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# ANALYSIS OF THE APICULTURAL INDUSTRY IN RELATION TO GEOTHERMAL DEVELOPMENT & AGRICULTURE IN THE IMPERIAL VALLEY, IMPERIAL COUNTY, CALIFORNIA

By

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ABSTRACT

PART I: Continuous exposure to 30 ppb $H_2S$ increased lifespan of caged worker honey bees, Apis mellifera L., 33%; whereas, bees exposed > 13 days to 100 ppb and 300 ppb $H_2S$ the lifespan was shortened 32% and 51%, respectively, over unexposed bees; bees exposed > 15 days to a combination of 300 ppb $H_2S$ + 50 ppm $CO_2$ the lifespan was shortened 4.4% more than 300 ppb $H_2S$ alone. The mean temperature and/or relative humidity did not exert a direct effect on the hazard to bees. A continuous exposure to 300 ppb $SO_2$ was detrimental to caged worker honey bees; and, a mean temperature of 27.2°C was 75.7% more toxic than the same dosage at 16.7°C. Worker bee lifespans exposed to 300 ppb $SO_2$ at 16.7°C and 27.2°C were shortened 13.5% and 79%, respectively, compared to unexposed bees. Therefore, both dosage and temperature exert direct effects on the hazards to bees.

PART II: The status of the apicultural industry in Imperial County, California, was outlined giving a short characterization of the area in relation to the apicultural industry. Agriculture utilizes 500,000 intensely farmed acres which generated a 11-year average income of $370 million. Over 40 agricultural commodities are produced. The apicultural industry is intimately involved in 25% of the total gross agricultural income. In addition, most of the flora growing in the desert community which comprises the remainder of the county are very important to honey bees by providing sustaining nectar and/or pollen for brood rearing. The bee foraged flora provides substantial bee forage when colonies are located outside of the agricultural area. The author concludes that geothermal resource development in the Imperial Valley is contemplated to have minimal effects on the apicultural industry.

# INTRODUCTION

This research was performed under contract W-7405-ENG-48 with the U. S. Energy Research & Development Administration (ERDA) as authorized by University of California Lawrence Livermore Laboratory (LLL) in th University of California, Riverside (UCR), Research Proposal dated 18 May 1976. The research is one section of an ongoing study of the Imperial Valley Environmental Project (IVEP) designed to assess the full range of environmental and social consequences that may arise from developing the region's potentially vast geothermal resources.

FIGURE I is enclosed to generally orient the reader to Imperial County; specifically to the KGRA areas, the native plant areas, and, the agricultural area. The map was adapted from Ermak, D. L. & D. W. Layton. 1976. Anticipated geothermal impact scenarios, p. 4, from Shinn, J. H., Editor: Potential effects of geothermal energy conversions on Imperial Valley ecosystems, Univ. California LLL, UCRL-52196. 77pp.

## PART I

### Analysis Of Geothermal Pollutant Effects Upon Honey Bee Production & Mortality In The Imperial Valley, California

By

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Before the use of filters, the fumes of smelters caused a heavy deposit of arsenic on plants and in soil for many miles around their location resulting in heavy honey bee kills. In recent years the use of filters and precipitation processes necessitated by concerns to reduce air pollution have removed most of the previously injurious chemicals out of the emissions from smelters (1).

Because air pollutants have moved into many agricultural areas, studies were conducted to determine if ozone and fluorine gas, two smog components, were detrimental to honey bees, *Apis mellifera* L.. Ozone was determined to be toxic to bees at continuous levels of 0.5 ppm killing worker bees at an accelerated rate thus shortening their adult lifespan 10% An ozone level of 0.25 ppm is common in the Los Angeles basin for 4 to 6 hours per day during part of the year. Other plant research has shown that crops foraged by bees — citrus and alfalfa, for example — are damaged by ozone well below 0.5 ppm. Thus, bees are more ozone-tolerant than their forage plants (2).

Fluorine gas was determined to be somewhat toxic to worker honey bees from continuous exposure to 4-5 ppb. The toxicity is expressed as an early acceleration of mortality of bees thus shortening their lifespan 13% at the time that worker bees are performing as foragers and pollinators, two of the important divisions of labor in a bee colony. On the other hand, many plants tested for adverse effects from fluorine are more seriously affected than are the bees (3). The effect upon the plants then also becomes important in that the foraging area from which bees gather nectar and pollen is diminished. The bees must be moved to prevent starvation.

The above studies indicated that emissions of geothermal pollutants might exert an effect on the beekeeping industry in Imperial Valley. Therefore, studies were conducted to determine the mortality and lifespan of worker honey bees exposed continuously to hydrogen sulfide, sulfur dioxide and carbon dioxide as air pollutants.

Effect of Hydrogen Sulfide as an Air Pollutant to Honey Bees

Hydrogen sulfide ($H_2S$) gas as an atmospheric air pollutant was researched to determine the environmental effects on the lifespan and mortality of exposed honey bee workers. This research was supported in part by: LLL Contract W-7405-ENG-48 US ERDA.

PROCEDURE

Controlled gas fumigation of caged honey bee workers were made in greenhouses operated at the Statewide Air Pollution Research Center, under the direction of Dr. C. Ray Thompson, whereby the effects on the lifespan and mortality of the bees subjected to continuous exposure to various concentrations of $H_2S$ were determined. During the tests the greenhouses were utilized to study the effects of $H_2S$, $CO_2$ and $SO_2$ on black lettuce, sugar beets, cotton, Hayden alfalfa, silver and big-leaf maple, Thompson seedless grapes and 2 species of pine trees growing in concainers. These plants required occasional chemical control of mites, aphids and caterpillars. Appropriate selective pesticides, which had a short residual activity and possessed low bee hazard, were applied with a frequency of approximately every 7 to 14 days. At the time of application the caged bees were precautoinarily removed from the smog houses prior to pesticide application and remained outside the chambers for a period of 24 hours.

Honey bees for the tests were obtained from the UCR, Dept. of Entomology Apiary colonies by shaking bees from hive frames into a stock bee cage. In the laboratory, honey bee workers were aspirated from the stock bee cage selecting only young individuals. Approximately 25 bees were transferredinto each 14- by 14- by 14-cm, 0.32 cm-mesh hardware cloth cage provisioned with a 15 ml glass vial containing honey-water (1:1) solution and stoppered with a cotton plug. Four to 5 cages were used as replicates for each dosage of $H_2S$ gas fumigation and for the carbon-filtered untreated check for each test series. A hydrothermograph was placed in the greenhouse to record the ambient temperature and relative humidity during the test. The feeders were replenished every 5 to 7 days. Mortality readings were recorded daily near mid-day. The cages, feeders and cage closures are those described in pesticide/bee toxicity laboratory tests (4).

The data obtained from the various treatments were corrected anainst the untreated checks for each series to determine the net effect caused by the treatment (5). The tests were repeated a minimum of 3 times at each dosage used. The continuous exposure dosages utilized were: $H_2S$ @ 300 ppb; 100 ppb; 30 ppb; and the combination of $H_2S$ @ 300 ppb + $CO_2$ @ 50 ppm.

## DISCUSSION & RESULTS

The data from the tests are summarized in Table 1 and Figure II. Table 1 gives the mortality as the lethal dose (LD) and lifespan (LS) of honey bee workers exposed to $H_2S$ gas as an air pollutant. The data for each dosage was calculated as a linear regression analyses to obtain the $LD_{10}$, $_{50}$ and $_{90}$ values expressed as the number of days of lifespan. The correlation coefficient value and number of probits for the slope and intercept are indicated as well as the range of percent mortalities for caged bees and all tests in the series at each indicated dosage. Figure II presents the linear regression data graphically as a time-mortality curve. It is interesting to note that as the continuous dosage increased the slope (hazard potential) increased progressively. These data indicate that worker honey bees' lifespan ($LS_{50}$) is lengthened (beneficial) 10.9 days (33.5%) when continuously exposed to 30 ppb $H_2S$ than is the lifespan of unexposed bees; that when bees are continuously exposed more than 13 days to 100 ppb $H_2S$, the lifespan ($LS_{50}$) is shortened (detrimental) 10.4 days (32%) than is the $LS_{50}$ of the check bees; and, than when bees are continuously exposed more than 14 days to 300 ppb of $H_2S$, the lifespan ($LS_{50}$) is shortened 16.5 days (50.8%) than is the $LS_{50}$ of the unexposed bees. When bees are continuously exposed more than 15 days to the combination of 300 ppb $H_2S$ + 50 ppm $CO_2$, the lifespan ($LS_{50}$) is shortened 0.7 day (4.4%) more than with 300 ppb $H_2S$ alone. The mean temperature and/or relative humidity did not exert a direct effect on the hazard to bees.

## APPRAISAL

These data show that continuous exposures to $H_2S$ gas as an air pollutant significantly shortens the lifespan of honey bee workers at concentrations of 100 ppb upwards. The $LD_{50}$ is 123 ppb at 19 days of continuous exposure. The $CO_2$ in the combination of 300 ppb $H_2S$ + 50 ppm $CO_2$ is more hazardous than 300 ppb of $H_2S$ alone.

The significance of these data under natural conditions needs to be considered in relation to the levels and duration of the levels of $H_2S$ found in nature in specific areas. Another consideration is whether plants attractive to bees can withstand these levels of $H_2S$. In other words, if no plants can survive in the area, honey bees will not be present because of the absence of food plants.

We need further data to determine the effect on honey bees of exposure to $H_2S$ at various dosages and for various intermittant periods of daily exposure.

Companion studies on plants which were conducted concurrently with the bee fumigation exposures, gave fumigation effects on alfalfa and cotton, two agricultural crops bees utilize for food foraging in Imperial Valley. Continuous fumigations in greenhouse grown alfalfa showed that $H_2S$ at 3000 ppb caused leaf lesions, defoliation, reduced growth and death of sensitive plants; $H_2S$ at 300 ppb caused lesser but similar effects; $H_2S$ at 100 ppb caused no effect on yield; and, $H_2S$ at 30 ppb caused significant stimulation in alfalfa during summer months (6). Also in alfalfa, Medicago sativa, adding 50 ppm $CO_2$ to 300 ppb $H_2S$ overcame growth depression caused by $H_2S$ alone or increased growth above controls. In cotton, Gossypium hirsutum, the fresh weight of leaves and dry weight of leaves and stems were unaffected by 300 ppb $H_2S$ but the addition of 50 ppm $CO_2$ caused an increase in weight (growth) over $H_2S$ alone (7). These studies also imply that plants which grow slowly, such as the native plamt species outside the agricultural crop areas , are generally more tolerant to air pollutants.

## Effect Of Sulfur Dioxide As An Air Pollutant On Honey Bees

Sulfur dioxide ($SO_2$) gas as an atmospheric air pollutant was researched to determine the environmental effects on the lifespan and mortality of exposed worker honey bees.

### PROCEDURE

Controlled gas fumigations of caged honey bee workers were made in the same facilities and in the same way as the hydrogen sulfide tests. The data obtained from the various treatments were corrected against natural mortality in the untreated checks for each series to determine the net effect caused by the treatment (5). The tests were repeated a minimum of 3 times at each dosage utilized. The continuous exposure dosages utilized were $SO_2$ at the rate of 300 ppb at mean temperatures of (1) 16.7°C and (2) 27.2°C.

### DISCUSSION & RESULTS

The data from the tests are summarized in Table 2 and Figure III. Table 2 gives the mortality as the lethal dose and lifespan of honey bee workers exposed to 300 ppb of $SO_2$ gas as an air pollutant at mean daily temperatures of 16.7°C and 27.2°C. The data for each treatment was calculated by linear regression analyses to obtain the $LD_{10}$, $_{50}$ and $_{90}$ values expressed as the number of days of lifespan. The correlation coefficient value and the number of probits for the slope and intercept are indicated as well as the range of percent mortalities for all caged bees and all tests in the series at each indicated treatment. Figure III presents the linear regression data graphically as a time-mortality curve. It is interesting to note that the continuous dosage of 300 ppb $SO_2$ at a mean temperature of 16.7°C shortened the honey bee workers lifespan at $LS_{50}$ 7.5 days (23%) more than the lifespan of the check bees: at a mean temperature of 27.2°C shortened the honey bee workers lifespan at $LS_{50}$ 26.5 days (81.3%) more than the lifespan of the check bees. The effect of the 10.5° increase in the mean temperature over the 16.7°C level reduced the lifespan 19 days (75.7%) with the same dosage of $SO_2$.

## APPRAISAL

These data show that $SO_2$ at a continuous exposure to 300 ppb was detrimental to honey bee workers; and, the higher mean temperature of 27.2°C was more highly toxic than the same dosage at 16.7°C. Therefore, both dosage and temperature are important considerations.

The significance of these data under natural conditions would need to be considered in relation to the levels and duration of the levels od $SO_2$; and in relation to the mean temperature prevailing during the pollution incident — the higher the temperature : the higher the hazard to honey bees. Another consideration, of course, is whether plants attractive to bees can withstand these levels of contamination. In other words, if no plants can survive in the area, honey bees will not survive because of the absence of food to forage upon.

We need further data to determine the effect on honey bees of exposure to $SO_2$ at other continuous dosages as well as at other intermittant periods of daily exposure. We also need further studies at other lower and higher mean temperatures within the range of temperatures that honey bees forage.

### Lifespan Of Smog-Free Bees

During the above tests studying the effect of $H_2S$, $CO_2$ and $SO_2$ on honey bees, the time-mortality curve for life expectancy (lifespan) of caged untreated honey bee workers in smog-free air was determined. These data are summarized in Figure IV. These data show that caged unexposed honey bee workers had a lifespan for 50% mortality ($LS_{50}$) of 14.7 days and a $LS_{90}$ of 39.8 days.

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# PART II

## Status Of The Apicultural Industry In The Imperial County, California

By

E. L. Atkins

A brief characterization of Imperial County in relation to the apicultural industry follows. In the absence of man, the vegetation of the Imperial Valley would be a creosote bush and bur bush desert community. However, because of man, there is a large irrigated agricultural area as well as a large inland salt water sea. Four ecological systems are present in the Imperial Valley: the agricultural, the Salton Sea, the wildlife refuges, and, the native desert communities (3). Imperial Valley is the only known section in California where there is a scarcity of pollen. Consequently honey bee colonies commonly cease rearing brood during October, November and December.

### The Agricultural Community

The climate of the Imperial Valley makes the area one of the most valuable agricultural resources in the nation. Imperial Valley is recognized as the nations winter vegetable source. During the 1965-1977 period, there were approximately 500,000 acres in agriculture production that generated an average gross sales of $390.3 million. Of this $390 million field crops accounted for an average of $154.9 million; livestock and livestock products, $112.7 million; vegetable crops, $93.7 million; seed and nursery, $5.7 million; and, apiary and apiary products and pollination services added $0.73 million (Table 7). These 500,000 acres are composed of more than 8,000 parcels and encompass approximately 17% of the county. Imperial Valley constitutes the largest contiguous area of irrigated agriculture in the Western Hemisphere. The climate of the area is hot and dry with an average annual rainfall of 6.9 cm and a maximum temperature over 38°C for more than 110 days per year.

The agricultural and native desert communities as they relate to the apicultural industry will be delt with in more detail.

The agricultural community was thoroughly explored by others (3). However, it should be explored in relation to the honey bee/agricultural interface.

There are approximately 35 commercial beekeepers in the county with 40 or more colonies. They manage an average of 40,000 colonies of honey bees. The number of colonies, the value of apiary products (honey, beeswax and pollination services) provide an average annual income of $732,272 (Table 3 ). It should be noted that of this income 67% is from honey, 3.9% from beeswax and 29% from pollination service rentals.

The breakdown of number of honey bee colonies and unit values of apiary products and pollination services are detailed in Table 4. These data were compiled from the Annual Reports of the Agricultural Commissioner (6-14). The honey bee colonies are usually protected from the sun and high ambient and soil temperatures by permenant ramadas (shades) spaced throughout the agricultural area and also throughout the native plant communities. The ramadas are located approximately every one-half mile and groups of 20 to 40 colonies of bees occupy them sometime during the year (15). It is estimated that 40% of the ramadas are occupied throughout the year; whereas, 60% of the ramadas are unoccupied during the winter months. During the winter months, when there is a dearth of pollen and nectar for the number of colonies in the valley, the colonies are moved to locations along the Colorado River; in foothills of San Diego County for avacodo and sage forage; to Arizona and Utah; and, to the San Joaquin and Sacramento Valleys of California for almond pollination.

In addition to the bee colonies registered in the county by Imperial County beekeepers an average of another 10,000 colonies of bees are in the county during the spring and summer. It is believed that most of these 10,000 colonies are owned by Imperial County beekeepers who register a portion of their colonies in San Diego County since the bees are wintered in that county.

There is an organized Imperial County Beekeeping Association which is not currently active. It is composed primarily of the commercial beekeepers and is not affiliated with the California State Beekeepers Association.

In Table 5 the 11-year average agricultural commodity income in Imperial County is given in relation to its dependence upon the apicultural industry. Apiary and apiary products income is given. Commodity income which is bee related is given in a breakdown of bee pollination necessary, enhanced or indirect. The crops requiring bee pollination are self-explanatory since these crops cannot be produced in commercially economical quantities without bee pollination. Bee pollinationenhanced indicates those crops which can be commercially produced without bee pollination, however, it has been demonstrated that cross-pollination significantly increases the quantity and/or quality of the crop. Indirect bee pollination dependence includes those crops such as alfalfa whose seed can only be produced commercially by utilizing honey bee pollination. Alfalfa for hay cannot be grown without alfalfa seed produced by bee pollination; cattle and dairy cows depend upon alfalfa hay for a significant portion of their food ration. The portion of cattle finishing ration which is composed od alfalfa hay is 20%; the portion of dairy cow ration which is composed of alfalfa hay is

55% (16).

The total value of bee pollination dependent commodities is $90.8 million which is 24.5% of the total Imperial County agricultural income of $370.3 million. Of the $90.8 million bee related income, apiary and apiary products comprise 0.81%; crops requiring bee pollination, 20.8%; crops enhanced by bee pollination, 0.44% (for a total of 22% from direct bee dependence and commodities indirectly bee dependent comprise 78%.

The value of non-bee dependent commodities total $279.5 million. The values for cattle and dairy have been adjusted by the amount indicated which is attributed to alfalfa hay. Other non-bee dependent commodities are crops such as field grains, sugar beets and vegetables which total $192.3 million.

Table 6 presents a recapitulation of the 11-year average acerage of agricultural crops grown and quantity of animal and animal products in Imperial County divided into bee foraged versus non-bee foraged crops. These basic data were adapted from the Imperial County Agricultural Commissioner Annual Reports (6-14). This recapitulation demostrates that 27.2% of the total acerage grown in the county comprises bee foraged crops and 72.8% comprises non-bee foraged crops. Some of the acerage is double-cropped, that is, more than one crop is harvested from the same acerage during a 12-month interval.

Table 7 presents a recapitulation of the 11-year average dollar value of agricultural commidity income in Imperial County. Of the total average agricultural commodity income of $370.3 million, field crops account for 41.8%; vegetable crops, 25.3%; livestock and dairy, 30.4%; fruit and nut crops, 0.53%; seed and nursery, 1.5% and, apiary, 0.2%, respectively.

It is my opinion that these data portray the importance, dependence and interrelationships of the apicultural industry to agricultural crops and commodities in Imperial County.

## Cities and Towns

The cities and towns comprise approximately 3.6% of the area. Ornamentals and various species of eucalyptus trees provide substantial bee forage in the residential areas..

## The Salton Sea Community

The Salton Sea community offers very little which relates to the apicultural industry (Table 8).

## The Wildlife Refuges Community

The wildlife refuges community share much of their attributes with the Salton Sea community with which they are closely associated. Consequently, they offer minimal foraging support to the apicultural industry (Table 8).

## The Desert Communities

The desert communities comprise about 73% of the county area and contain various plant species which provide a succession of honey bee forage for extended periods of time throughout the year. The plant species which survive in this area are mostly all utilized by honey bees for nectar and/or pollen. The breakdown of the native flora occurring here which are utilized by bees are listed in Table 8.

These flora are very important to honey bees by providing sustaining nectar and/or pollen for brood rearing. Creosote bush or greasewood is chiefly of value to stimulate brood rearing. Taken together they provide substantial bee forage when the colonies are located outside of the agricultural area.

This inventory of farm commodities, crop and native flora, honey bee food sources, will be useful at a future time to determine significant shifts in plant species occurring in the county. Honey bee food source shifts, removal or additions can be monitored to determine if geothermal development displacements or shifts of plant species occur.

Verification of plant species as honey bee forage plants was made using references cited (1-5).

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## DISCUSSION & CONCLUSIONS

The environmental impact on honey bees, Apis mellifera L., of geothermal emissions contemplated in Imperial County have been explored together with the status of the apicultural industry and its relation to the well being of agriculture.

Honey bees are known to be capable of avoiding stress factors such as noxious gases ans small dust particles for short periods of time (cir. 15 seconds) by temporary spiracle closure. Honey bees continuously exposed to certain doses of hydrogen sulfide, sulfur dioxide and carbon dioxide showed no discernible behavoiral responses.

Honey bee disturbances at crital periods such as intermittant high level noise will temporarily stop bee foraging. However, since bees adjust, noise is usually not a factor of continuing importance.

Honey bee colony productivity can be affected by temperature, density or number of colonies per acre, quantity and quality of plants, and, honey bee diseases.

Temperature: It is common practice in Imperial County to erect and maintain permenant or temporary sunshades for honey bee colonies. Ambient temperatures exceed 38°C for over 100 days a year and have ground surface temperatures reaching or exceeding 65.6°C. Beeswax melts at approximately this temperature. Additionally it is imperative that water of a quality bees will use is available to enable bees to cool their brood nest to 34.4°C.

Honey production is dependent upon the following factors: 1) colony weight gain per day (this can be used to quantify condition of bee colonies in an area); 2) density or number of colonies per acre (if too many colonies of bees are located in an area for the amount of forage available, no surplus honey will be stored; there can be a net loss because bees will use up hive stores); 3) cotton, alfalfa and citrus in the Imperial Valley are primary sources of honey production in the agricultural areas; 4) native plants in the desert area are also primary nectar sources for honey production and colony sustenance; 5) plant nectar availability varies with temperature and water stresses (data is available indicating that seed alfalfa and cotton cease nectar secretion completely near mid-day in many instances).

The success of honey bees as pollinators of agricultural crops and as honey producers depends upon plant condition. This is an indirect effect.

If bee attractive plants are growing under optimum conditions, then honey bees should be effective pollinators and/or honey producers.

Efficacious honey bee pollination depends on the frequency and duration of visits to plants. Bee foraging profiles are available for many agricultural crops (1). Seed alfalfa and seed onions require honey bees for effective pollination to set seeds. All cucurbits and tangerines require honey bees for effective cross-pollination to assure maximum quantity and quality production.

Honey bees are attracted to plants by the availability of nectar and/or pollen. Honey bees will not be effective pollinators if the plants requiring bee pollination do not attract bees with available nectar and/or pollen. Adequate quantities of nectar are necessary to sustain the adult worker and adequate amounts of pollen are necessary to produce brood which in turn become the replacement workers in a colony. Adult workers live approximately 6 weeks during the active portion of the year. Therefore, honey bees must have adequate sources of nectar and pollen to be effective pollinators. The nectar and pollen do not have to come from the same plant source.

Honey bee diseases are kept under satisfactory control in Imperial County. Honey bee diseases, parasites and predators will probably not be affected by air pollution. There is no known indication that the incidence of disease or parasites of the brood or adults will be intensified or altered by geothermal development.

Honey bee colony response quantification is able to determine the effects of air pollution and/or pesticides using one or more of the following methods. Worker bee lifespan studies such as utilized in Part I on hydrogen sulfide, sulfur dioxide and carbon dioxide can be used to determine whether bees live longer, shorter or the same average length of time when exposed to pollutant emissions or pesticides. Worker bee and brood can be utilized with more highly toxic levels. Honey production can be quantified by determining actual amounts of surplus honey removed from colonies or on a short-term basis by colony weight gain or loss. Usually there is little or no surplus honey production while bees are being used intensively for pollination of agricultural crops. In fact, if sufficient numbers of colonies of adequate strength are provided, the numbers of foragers provided will usually prevent the gathering of surplus honey. This fact is utilized as a guideline to indicate an adequate availability of pollinators. Seed and fruit production can be quantified by measuring seed and fruit quantity and quality produced per colony of bees and average strength of colonies of bees used. Honey bee colony quality and strength can be determined by measuring the number of square inches of brood (eggs, larvae and capped brood) and number of worker bees present; pollen stores present (protein food) and honey stores present (carbohydrate food).

Controlling pests of agricultural crops is as important as good seed, sufficient rain or water of high quality, intelligent use of fertilizers and proper cultivation for economical production of an adequate supply of food and fiber for the increasing number of people throughout the world. Practically every plant has disease, insect or weed pests which significantly influence its growth. Agricultural chemicals or pesticides for specific purposes are utilized to alleviate the countless pests of plants. Therefore, individual problems are controlled with chemicals for specific uses such as acaricides, antibiotics, chemosterilants, defoliants, desiccants, fungicides, herbicides, insect growth regulators, insecticides, nematocides and plant growth regulators. Unfortunately, the honey bee is susceptible to many pesticides used in such an intensive pest control program. As a result, the honey bee is subjected to intensive and continuous chemical poisoning that overshadows other problems including bee diseases (2).

The practice of chemical control, the elimination of fences and open ditches has eliminated most of the solitary bees that once nested in such sites and served to pollinate the family orchard or crops on small farms. Most species of solitary bees are more susceptible to pesticides than is the honey bee. Consequently, the honey bee has become more important as the only significant manageable pollinator in the Imperial Valley. The hot and dry climate has added its effect in limiting the survival of other maneageable pollinators such as the alfalfa leafcutter bee, Megichile pacifica (Panzer), and the alkali bee, Nomia melanderi Cockerell. The honey bee is the only insect pollinator which can be increased easily and which can be moved quickly and in the desired numbers to the crop requiring pollination. Nevertheless, the beekeeping industry is having a difficult time maintaining an adequate number of bee colonies in the intensively cultivated areas because of losses from pesticide poisoning.

Research on the effect of pesticides has provided information which enables one to minimize losses of bees from pesticides (3, 4, 5).

Various integrated pest management strategies which can be used on agricultural crops to reduce pesticide kills of honey bees to protect the pollinating bees are: 1) using night applications instead of morning applications, if possible; 2) using lower dosages and/or less toxic and/or less persistent formulations of pesticides, if possible; 3) using combinations of pesticides which are less hazardous to bees than are the same pesticides applied separately; 4) pesticide and repellent studies have indicated the feasibility of reducing honey bee/pesticide hazards by adding a repellent to a toxic pesticide spray; 5) the distance bee colonies are located from a treated crop may be utilized for protecting the bees in honey producing colonies; 6) the new class of synthetic pyrethrums called pyrethroids, even though they are highly toxic to bees, can usually be applied safely if the applications are properly timed; 7) methods are available to predict the honey bee hazard of toxic pesticides.

There are other actions which can be utilized by the grower, the pest control advisor, the applicator and the beekeeper to protect honey bees and lessen the hazard of causing a serious bee kill when applyong pesticides.

Several people from Imperial County were interviewed to obtain their opinions regarding the effects of geothermal resources development on the agricultural industry and the apicultural industry. The Agricultrual Commissioner stated that he believed there would be no effect on alfalfa hay or citrus because hydrogen sulfide and sulfur dioxide will be below the adverse effects level. Geothermal electricity generation would be beneficial because it would provide primary employment; generate secondary sources of employment. Tax revenue would rise in general because of a higher tax base. Electricity cost would not be lower, but more electricity would be available (6).

The Director of the University of California Agricultural Cooperative Extension Service stated that there would be little effect overall. That geothermal plants will take out some agricultural land and that electric transmission lines may cause some problems. Pollutants may cause problems at certain times. He thought that geothermal electricity generation would provide the needed additional energy source; that related agricultural industries will probably come into the area; and, that the additional electrical energy may help workers economically who possess needed skills required in intensified agri-business (7).

The Secretary/Manager of the Imperial County Farm Bureau believed that geothermal electricity generation will generally be beneficial to the county; that the Farm Bureau was pro geothermal energy, pro nuclear energy, and there would be some minor agricultural benefits. There will be tradeoffs. On the negative side he believed that transmission lines will be a problem; that cooling water will consume some of the water needed for agriculture; that geothermal activity will displace around 2 to 4 percent of the agricultural crops and that these probably cannot be replaced because of a general lack of water and/or location of new agricultural areas further from available sources of water. Essentially all land which is farmable is being farmed. The important limitation is water (8).

The opinion of the Executive Director of the Imperial Irrigation District was that geothermal development would be beneficial to the county providing a source of energy at a lower cost than either nuclear or fossil fuel generated electricity; releaving the dependence on oil and coal. There was a possibility that agricultural land prices would increase by $500 per acre; that there would be no displacement of agricultural crops; and, that there would probably be no effect on water supplies (9).

The view of the Manager of the Imperial Valley Growers was that vegetable crops would benefit in that geothermal development would bring in freezing plants as an expansion; that geothermal generated energy would decrease need for oil and coal burning; that pollution from geothermal development does not offer a problem; and, that there will be no problem with land use in most cases. On the other hand, water needsin the area, already with a short supply, might cause a conflict (10).

A resident beekeeper and owner of the American Honey Company believed that there would be no unsolvable problems for the apicultural industry (11).

The author's opinion is generally the same as the views of those interviewed. There will be some minor problems which can be solved over a period of time. Overall, however, geothermal resource development in Imperial Valley will be beneficial to the apicultural and agricultural industries.

DISCUSSION & CONCLUSIONS

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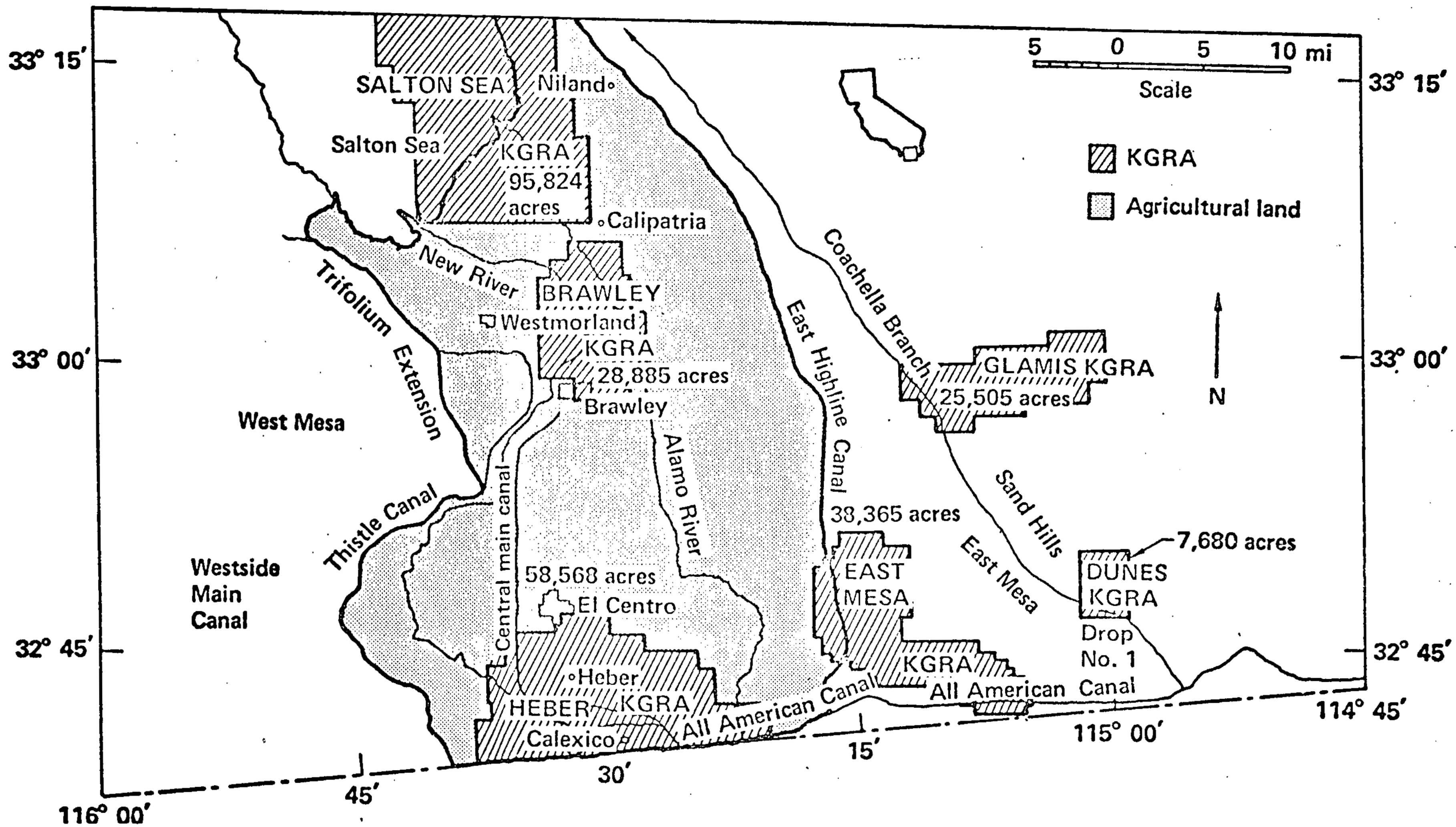


FIGURE I — Known Geothermal Resource Areas (KGRA) in Imperial County, California

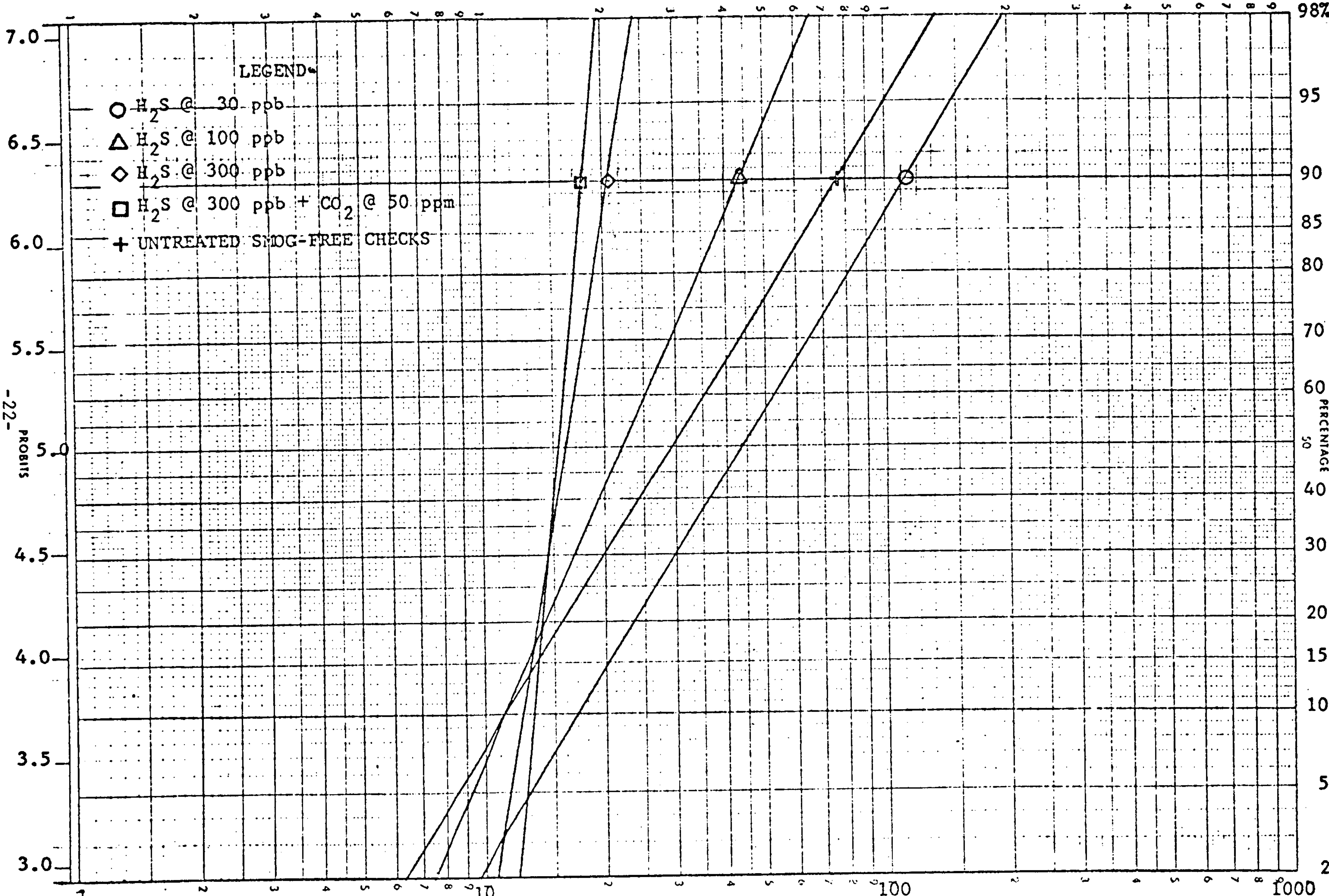


FIGURE II - TIME/MORTALITY CURVE: DAYS OF CONTINUOUS TREATMENT OF $H_2S$ & ITS EFFECT ON WORKER HONEY BEE LIFESPAN.

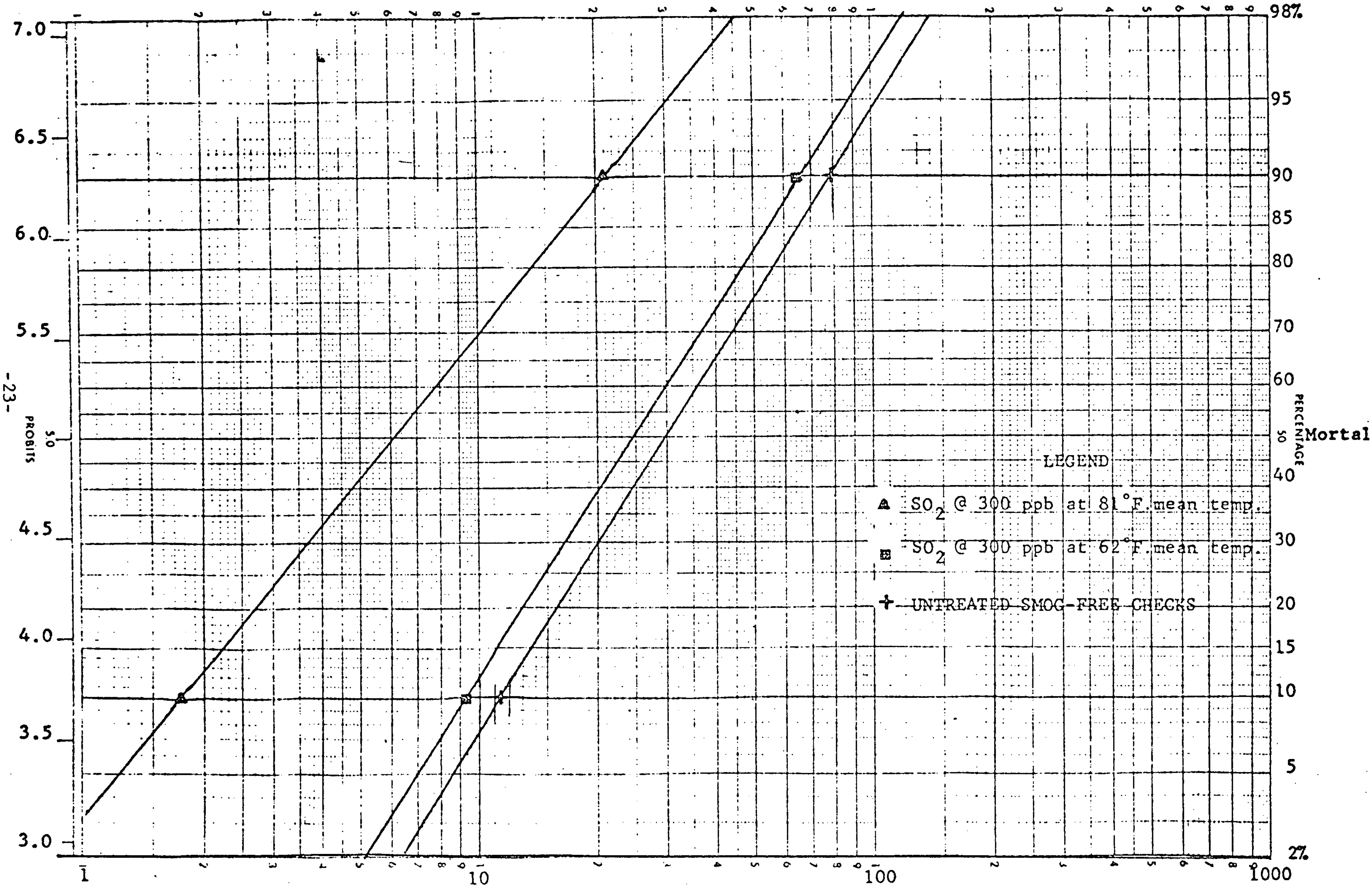


FIGURE III-DAYS OF CONTINUOUS TREATMENT OF $SO_2$ & ITS EFFECT ON HONEY BEES. Time/Mortality Curve

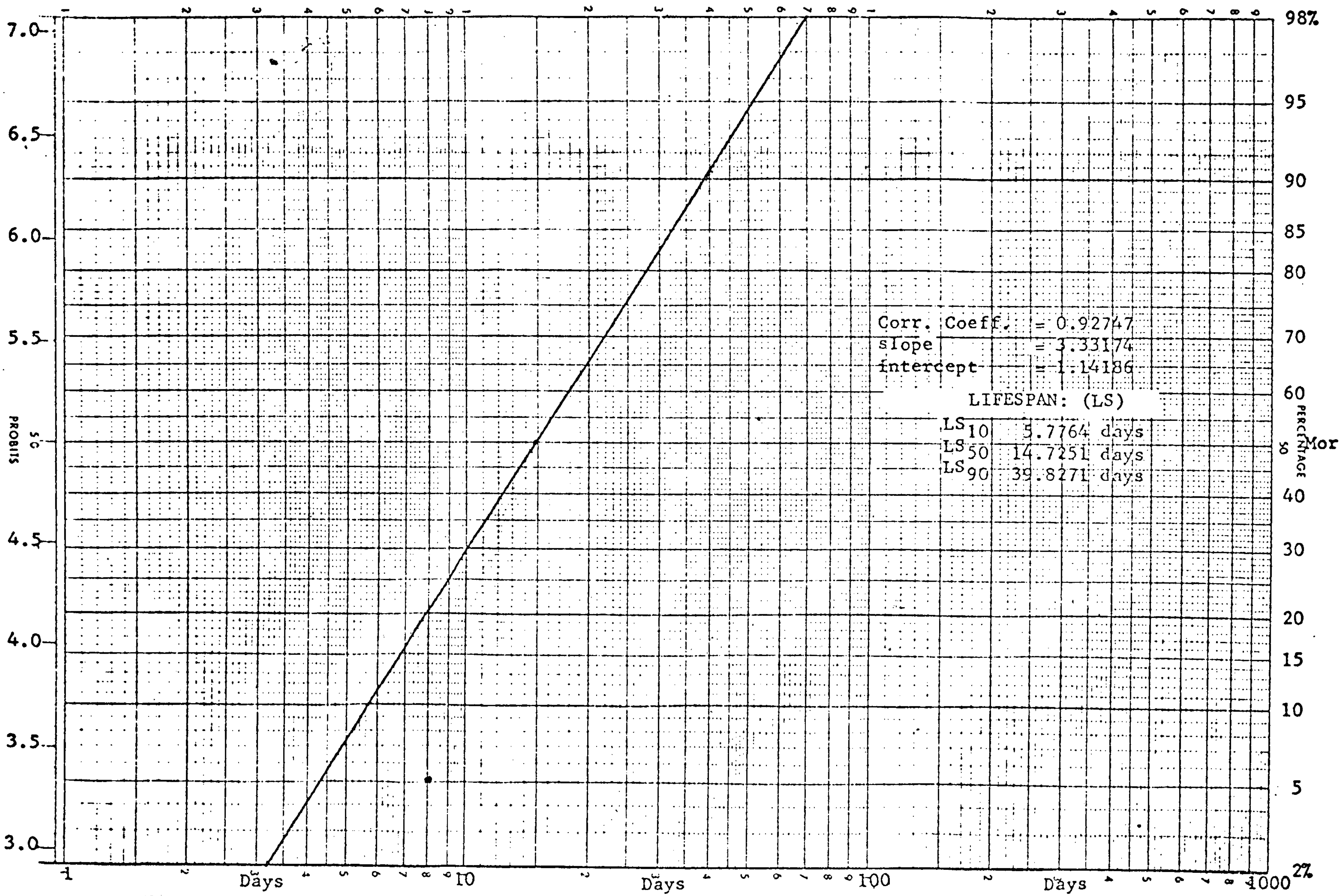


FIGURE IV — TIME-MORTALITY CURVE: Days of Lifespan of Caged Untreated Worker Honey Bees in Smog-free Air.

## APPENDIX

TABLE 1 — The Lifespan & Mortality Of Honey Bees Exposed To Hydrogen Sulfide Gas As An Air Pollutant, 1976-77

| Continuous Exposure Dosage | $H_2S$ @ 30 ppb | $H_2S$ @ 100 ppb | $H_2S$ 300 ppb | $H_2S$ @ 300 ppb + $CO_2$ @ 50 ppm |
|---|---|---|---|---|
| Correlation Coefficient | 0.97623 | 0.87025 | 0.93836 | 0.96171 |
| Probits: | | | | |
| Slope | 3.87485 | 4.37322 | 12.64327 | 20.80678 |
| Intercept | −1.18613 | −0.84141 | −10.14931 | −19.58215 |
| % Mortality (LD) | Lifespan (LS), Number of Days: [1] | | | |
| 10 | 17.6 (15-20) | 11.4 (4-16) | 12.5 (12-13) | 13.3 (13-14) |
| 50 | 43.4 (35-52) | 22.1 (10-33) | 16.0 (15-17) | 15.3 (14-16) |
| 90 | 119.3 (61-178) | 44.2 (28-66) | 20.5 (18-23) | 17.7 (16-19) |

[1] First number is average number of days to reach lifespan (LS) % mortality indicated; numbers in paranthèses give the range of % mortalities for all caged bees and all tests in series at each indicated dosage utilized.All data from treated series corrected against untreated bees' lifespan using Abbott's formula.

TABLE 2 — The Lifespan & Mortality Of Honey Bees Exposed To Sulfur Dioxide Gas As An Air Pollutant, 1976-1977

| Continuous Exposure Dosage | $SO_2$ @ 300 ppb 16.7°C | $SO_2$ @ 300 ppb 27.7°C [1] |
|---|---|---|
| Correlation Coefficient | 0.90251 | 0.89421 |
| Probits: | | |
| Slope | 10.30056 | 2.29851 |
| Intercept. | −7.95173 | 3.31044 |
| % Mortality (LD) | Lifespan (LS), Number of Days: [2] | |
| 10 | 12.1 (8.7-15) | 1.8 (1.5-3) |
| 50 | 25.1 (16-39) | 6.1 (3.4-8.5) |
| 90 | 79.5 (20-197) | 22.0 (15-27) |

[1] Mean daily temperature during exposure.

[2] First number is average number of days to reach lifespan (LS) % mortality indicated; numbers in parantheses give the range of % mortalities for all caged bees and all tests in series at dosage and indicated mean temperature utilized. All data from treated series corrected against untreated bees' lifespan using Abbott's formula.

TABLE 3 — Number of Honey Bee Colonies and Value of Bee Products & Pollination Services in Imperial County, California

| | APIARY PRODUCTS | | | | |
|---|---|---|---|---|---|
| Year | Number of Colonies | Honey Value, $ | Wax Value, $ | Pollination Value, $ | Annual Industry Value, $ |
| 1965 | 51,000 | 342,000 | 27,000 | 65,000 | 434,000 |
| 1966 | 47,000 | 295,000 | 22,000 | 83,000 | 400,000 |
| 1969 | 31,000 | 164,000 | 15,000 | 159,000 | 338,000 |
| 1970 | 34,000 | 143,000 | 10,000 | 100,000 | 253,000 |
| 1971 | 35,500 | 293,000 | 16,000 | 162,000 | 471,000 |
| 1972 | 42,000 | 529,000 | 17,000 | 150,000 | 696,000 |
| 1973 | 39,000 | 1,196,000 | 32,000 | 250,000 | 1,478,000 |
| 1974 | 42,000 | 766,000 | 47,000 | 298,000 | 1,102,000 |
| 1975 | 40,000 | 677,000 | 43,000 | 327,000 | 1,047,000 |
| 1976 | 40,000 | 535,000 | 35,000 | 390,000 | 960,000 |
| 1977 | 38,000 | 459,000 | 54,000 | 363,000 | 876,000 |
| 11-yr av | 39,955 | $490,818 | $28,909 | $212,545 | $732,273 |
| % of Total: | | 67% | 3.9% | 29% | 100% |

TABLE 4 — Quantity & Unit Value of Apiary Products & Pollination Services in Imperial County, California

| | HONEY | | | WAX | | POLLINATION | |
|---|---|---|---|---|---|---|---|
| Year | Yield, Lbs/Col | Production, Lbs | Price Per Lb | Product-ion, Lbs | Value, $ | No. Of Colonies | Income Per Colony, $ |
| 1965 | 67 | 3,417,000 | 0.10 | 57,000 | 0.48 | 17,000 | 3.82 |
| 1966 | 57 | 2,679,000 | 0.11 | 44,600 | 0.50 | 21,200 | 3.91 |
| 1969 | 44 | 1,364,000 | 0.12 | 22,700 | 0.67 | 37,700 | 4.85 |
| 1970 | 30 | 1,020,000 | 0.14 | 17,000 | 0.61 | 22,000 | 4.54 |
| 1971 | 40 | 1,420,000 | 0.206 | 25,000 | 0.64 | 32,000 | 5.06 |
| 1972 | 40 | 1,680,000 | 0.315 | 26,000 | 0.65 | 26,000 | 5.77 |
| 1973 | 66 | 2,600,000 | 0.46 | 41,000 | 0.78 | 29,000 | 8.62 |
| 1974 | 48 | 2,016,000 | 0.48 | 39,000 | 1.20 | 29,000 | 9.97 |
| 1975 | 47 | 1,880,000 | 0.36 | 38,000 | 1.13 | 34,500 | 9.48 |
| 1976 | 36 | 1,447,000 | 0.37 | 29,000 | 1.21 | 39,500 | 9.87 |
| 1977 | 31 | 1,178,000 | 0.39 | 29,800 | 1.82 | 35,800 | 10.14 |
| 11-yr av: | 46 | 1,881,909 | 0.277 | 33,555 | 0.881 | 28,973 | 6.91 |

TABLE 5 – Eleven-Year Average Agricultural Commodity Income In Imperial County And Its Dependence Upon The Apicultural Industry

| Bee & Bee Related Commodity | | BEE POLLINATION DEPENDENCE | | | Totals |
|---|---|---|---|---|---|
| | | Necessary | Enhanced | Indirect | |
| Apiary, apiary products | $732,273 | | | | |
| Seed Crops: | | | | | |
| Alfalfa | | $1,637,636 | | | |
| Misc. Vegetable & Flowers | | 1,872,545 | | | |
| Cantaloupe | | 10,303,455 | | | |
| Cucumber | | 326,750 | | | |
| Melons, other | | 1,436,818 | | | |
| Squash | | 991,818 | | | |
| Watermelon | | 2,054,909 | | | |
| Tangerine | | 248,000 | | | |
| Flax seed | | | $288,000 | | |
| Safflower | | | 115,500 | | |
| Hay, Alfalfa | | | | $48,495,909 | |
| Cattle | | | | 21,702,290 [1] | |
| Dairy cows, milk & milk products | | | | 583,310 [1] | |
| Value: | $732,273 | $18,871,931 | $403,500 | $70,786,509 | $90,794,213 |
| Percent: | 0.81% | 20.8% | 0.44% | 78% | 24.5% |

| Non-Bee Related Commodity | Value | Totals |
|---|---|---|
| Cattle | $86,809,160 | |
| Dairy cows, milk & milk products | 477,254 | |
| All Other | 192,256,673 | |
| Value: | | $279,543,087 |
| | | 75.5% |
| Total Agricultural Income: | | $370,292,300 |

[1] Portion of cattle finishing ration which is alfalfa hay, 20%; portion of dairy cow ration which is alfalfa hay, 55%.

TABLE 6 —RECAPITULATION — Eleven-Year Average Number Of Acres Of Agricultural Crops Grown & Quantity Of Animal & Animal Products In Imperial County, California: Bee Foraged Crops versus Non-Bee Foraged Crops

| Crop/Commodity | 11-Year Average Number Acres: Bee Foraged Crops | 11-Year Average Number Acres: Non-Bee Foraged Crops |
|---|---|---|
| Alfalfa, seed [1] | 9,545 | |
| Asparagus | 3,517 | |
| Cantaloupe [1] | 9,199 | |
| Citrus | (2,570) | |
| Grapefruit | 413 | |
| Lemon | 707 | |
| Orange, Valencia | 801 | |
| Oranges, other | 135 | |
| Tangerine [1] | 514 | |
| Cotton | 55,292 | |
| Cucumber [1] | 441 | |
| Date | 146 | |
| Flax | 1,968 | |
| Melons, other [1] | 881 | |
| Misc. Vegetables & Flowers, seed [1] | Unknown | |
| Milo, grain | 52,291 | |
| Safflower | 1,245 | |
| Sorghum, seed | 132 | |
| Squash [1] | 733 | |
| Sweet Corn | Unknown | |
| Tomato | 2,539 | |
| Watermelon [1] | 3,121 | |
| Alfalfa, hay | | 148,164 |
| Barley, grain | | 43,745 |
| Barley,Ryegrass, Triticale seed | | 746 |
| Cabbage | | 917 |
| Carrot | | 4,241 |
| Lettuce | | 42,254 |
| Mixed Vegetables | | 2,344 |
| Onions, dehydrated | | 1,597 |
| Onions, market | | 1,653 |
| Sorghum, sileage | | 1,349 |
| Sudan Grass | | 4,145 |
| Sugar Beets | | 61,250 |
| Wheat, grain | | 70,864 |
| Wheat, seed | | 1,478 |
| No. Acres: | 143,620 | 384,747 |
| Percent of Total: | 27.2% | 72.8% |
| | Total Acres: | 528,367 |

| Animals & Animal Products | Quantity |
|---|---|
| Cattle | 614,091 head |
| Sheep | 143,000 head |
| Hogs | 854 head |
| Chickens | 1,182 head |
| Eggs | 29,363 doz. |
| Milk | 161,490 cwt. |
| Wool | 700,182 lbs. |

[1] Bee pollination required (Total bee pollinated acerage > 24,434)

TABLE 7.– RECAPITULATION – Eleven-Year Average Value Of Agricultural Commodity Income In Imperial County, California

| Year | Field Crops | Vegetable Crops | Livestock & Dairy | Fruit & Nut Crops | Seed & Nursery | Apiary | Total Value, $ |
|---|---|---|---|---|---|---|---|
| | | | Thousand Dollars | | | | |
| 1965 | 94,862 | 36,440 | 64,405 | 1,331 | 2,714 | 434 | 200,186.2 |
| 1966 | 84,776 | 72,520 | 70,566.7 | 848 | 2,654 | 400 | 231,767.4 |
| 1969 | 88,551 | 66,522 | 88,264 | 988 | 1,939 | 338 | 246,602 |
| 1970 | 91,298 | 60,812 | 101,030.9 | 1,033 | 2,751 | 253 | 257,177.9 |
| 1071 | 109,404 | 80,089 | 107,687 | 1,318 | 2,316 | 471 | 301,785 |
| 1072 | 112,487 | 93,174 | 119,741 | 1,471 | 2,999 | 696 | 330,568 |
| 1973 | 169,871 | 119,102 | 190,644 | 2,234 | 6,440 | 1,478 | 489,770 |
| 1974 | 284,242 | 102,763 | 155,182 | 2,122 | 11,870 | 1,102 | 557,281 |
| 1975 | 215,967 | 142,288 | 127,224 | 2,896 | 10,780 | 1,047 | 500,202 |
| 1976 | 265,783 | 121,806 | 113,436 | 3,380 | 15,355 | 960 | 520,716 |
| 1977 | 186,408 | 135,301 | 101,670 | 3,865 | 9,040 | 876 | 437,160 |
| 11-yr Av | $154,877.2 | $93,710 | $112,713.7 | $1,953.4 | $5,730 | $732.3 | $370,292.3 |

TABLE 8 — Flora In The Native Desert Community Of Imperial County Utilized By Honey Bees As Forage For Obtaining Nectar & Pollen Sustenance

| GLAMIS KGRA | EAST MESA KGRA |
|---|---|
| (30% bajada mixed community)<br>ironwood, *Veronia* spp.<br>creosote bush, *Larrea tridentata*<br>mesquite, *Prosopis julifolia*<br>paloverde, *Cercidium floridum*<br>smoke tree, *Dalea spinosa*<br>desert gold, *Baeria chrysostoma*<br>browneyed primrose, *Oenothera* sp.<br>dune primrose, *Oenothera* sp.<br>plantain, *Plantago* spp.<br><br>(55% shifting dunes community)<br>wild sunflower, *Helianthus* spp.<br>prairie tea, *Croton palafoxia*<br>desert lily, *Hesperocallis undulata*<br>desert buckwheat, *Erigonium* sp.<br>ironwood, *Olneya Tesota*<br>smoke tree, *Dalea spinosa*<br>mesquite, *Prosopis julifolia*<br><br>(15% creosote bush forest comm.)<br>Area with up to 700 creosote bushes per acre; they never wilt<br><br>creosote bush, *Larrea tridentata*<br>ephedra, *Ephedra* spp.<br>mesquite, *Prosopis julifolia*<br>desert buckwheat, *Erigonium* spp. | (50% creosote bush community)<br>90%<br>creosote bush, *Larrea tridentata*<br>10%<br>ephedra, *Ephedra* spp.<br>cheese bush, *Hymenoclea Salsola*<br>brittle bush, *Encelia* sp.<br>coldenia, *Coldenia* sp.<br><br>(winter ephemerals)<br><br>jackass clover, *Wislizenia refracta*<br>desert gold, *Baeria chrysostoma*<br>plantain, *Plantago* spp.<br>cryptantha, *Cryptantha nevadensis*<br><br>(summer ephemerals)<br><br>sand mat, *Euphorbia* spp.<br>mustards, *Brassica* spp.<br><br>(40% dunes community)<br>Species present similar to those above but of 10% the plant density. |
| **SALTON SEA KGRA** | **DUNES KGRA** |
| (fresh water washes)<br>salt cedar, *Tamarix* spp.<br>arrowweed, *Plucha serica*<br>heliotrope, *Heliotropium* sp. | (50% creosote bush community)<br>Area with densities of creosote shrubs of approximately 100 plants per acre and existing plants are water stressed and are often wilted.<br><br>creosote bush, *Larrea tridentata*<br><br>(50% dunes community)<br>Area occupied by plant species similar to those listed for the Glamis shifting dunes community. |