infestation and its complex of at least 8 Hymenopterous species which appear to provide sufficient biological control. Several insects found under Arizona conditions whose pest status remains to be determined include the pale striped flea beetle Epitrix subcrinita, the bandedwinged whitefly Trialeurodes abutilonea, and the sweetpotato whitefly Bemisia tabaci (106).

In studying the growth and damage to the buds of guar, Rogers (78, 81) determined that under Texas conditions, the most critical period of infestation was the second trimester of development (45 - 90 days) since this was the period when the majority of buds were produced, and any damage to buds during this period produced the most marked reductions in yield. The potential of extended growing seasons in Arizona has given evidence that *Asphondylia* sp. could become a serious pest (33, 106), since damage to late set pods, which do not normally mature before harvest, would be reflected in reduced yield. By avoiding a long season crop, this and other problems might be prevented (33).

In 1976, Rogers (79) proposed an economic threshold for *C. texana* under Texas conditions and pointed out that in determining an economic level one must take in consideration market value, management costs, (including irrigation, pesticide costs and cultural practices) and length and time of control measures, which under Texas conditions would be the 45 day middle trimester. In order to effectively use any threshold levels, however, an effective sampling method is necessary and it was for this reason that Slosser and Rogers (92) studied this topic. They proposed a sequential sampling method requiring the collection of approximately 26 buds and taking an average of 16 minutes to complete which produced results enabling one to make treatment decisions which agreed with the results obtained from fixed point sampling 92% of the time.

In a 1977 study of the natural controls of *C. texana* and *Asphondylia* sp. (80), it was discovered that of the arthropod predators present in guar plantings, the most conspicuous were spiders. These were identified and it was determined that different groups of predatory spiders were active at various levels of the plant biosphere, leaving room for considerable research on the effectiveness of these predators. Effective chemicals for insect control have been examined

(107) and there are currently two federally registered compounds for use on guar insects in Arizona; azodrin and diazinon. As seen in Table 2, methyl parathion holds a 24C registration. Generally, adhering to proper planting schedules and employing resistant varieties are felt to be the key means for developing insect control (33, 106).

Table 3. Insects and Pathogens Recorded on Guar.

INSECTS	PATHOGENS
Aceratagallia uhleri (van Duzee)[1]	*Alterlaria brassica* (Berk) Sacc.[1,2]
Acythrosiphon pisum (Harris)[1]	*Alternaria cucumerina* var. *cyamopsidis*[1]
Alcidodes bobo (Fabricius)[1]	*Cercospora kikuchii* (T.Matsu and Tomoyasu) Chupp.[1]
Amscata moorei Butler[1]	*Colletotrichum capsici* (Syd.) Butl. and Bisby[1]
Aphis craccivora Koch[1]	*C. capsici* f. *cyamopsicola* Prasad and Desai[1]
Asphondylia sp.[1]	*C. dematium* f. *truncata* (Schw.) von Arx[1]
Caliothrips phaseoli (Hood)[1]	*Curvularia lunata* (Wakker) Boed[1]
Contarina texana (Felt)[1]	*Fusarium moniliforme* (Sheld.)[1]
Empoasca sp.[1]	*F. coeruleum* (Lib.) Sacc.[1]
Heliothis zea (Boddie)[1]	*Leveillula taurica* (Lev.)[1]
Languria sp.[1]	*Macrophomina phaseolina* (Tassi) Gold[1]
Phyllophaga sp.[1]	*Meloidogyne* sp.[1,2]
Platymota stultana Walsingham[1]	*Memnoniella echinata* (Riv.) Galloway[1]
Spissistilus festinus (Say)[1]	*Myrothecium rorodum* Tode ex fr.[1]
Tathorhynchus angustiorata (Grote)[1]	*Ozonium texanum* Neal and Webster var. *parasitium* Thirum[1]
Trialeurodes abutilonea (Haldeman)[1]	*Oidium* sp.[1]
	Phyllosticta sp.[1]
	Pseudomonas syringae van Hall[1]
	Phymatotrichum omnivorum (Shear) Dug[1,2]
	Rhizoctonia solani Kuhn[1,2]
	Sclerotium rolfsii Sacc.[1,2]
	Synchytrium cyamopsae Gupta and Sinka[1]
	Xanthomonous cyamopsidis[1]
	Curly Top[2]
	Mosaic[2] unidentified
	Streak[2] unidentified
	Tobacco necrosis[2]
	Tobacco ring spot virus -- top necrosis[1]

1 = from Whistler and Hymowitz (107)
2 = from USDA Index 1970 (5)

Table 3 also lists the diseases of guar. In 1948, Matlock and Aepli (54) mentioned at least 13 diseases which were suspected of causing problems in guar; 5 of which were either of unknown causes or were inconclusively proven as causal agents. The U.S.D.A. Index of Plant Diseases (5) listed only 9 diseases of importance to guar and Whistler and Hymowitz (107) list no less than 20 fungi, 2 bacteria, 1 virus and root knot nematode as being pathogenic to guar. The controls of the more common diseases are achieved through such simple practices as using disease free seed, using better water management, avoiding continuous cropping, and cleaning up fields at the end of the season. For others such as Texas Root Rot (*Phymatotrichum omnivorum*), the plants appear to be resistant or immune to the effects of the pathogens (19, 30, 54, 107). Chaudhary & Gupta (21) investigated the control of *Sclerotium rolfsii* in greenhouses by the addition of *Streptomyces nigrifaciens* to the soil and found reduced disease incidence when the actinomycete was applied to the soil 7 days prior to inoculation with the pathogen. Effective water management, proper planting dates and the use of resistant varieties should prove to be the most effective control measures (33, 106). Chemicals have been tested for use in control of diseases such as powdery mildew, (45, 90, 93, 94) although none have as yet received clearance for use in the United States. It should be mentioned that the argument for the use of guar in a rotation schedule has been strengthened by the findings (26, 46, 47) that an exudate or extract from the roots of guar has been noted to reduce the incidence of certain root rotting organisms in the field that are detrimental to wheat, cotton and several other crops. This could prove to be a plus in guar production since wheat and cotton are of importance in Arizona.

Until recently, TRSV (tobacco ring spot virus) was the only virus listed on guar (5, 107) but it has also been found to host a potyvirus entitled GSV (guar symptomless virus) (41) and possibly a strain of TNV (tobacco necrosis virus) (76). Viruses are normally controlled by the use of heat treatments and certified seed but there is some evidence (100) that treatment with an extract from *Boerhaavia diffusa* can induce resistance in plants treated with an inhibitory agent in the extract. In a recent study (84) it was found that inhibition of virus induced lesions may be improved thru the treatment of plants with some water soluble vitamins.

Guayule

Guayule, Compositae *Parthenium argentatum* Gray, is a slow growing, hardy, woody, erect, perennial desert shrub which typically grows to a height of 61 to 76 cm. and commonly lives for 40 to 50 years in the wild (27). Guayule grows naturally in southwestern North America on the "wastelands" covering the Chihuahuan Desert of Mexico and the Big Bend plateau area of Texas (27, 101). Stands are found in areas where other competing plants do poorly, from 600 - 1200 m. in altitude and on calcareous, well drained soil. In its natural habitat plants normally receive from 23 to 40 cm. of rainfall annually. Where rainfall is less than 40 cm. per year, irrigation is required for establishment, after which time it is able to withstand drought. Areas of potential production in the United States include southern Arizona and New Mexico, southwestern Texas, and southern and central California. Experimental plantings have been grown in Argentina, southern Africa, Spain, southwest Australia and the Soviet Union. It appears that this plant has potential for being successfully grown in other areas which contain suitable soils, high summer temperatures, low rainfall and no freezing winters. The temperature optimum is in the range of 29° to 38° C and it appears to do poorly when the temperatures fall below -9° C. High light intensities are best and deep, well drained, medium to light textured soils are preferred. The plant is not noted as being salt tolerant (86).

Guayule is the only member of the 16 species _Parthenium_ genus which produces significant amounts of rubber. It has no latex containing canal as do other hydrocarbon-producing plants, but sequesters its rubber within plant cells which must be disrupted in order to extract the rubber (this requires special harvesting and processing equipment and techniques) (59).

Early in the nineteenth century the Continental Rubber Co. was involved in the extraction of rubber from wild guayule plants in Mexico. This endeavor was so successful that by 1910 this was the sixth largest company in Mexico and was supplying half of the rubber demand of the United States. In 1916 a large planting was established south of Tucson, Arizona and the company changed its name to the Intercontinental Rubber Company. In 1925 the operation was moved to Salinas, California and from 1931-1941 this company was turning out an average of 158,757 kg. of rubber a year from its operation in Mexico and California. In 1942 the research on native rubber producing plants was taken over by the Emergency Rubber Project (ERP) to aid in the war effort and extensive research concerning the agronomics and yield ability of this crop was undertaken. By 1959, 25 separate lines were sent to the seed storage center in Ft. Collins, Colorado as the result of breeding experiments carried out under the auspices of the ERP and the USDA. These twenty five lines were the starting place in 1976 when renewed interest in this plant led to a search for germ plasm.

There are currently three popular methods employed in the propagation of guayule. These are: 1) greenhouse planting with subsequent field transplanting, 2) plantings in field nurseries with later rootstock transplanting, and 3) direct seeding into production fields. The first method is the most commonly used since it is the fastest to employ; while the last method, although the easiest to use, increases the vulnerability of the plants to diseases and weed and insect infestation. Where irrigation is to be employed, it is best to plant on raised beds where water does not stand for periods of greater than 12 hours since longer periods can increase disease susceptibility (86).

The ERP of World War II identified at least 20 potential pathogens of guayule with soil borne fungi being the most important (2). Even with such a number of potential pathogens, the ERP experienced essentially no loss due to disease on their 13,365 ha. of dry and irrigated lands (3). Current research is directed at screening fungicides for use in pre- or post-emergence application as well as investigating the possibilities of antagonistic bacteria in biological control and the use of resistant cultivars (particularly as in the case of Verticillium wilt (2). Verticillium wilt was a disease of serious consequence encountered by the ERP and surveys indicated that in some areas of California, fields were as much as 75 - 100% infested with *Verticillium* sp. Recent research has looked at the resistance of guayule to at least 8 different strains of *Verticillium* and found that guayule is quite susceptible to infection, with the younger plants being more so than older ones and diploid plants more so than tetraploid ones (22). For the most part, disease losses have occurred where soil drainage was poor or where excessive water was applied (86). In 1947, Campbell and Presley (16) identified the causal agent of a bacterial disease of guayule as being an *Erwinia* species and noted that the chief means for effective control was water management. Goddard and Thomas (36) related a study where guayule strain 593 was used in a suitability test involving several species of nematode. The results of this study indicated that this variety suffered no significant reduction in growth and nematode numbers decreased from the inoculation level. Table (4) lists the pathogens which have been identified as occurring on guayule.

Table 4. Pathogens Identified as Affecting Guayule.

Alternaria sp.[1]
Botrytis cinerea Pers. ex Fr.[1,2]
Cuscuta sp.[2]
Diplodia theobromae[1,2]
Erwinia carotovora (L.R. Jones) Holland f. *parthenii* Starr[1]
Erwinia chrysanthemi[2]
Fusarium sp.[2]
Macrophomina phaseoli (Maubl.) Ashby[1,2]
Meloidogyne sp.[1] (believed resistant to M. incognita)
Phoma sp.[2]
Phymatotrichum omnivorum (Shear) Dug.[1,2]
Phytophthera drechsleri Tucker[1,2]
Puccinia parthenii[3]
Pythium aphanadermatum[2]
Pythium ultimum Trow[1,2]
Rhizoctonia solani Kuehn[1,2]
Sclerotinium bataticola Taub.[3]
Sclerotinia minor Jagger[1]
Sclerotinia sclerotiorum[2]
Sclerotium rolfsii Sacc.[1,2]
Verticillium albo atrum[1]
Verticillium dahliae[2]

noted as affecting other Parthenium species
Albugo tragopogonis Pers. ex S.F. Gray[1]
Cercospora partheniphila Chupp & Greene[1]
Coleosporium terebinthinaceae (Schw.) Arth.[1]
Pucccinia parthenii (Speg.) Arth.[1]
P. melampodii Diet. & Holw.[1]
Yellows (Chlorogenus callistephi Holmes, Callistephus virus I K.M.Sm.)[1]

1 = from USDA Index 1970 (5)
2 = from Alcorn 1982 (2)
3 = from Hammond and Polhamus 1965 (40)

Since seedlings grow slowly, weed control is an important part of any guayule program. Cultivation is an important control but chemicals are a must if the costs of production are to be kept low. Early nursery attempts almost saw the fledgling industry come to a halt since hand weeding was so expensive and hazardous (seedlings were often removed with the weeds), but the judicious use of hand weeding and selective oil sprays overcame this obstacle. The method of preference that the ERP worked out involved early seedbed preparation (approximately 2 weeks) with a preplant irrigation to promote weed growth. The day of planting an oil spray is applied to the weeds, the beds were planted with a minimum of disturbance, and the weeds were treated again 4 weeks after seedling emergence. Under plantation settings, the control program was much the same except that weeds in the row were controlled by hand weeding until 1944 when effective machinery for in row cultivation was developed. Even at this early stage of developing chemical controls, a number of weeds (in Texas) including London Rocket (Sisymbrium irio L.) and Johnsongrass (Sorghum halepense (L.) Pers.) were noted as expressing resistance to the oil sprays (40). Hand weeding may be required to help establish the crop when mechanical means prove unfeasible, and good water management is important in preventing weed problems during establishment periods (27).

It is recommended (85) that plantings be established in single rows at 69 cm. to enhance rubber yield and facilitate cultivation since no chemicals are as yet cleared for use on weeds in guayule. Recent study directed towards discovering effective herbicides has been carried out with good results. A four year study under greenhouse and field conditions (108) concluded that on direct seeded guayule, DCPA was the most effective compound, while for transplanted or established plants, the dinitroanilines were the most effective. Some compounds gave excellent control while causing some stand reduction and the use of a pendimethalin/oxyfluorfen mix gave wide control on transplants with no apparent damage. Another researcher studying diuron, simazine, trifluralin and pendimethalin reported (49) that the dinitroanilines appeared to be the more effective with the least amount of stand damage but as the age of the stands increased, the damage to the stands by all four compounds decreased, giving better control of weeds. This information is useful in that it corroborates the effectiveness of the dinitroanilines; however, it also points out that good weed control during the most critical phase of a guayule planting (during establishment) has not yet been provided without some stand injury. There are currently no compounds possessing federal or 24C registrations for use on weeds in guayule (Tables 1 & 2).

A wide variety of insects has been identified in association with guayule (2, 18, 50), and with the exception of grasshoppers and lygus bugs they are all considered to be of minor importance (18, 40). Infestations of *Lygus hesperus* were shown to greatly retard growth with females ovipositing in flower heads where nymphs and adults would feed on developing seeds. In the absence of seeds, feeding would occur on growing stem tips causing cessation of meristematic growth (1). Table 5 gives a listing of the major (according to the investigators) insects found on guayule. It must be kept in mind when reviewing this list, that these plantings were mainly in California or Texas and the importance of the pest must be considered accordingly. Cassidy was fortunate enough to have made the discovery that in at least one case (the false chinch bug) infestation was closely correlated to the degree of mustard infestation in the field (18). Whether or not this type of information is readily transferable to other insect pests and weed plants has not been determined. Table 2 lists methyl parathion as the only compound holding a 24C registration on guayule in Arizona.

Table 5. Insect Pests Identified as Occurring on Guayule.

Acari
- Tetranychus bimaculatus[2]

Coleoptera
- Blapstinus rufipes Casey[1]
- Carneocephala fulgida Nottingham[1]
- Diabrotica undecimpunctata[1,2]
- Draeculacephala minerva Ball[1]
- Empoasca arida Del[1,2]
- Epitrix spp.[2]
- Ligryus cilifornicus Csy.[1]
- L. gibbosus (DeG.)[1,2]
- Limonius californicus Mann[1]
- L. canus Lec.[1]
- L. infuscatus Mots[1]
- Listroderes obliquus Gyll[1]
- Macrosteles diolsus (Uhler)[1]
- Pityophthorus nigricans Bland[1]
- Systena taeniata (Say)[1]
- Ulus crassus[2]

Diptera
- Agromyza virens[1,2]
- Bradysia spp.[2]
- Liriomyza flaveola (Fallen)[1]
- Phytomyza atricornis[2]

Heteroptera
- Corythuca morilli[2]
- Lygus sp.[1,2]
- Sixeonotus aerolatus[2]
- Tingids[1]

Homoptera
- Aphis helichrysi Kalt.[1]
- Aleyrodes spiraeoides[2]
- Cerosiphan sp.[1]
- Myzus persicae (Sulzer)[1]
- Orthezia sp.[1]
- Phenacoccus gossypii[2]
- Puto (Ceroputo) yuccae (Coq)[1]
- Rhuzasoidiotus dearnessi (Cockerell)[1]
- Tachardiella cornuta[2]

Homoptera (cont'd)
- Targionia yuccarum[2]
- Trialeurodes vapirariorum[2]

Hymenoptera
- Atta texana[2]
- Harvester ants[1]
- Cynipidae sp.[1] Gall fly
- Pogonomyrmex spp.[2]
- Soleonopsis xyloni var maniosa[2]

Isoptera
- Amitermes (Gnathamitermes) tubiformes[2]
- Termites[1]

Lepidoptera
- Agrotis ypsilon Rott.[1]
- Estigmene acrea Drury[1,2]
- Heliothis phyloxiphaga[1]
- Mamestra picta Linn.[1]
- Peridroma margaritosa (Haw.)[1]
- Prodenia (Spodoptera) ornithogalli[2]
- 2 unidentified armyworm species[1]
- 2 unidentified geometrid larvae[1]
- 1 micro lepidopteran (unidentified)[1]
- Venessa cardui Linn[1]

Malacostraca
- Armadillidium vulgare[1]
- Porcellio laevis[1]
- P. scaber[1]

Orthoptera[1]
- Melanoplus spp.[2]
- Oedaleonotus spp.[2]
- Acheta spp.[2]

Thysanoptera
- Frankliniella moultoni Hood[1]
- F. occidentalis (Perg.)[1]
- F. minuta Moulton[1]
- Thrips tabaci Lind[1]

1 = from Lange 1943 (50)
2 = from Alcorn 1982 (2)

Jojoba

Jojoba, Simmondsia chinensis is a bushy, long lived, dioecious, perennial shrub which is found in natural populations in an area covering approximately 259,000 kilometers between latitudes 25° and 31° north and longitudes 109° and 117° west (35). This is an area bounded by a line from Riverside, Ca. to Globe, Az. to Guaymas, Sonora, Mexico to Cabo San Lucas, B.C., Mexico and back to Riverside. It is found from sea level to 1500 m. in elevation on soils characterized as course, sandy or gravelly with good water penetration and having pH ranging from 5 to 8. Where precipitation averages approximately 75 cm. plants will grow 90-120 cm. in height; however, when plants receive as much as 250-400 cm. they can attain heights of 5 m. Male and female flowers are produced (on separate plants) late in the summer and pollination, which is believed to be entirely by the wind, occurs in early winter; seeds mature in August or September at the rate of 1 to 3 seeds per fruit (111). Successful seed germination requires darkness, warm temperatures and high moisture for up to 20 days. Under such conditions, germination is high (91).

Due to unique properties of jojoba, there is considerable confusion as to whether it should be considered the sole member of the monotypic genus Simmondsia of the family Buxaceae or the sole member of the monotypic family Simmondsiaceae. It is also because of its unique chemical and physical properties that there has recently been so much interest in this plant as a potential crop. This interest results from 1) the liquid wax contained in the seed, 2) the apparent drought resistance, 3) its ability to grow in marginal areas of poor fertility, high atmospheric temperatures, high salinity and low moisture, 4) its low fertilizer and energy requirements, 5) its ability to be grown and processed using commercially available equipment, and 6) its apparent potential in several semiarid areas with high population densities and limited employment opportunities (111).

Sherbrooke and Hasse (91) noted that Gentry had proposed three criteria for the successful establishment of a cultivated crop. These are 1) it must yield a product of relative abundance, 2) the plant must be responsive to the artificial environments of man, and 3) the plant must have a genetic endowment which will support intensive selection of varieties. Efforts at domesticating jojoba have been underway in the United States, Mexico and Israel since the mid 70's. Jojoba responds well to fertilization and irrigation (0.185 ha. m./ha. (1 1/2 acre ft./acre) annually appears sufficient) and heavy pruning and grafting of male branches onto female plants (and vice versa) does not adversely affect the plants. The time of greatest water demand is in late winter and spring, thus avoiding competition with other crops requiring irrigation. Presently jojoba is grown in rows spaced 3 to 7 meters apart with 1 to 1.5 meters separate in the row. Propagation is through tissue culture, cuttings and seed. Asexual methods are preferred since knowing the plant sex facilitates the incorporation of predetermined sex ratios (111). However, the majority of the current plantings have been established from direct seeding (70).

In 1978 when Yermanos wrote his report on jojoba (111), he noted that weed control was no problem since there were several effective herbicides available, and insect and disease problems were not of concern since none had yet been identified. Hogan (43) Palzkill et. al. (70) and Childs (23) agree basically with this opinion of the insect and disease problem. However, these researchers stated that weeds and weed control were a significant factor to be considered in the total expenditure necessary in establishing a jojoba planting since there is a conspicuous lack of registered compounds available for weed control, (see Tables 1 & 2), thus requiring labor intensive methods. Chemical and mechanical methods are effective, but chemical methods are not readily available due to the lack of cleared compounds; and since most jojoba plantings are under some type of irrigation regime, mechanical practices are necessarily affected by the type of irrigation being employed (43).

Until recently it was believed that Jojoba was relatively free of both insects and diseases possibly due to the lack of sufficient study on native stands. Boyd (12) made particular mention of the fact that our knowledge concerning pests under plantation conditions was lacking. Studies are now beginning to indicate that there may be a considerable number of diseases and insects capable of inflicting damage to jojoba plantings.

Hogan (43) quotes from the literature that 9 different disease agents have been identified in association with jojoba while other researchers have identified at least 3 others (Table 6). Young and Alcorn (115) did not consider that the *Coniothyrium* sp. which they isolated was of significance to commercial stands established by direct seeding unless such plantings were located near native plants such as *Agave* sp. and *Perezia nana* Gray (desert holly) since they are also susceptible to the disease. The spread of this disease is facilitated by overhead irrigation and wounding of the plants which would mean that precautions against spreading infection would be necessary when pruning the plants. Boyd (12) noted that this possible means of spreading disease was important in considering the design and use of mechanical harvesting devices.

Table 6. Pathogens Recorded on Jojoba.

Alternaria sp.[1,4]
Alternaria tenuissima[2]
Coniothryrium sp.[1,3]
Fusarium sp.[1]
Fusarium oxysporum[4]
Macrophomina phaseoli[4]
Phymatotrichum omnivorum[1,4]
Phytophthora parasitica[1]
Pythium aphanidermatum[1]
Rhizoctonia solani[1]
Strumella simmondsiae[1]
Verticillium dahliae[1]

1 = from Hogan 1979. (43)
2 = from Gupta and Ghosh 1981. (38)
3 = from Young and Alcorn 1981. (115)
4 = from Lopez et.al. (52)

One of the earliest references to insect pests on jojoba is recorded by Gentry (35). In this report, he noted that insect visitors to wild jojoba included katydids, grasshoppers, darkling beetles, leaf chewing larvae, wood boring insects, a bostrychid beetle, and a micro lepidopteran which was considered as being the only serious insect pest. It was not until just recently that researchers looked more closely at the insects found in association with jojoba. The researchers Pinto and Frommer (74) observed and compiled a list of insects visiting wild jojoba which included 11 orders represented by 221 species, of which 25 have actually been identified as feeding on jojoba (see Table 7). F. J. Gonzalez Vazquez (37) studied the insects visiting jojoba on a plantation outside of Hermosillo, Mexico and identified 8 plant feeding species, 6 of which were not included on the list prepared by Pinto and Frommer. These 6 species were; Empoasca sp., Liorhyssus sp., Ollarianus strictus (Ball), Lygus sp., Pseudatomosceelis seriatus (Reuter), and Spanagonicus albofasciatus (Reuter).

Table 7. Phytophagous Insects Found on Jojoba. (From Pinto and Frommer 1980 (74).

Acarina
- Tetranychus sp.

Coleoptera
- Megrorama frontalis (LeConte)
- Ozognathus cornutus (LeConte)
- Tricorynus obsoletus (LeConte)
- Amphicerus simplex (Horn)
- Acmaeodera doloroa Fall
- Chrysobothris lucana Horn
- Trichinorhipis knulli Barr
- Pseudomethia arida Linsley

Diptera
- Asphondylia sp. n.

Hemiptera
- Crophius near scabrosus (Uhler)
- Nysius sp.
- Irbisia setosa (Van Duzee)
- Chlorochroa uhleri (Stal)
- Thynata pallidovirens (Stal)

Homoptera
- Cicadidae
- Aceratogallia californica (Baker)
- Homalodisca lacerata Fowler
- Dictyssa marginepunctata (Melich.)
- Aphis craccivora Koch
- Aspidiotus nerii Bouche
- Diaspis simmondsiae Ferris
- Situlaspis yuccae (Cockerell)

Homoptera (cont.)
- Phenacoccus alleni McKenzie
- Phenacoccus solenopsis Tinsley
- Puto simmondsiae McKenzie
- Spilococcus pressus Ferris
- Orthezia near artemisiae Cockerell

Isoptera
- Incisitermes fructicavus Rust
- Reticulotermes sp.
- Amitermes minimus Light

Lepidoptera
- Estigmene acrea (Drury)
- Holocerca sp.
- Anacamptodes clivinaria impia Rindge
- Pero mcdunnoughi C.&S.
- Orgyia vetusta (Boisduval)
- Xylomyges curialis Grote
- Epinotia kasloana McD.
- Sosipatra thurberiae (Dyar)
- Hemileuca electra Wright
- Periploca sp. n.

Orthoptera
- Schistocerca alutacea shoshone Thomas

Thysanoptera
- Dactuliothrips spinosus Moulton
- Haplothrips mali (Fitch) complex
- Frankliniella occidentalis (Pergande)
- Scirtothrips ewarti Bailey

In addition, Vazquez noted that there were at least 10 species of beneficials identified visiting the observed plants while Pinto and Frommer listed almost 50. Reporting on insect pests on a 7 year old planting on 2 ha., Yermanos (112) noted that at no time did insect populations reach levels which were considered economic and therefore no protective measures had to be implemented. This was in spite of the fact that a variety of phytophagous insects did visit the plants. There are as yet no federally registered compounds for use on jojoba (Table 1), but there are compounds registered for use through the special local needs (SLN) program (Table 2) in Arizona.

Gentry (35) identified chipmunks, ground squirrels, rabbits, pack rats, and gophers as animals found in close association with wild jojoba. According to Hogan (43), the vertebrate pests and the problems they caused included such things as rabbits on young plantings, ground squirrels on transplants, and range cattle and deer on young, unprotected plants. These pests appear to be of significance chiefly on young plants and therefore the plants require protection primarily during the first few years of establishment.

Plantago

The use of the term "Plantago" in this paper will refer to the species Plantago insularis, P. ovata and P. psyllium, or any of their several hybrids currently being studied for production. Plantago is a member of the family Plantaginaceae of which there are over 200 species worldwide. These annual or perennial herbs and shrubs have leaves which arise without distinction between stalk and blade. Flowers are inconspicuous, occur on heads or spikes and are wind and partly insect pollinated (109). The importance of plantago arises from the fact that a few of the species possess a mucilaginous seed coat which swells upon wetting and is of commercial value. In

Arizona, plantago is grown as a winter annual at elevations below 763 meters. It is planted in November or December, with seed stalk initiation beginning in February and seed maturity and harvesting occurring in April or May. The main requirements for successful production are weed-free, frost-free and well-drained light sandy loam soils. For the most part, these requirements have been met by the use of new/uncultivated lands. In Arizona, there have been as many as 810 ha. devoted to the production of this crop (87). In 1974, Modi et.al. (63) published an article covering the basic essentials of cultivation and harvesting as practiced on the Indian subcontinent where as many as 16000 hectares have been cultivated for the production of P. ovata.

Plantago is grown for its seed mucilage which is used primarily in pharmaceuticals as a safe laxative. It is also used in the textile industry in printing and finishing cloth, in ice cream manufacturing as a stabilizer and in the cosmetic industry in hair setting lotions. In the earlier part of this century, P. psyllium provided the majority of seed mucilage for use in the pharmaceutical industry. In the 1950's this was replaced with P. ovata (blond psyllium) as the main source of seed mucilage. These two species of plantago have been historically imported from India and Pakistan where they are grown commercially. More recently, attempts have been made to develop hardy strains for Arizona by crossing the Indian varieties with the native variety P. insularis (Indian Wheatgrass) which produces larger seed and expresses disease and frost resistance but also suffers from greater seed shatter during harvest. Plantago may be grown on the flat between borders as is alfalfa, on corrugated soil, or on raised beds. The consumptive use of plantago is less than 51 cm. of water and, although adequate irrigation is essential, over-irrigation increases weed growth and disease and can actually reduce yield (29).

In the past, the chief obstacle to plantago production in Arizona has been crop failure due to weeds, disease, or frost damage. There is little mention in the literature of any insect problems. Aphids have been noted as a problem (29, 87) as have white flies (25), the painted lady butterfly, Venessa cardui (29) and a white root grub or cut worm (63). There is brief mention (88) of the tobacco crambus or corn root webworm, Crambus caliginosellus Clem. attacking P. lancelota along the atlantic seaboard and the root worm Euxoa segetum from Russian Turkistan attacking various plantago species as well as cotton (99).

Plantago is a poor competitor to weeds; hence weed control is essential for stand establishment and viability as a crop (25, 29, 39, 87). Where weeds are expected to be a problem, preplant irrigation to germinate weed seeds followed by tillage to destroy germinating seedlings prior to sowing has proven helpful. Mustards and other winter annuals have been early season pests while late season weeds such as knotweed and lambsquarter and early spring weeds have caused serious problems, particularly at harvest time. Paraquat has been successfully used to control weeds in plantago but as yet has not been cleared for use on this crop (29). One source (63) discusses the normal method of weed control which consists of cultural control and hand weeding but the latter is not an option readily available for use in this country. Recent research has concerned itself with control of the winter complex of weeds either via chemical or mechanical methods (25, 39). There has yet to be a compound registered for use on this crop for weed control, probably due to the extremely limited acreage upon which this crop will be grown (currently less than 41 ha. in Arizona).

There is more in the literature concerning the diseases of plantago. Downy Mildew, on _P. ovata_, caused by _Peronospora plantaginis_ was reported as being controlled by aureofungin (31) when applied after the onset of the disease. It was shown that best results occurred when infected seeds were treated prior to sowing. _Fusarium oxysporum_, was reported on _P. ovata_ (89) as the causal agent of preemergence damping off or rapid wilt of 120 to 150 day old plantings grown experimentally in Arizona. First year crops were apparently unaffected by this disease, but subsequent monoculture cropping led to a high incidence of plant death. Tests with the crop indicated at least a superficial association of the fungus with the seed and it was recommended that clean seed be used as a means of control as well as using plantago in a rotation schedule and avoiding continual monocropping. Elsewhere, (20) Chastagner, Ogawa and Sammata reported on the cause and control of early damping off caused by _Pythium ultimum_ Trow on _P. ovata_. Marked seedling death was noted when grown on infected soil. Chemical treatment of the soil and the seed was investigated and it was found that seed treatment appeared to be most efficacious. Bhargava et.al. (10) studied downy mildew and its relation to sowing date, nitrogan levels and its control by a fungicide. Their results indicated that an early sown crop (Oct. 1979) produced minimal expression of the disease. High nitrogen applications (60 kg/ha) appeared to favor the incidence of the disease and the application of the fungicide being tested (Ridomil) twice at 0.2% effectively checked the disease.

Recent crosses between P. ovata and P. insularis have been concerned with, among other things, incorporating the greater resistance to fusarium diseases of the native plant into the traditional crop plant P. ovata (29). There are additional papers available which consider diseases of other plantago species which may be of interest. Staniulis and Genyte (95) studied Mycoplasma Like Organisms (MLO) causing plantago yellows and its relation to clover yellows, and Hitchborn et.al. (42) described the presence of virus particles resembling Vesicular Stomatitis Virus (VSV) on P. lancelota. The handbook, Index of Plant Diseases in the United States (5), lists 37 different diseases affecting 8 plantain species, none of which are the three species of concern here. As with most other crops, control of diseases is chiefly affected by the employment of cultural procedures (e.g. planting on beds) (29); but, as evidenced in the above literature, there is research being done involving the use of chemicals for control of some pathogens. Tables 1 and 2 reflect the lack of compounds available for use on Plantago in this state.

Tepary Bean

Tepary beans, Leguminosae Phaseolus acutifolius, are native to southwestern North America and have been a cultivated crop for at least

5,000 years (48). Wild teparies (P. *acutifolius* var *gray*) are annual legumes which express indeterminate vining habit. They have inconspicuous self pollinating (cleistogamous) flowers, explosively dehiscent pods and non-glossy, variously colored seeds. They possess an unusually short life cycle of 60 - 90 days which enables these heat and drought tolerant plants to function as warm season ephemerals with flowering coinciding with the summer rainy season of the southwest. The domesticated tepary is classified *Phaseolus acutifolius* var *latifolius* Freeman. This differs most notably from the wild type in the characteristics of the seed such as seed size, number of seeds per pod, no explosive dehiscence, and no delayed germination. Records indicate that in 1716 the Papago Indians were harvesting tepary beans as their major crop. The growing methods which they employed ranged from simple dry land farming to some elaborate irrigation systems (69).

Around the turn of the century George F. Freeman of the University of Arizona began a program of tepary bean testing and selection which brought this bean into the view of growers everywhere. By 1913 teparies were deemed as being the only seed crop capable of producing anywhere close to paying quantities without supplemental water under dry land conditions. It has been estimated that in 1918 in California alone there were as many as 42,000 ha. devoted to this crop (69). It was quite soon after this that their popularity fell off, however, due to factors such as small seed size, flavor and odor when cooked, changing land use trends and cultural preferences (48, 69).

Recently there has been increased interest in tepary beans for reasons which include their historical significance, their drought tolerance and their apparent lack of serious pest problems. As early as 1912 Freeman (34) noted that the Pima Indians of Arizona recognized that when insects destroyed other bean crops, the teparies were unaffected.

The available literature on the pest problems encountered in growing teparies reflects this apparent lack of serious pest problems. Wolfenbarger and Sleesman (1961) (110) reported that at least one variety of tepary bean was susceptible to damage by the mexican bean beetle *Epilachna varivestis* Muls. In Arizona, the pests have apparently been limited to spider mites and white flies (13, 44) and these have been avoided by altering planting dates. One researcher in Mexico found that the growers there considered grasshoppers, leaf miners and aphids (because of honey dew) as pests of concern on their crops (11). For the most part, the pests have been fairly insignificant and have been easily dealt with, but there are no insecticides approved for use on teparies in the event that other more serious pests develop.

The diseases of teparies, although few, are better documented (Table 8). Teparies have proven to be fairly resistant to a large number of the diseases which are prevalent with the more common bean crops and are therefore felt to be a good source of germplasm for use in imparting resistance to disease in the more common bean varieties (14, 15, 96, 97, 98, 113, 114). The hope of imparting resistance in a plant works both ways, and Provvidenti & Cobb (1975) (75) suggested crossing *P. acutifolius* with *P. vulgaris* to produce resistance in tepary to Bean Common Mosaic Virus (BCM) which is seed transmitted. Of course, the use of clean seed would do much to prevent the spread of this disease in tepary fields as well.

Table 8. Pathogens Identified as Affecting Tepary Bean.

Erysiphe polygonia[2]
Fusarium solani f.sp. *phaseoli*[1,2]
Phymatotrichum omnivorum[2]
Pseudomonas phaseolicola[1]
Sclerotium rolfsii[2]
Sclerotinia sclerotiorum[1]
Uromyces phaseoli var. *typica*[1,2]
Xanthomonas phaseolicola[1]
Alfalfa Mosaic[1]
Bean Common Mosaic[1]
Bean Golden Mosaic[1]
Curly Top[1]
Pod Mottle[1]
White fly transmitted agents[1]

1 = from Kaiser 1981 (48)
2 = from USDA Index 1970 (5)

Weeds are the most serious problem to be encountered in the production of this crop (44). This is due in part to the fact that there are no chemicals cleared for use on this crop in this country (Tables 1 & 2). Water management along with a cultivation program has provided a modicum of control; however, this has not been satisfactory in the long run (13, 44). Field rotations about every three years have been employed and the hope has been that herbicides will eventually be cleared for use.

CHAPTER 4

METHODS AND MATERIALS

The material for this thesis was gathered between September 1981 and May 1983. In addition to the normal literature search, two computer assisted literature searches were conducted. The first was in October 1981 and the second in October 1982 with the aid of computer access systems at the University of Arizona Science Library. These searches made use of the computer files of AGRICOLA, Biosciences Information Service (BIOSIS), and Commonwealth Agricultural Bureaux (CAB) Abstracts.

The traditional crops used in this study were chosen with the aid of Arizona Agricultural Statistics (9) and Arizona Board of Pesticide Control 10-80 report for the year 1980. The 10-80 reports include actual applications by commercial applicators in the state. Growers who contract for commercial application are required to submit this report; hence, growers who purchase and apply compounds based upon their own expertise will not be included in the annual 10-80 figures. Since the non-reporting group is not considered large, the 10-80 figures provide a fairly accurate picture of pesticide use in this state. This report lists information according to site (e.g. cotton), pest (e.g. lygus bug), pesticide (e.g. aldicarb), and area covered (e.g. 32 ha.). The application of multiple pesticides for the same pest on the same site and acreage can give a false impression of the area treated, but a general feeling of the state pesticide picture can be obtained through use of these reports. The choice of traditional and non-traditional crops under investigation was facilitated by the use of an in-house survey and guidance from the thesis committee. Once the crops were selected, a survey questionnaire was developed and sent out to various persons around the state for their input regarding pests and pest controls on the chosen crops. Additionally, several individuals were interviewed concerning crops with which they were familiar.

Choosing the traditional crops

To provide a point of reference for the non-traditional crops as related to pest problems and pest controls, several traditional crops and some of their pest control histories were included in this study. The traditional crops, were selected using factors considered representative of many crops. This was achieved by developing a matrix using data such as acreage, value per acre, pests, and pesticides cleared for use on the crop. Information concerning acreage and value of established crops was obtained from Arizona Agricultural Statistics 1981 (9). To this information was added the 1980 "10-80" information covering pests and pesticides reported on the crops. Table 9 gives the crops which were considered and how they were ranked according to acreage, value, pesticides used in Arizona, and reported pests. From this comparison, representative crops were chosen ranging over large to small acreage, high to low value and few to many recorded pests. A total of 5 traditional crops (3 annual and 2 perennial) were picked for brief review: carrots, cotton, grape, lettuce, and pecan.

Table 9. Criteria for Choosing Traditional Arizona Crops.

CROP	1976	1977	1978	1979	1980
BARLEY	2 - - 3	2 - - 3	2 - - 3	2 - - 3	2 2 3 3
BROCCOLI	3 - - 1	3 - - 1	3 - - 1	3 - - 1	3 1 1 1
CANTELOPE	3 - - 1	2 - - 1	3 - - 1	3 - - 1	3 1 1 1
CARROTS	3 - - 2	3 - - 1	3 - - 1	3 - - 1	3 2 2 1
CAULIFLOWER	3 - - 1	3 - - 1	3 - - 1	3 - - 1	3 1 1 1
CORN	2 - - 3	2 - - 3	2 - - 3	2 - - 3	2 1 1 3
COTTON	1 - - 2	1 - - 2	1 - - 2	1 - - 2	1 1 1 2
DRY ONIONS	3 - - 1	3 - - 1	3 - - 1	3 - - 1	3 2 2 1
GRAPE FRUIT	2 - - 3	2 - - 2	2 - - 3	3 - - 2	3 2 2 2
GRAPES	3 - - 1	3 - - 1	3 - - 1	3 - - 1	3 2 2 1
HAY	1 - - 3	1 - - 3	1 - - 3	1 - - 3	1 1 1 2
HONEYDEW	3 - - 2	3 - - 1	3 - - 1	3 - - 1	3 1 1 1
LEMON	2 - - 2	2 - - 2	2 - - 2	2 - - 1	2 2 3 1
LETTUCE	2 - - 1	2 - - 1	2 - - 1	2 - - 1	2 1 1 1
ORANGES	2 - - 3	2 - - 2	2 - - 1	2 - - 1	2 2 2 2
POTATOES	3 - - 1	3 - - 1	3 - - 1	3 - - 2	3 2 2 1
SAFFLOWER	- - - -	2 - - 3	3 - - 3	2 - - 3	3 3 3 3
SORGHUM	2 - - 3	2 - - 3	2 - - 3	2 - - 3	2 2 2 3
SUGAR BEETS	2 - - 2	2 - - 2	2 - - 3	2 - - 2	3 1 1 -
TANGERINES	3 - - 2	3 - - 2	3 - - 1	3 - - 2	3 - - 2
WATERMELONS	3 - - 2	3 - - 2	3 - - 1	3 - - 2	3 2 2 1
WHEAT	1 - - 3	1 - - 3	1 - - 3	1 - - 3	1 1 3 3

CATEGORY	ACREAGE (col. 1)	PESTICIDES (col. 2)	PESTS (col. 3)	VALUE/ACRE ($) (col. 4)
1	>100,000	>20	>10	>1000
2	10000 - 100,000	10 - 20	5 - 10	500 - 1000
3	<10000	<10	<5	<500

The figures represented were generated out of the 1981 edition, Arizona Agricultural Statistics, plus the 1980 Board of Pesticide Control 10-80 results. Only in the 1980 column are all four values given.

Choosing the non-traditional crops

The non-traditional crops considered were chosen with the use of a survey of faculty members of the departments of Plant Science, Plant Pathology and Entomology at the University of Arizona. Participants were given a list of 12 candidate plants and asked to evaluate these plants, based upon their own knowledge and experience, as to likelihood of succeeding as a commercial crop in Arizona (Table 10). From this initial list of potentials, 5 crops were chosen, one of which (tepary bean) was included simply due to the fact that there had been considerable interest expressed in this crop within the Department of Plant Sciences at the University of Arizona. The other plants chosen for study were guar, guayule, jojoba and plantago.

Table 10. Results of Survey Used to Pick Non-traditional Crops.

Crop Rating scale:	0	1	2	3	4	5
Amaranth	3	1	2	1	-	2
Buffalo Gourd	-	1	3	4	-	1
Cacti	-	4	3	-	-	2
Cassava	3	-	1	2	-	3
Euphorbia	-	-	-	4	1	4
Guar	-	1	7	-	1	-
Guayule	-	1	5	1	1	1
Jojoba	-	4	4	-	1	-
Kenaff	4	-	-	4	1	-
Mesquite	1	1	1	2	1	3
Plantago	2	-	3	3	1	-
Tepary Bean	3	2	-	2	2	-

crops were rated according to the following scale:

0 = am not familiar with this crop
1 = crop highly likely to succeed in Arizona agriculture
2 = likely to succeed in Arizona agriculture
3 = unsure
4 = unlikely to succeed in Arizona agriculture
5 = highly unlikely to succeed in Arizona agriculture

This survey was circulated among 12 faculty members of the University of Arizona College of Agriculture, 9 of which responded

The Survey

Once the traditional and non-traditional crops had been chosen, a survey panel had to be established. One hundred and three persons from various agricultural interests were contacted and asked to participate in this study. Of these 100 plus individuals, 55 expressed their willingness to help and these 55 people made up the panel.

The survey used was based on the DELPHI method with slight modification. The DELPHI method (51) is a tool of research which allows a researcher to poll a panel of experts on a given topic and to use their responses to point out areas of difference or predict future trends. This system generally calls for a three round survey. In the first round, panelists are sent an open ended questionnaire where they are introduced to the topic under consideration and allowed to generate the questions which need to be addressed concerning that topic. Once the pertinent questions have been established, the panelists are then asked (round two) to provide answers to the questions which they generated. After these answers have been received, the panelists are then sent the same questions and a summary of the results from the second round. This third round enables panelists to reconsider their previous answers in light of the opinions of their peers.

In this study, panelists were sent only two rounds of the survey. This modification came about chiefly due to the fact that of the small panel (55 persons), 64% responded on the first round and only 45% responded on the second. The complexity of the questionnaire, the slowness in participant response plus the fact that the information desired had been generated by the two rounds made dispensing with the third round acceptable.

The first round survey (Appendix B) was directed at establishing the general pest types and control strategies, on the given crops, with which the panelists were familiar. They were also asked to list future desired strategies and then indicate any constraints which they felt could interfere with the implementation of the desired control methods which they had mentioned. Since this round was designed to establish the pests, strategies and constraints for the selected crops, nonresponses at this point were considered unimportant.

After the results of the first round survey were received (Appendix C), they were translated into graphic form for ease of reading and resubmitted to the panel as the second round (Appendix D). The bar graphs generated were designed to directly reflect the answers of persons responding to a specific crop, ignoring those respondents that did not reply. It was therefore conceivable that if 8 persons answered that weeds were a pest on jojoba and all 8 said that chemical, cultural, biological, and IPM were methods of choice for control, then the graphs would reflect 100% response to each of these methods. It was also possible that if 4 people said insects were a pest on tepary beans and only 2 mentioned any controls (one saying biological the other saying cultural), than the graph would reflect a 25% response for biological and a 25% response for cultural control of insects on this crop. This method was used since persons responding were felt to be cognizant of the problems on that crop and their answers were of much more significance than the responses of persons unfamiliar with the problems associated with that crop.

These graphs were provided to the panelists to give them an idea of the relative importance placed by their peers on certain pests and control measures. After being able to see how their peers responded, the panelists were asked to rank the pests and control measures according to important, not important, or don't know. This enabled respondents to reconsider their previous answers and then reaffirm or change them. Also in the second round, several of the responses regarding pest control strategies were combined to simplify the design. These responses and their placement were resistant varieties and mechanical and physical methods under the heading of cultural controls, and regulatory and legislative controls (not normally considered to be an option to the individual grower) under the general heading of IPM.

Finally, the second survey listed the constraints identified during the first round and panelists were asked to tell which constraints would most likely effect which crop.

Individual Interviews

In addition to the literature search and the DELPHI questionnaire, several individuals who were acknowledged as being well versed in the history and current problems dealing with the traditional and non-traditional crops were interviewed. These persons were asked to discuss the pest problems and pest controls which were in operation on certain crops and possible future trends or potential problems which must be considered.

CHAPTER 5

RESULTS AND DISCUSSION

Results

Figures 1 through 7 reflect the results of the first round survey (see Appendices B and C). As can be seen (Fig. 1 page 66), weeds were named most often as a pest on the non-traditional crops, and with the exception of carrots, insects were named most often as a pest on the traditional crops.

For controlling pests, Figure 2 (p. 67), indicates that chemicals are overwhelmingly the current method of choice for insect control. However, Figure 3 (page 68) indicates that for the future there is an apparent desire to diversify control strategies on the traditional crops with continued emphasis on chemicals for the non-traditional crops. In light of the lack of information available regarding chemical use or research on these "new" crops, this response was surprising.

Figures 4 and 5 (pages 69 and 70) reflect the responses concerning weed controls, present and future. Figure 4 demonstrates that chemical control was the predominate method indicated for current use on the "old" crops, with some mention of cultural methods. On the "new" crops, chemical and cultural controls were mentioned with almost equal frequency; again this was interesting since no chemicals are currently cleared for use on weeds in two of the three crops and the literature does not indicate that compounds are being studied.

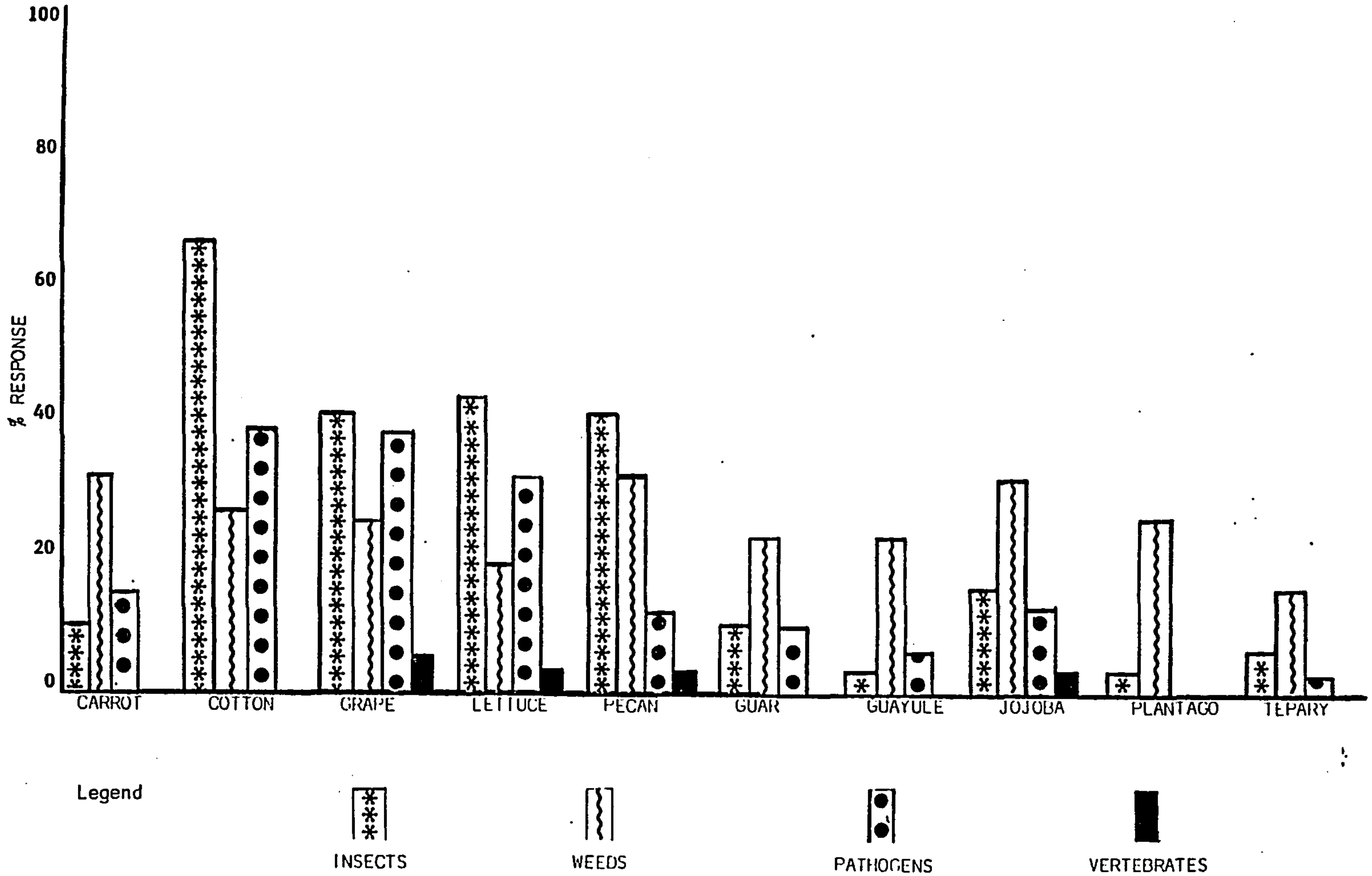


Figure 1. Pest Types

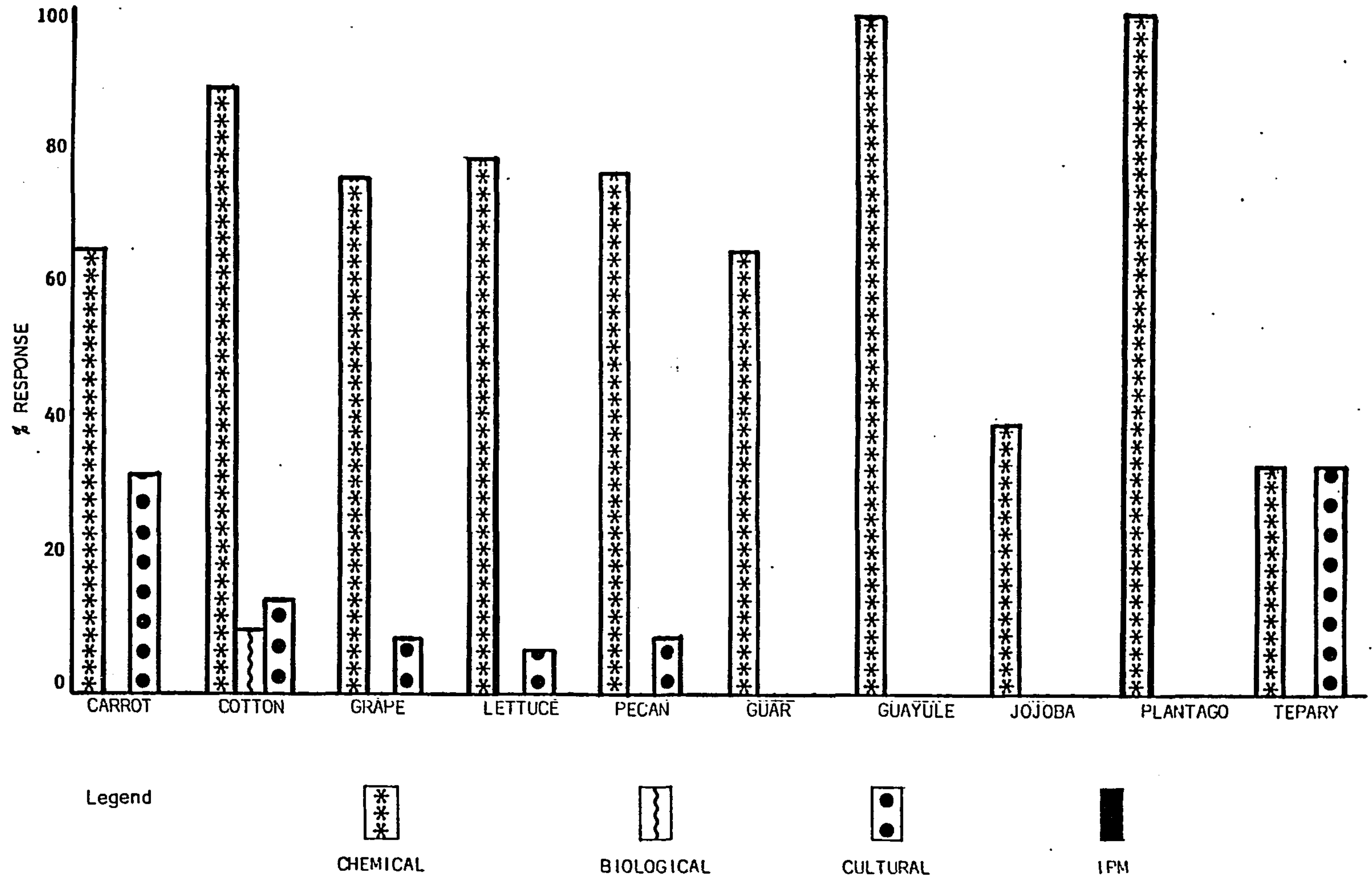


Figure 2. Insect Control Strategies, Present.

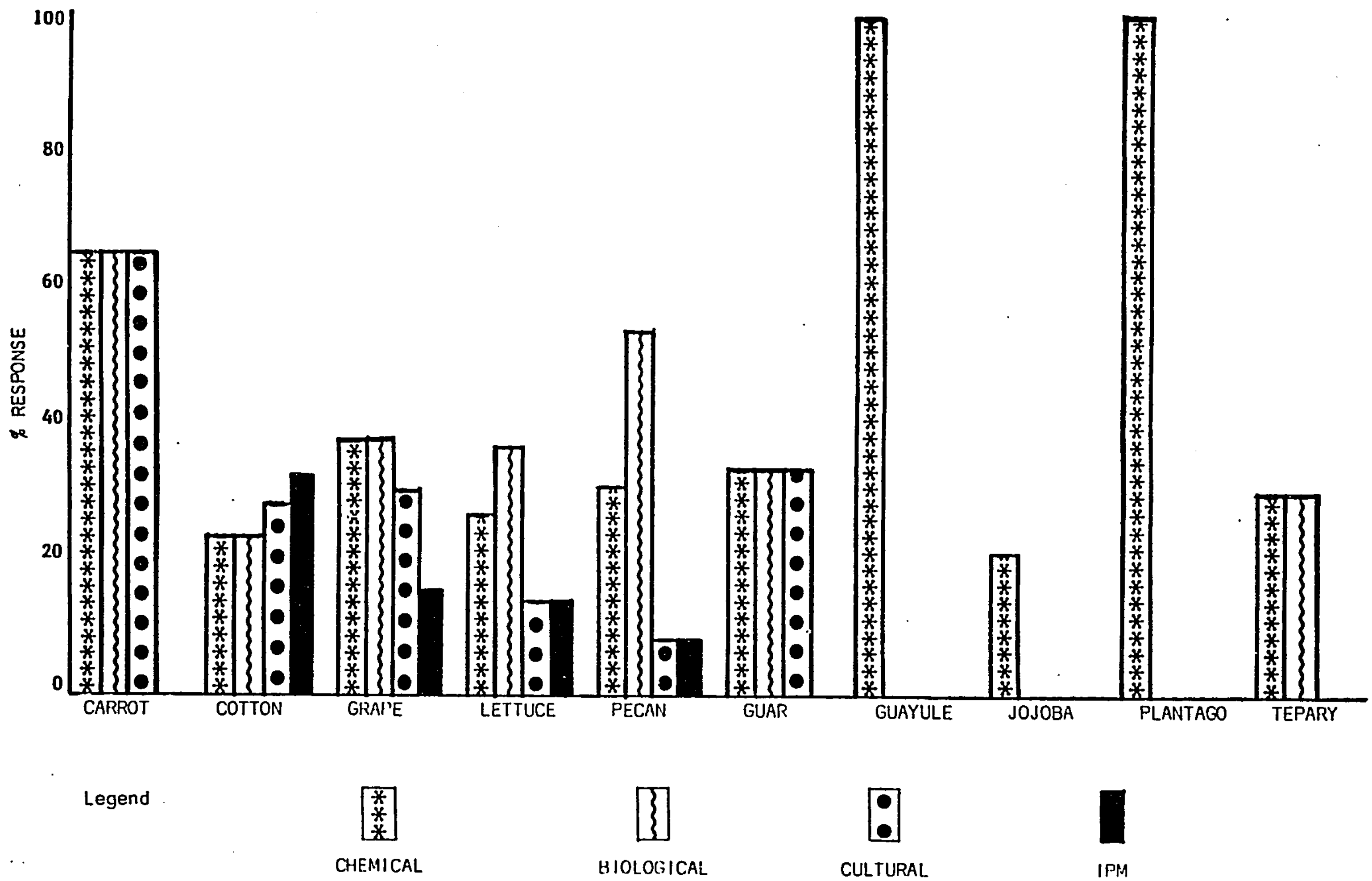


Figure 3. Insect Control Strategies, Future.

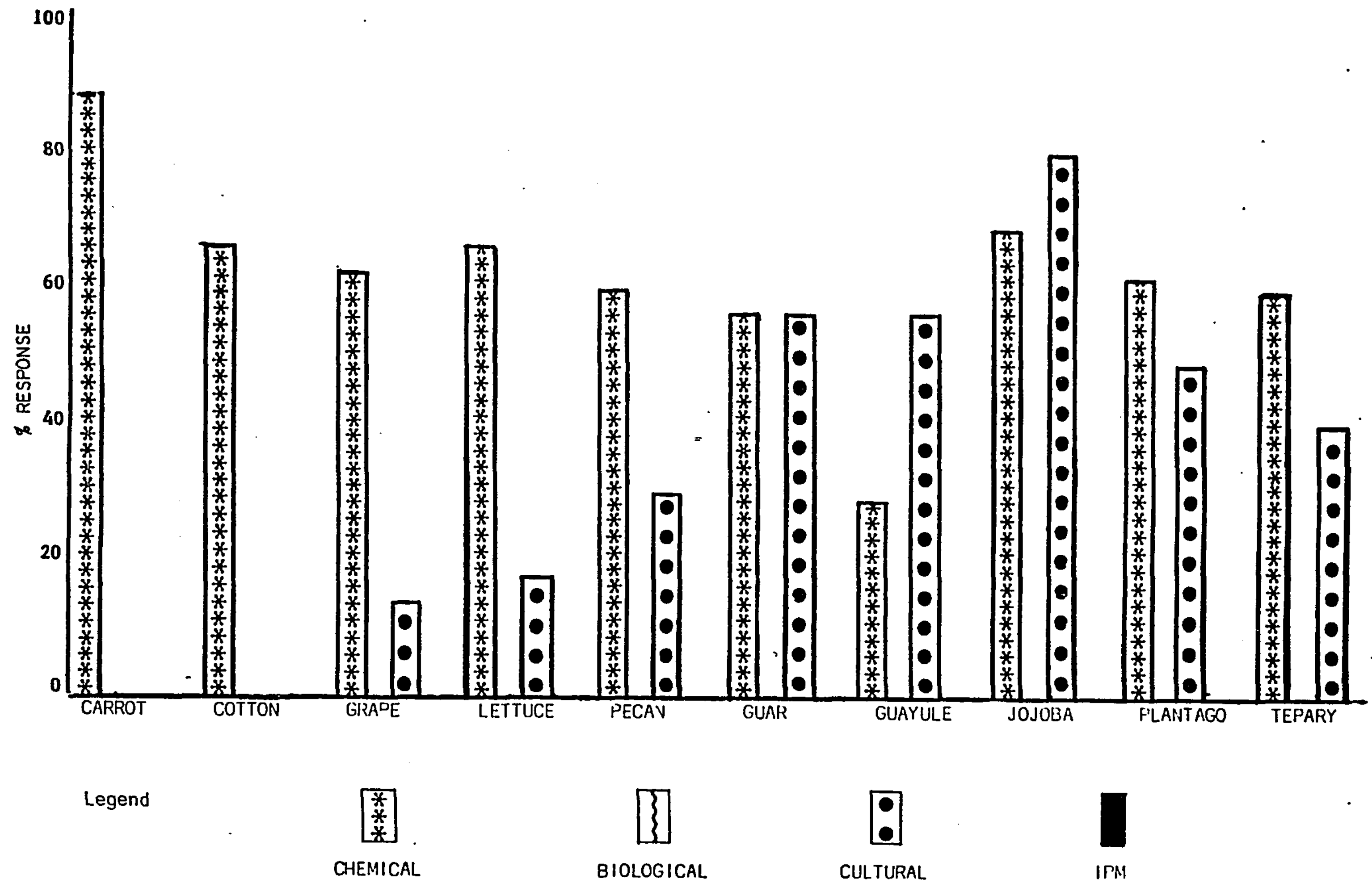


Figure 4. Weed Control Strategies, Present.

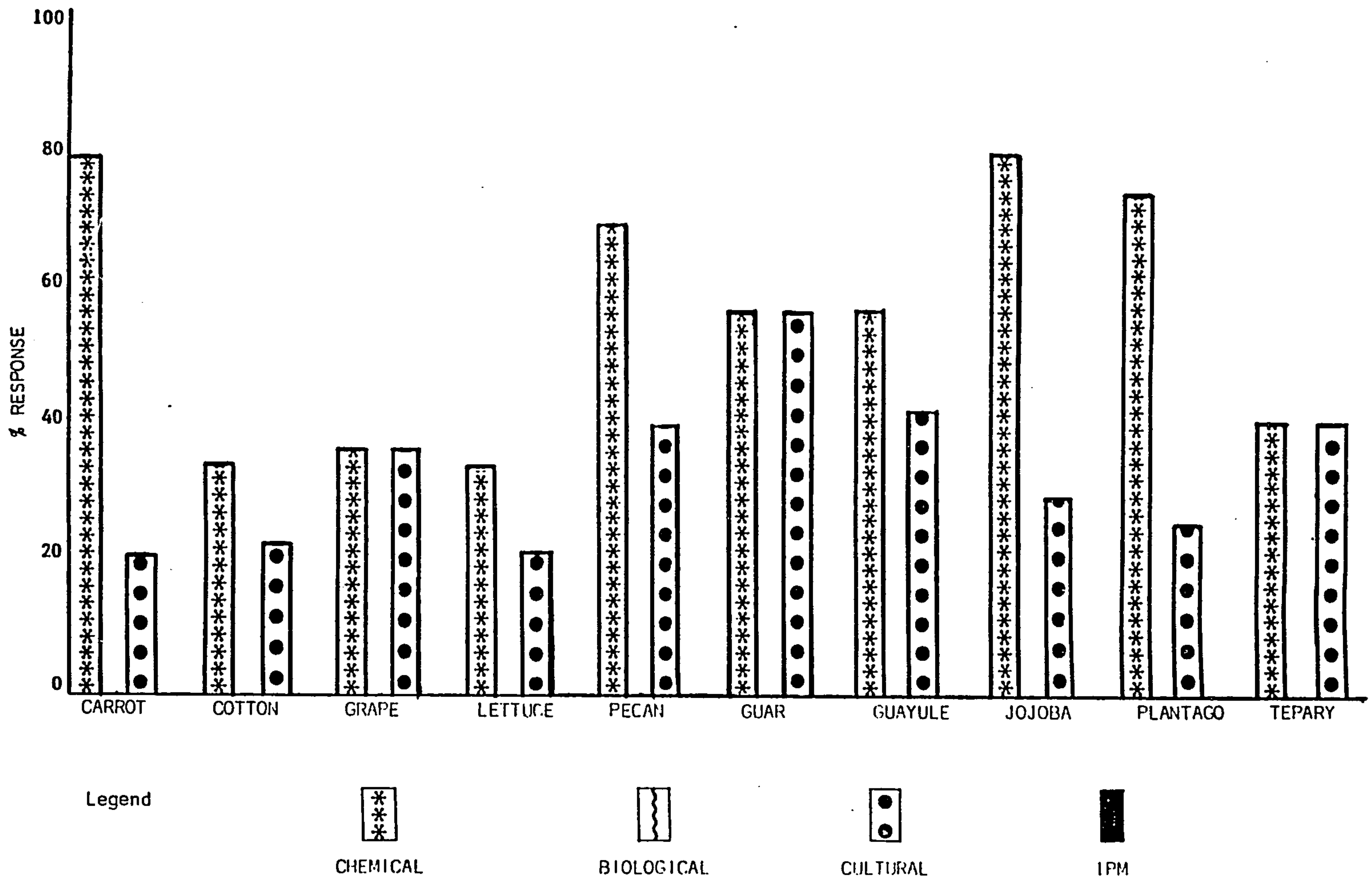


Figure 5. Weed Control Strategies, Future.

Figure 5 reflected a change in the emphasis placed on future control strategies. For the traditional crops, the emphasis on chemicals drops off while there is a subsequent increase in responses for cultural controls. With the exception of guar, which remained unchanged, the responses for the non-traditional crops reflected an opposite trend, showing an increase in respondents desiring chemical controls and a general reduction in the importance placed on cultural methods.

Figures 6 and 7 deal with the present and future control methods to be used on the pathogens affecting these crops. Chemical and cultural methods, (Fig. 6 page 72), are essentially what the respondents to this questionnaire are relying on for disease control on the traditional crops. There appears to be little known about the disease controls on the non-traditional crops since no control methods are mentioned. This reflects what is in the literature since several of the "new" crops have been considered to be disease free and are just beginning to be studied for disease problems.

Figure 7 (p. 73) indicates a future trend away from the preference for chemical controls and a tendency towards using a more diversified set of strategies for controlling diseases (except in the case of carrots which remained unchanged). Cultural controls are stressed much more for the future and there is also a desire to see biological and IPM strategies employed (a trend which finds some support in the literature). An apparent lack of knowledge concerning the control of diseases on some of the non-traditional crops is again reflected by the future control responses.

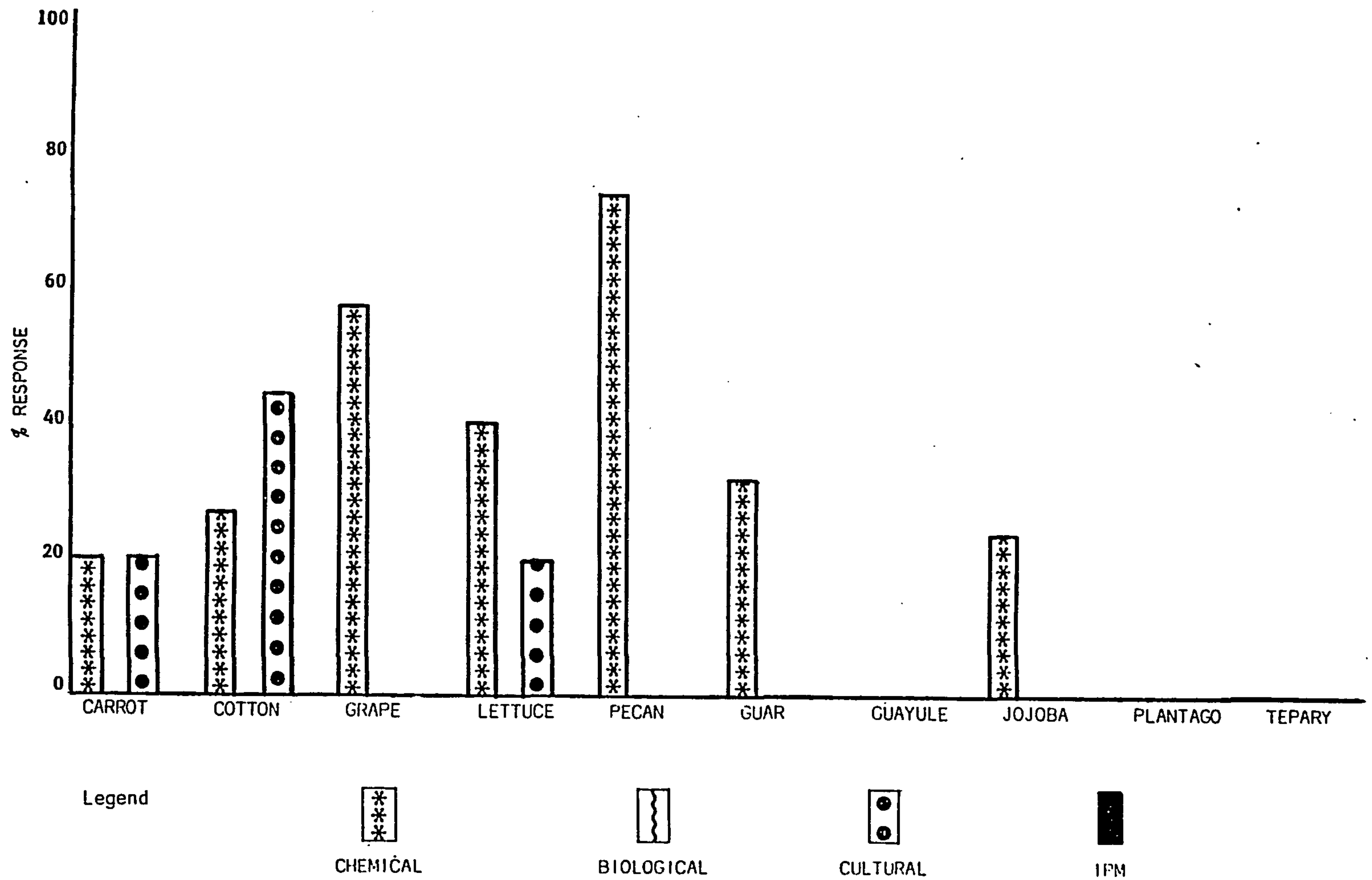


Figure 6. Disease Control Strategies, Present

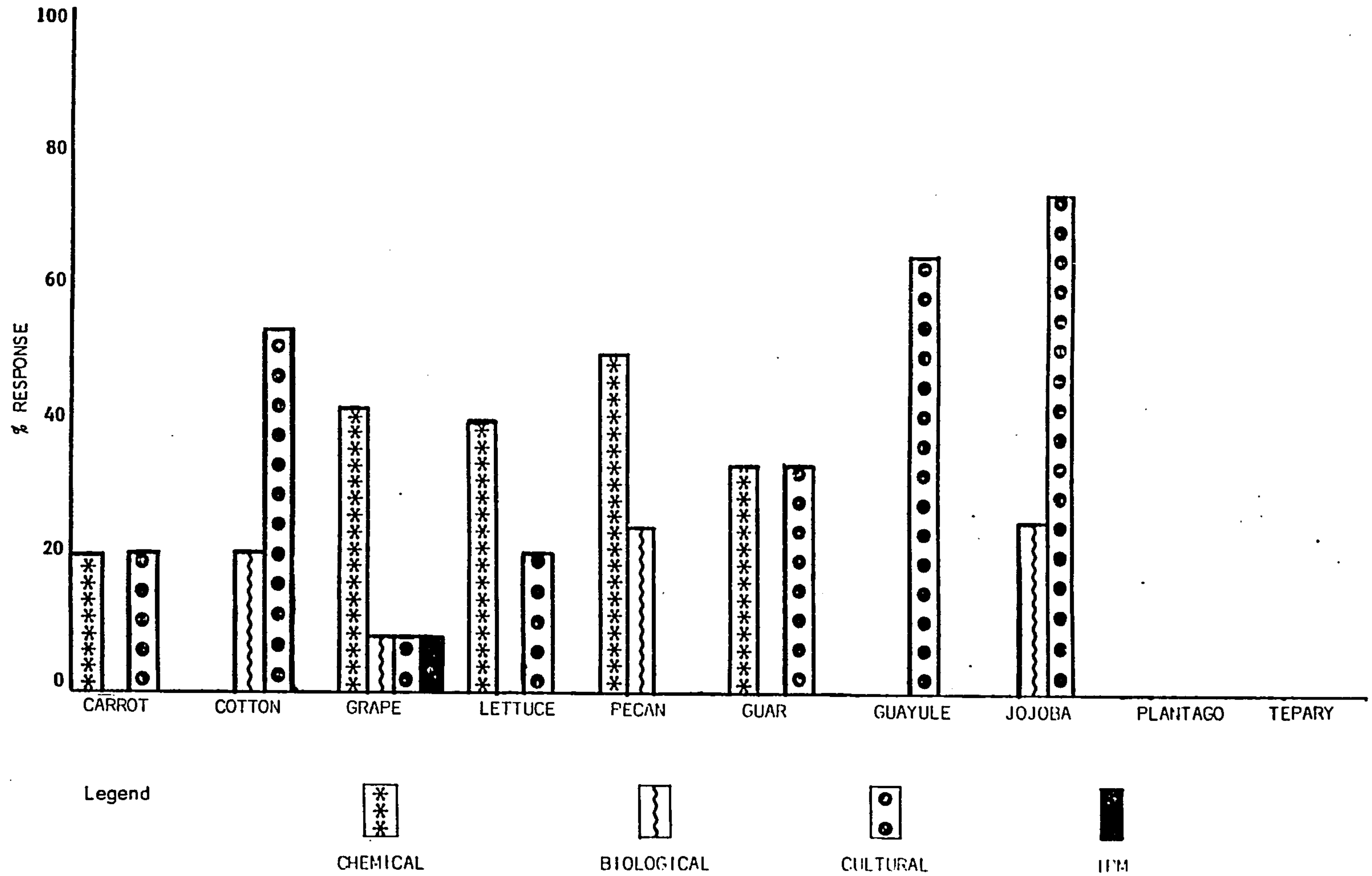


Figure 7. Disease Control Strategies, Future.

Respondents were also asked to indicate, by crop, any constraints which they felt may hinder implementation of the given control methods (Table 11 page 75). Several were identified and these were then grouped into the 7 basic categories found in the table. Major points from this table include; the questioning of the viability of pecan as a competitive crop; the unanimous mention of regulatory and legislative obstacles; the lack of research interest or money for cotton or grapes (perhaps the two best documeted crops in this entire study); and availability of effective pesticides not being mentioned for cotton or guar, (understandable for cotton which has such a wide variety of compounds available but surprising for guar which has the most compounds available of the non-traditional crops, but these are still only a very few).

The results of the second round are recorded in Tables 12 - 15. In this round of questions, the participants were asked to indicate whether a certain control strategy was important, not important, or that they did not know the importance of a particular method. They could also state if they were not familiar with the crop since a distinction should be made between simply not knowing the importance of a strategy and not being familiar with the crop. It is of note that of the participants in this round, over 50 % indicated that they were unfamiliar with carrots, guayule, plantago and tepary beans and nearly 50 % were unfamiliar with guar and jojoba. This is quite large when one considers that these are persons involved in agriculture and agricultural research.

Table 11. Constraints to the Implementation of Desired Pest Control Strategies, Identified From the First Round Survey. An X Indicates That a Constraint was Mentioned at Least Once for a Marked Crop.

CONSTRAINT	CROP									
	Carrot	Cotton	Grape	Lettuce	Pecan	Guar	Guayule	Jojoba	Plantago	Tepary
Viability as competetive crop.	-	-	-	-	X	-	-	-	-	-
Lack of sufficient understanding of plant/pest relationship.	X	-	X	X	X	X	X	X	X	X
Availability of effective pesticides.	X	-	X	X	X	-	X	X	X	X
Lack of research interest or money.	-	X	X	-	-	-	-	-	-	-
Changes in pest complex.	X	X	X	X	X	X	X	X	-	-
Lack of convincing evidence for altering farm practices.	X	X	X	X	-	-	-	-	-	-
Regulatory/legislative obstacles.	X	X	X	X	X	X	X	X	X	X

If one can assume that the more often a response of "Important" is given, the more important that item actually is, then a comparison of the information in this table with that presented in the previous figures highlights some changes in the pattern of responses. Comparing Table 12 (p. 77) with Figure 1 (p. 66) shows that while the relative importance of the pest types listed for carrot, lettuce, guayule and jojoba remained essentially unchanged, the other crops showed differences. Weeds are now first in cotton, followed by insects and pathogens where before weeds were last in importance. In grapes, pathogens appear most important followed closely by insects and weeds while insects had been most prominent followed by pathogens and weeds. Weeds in pecans are followed by insects in importance which is opposite of the first survey and pathogens in guar which had been indicated as often as insects are now listed as virtually unimportant. Insects, originally noted on plantago and tepary beans, are no longer listed on these crops. Finally, vertebrates, although essentially rated as not important, are now listed as a pest of at least some importance on all crops except tepary beans.

On the non traditional crops, the number of "do not know" responses on all pest types except for weeds indicates the general uncertainty regarding the pests on these crops. This is not surprising since this same uncertainty is reflected in the literature which was reviewed earlier. What is surprising is that rather than indicating a general lack of familiarity with the crops (done by drawing a line through the crop name) these respondents claim to be familiar with the crops but express a low level of knowledge regarding their pests and controls.

Table 12. Second round survey responses to pest types.

	PEST TYPES												
	INSECTS			WEEDS			PATHOGENS			VERTEBRATES			L O
CROP	I	N	X	I	N	X	I	N	X	I	N	X	
CARROTS	5	5	2	10	1	1	8	2	2	1	6	5	13
COTTON	21	-	1	22	-	-	19	1	2	3	13	6	3
GRAPE	14	-	3	11	3	3	15	-	2	6	7	4	8
LETTUCE	18	-	1	14	3	2	17	-	2	4	8	7	6
PECAN	11	3	2	12	3	1	6	6	4	2	8	6	9
GUAR	6	3	4	11	-	2	1	6	6	1	6	6	12
GUAYULE	2	4	4	7	1	2	3	3	4	1	4	5	15
JOJOBA	4	3	6	12	-	1	4	3	6	2	3	8	12
PLANTAGO	-	3	6	7	-	2	3	1	5	1	1	7	16
TEPARY BEAN	-	3	7	7	-	3	-	2	8	-	2	8	15

Note: I = important
N = not important
X = do not know
LO (Lined out) = am not familiar with this crop

The responses on pest control strategies also indicated change from the first round survey. For insect control (Table 13, p. 78), chemicals are still the method of choice on all crops but cultural practices appear to be more important on both the traditional and non-traditional crops than first noted (Fig. 2, p. 67). Integrated Pest Management is also mentioned as currently employed on all traditional crops, (not the case in the first round), but it does not appear to be of much significance.

For future insect controls on the traditional crops chemicals drop slightly in importance while biological, cultural, and IPM strategies increase in importance, much as they did in round one (compare with Fig. 3, p. 68). This does not necessarily reflect a trend towards less reliance upon chemicals but a more expanded approach towards controlling insect problems in which other methods are regarded as being equally important. With the non-traditional crops, there were

Table 13. Second round survey results on insect control.

INSECT CONTROL

CROP	CHEMICAL						BIOLOGICAL						CULTURAL						I P M						LO
	PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			
	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	
CARROTS	8	1	3	7	2	3	1	8	3	6	2	4	8	1	3	8	1	3	2	7	3	8	2	2	13
COTTON	19	-	3	16	3	3	13	4	5	18	-	4	15	2	5	17	-	5	8	8	6	16	1	5	3
GRAPE	14	-	3	12	2	3	6	6	5	12	1	4	11	3	3	12	2	3	5	7	5	10	3	4	8
LETTUCE	17	-	2	15	2	2	8	7	4	15	1	3	11	5	3	14	2	3	4	8	7	11	3	5	6
PECAN	13	1	2	12	2	2	5	6	5	9	2	5	7	5	4	11	2	3	3	8	5	8	4	4	9
GUAR	7	1	5	8	-	5	4	4	5	5	3	5	8	1	4	7	1	5	2	5	6	4	3	6	12
GUAYULE	3	2	5	4	2	4	1	4	5	3	3	4	3	2	5	5	1	4	-	5	5	2	3	5	15
JOJOBA	5	2	6	6	1	6	2	4	7	3	3	7	5	2	6	6	1	6	-	5	8	3	3	7	12
PLANTAGO	-	2	7	1	1	7	1	1	7	1	1	7	1	2	6	1	1	7	-	2	7	1	1	7	16
TEPARY BEAN	1	2	7	3	1	6	1	2	7	2	1	7	3	1	6	3	-	7	-	3	7	1	2	7	15

Note: I = Important
N = not Important
X = do not know
LO (Lined out) = am not familiar with this crop

slight increases in the importance of chemical, biological, and IPM strategies while cultural strategies remain essentially unchanged. As with pest types, a large number of respondents indicated that they did not know what the importance of any given insect control strategy was. For all of the crops, this second round provided a different picture of insect control than what was given in the first round.

In the second round (Table 14, p. 80), chemicals were again the most important method given for weed control on the traditional crops. Unlike the first round (Fig. 4, p. 69), however, cultural methods were mentioned as important with almost equal frequency. Biological and IPM practices, which had not been indicated during the first survey, were mentioned during this round although the overall responses indicated that these programs, if used, were possibly not considered to be of much importance. On the non-traditional crops chemical and cultural control methods are ranked much the same as they were in the first round and there is only token mention of the biological and chemical methods.

Chemical and cultural methods maintain their positions of importance for weed control of the future on the traditional crops. While there was a slight increase in the role of biological control the general consensus appears to be that this method will remain relatively unimportant. IPM, not mentioned in round one (Fig. 5, p. 70), is seen to almost double in importance while those saying that this was not an important method were reduced almost by half. As in the case of insect control, there appears to be a trend on the part of the traditional crops to diversify the approach to weed control.

Table 14. Second round survey results on weed control.

WEED CONTROL *

CROP	CHEMICAL						BIOLOGICAL						CULTURAL						I P M						LO
	PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			
	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	
CARROT	11	-	1	11	-	1	2	8	2	3	6	3	8	2	2	10	1	1	3	7	2	6	4	2	12
COTTON	17	-	4	16	1	4	4	10	7	6	7	8	15	1	5	16	-	5	6	8	7	11	3	7	3
GRAPE	13	-	3	13	-	3	3	9	4	2	9	5	12	1	3	13	-	3	4	9	3	8	5	3	8
LETTUCE	15	-	3	15	-	3	2	10	6	4	7	7	12	2	4	13	1	4	3	9	6	8	4	6	6
PECAN	14	-	1	14	-	1	2	9	4	3	7	5	13	-	2	13	-	2	4	8	3	8	4	3	9
GUAR	10	-	3	9	-	4	1	6	6	2	5	6	9	-	4	8	-	5	2	6	5	5	3	5	11
GUAYULE	5	1	4	6	-	4	-	5	5	-	5	5	5	-	5	5	-	5	-	5	5	3	3	4	14
JOJOBA	8	-	4	8	-	4	-	5	7	-	6	6	8	-	4	7	-	5	-	6	6	2	4	6	12
PLANTAGO	3	-	6	3	-	6	-	2	7	-	2	7	3	-	6	2	-	7	-	3	6	1	2	6	15
TEPARY BEAN	3	1	6	5	-	5	-	3	7	-	3	7	5	-	5	4	-	6	-	4	6	1	2	7	14

* Note: there is a total of only 24 responses to this question since one respondent ommitted answering this page.

Note: I = Important
N = not Important
X = do not know
LO (Lined out) = am not familiar with this crop

On the "new" crops, chemical and cultural methods were noted as continuing to remain important with almost equal frequency although there had been a change in their apparent status during round one. There was a perceived increase in the importance of IPM, and biological methods remained basically unchanged and unimportant for future use.

Disease control on the traditional crops (Table 15, p. 82) by chemical and cultural methods were currently of nearly equal importance; this had not been reflected in the first round (Fig. 6, p. 72) on any of the traditional crops, especially grapes or pecans. Biological controls were considered essentially unimportant while IPM reflected an uncertainty among respondents as to the current significance of this method. Future disease control methods on these traditional crops indicate chemicals remaining basically the same in importance, biological methods increasing in importance but remaining uncertain as to how important, cultural controls increasing slightly in importance, and IPM doubling in importance in most cases. This is considerably different from the picture presented from the results of the first round (Fig. 7, p. 73).

For the non-traditional crops, the responses also differed from the first round. The number of persons responding "do not know" was close to or greater than 50% in most instances, reflecting the results of the first round. Cultural control methods were the most important current method with chemical controls next on all "new" crops except plantago where no other control measure was mentioned. Chemical controls could be considered of very minor importance due to the large number of "not important" responses. For future use, cultural controls

Table 15. Second round survey results on disease control.

	DISEASE CONTROL																								
	CHEMICAL						BIOLOGICAL						CULTURAL						I P M						LO
	PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			PRESENT			FUTURE			
CROP	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	I	N	X	
CARROT	7	3	2	7	2	3	3	5	4	4	4	4	7	2	3	8	2	2	3	5	4	7	3	2	13
COTTON	16	3	3	17	1	4	6	8	8	8	5	9	15	3	3	16	1	5	8	7	7	14	3	5	3
GRAPE	13	-	4	13	-	4	4	8	5	6	6	5	12	2	3	13	1	3	4	8	5	9	4	4	8
LETTUCE	14	2	3	14	1	4	4	9	6	6	6	7	13	2	4	14	-	5	5	8	6	11	3	5	6
PECAN	10	3	3	10	2	4	3	7	6	5	4	7	8	4	4	9	3	4	5	6	5	9	4	3	9
GUAR	4	3	6	6	1	6	1	6	6	2	5	6	6	2	5	6	1	6	2	5	6	6	2	5	12
GUAYULE	1	4	5	3	2	5	-	5	5	1	4	5	3	2	5	3	2	5	-	5	5	4	2	4	15
JOJOBA	1	5	7	2	2	9	-	6	7	-	4	9	5	2	6	3	2	8	-	5	8	4	2	7	12
PLANTAGO	-	1	8	-	1	8	-	1	8	-	1	8	2	-	7	1	-	8	-	1	8	1	1	7	16
TEPARY BEAN	1	1	8	1	1	8	1	2	7	1	2	7	3	-	7	2	-	8	-	2	8	1	2	7	15

Note: I = Important
N = not Important
X = do not know
LO (Lined out) = am not familiar with this crop

remained important. Where the number of important responses decreased, the number of "do not know" responses correspondingly increased. Chemical controls and IPM also saw an increase in "important" responses while biological control appeared to remain basically unimportant.

Participants were again asked to indicate constraints which they felt were important in the development of any of the crops under consideration in this study. In this case, the generalized constraints from the first round were given, and respondents were asked to identify which constraint applied to which crop. The results from this round were significant in two respects; first, the number of persons identifying certain constraints with certain crops, and second, many of the constraints not mentioned on a crop in the first round are found in the second round. A major problem with this question in the second round was that not all respondents answered it, giving the impression that either there were no constraints to the development of the crop, or that the constraints were unknown.

When the responses to this question (Table 16, p. 84) are considered in light of the number of persons responding to each specific crop, they become significant. Viability as a competitive crop, noted only on pecans in the first round (Table 11, p. 75) was mentioned by only one panelist (6 % of those responding to pecan) in the second round. This same factor was the single most important constraint mentioned for all of the non-traditional crops where (for example), 13 persons responded to guar and of those 13, 4 (or 31 %) listed this as being a constraint, while 6 of 10 (or 60%) responding to tepary bean listed the same constraint. This was followed in

Table 16. Constraints to the Implementation of Desired Pest Control Strategies, Identified From the Second Round Survey. Numbers Indicate the Number of Respondents Identifying the Particular Constraint With the Crop.

CONSTRAINT	CROP									
	Carrot	Cotton	Grape	Lettuce	Pecan	Guar	Guayule	Jojoba	Plantago	Tepary
Viability as competetive crop.	3		3	1	2	4	6	6	5	6
Lack of sufficient understanding of plant/pest relationship.	1	4	2	2	4	6	6	7	2	2
Availability of effective pesticides.	3	4	4	6	4	4	2	4	2	3
Lack of research interest or money.	3	1	5	5	3	5	2	2	3	5
Changes in pest complex.	3	9	6	7	2	1	-	-	-	-
Lack of convincing evidence for altering farm practices.	4	7	4	4	3	3	2	2	2	1
Regulatory/legislative obstacles.	3	5	3	3	1	1	1	1	1	2
No. of persons responding for each crop.	12	22	17	19	16	13	10	13	9	10

importance on the non-traditionals by the factor "understanding the pest/host relationship". Changes in pest complex appeared to be a significant constraint on traditional crops as did lack of effective pesticides. Lack of research interest or money, noted only on cotton and grapes in the first round, is now seen to be of more relative importance on other crops discussed and almost insignificant with regard to cotton. Regulatory/legislative obstacles, the only constraint receiving unanimous mention during the first round, is again mentioned on all crops in this survey but is apparently of only minor significance as a constraint.

Several reasons exist for the differences which have been noted in the responses between the first and second round questionnaires. As noted in the discussion on the DELPHI method on page 61, this type of survey provides feedback to the participants so that they can see how their peers have evaluated a situation before commenting again. By the nature of such a system, one can expect to see some type of change in response. There is also the possibility that as problems become more clearly defined (as the questionnaire progresses), respondents no longer have to give any question considerable thought, as in the open-ended first round, and may be prone to respond quicker to a given option than if they were required to write out an answer.

The uncertainty of the problems and their resolutions also tend to produce different responses just by separating the questions over time. If, for example, at the time of the first questionnaire jojoba were not known to have any insect pests, than this pest would not be expected to be identified on that plant. However, if by the second round it had been discovered that there was a major and catastrophic pest (along the lines of the boll weevil) then insects would now be the prominent pest.

Finally, a shift in the responding population will bring about differences. Even though the same population is questioned, the failure of one segment to respond can skew results as may have happened in this instance (see Table 17).

Table 17. Respondent Categories.

Category	Number Mailed		Number Responded	
	round 1	round 2	round 1	round 2
Administration	3	3	2	1
Research/Extension	27	27	17	15
PCA/Consulting	4	4	3	1
Grower/Producer	21	21	10	6
Not identified	-	-	-	2
Total	55	55	32	25

Discussion

The results of this study have highlighted several key points on the status and needs of pest control on the non-traditional crops in Arizona. These points can be summed as follows:

1. Understanding the successes and failures of pest control programs on the traditional crops would be greatly enhanced if one were able to go to a single source on the subject for each crop.

2. A large part of the agricultural community is unaware of the actual and potential pest problems on the non-traditional crops.

3. The literature is just beginning to reveal the possible pest problems on these "new" crops; where these pests are known, control methods need modernizing as in the case with guayule where pests and controls were worked out in the 40's.

4. The results of the survey indicated that weeds were the pest of major concern on all of the non-traditional crops, but the literature did not reflect this concern as the vast majority of the reports available dealt with insect or disease problems.

5. Significant emphasis is placed on chemicals for current pest control on the "new" crops; however, the data (Tables 1 and 2) does not indicate that there are sufficient compounds available to warrant this.

6. Survey responses indicated an increasing role for chemicals in the future of the "new" crops. This was also indicated in the literature for insect and disease problems and to a lesser degree for weeds.

7. According to the survey, a great deal of emphasis is placed on using alternatives to chemicals in the future, but the literature does not indicate that the research is being done to support this approach.

Traditional crops were included in this study to provide a background for discussing pest control strategies and to point out any important successes or failures which might be instructive when developing strategies for the non-traditional crops. Early in the review of these traditional crops, it became apparent that there were many sources (e.g. journals, bulletins, handbooks and books) discussing current pests on these crops, but there were no good single sources addressing the history of pest problems and control strategies on them. If we are to learn from past mistakes and successes it is necessary that we be able to readily identify what they are or take the chance of ignoring history and rediscovering the wheel.

Of the traditional crops studied, all have over 70 years of experience in Arizona and of these, cotton was introduced into a situation where a wild plant of very similar properties already existed. Because of the existence of this native plant, a great deal of early energy was directed towards controlling this plant and its feared pest (the boll weevil) with near disastrous results. For three of the "new" crops (guayule, jojoba and tepary beans) this type of experience might prove important since these are of native origin; hence, host/pest complexes are most likely already in operation. Under such circumstances, the chances are good that very effective natural control mechanisms are also already in operation (note the general belief from the literature that these crops are pest free) and if identified, might be incorporated into the overall development of these plants as crops. The growing of these non-traditional plants under plantation type conditions can also be expected to have an effect on the environment of each plant which might influence the relative effectiveness of any existing control mechanism.

The participants in this survey were all persons involved in some phase of agriculture and most had some experience with one or more of the non-traditional crops under consideration. Knowing these facts, It was surprising that close to 50% of the respondents indicated that they were not sufficiently familiar with the crops to make judgments regarding the importance of a pest or a control measure. A larger survey population may have prevented this problem; however, a similar conclusion is gained from the general lack of information available in the literature. This did highlight an educational problem, for if researchers and knowledgeable growers are unfamiliar with the pests found on these crops, it is going to be quite difficult to educate new and existing growers regarding adequate pest control programs. This question of education was not addressed in this study but it is a topic which should be studied as there is so much current interest in developing these crops for Arizona.

All of the "new" crops examined in this study are affected by pests to one degree or another. With guar and guayule, researchers have studied a wide variety of pest problems under various conditions and these studies have been published. Unfortunately, with guar, the research has been carried out in other states or other parts of the world where growing conditions cannot be directly correlated with those found in Arizona. With guayule, the studies were under Arizona conditions but were conducted by the Emergency Rubber Project (ERP) during a period (the 1940's) technologically removed from the agricultural environment in the state today. Changes in cropping practices coupled with the elimination of most of the old compounds used for insect and weed control have made new research necessary.

Jojoba, plantago, and tepary beans are only beginning to be studied for pests; plantago and tepary beans, although in Arizona agriculture for several decades, are still not receiving much study in the area of pest control. Jojoba, on the other hand, is the newest of the newcomers and there is a growing realization that this plant is not as pest free as once believed. There is great hope placed in the success of jojoba; for example the Office of Arid Land Studies at the University of Arizona has compiled a bibliography entitled Jojoba: Guide to the Literature (1982, Elias-Cesnik editor, 685 citations) which covers all of the material which they are aware of on this crop. Since this is such a new crop, the majority of this material is concerned with economic and industrial studies on the development of the crop with only a very small amount discussing pest problems and controls. Research is beginning to look more closely at these problems but as noted by Boyd (12), there is little known about the diseases and pests of jojoba under plantation conditions.

The results of the survey gave the overall indication that weeds are the pests of major importance on the new crops (Fig. 1 and Table 12). This was a consistent response for both rounds of the survey and was the general impression received from personal interviews regarding these crops. This was not, however, reflected in the literature as the majority of papers (approximately 80%) reviewed were devoted to insect or disease problems. Chemical and cultural controls were indicated as the methods of choice for controlling this pest but, chemical controls are very slow in being approved for use on non-traditional crops. More effective cultural methods will become available with changes in technology and as we develop our understanding of the relationship with these plants and weed pests. Weed control is one area in which more research is definitely indicated. When considering growing any of the non-traditional crops, a grower need be aware that weeds will probably be the most serious pest to be encountered and that there is little indication that any method other than water management and cultivation will be available in the near future.

Tables 1 and 2 indicate that there are only a few chemicals available for use on most of the non-traditional crops and that there are no registered compounds available on plantago or tepary beans. The literature reviewed did not indicate that a great deal of research is being conducted along these lines either so that when chemical control appeared as being presently important for pest control with a trend to becoming more important in the future, it was surprising. Not that the use and importance of a chemical control program is not recognized, but very little information is currently available and for the most part, the chemicals available are from the Special Local Needs (SLN) (under the Federal Insecticide Fungicide and Rodenticide Act) or the Inter Regional 4 (IR-4 under the USDA) programs. The IR-4 program, not previously discussed, is another means by which chemicals are made available to growers. Under this program a committee chooses compounds to study which have generated sufficient interest among growers of minor use crops. This is a compound which has already been registered on another crop but since there is insufficient demand or monetary incentive, residue data has not been established for minor use crops. The IR-4 program will develop the residue data necessary at no cost to the manufacturer; however, if the manufacturer applies for and receives registration of the compound based on the data generated by the IR-4 program, the manufacturer assumes liability for any litigation which might result. Although a viable alternative, the IR-4 program has yet see much application on these "new" crops.

A recent decision by the EPA reported in the Federal Register Vol. 48, No. 128, Wednesday, June 29, 1983 pp 29855 - 29862 addressed crop grouping in which it stated: if a crop were placed within a particular grouping (e.g. tepary bean and guar under the grouping legume vegetables) where there is a tolerance established or proposed for all of the representative commodities for a specific group or related commodities, a tolerance may be established for all commodities in the group. The representative crops are given to indicate the minimum residue data base acceptable. This essentially reduces the amount of study required in order to make a product available for use on a non-traditional crop as long as that crop is included under a grouping and does not contain residues exceeding the established tolerance for the representative crops of that group. This regulation along with the SLN and IR-4 programs should prove to be major avenues in making compounds available to these "new" crops until such time arises that the acreage devoted to them has reached sufficient level to be of economic interest to commercial chemical companies.

The number of responses in the survey which indicated an increasing role for alternative pest controls for the future revealed a trend towards diversifying approaches to pest control rather than relying on one single method, which is also the goal of IPM. There is evidence that this approach is being investigated by researchers, but reference to them in the literature is not as often as the survey responses indicated that it should be. It is generally agreed that in the real world if industry is reluctant to provide money for researching alternatives to chemical methods on the traditional crops, chances are they will not be willing to provide funds for developing thresholds and sampling techniques for crops which will be of minor importance for some time yet.

Part of the reluctance expressed by industry in dealing with these minor use crops is centered around the topic of liability as described above under the IR-4 program. The reality of this situation was brought home just recently in a suit involving a Special Local Needs registered compound (simizine). An Arizona jojoba grower is bringing suit against the chemical manufacturer, the chemical outlet, and all parties involved in the SLN registration process including the University of Arizona. As this case is still in litigation, it is difficult to guess what effects the outcome may have on the willingness of companies to accept liability for allowing their products to be used and University research programs to make recommendations regarding such use. However, one can envision a marked reduction in such willingness should the litigation go against the parties involved. We have a unique opportunity with these non-traditional crops in that we can follow along the same road established for the traditional crops and develop a single faceted control program focused on chemical control technology or we can embark on a new direction of investigating and developing alternative technology from the outset and avoid some of the pitfalls which have plagued heavy reliance upon chemicals.

Summary

The results of this study have indicated that there has been a general lack of information concerning non-traditional crop pests and their control. It has taken over 70 years to develop many of the programs currently in use on the traditional crops and we have seen the progression from simple cultural methods (as nothing else was available) to almost exclusive use of chemicals and more recently a trend towards an integrated approach using as many of the tools at our disposal as possible without significant reliance upon any single method. The survey results indicated that most respondents would like to see a greater reliance on all types of pest control. This would dictate that areas of research which need to be investigated include: 1) identification of the real pests of these crops; 2) developing chemical control measures for weeds particularly and all pests generally; 3) investigating and implementing other control measures such as more effective rotation regimes, the use of antagonistic organisms to control pests; 4) developing economic thresholds and effective sampling systems; and 5) getting information out to the growers and the researchers in a fashion as to make it usable and timely for if we are going to grow the crops we ought to know their associated problems and have a means of dealing with them.

In the meantime, the pests (identified or not) on these non-traditional crops are going to have to be dealt with. Of the pest control strategies discussed in this paper, there is one which stands out as being the easiest to employ and the most immediately available to growers of any minor or non-traditional crop. This is the method described earlier as cultural control, and which the survey results indicated should have a greater role in the future of the crops considered here. There are several reasons for making this statement and these include; 1) no federal clearances are required for its use, 2) many of the effective practices are already employed, and 3) in the search for the best agronomic practices, many more cultural techniques will be discovered.

APPENDIX A

COMMON AND CHEMICAL NAMES OF COMPOUNDS MENTIONED IN TEXT

Common Name	Chemical Name
Calcium Arsenate	calcium arsenate
Cryolite	sodium aluminoflouride
DCPA	dimethyl tetrachloroterephthalate
Derris	rotenone
Diazinon	0,0-diethyl-0-(2-isopropyl-6-methyl-4-pyrimidinyl)-phosphorothionate
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
Glyphosate	N-(phosphonomethyl)glycine
Metalaxyl	N-(2,6-dimethylphenyl)-N-(methoxyacetyl)-alanine methyl ester
Methyl parathion	0,0-dimethyl 0-(p-nitrophenyl) phosphorothioate
Monocrotophos	dimethyl phosphate ester with (E)-3-hydroxy-N-methylcrotonamide
Nitralin	4-(methylsulfonyl)-2,6-dinitro-N,N-dipropyl-aniline
Oxyflurofen	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoro-methyl) benzene
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion
Paris Green	copper acetoarsenite
Pendimethalin	N-(1-ethylpropyl)3,4-dimethyl-2,6-dinitro-benzenamine
Profluralin	N-(cyclopropylmethyl)-α,α,α-trifluoro-2,6-dinitro-N-propyl-p-toluidine
Simazine	2-chloro-4,6-bis(ethylamino)-s-triazine
Trifluralin	α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine

APPENDIX B

ROUND ONE PEST CONTROL SURVEY

AGRICULTURE PEST CONTROL STUDY SURVEY

Please return to Council for Environmental Studies College of Agriculture, University of Arizona, by May 7, 1982.

There are three questions presented: 1. Self evaluation; 2. Pest Types; 3. Control Strategies. Responses should be general and related to agriculture in Arizona. Specific instructions are given with each question.

1. (a) Check the category that best describes your attitude concerning the production of old/traditional crops and the potential production of new/non-traditional crops.

	Old/ Traditional	New/Non- Traditional
Favorable	________	________
No Opinion	________	________
Unfavorable	________	________

(b) Identify your career field.

	Check One
Administration	________
Research	________
PCA/Consulting	________
Commercial Production/Grower	________

2. Based on the pest control methods currently used, what are the major pest types for the crops listed? (Response should be general, e.g., insects, weeds, pathogens or vertebrates, not Lygus Bug, London Rocket, Sore Shin or Rabbits).

CROP	PEST TYPES
Carrot	________
Cotton	________
Grape	________
Lettuce	________
Pecan	________
Guar	________
Guayule	________
Jojoba	________
Plantago	________
Tepary Bean	________

3. Based upon your responses to question #2, identify the pest control strategies which you consider presently effective and those pest control strategies which are preferrable for the near future (5 years). (Responses should be general, e.g., biological controls or herbicides, not *Bacillus thuringiensis* or Glyphosate). On the lines marked"reason", indicate those resons why the strategy is used or preferred. In the unknown factors or possible constraints column, list any factors which might interfere with or prevent the use of the preferred future strategy.

CROP		CURRENT STRATEGIES	PREFERRED (5 YR) STRATEGIES	UNKNOWN FACTORS OR POSSIBLE CONSTRAINTS
	Strategy			
Carrot				
	Reason			
	Strategy			
Cotton				
	Reason			
	Strategy			
Grape				
	Reason			
	Strategy			
Lettuce				
	Reason			
	Strategy			
Pecan				
	Reason			

Question 3 continued.

CROP		CURRENT STRATEGIES	PREFERRED (5 YR) STRATEGIES	UNKNOWN FACTORS OR POSSIBLE CONSTRAINTS
Guar	Strategy			
	Reason			
Guayule	Strategy			
	Reason			
Jojoba	Strategy			
	Reason			
Plantago	Strategy			
	Reason			
Tepary Bean	Strategy			
	Reason			

APPENDIX C

RESULTS OF THE FIRST ROUND QUESTIONNAIRE
(Numbers indicate actual responses received)

1. (a) Attitude towards crop potential.

	Old/ traditional	New/Non- traditional
Favorable	27	16
No Opinion	1	4
Unfavorable	1	6

(b) Career field

Administration	2
Research	17
PCA/Consulting	3
Commercial	
Production/Grower	10

2. Major pest types and control strategies indicated.

PEST TYPES

CROP	INSECTS	WEEDS	PATHOGENS	VERTEBRATES
Carrot	3	10	5	-
Cotton	21	9	11	-
Grape	13	8	12	2
Lettuce	14	6	10	1
Pecan	13	10	5	-
Guar	3	7	3	-
Guayule	1	7	2	-
Jojoba	5	10	4	1
Plantago	1	8	-	-
Tepary Bean	3	6	1	-
Total	74	81	54	4

INSECT CONTROL STRATEGY

	PRESENT				FUTURE			
	CHEM	BIOL	CULT	IPM	CHEM	BIOL	CULT	IPM
CARROT	2	-	1	-	2	2	2	-
COTTON	18	2	3	3	5	5	6	6
GRAPE	10	1	1	-	5	5	4	2
LETTUCE	1	1	-	-	4	5	2	2
PECAN	10	-	1	-	4	7	1	1
GUAR	2	-	-	-	1	1	1	-
GUAYULE	2	-	-	-	1	-	-	-
JOJOBA	2	-	-	-	1	-	-	-
PLANTGO	1	-	-	-	-	1	-	-
TEPARY BEAN	1	-	1	-	1	1	-	-

WEED CONTROL STRATEGY

	PRESENT				FUTURE			
	CHEM	BIOL	CULT	IPM	CHEM	BIOL	CULT	IPM
CARROT	9	1	-	-	8	-	2	-
COTTON	6	-	-	-	3	-	2	-
GRAPE	5	-	1	-	3	-	3	-
LETTUCE	4	-	1	-	3	1	-	-
PECAN	6	-	3	-	7	-	4	-
GUAR	4	-	4	-	4	-	4	-
GUAYULE	2	-	4	-	4	-	3	-
JOJOBA	7	-	4	-	8	1	3	-
PLANTGO	5	-	4	-	6	-	2	-
TEPARY BEAN	3	-	2	-	2	-	2	-

DISEASE CONTROL STRATEGY

	PRESENT				FUTURE			
	CHEM	BIOL	CULT	IPM	CHEM	BIOL	CULT	IPM
CARROT	1	-	1	-	1	-	1	-
COTTON	3	1	4	-	-	5	4	-
GRAPE	7	-	-	-	5	2	-	1
LETTUCE	4	-	2	-	4	1	1	-
PECAN	3	-	-	-	2	-	1	-
GUAR	3	-	-	-	1	1	-	-
GUAYULE	-	-	-	-	-	1	1	-
JOJOBA	1	-	-	-	-	2	2	-
PLANTGO	-	-	-	-	-	-	-	-
TEPARY BEAN	-	-	-	-	-	-	-	-

APPENDIX D

AGRICULTURAL PEST CONTROL SURVEY STUDY
(ROUND TWO)

Please return to: Council for Environmental Studies, College of Agriculture, University of Arizona, by July 2, 1982.

1. Self evaluation question. Answer the questions below as indicated. The numbers found in parentheses under part (a) indicate what percentage of the total respondents checked that blank on the first round. On part b), the number in parentheses on the left of each line indicates how many persons from that career description were sent questionnaires, while the numbers in parentheses on the right of the line indicate the percentage of those people that responded.

(a) Check the category that best describes your attitude concerning the production of old/traditional cropsandthepotential production ofnew/non-traditionalcrops.

	Old/ Traditional	New/Non-Traditional
Favorable	(27)	(16)
No Opinion	(1)	(4)
Unfavorable	(1)	(6)

(b) Identify your career field

CHECK ONE

Administration	(3)	(66)
Research/Extn.	(28)	(61)
PCA/Consulting	(4)	(75)
Commercial Production/Grower	(21)	(48)
Total	(55)	(57)

Note on abbreviations and graphs:

Abbreviations used in this questionnaire and their meanings:

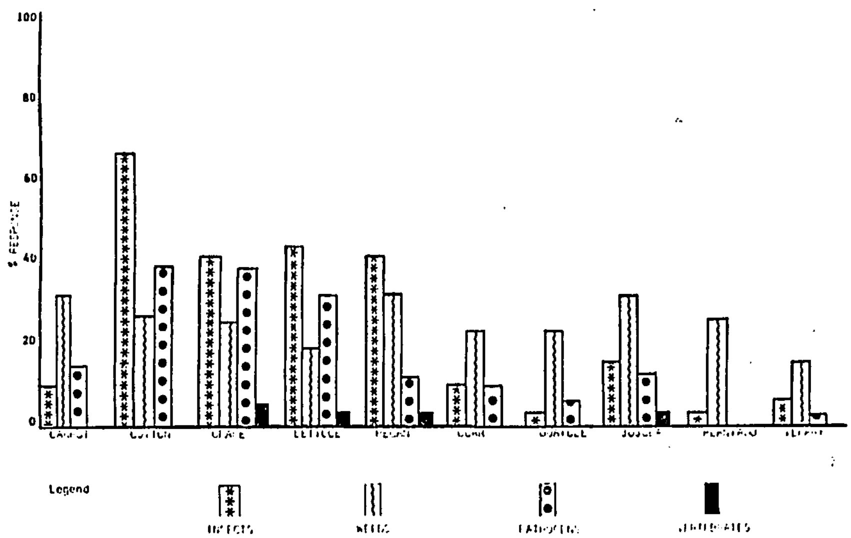
Chem. = Chemical control methods
Biol. = Biological control methods
Cult. = Cultural control methods, including the use of resistant varieties and mechanical and physical methods where applicable.
IPM = Integrated Pest Management practices, incorporating all of the above practices. Regulatory and legislative controls have been included under this category to conserve space.

On the graphs, the percent response consists of that percent of persons responding to a question by identifying one or more specific control methods. One person could have identified more than one control method for a particular pest type; accordingly, the percent response will reflect multiple entries.

For example, on the graph on Weed Control Strategies (graph 2) of 6 persons identifying weeds as a pest on Lettuce, chemicals were indicated 4 times (67%) as one of the current methods of control and cultural methods were identified 1 time (17%) as a method of control. By the same system, of 10 persons identifying weeds as a pest of Jojoba, chemicals were indicated 7 times (70%) as a current method of control and cultural methods were identified 8 times (80%) as a current method of control.

2. The major pest types identified for the crops listed in the first questionnaire are shown below. Nematodes have been included in the category PATHOGENS.

CURRENT PEST PROBLEMS



2a. Rate the importance of the pest types for each crop. For each crop with which you are familiar, fill in all blanks as follows:
I = Important N = Not Important X = Do not know
Draw a line thru any crop which you are not familiar with

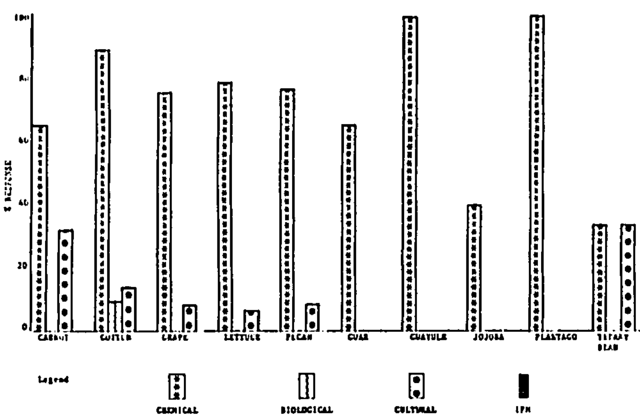
<u>Pest types</u>

CROP	INSECTS	WEEDS	PATHOGENS	VERTEBRATES
Carrot	____	____	____	____
Cotton	____	____	____	____
Grape	____	____	____	____
Lettuce	____	____	____	____
Pecan	____	____	____	____
Guar	____	____	____	____
Guayule	____	____	____	____
Jojoba	____	____	____	____
Plantago	____	____	____	____
Tepary Bean	____	____	____	____

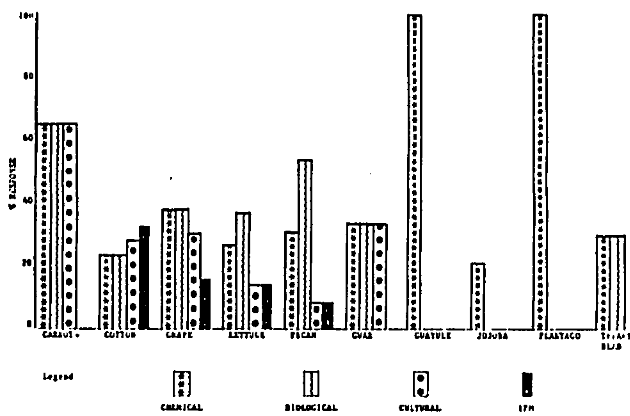
3. Strategies used (present) and preferred (future) are given below for each pest type according to responses received. Beneath each set of graphs is a question addressing the strategies used with each pest type.

STRATEGIES FOR INSECT CONTROL

Present



Future



3a. Rate the insect control strategies given below (include resistant varieties physical and mechanical practices in CULTURAL, regulatory and legislative methods in IPM). Fill in the blanks for each crop with which you are familiar with the following symbols:

I = Important N = Not important X = Do not know

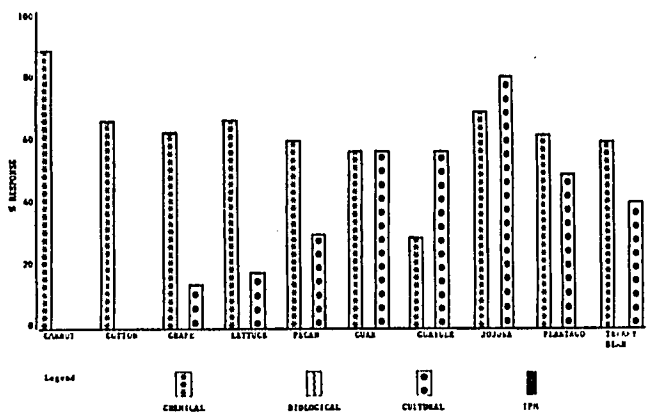
Draw a line thru any crop with which you are not familiar:

INSECT CONTROL STRATEGIES

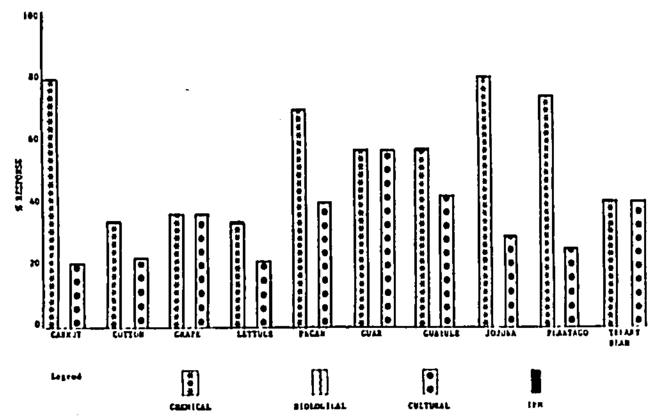
	Present				Future			
Crop	Chem.	Biol.	Cult.	IPM	Chem.	Biol.	Cult.	IPM
Carrot								
Cotton								
Grape								
Lettuce								
Pecan								
Guar								
Guayule								
Jojoba								
Plantago								
Tepary Bean								

STRATEGIES FOR WEED CONTROL

Present



Future



3b. Rate the weed control strategies given below (include resistant varieties physical and mechanical practices in CULTURAL, regulatory and legislative methods in IPM). Fill in the blanks for each crop with which you are familiar with the following symbols:

I = Important   N = Not important   X = Do not know

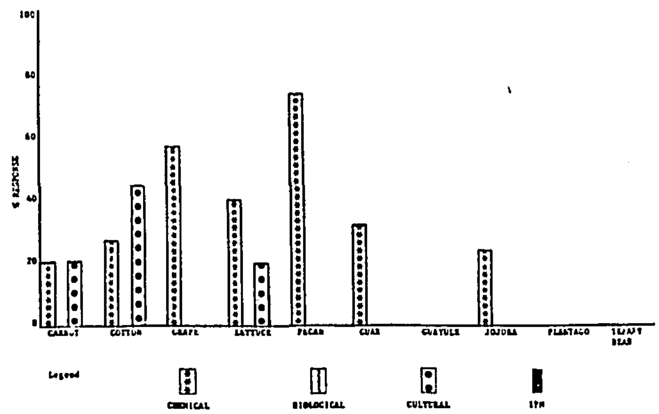
Draw a line thru any crop with which you are not familiar:

WEED CONTROL STRATEGIES

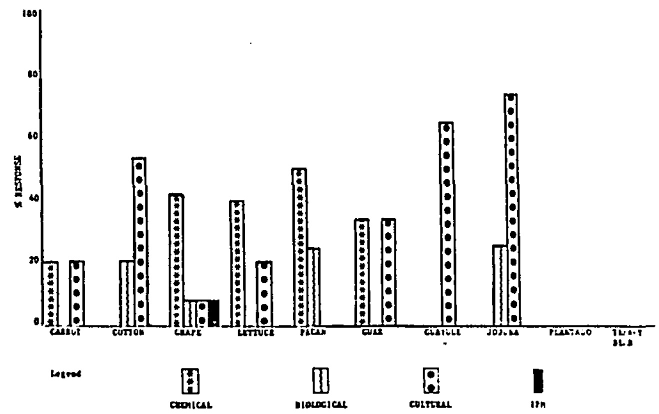
	Present				Future			
Crop	Chem.	Biol.	Cult.	IPM	Chem.	Biol.	Cult.	IPM
Carrot	___	___	___	___	___	___	___	___
Cotton	___	___	___	___	___	___	___	___
Grape	___	___	___	___	___	___	___	___
Lettuce	___	___	___	___	___	___	___	___
Pecan	___	___	___	___	___	___	___	___
Guar	___	___	___	___	___	___	___	___
Guayule	___	___	___	___	___	___	___	___
Jojoba	___	___	___	___	___	___	___	___
Plantago	___	___	___	___	___	___	___	___
Tepary Bean	___	___	___	___	___	___	___	___

STRATEGIES FOR DISEASE CONTROL

Present



Future



3c. Rate the disease control strategies given below (include resistant varieties physical and mechanical practices in CULTURAL, regulatory and legislative methods in IPM). Fill in the blanks for each crop with which you are familiar with the following symbols:

I = Important N = Not important X = Do not know

Draw a line thru any crop with which you are not familiar:

DISEASE CONTROL STRATEGIES

	Present				Future			
Crop	Chem.	Biol.	Cult.	IPM	Chem.	Biol.	Cult.	IPM
Carrot	____	____	____	____	____	____	____	____
Cotton	____	____	____	____	____	____	____	____
Grape	____	____	____	____	____	____	____	____
Lettuce	____	____	____	____	____	____	____	____
Pecan	____	____	____	____	____	____	____	____
Guar	____	____	____	____	____	____	____	____
Guayule	____	____	____	____	____	____	____	____
Jojoba	____	____	____	____	____	____	____	____
Plantago	____	____	____	____	____	____	____	____
Tepary Bean	____	____	____	____	____	____	____	____

3d. Vertebrates were identified as a pest on three crops and two control methods were given. Below are listed the crops and controls; space is provided for including any crops or methods omitted.

VERTEBRATE CONTROL STRATEGIES

Crop	Barriers	Scare tactics	Other (Specify)
Grape	____	____	____________
Lettuee	____	____	____________
Jojoba	____	____	____________
Other	____	____	____________

4. Listed below are the possible constraints and problems identified in the first questionnaire, along with a corresponding letter. Below this list are the crops being considered. For each crop with which you are familiar, enter the letter(s) in the space provided which corresponds to the factor(s) or constraint(s) that you feel apply to that crop.

Letter	Factors/Constraints
A	Viability as a competitive crop is very questionable
B	Lack of sufficient understanding of plant/plant pest relationships
C	Availability of effective pesticides
D	Lack of research interest or money for studying a crop
E	Changes in pest complex such as resistance, new pests, and others
F	Lack of sufficient evidence to encourage changing current cropping practices
G	Regulatory/legislative obstacles
H	Other (specify)____________
I	Other (specify)____________

Crop	Factors	Comments
Carrot	____________	____________
Cotton	____________	____________
Grape	____________	____________
Lettuce	____________	____________
Pecan	____________	____________
Guar	____________	____________
Guayule	____________	____________
Jojoba	____________	____________
Plantago	____________	____________
Tepary Bean	____________	____________

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