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The Bug House
History of the Colorado Insectary, Palisade, Colorado

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THE COVER: By Julia Poole, Palisade, Colorado. Julia is a long time resident of the Grand Valley and works as an R.N. nationally. Art is her passion–especially water color.

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Colorado Insectary Building, Palisade Colorado. (Photo courtesy of author.)

The Bug House
History of the Colorado Insectary, Palisade, Colorado
By Carrie Clark*

The Colorado Insectary, located in Palisade, Colorado, was established in 1945 through a partnership with the Board of Control, Mesa County Peach Marketing Order (BOC) and the Colorado Department of Agriculture to mass produce, liberate, and observe a biological enemy (insect parasite) of the Oriental fruit moth, *Grapholitha molesta*. The Oriental fruit moth was, and still is, capable of destroying entire peach crops, and the use of pre-World War II chemical pesticides was not effective in controlling it.[1] In December 1944, the BOC passed a resolution to take the necessary steps to fund an insectary in order to help save the Grand Valley's peach industry,[2] which in 1943 alone had returned $7,500,000 in gross revenues to Grand Valley peach farmers. "The Bug House," as it has been fondly dubbed by locals, is an important part of the horticultural history of the Grand Valley, Colorado, and indeed the world. This paper will examine the conditions that existed, and the work already completed in Colorado and the Grand Valley leading up to the construction of

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the Colorado Insectary. The model used for the Insectary and the evolution of this operation over the next fifty-five years will also be discussed, demonstrating the effectiveness of biological alternatives to pesticides and herbicides in controlling insect and weed problems.

The Colorado Insectary was one of the first government sponsored, taxpayer supported operations for innovative biological pest control in the United States. Today there are six government supported insectaries nationally.[3] Chemicals would remain the first line of defense for other control problems orchardists were having with fungi, insect pests, and weeds, especially after the scientific discovery of "miracle" synthetic pesticides like DDT during World War II. However, by the mid 1960s resistance to these pesticides, public environmental concerns, and government regulations began to slow chemical use. By the mid 1970s biological insect pest control became a more environmentally sound solution, garnering a wider base of acceptance and support among the public and within the government. During this time the United States Department of Agriculture (USDA) and the Colorado Insectary expanded biological control research to include other crops, such as noxious weeds, through the use of natural insect predators. This method still has not replaced the use of pesticides and herbicides, but it does offer a safe, effective, and economical alternative for the control of many pests and weeds. Activities the Insectary are involved with today are the result of a long and evolving process that began in Colorado during the late part of the nineteenth century.

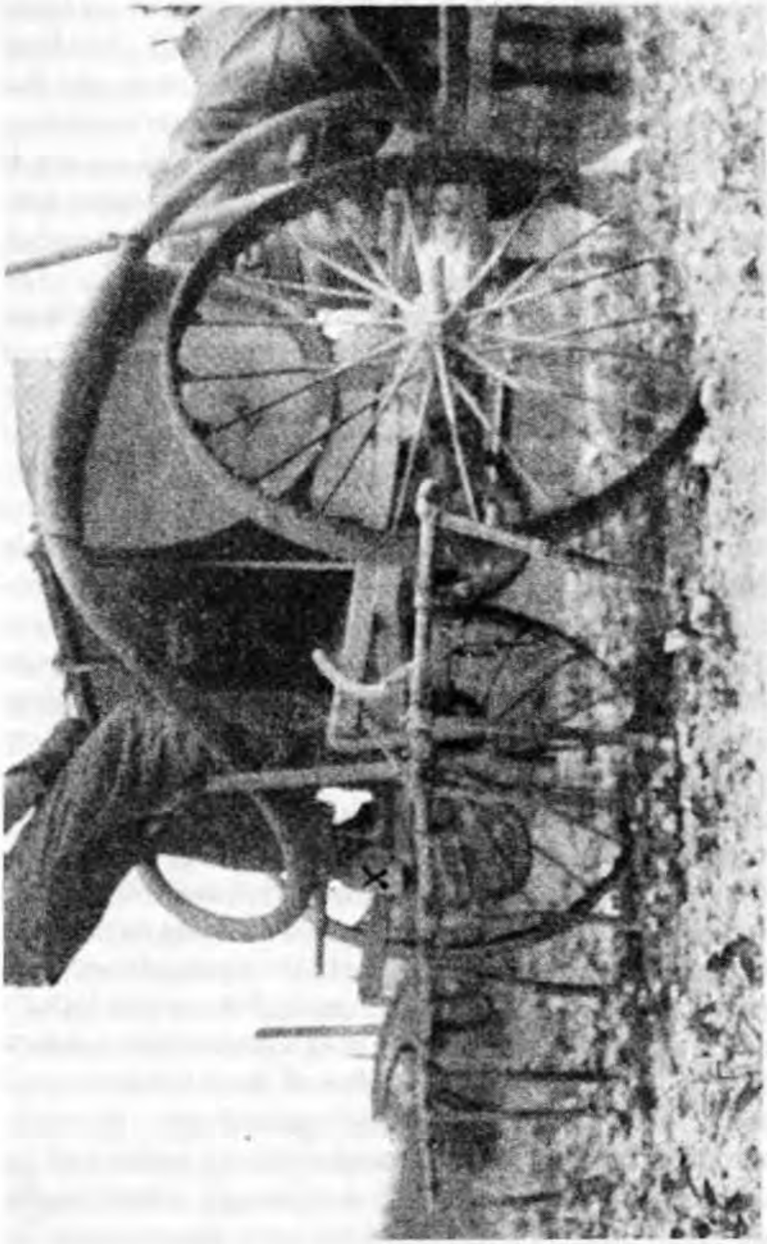
Entomology, the study of insects, began to play an important part in Colorado's agricultural history in 1875, the year before Statehood. During that year a plague of locusts infested what is now eastern Colorado prompting the Secretary of War to designate a "grasshopper appropriation" of

$138,000 to be used in relief work, providing food and clothing for farmers whose crops had been obliterated by the locusts.[4] Colorado's first Governor, John L. Routt, in his message to the First General Assembly of the State of Colorado on November 7, 1876, urged the appropriation of money to be used "in the investigations of the history, haunts, and means of exterminating this insect...," and also recommended that various states appoint their own Commissions of Entomologists to cooperate with the federal government and the United States Commission of Entomologists to suggest remedial measures, and investigate and issue bulletins of warning.[5] Colorado's legislature created such a commission in 1877 with an appropriation of $18,000 for "carrying on the work as outlined in the Act."[6] The Colorado General Assembly of 1883 enacted legislation creating the State Board of Horticulture, which included the work of the Entomologist. In 1907 the office of State Entomologist was created, followed by the establishment of the Bureau of Plant and Insect Control, with the State Entomologist as its chief, in the Code Bill of 1933.[7] The fact that the office of the State Entomologist is "perhaps the oldest Agriculture Regulatory Service of the State [of Colorado]," demonstrates the importance of insect control in Colorado.[8]

In 1900 Colorado was primarily a mining state, with mining revenues returning approximately $50,000,000 to the state during that year.[9] However, production of fruit and other agricultural crops was expanding, becoming another profitable element in the state's growing economy. By1945 agricultural-related industries returned revenues to the state in the amount of $300,000,000.[10] By 1943 the gross returns for peach farmers in "Mesa county-Palisade and Delta county [sic]" alone was $7,500,000, a large part of the Grand Valley's economic base.[11] In 1907, when the office of the State Entomologist was established, its focus was on nursery and orchard inspections for the growing agricultural industry. It was staffed with part-time employees who also taught entomology classes at Colorado State College in Fort Collins where the state office was located. The office was increasingly concerned over the importation of insects and plant diseases, without the importation of the natural parasites that held these pests in check in their native lands. The absence of this natural defense system could allow these pests to spread uncontrolled, causing damage to their new home.[12]

In 1925 the office of the State Entomologist released its seventeenth annual report, containing a summary of the work of the office for the state during that year. Activities with which the State Entomologist was involved were broad and extensive in scope, including inspections and control work on insect pests, rodents, and noxious weeds statewide. On the Western Slope control of the codling moth, alfalfa weevil, and Mexican bean beetle received much attention. Entomologists prepared life histories of the generations of these insects, and reported the results of experiments in different methods of control for them. In the case of the codling moth, which was seriously affecting pear and apple orchards, laboratory work recorded egg deposition, egg incubation, and moth emergence. At the time, application of chemicals was the standard method used to control this pest and other insects.

Chemical pesticides during this period, far different from pesticides used after World War II, consisted primarily of arsenical sprays (stomach poisons) which had to be ingested by the insect in order to kill. Commonly used was a lead arsenate based "soup" mixture. It was applied by spraying at various times during the season, based upon the calculated development of the generations of the insect to be controlled. Spray dates to maximize control of the codling moth



Horse drawn equipment spraying a bean field for Mexican bean beetles in 1925.

(Photo courtesy of Colorado Department of Agriculture.)

were published in the local daily newspaper and were based upon daily charts kept of the insect's activities.[13] The State Entomologist writing the 1925 report expressed concern that growers were not using this information to their advantage, showing indifference to spray dates and spraying too late to be effective. Lack of spraying equipment and varied thoroughness of spraying by individual growers also hindered efficient insect control.[14]

In addition to spraying, in 1922 aromatic insect traps began to be used for control, and to survey the extent of pest infestation in orchards.[15] In theory, if a trap (a wide mouthed quart fruit jar) containing an odorous solution of fermented boiled apple juice and an aromatic chemical that was attractive to the moth were hung in every tree, it would attract and trap the codling moth before eggs could be laid.[16] This would significantly reduce worm injuries to pears and apples by naturally removing the pest, and would also alert the grower to spray for control. Twenty-nine different aromatic chemicals had proven attractive to the codling moth. As with spraying, success of this type of control method depended upon the systematic cooperation of all growers. The State Entomologist believed this to be one of the most practical methods of control "because of the low cost, small amount of work necessary for operation, and the large number of moths that [could] be trapped."[17] Current traps, based on the same premise, are baited with synthetic pheremones of the chemical scent of an insect, producing specific responses from the targeted pest.[18]

A small portion of the State Entomologist's annual report of 1925 related to studies of the *Thrichogramma minutum,* an insect parasite of codling moth eggs. This natural insect predator would parasitize the egg of the codling moth by laying its own egg in the host egg, destroying the moth egg before it hatched and the larvae (worm) could do damage. A test was done in which eighty codling moth eggs were hung in a Bartlett pear tree for 24 hours. Entomologists examined the eggs and found 100 percent of them parasitized and dead. The entomologist writing the report, C. P. Gillette, felt that with a little artificial help this parasite could play an important role in codling moth control, stating, "This unworked phase of codling moth control should be investigated further, as no doubt there are some good possibilities connected with it."[19]

In 1911 the Eighteenth General Assembly of Colorado passed the Pest Inspection Act, providing for "the formation of pest districts for the control of injurious rodents, insects, weeds, and plant diseases," and had an annual budget of $2,000.[20] This act was succeeded by similar acts over the next several years. In 1924 the state legislature passed two bills relating to the organization of pest districts, one of which opened the door for a strong working relationship between the State Entomologist and the United States Bureau of Biological Survey, "with the Survey in charge of the control work in the field, but in accordance with a plan approved by the State Entomologist."[21] In 1936 the Colorado Division of Agriculture was organized under the State Administrative Code and the Bureau of Plant and Insect Control headquarters were moved from Fort Collins to Denver. The Bureau of Plant and Insect Control made a request to the General Assembly to "divorce completely" the Bureau from the State Agricultural College in Fort Collins and locate it all under one roof at the Colorado Division of Agriculture's office in Denver, located in the State Museum Building.[22] This request was fulfilled when the Colorado Department of Agriculture was created by an act of the 1949 Colorado General Assembly to be an administrative department in the executive branch of the state government primarily to consolidate under one department the state's numerous agricultural regulatory agencies. The Bureau of Plant and Insect Control was now a branch of this department and renamed the Plant Industry Division.[23] The groundwork was now laid for the peach producers in the Grand Valley to organize and get help from the state and federal government in protecting their livelihoods against harmful insects.

In the 1930s peach growers faced a major problem in Mesa County—the peach mosaic virus. In 1934, to help in the eradication of this deadly, insect-borne virus, a pest control district was formed in Mesa County by popular vote of local peach growers.[24] An eradication campaign was undertaken by the State Bureau of Plant and Insect Control, in cooperation with the local Peach Mosaic Advisory Committee and the Federal Bureau of Entomology and Plant Quarantine. It included surveying all orchards and destroying any infected trees.[25] Four crews, headed by a deputy entomologist employed by the Bureau of Plant and Insect Control, closely monitored the orchards. When they discovered a tree infected with peach mosaic, they chopped it down, burned the stump and tree, and recorded its location. Al Merlino, an Insectary employee who worked on these crews, recalled how "heartsickening [it was] to go into an orchard, especially a young one, and have to destroy the infected trees."[26] The Bureau also had the authority to serve notice and destroy infected trees found on property owned by growers who were opposed to the peach mosaic eradication program. The Mesa County attorney, district attorney, and sheriff helped to enforce the removal of infected trees on property owned by those in opposition. Enforcement was necessary in order to protect other orchards.[27]

By the 1940s peaches had become a very profitable crop for Mesa County orchardists. The Colorado Special Fruit Report, issued by the USDA in July 1940, reported that Colo-

Elberta peach tree showing severe symptoms of peach mosaic virus.
(photo courtesy of Colorado Department of Agriculture.)

rado would market and ship approximately 400,000 bushels of peaches in excess of what was shipped in 1939, the majority coming from the Western Slope.[28] With many more growers and varied grades and qualities of peaches being sold, those in the peach industry believed it would be in the best interest of all growers to have some way to control and regulate the industry to ensure high standards and pricing. To achieve this end, Mesa County peach growers established a Board of Control, Mesa County Peach Marketing Order (BOC), with the organizational meeting held on August 11, 1939. Acting Chairman was Howard D. Finch, County Agent, representing the Office of the State Director of Agriculture. S. L. Pobst attended, representing the Office of the Secretary of the USDA.[29] Growers also chose nine local members, prior to this meeting, to sit on the BOC, "five representing the growers and four from the shippers."[30] One grower from each of the five local districts was chosen during separate meetings: Redlands, Clifton, East Orchard Mesa, Palisade, and Vineland; and the shippers selected four: two chosen by the United Fruit Growers, and one each by the Colorado Producers Co-operative and the independent shippers.[31] The BOC's function was to represent the interests of all Mesa County peach growers by regulating the handling of peaches grown in Mesa County. They oversaw shipping, price posting, advertising and promotion, and grade and size regulations of peaches being shipped to ensure the highest quality and profit returns for the grower. The BOC also issued an annual recommendation to the Director of Agriculture for the State of Colorado requesting an "order" that peaches to be shipped meet the standards set by the U. S. Standards for Peaches, issued by the USDA.[32]

All growers were subject to these standards, but a regulation was adopted that allowed any grower to request an exemption for grade and size regulations in order to ship a crop that did not meet industry standards.[33] The BOC closely reviewed exemption requests. They felt it was in the best interest of all growers that only high quality peaches be distributed in order to ensure stability in the market, the highest asking price and profit for all growers, and a return business the following year. If the BOC denied a request, the grower could not ship the fruit.

Growers were assessed to finance the BOC, the rate of assessment being determined by a resolution passed by the Administrative Committee of the BOC. The Secretary's findings of expected expenses to be incurred for the year were pro-rated based upon the expected number of bushels of peaches to be shipped. A per bushel and per box amount was established to meet expenses, and each grower would pay this amount on each bushel marketed. For example, if annual expenses were estimated at $1,600 and 800,000 bushels of peaches were to be shipped, each grower paid $.002 per bushel they shipped to cover the budget (.002 x 800,000 = 1600).[34]

Several peach growers eventually challenged the constitutionality of the Colorado Agricultural Marketing Act of 1939, the Director of Agriculture, and the subsequent enforcement of said order by the BOC members of Mesa County. These growers served the BOC with a preliminary injunction on August 12, 1940.[35] The plaintiffs argued that the marketing order and regulations asserted upon them were "unreasonable, arbitrary and discriminatory" and that their enforcement "inflicted...continuous and recurring damage and injury" by way of lost produce and income.[36] District Judge Straud M. Logan ruled in favor of the defendants in his findings on May 5, 1941. The plaintiffs, he found, had not proven that their constitutional rights had been clearly violated or that they had been "injuriously affected by the Act."[37]

Ensuring that only high-grade fruit be sold was beneficial to all growers. It became increasingly important to

Local growers bringing their peaches into United Fruit Growers Association railroad shipping yards, Palisade, CO. (circa 1951-1952)

(Photo courtesy of Al Merlino.)

protect their orchards using all of the resources at hand. Most growers realized that insects were a major threat to their crops and livelihood, and relied on the BOC to stay abreast of this menace. It was becoming an industry standard for the BOC to work closely with the State Entomologist, listening attentively to his concerns and recommendations in regards to insect control and then taking the necessary steps to ensure a healthy peach crop for Mesa County.

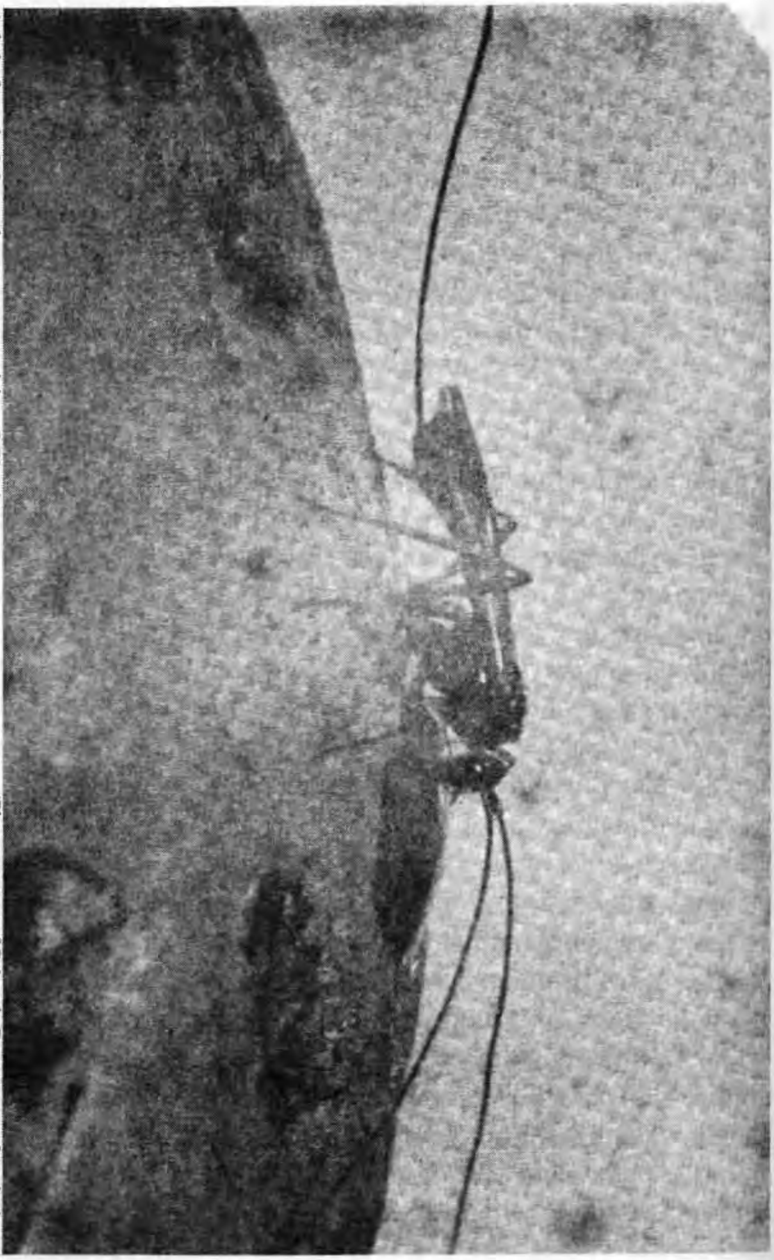
State Entomologist F. Herbert Gates brought possible infestation of the Oriental fruit moth (OFM) of local peach orchards to the attention of the BOC on August 19, 1942. His concern was the need for "full cooperation of the growers for the protection of their orchards."[38] The OFM was being transported into the state from infested areas by way of containers, cardboard boxes or wooden baskets, which local growers reused. Because of war time shortages of materials to produce new containers, many growers needed the used containers to pack and ship their fruit. However, the containers could harbor OFM cocoons that would hatch in Colorado, infest orchards, and ruin peach production. Strict inspections were administered to enforce prohibited use of used containers. This elicited frequent criticism, but the State Entomologist felt that "the 'war' on insects [was] total war with no Armistice."[39]

Growers expressed full cooperation with any regulatory measures necessary to prevent infestation of their orchards. The State Entomologist declared a quarantine on nursery stock, fruits, and containers coming into the State from infested areas.[40] Inspections were also conducted on containers brought in by truck or rail car. Gates informed the BOC of some Denver wholesalers who were trying to stop the quarantine. If the OFM was allowed to infest the orchards, it "would literally ruin the Peach Industry."[41] During the November 2, 1942 meeting, the BOC passed a resolution urging the Director of Agriculture to "take whatever steps are deemed necessary to protect the fruit industry against infestation of the Oriental Fruit Moth thru [sic] condemnation of all possible carriers,..."[42] It was further requested that the Director of Agriculture and the State Entomologist confer closely with the BOC concerning enforcement of the quarantine act.

Orchardists in Mesa County recognized the danger the OFM posed, and the issue became a high priority with the BOC. If an OFM infestation occurred, there was no known chemical pesticide to kill it. When the eggs hatched in the spring, the larvae immediately bore into the tree terminals (new growth), ejecting the first few bites, creating what is called a "frass pile." As mentioned earlier, stomach poisons (arsenicals) were used to control pests at this time and were sprayed on the surface of the tree. This was the part being spit out by the OFM larvae as it bore into the terminal, thus sparing its life.[43] The generational life cycle of the OFM: egg, larvae, pupae, and adult, is repeated four times during a growing season. Eggs are deposited on the terminals of the fruit tree usually two days after the female moth emerges, with egg-laying continuing for seven to ten days.[44] The insect's larvae continue to feed on the interior of the terminal until the terminal hardens off. At this time the larvae enters the fruit at the stem end to continue feeding.[45] Although the peach might look perfect on the outside, inside there is a worm and the fruit is considered inedible. Even if there is no fruit crop, the OFM larvae can pupate on the tree, emerge as a moth in the spring, lay eggs on the terminals, hatch and feed, assuring survival and propagation. This causes severe damage to the tree by destroying the new terminal growth.

State Entomologist Gates suggested immediate steps should be taken to stop this pest before it became established in Colorado orchards. In June 1944 he traveled to California, where the OFM had established itself in 1942.[46] The two-week trip familiarized Gates with the extensive research being done in California for the biological control of this pest. The University of California and the California State Department of Agriculture had undertaken research to develop a control method for the OFM.[47] Through the work of the California Division of Biological Control, studies were done using artificial (pesticides) and biological (parasite) methods of control. Parasitic control seemed the most promising method. The California Experiment Station developed a new and rapid technique for the mass production of a natural predator of the OFM, the *Macrocentrus ancylivorus* (Mac), which was raised on the larvae of the potato tuber moth, *Gnorimoschema operculella*, in a laboratory setting and later released into the orchards.[48] Mass production, the development of six to eight generations of Mac parasites per year, was important so that liberations could be made in the field during the entire fruit growing season. This method of mass production was compared to the mass production of baby chicks in a commercial incubator rather than "relying on the process of nature (the old hen) to hatch a few baby chicks."[49] This rearing technique took place in a laboratory under temperature and humidity controls, which allowed many generations of the potato tuber moth to develop on potatoes.

In California potato tuber moths were placed in oviposition cages (300 moths per cage), where they laid their eggs on Hope muslin cloth. The cloth with the eggs was removed daily and placed on top of potato tubers in rearing cages. The eggs would hatch and the larvae would crawl onto the potato and enter it. Around the tenth day after this took place, the Mac parasite—a tiny, delicate wasp-like insect about 1/2" long with a 1/4" wingspan—was introduced to



Adult female Mac, about to parasitize OFM larvae (magnified eight times).

(Photo courtesy of Colorado Department of Agriculture.)

the cage. The Mac would "sting" the potato tuber moth larvae, laying its own egg in this factitious (surrogate) host. Not all larvae would be stung, or parasitized. The Mac egg would hatch inside the host larvae, go into diapause (a resting period), only feeding on non-vital organs and not killing the host at this stage, letting it mature to become a better food source. The potato tuber moth larvae, both parasitized and not, would leave the potato and spin a cocoon in a thin layer of sand on cardboard at the bottom of the rearing cage. The Mac larvae, which was inside the host, would then finish devouring the tuber moth worm and spin its own cocoon inside the host's cocoon. All cocoons were removed, still attached to the cardboard, and taken to the orchard where the Mac cocoon would hatch, as would the unparasitized tuber moths.[50] The liberated female adult Mac wasp was then ready to parasitize the OFM in the peach orchards in the same manner it parasitized the potato tuber moth in the lab.

The adult female Mac wasp seeks out the tunnels of OFM larvae, being guided to it by the frass piles left on the terminals, which are thrown out when the OFM larvae chews its way inside.[51] The Mac stings these larvae, laying a Mac egg inside the OFM larvae, parasitizing the larvae. The Mac egg hatches, feeds on non-vital organs of the OFM larvae, and after this larvae spins its cocoon, the Mac devours it. The Mac larvae spins its own cocoon inside the OFM cocoon and then transforms into an adult wasp that seeks out the next generation of OFM larvae to parasitize. One adult female Mac can parasitize several hundred OFM larvae, killing them before they can move into the fruit, or damage the tree terminals.[52]

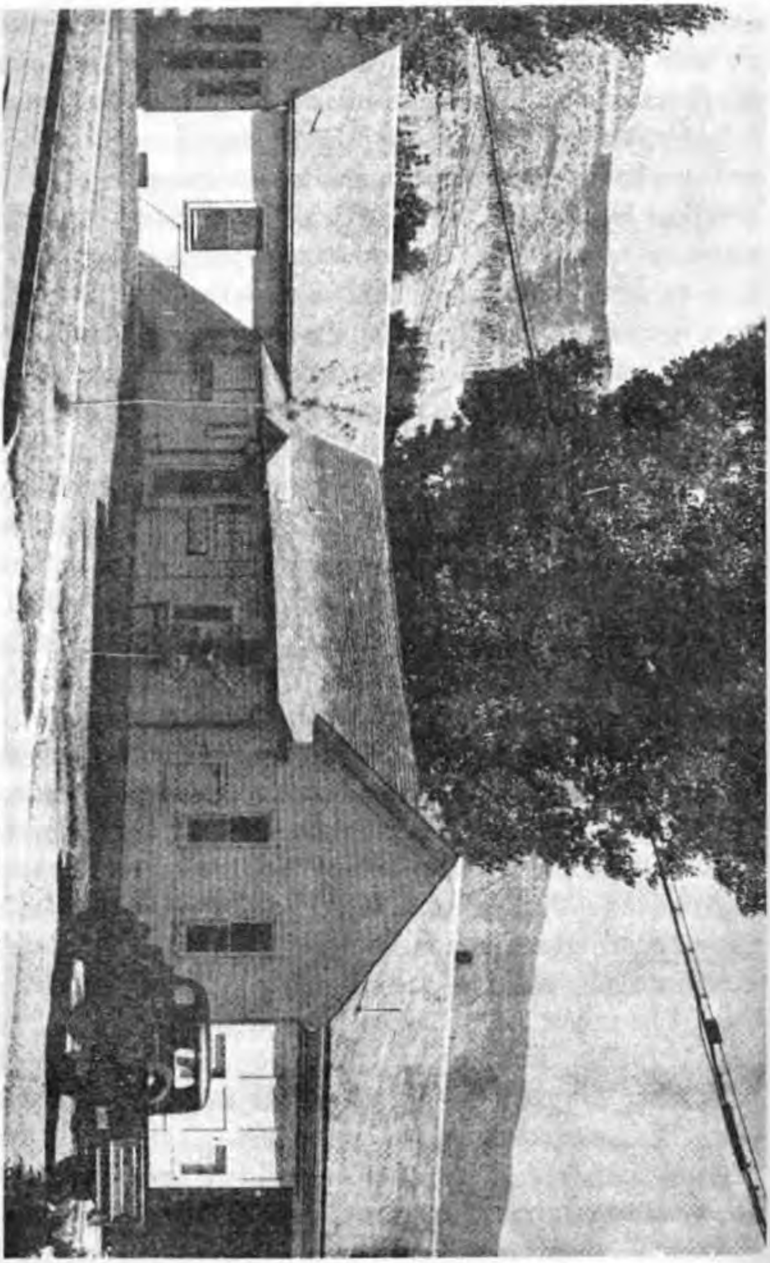
Gate's trip to California was well timed because in September of that same year, 1944, the OFM was discovered in the railroad yards of Grand Junction. The BOC was informed and Gates recommended to them that an insectary, based on the one he had just visited in California, be installed to mass-produce the Mac parasite to combat this pest.[53] He then began to investigate financing such a project through a State appropriation. In December 1944 a resolution was passed by the BOC to:

> ...immediately take the necessary steps to finance and construct in Mesa County whatever facilities are declared necessary for the propagation of the proper parasites to be used in combating this dangerous menace to the peach industry…the peach growers of Mesa County to facilitate the assessment and collection of funds and to act as agents for the growers in the setting up of proper facilities in order to accomplish this necessary task.[54]

This resolution was passed in response to funds made available to the Colorado Division of Agriculture and the Bureau of Plant and Insect Control on July 1, 1945, to prevent or eradicate insect pests and plant diseases in the State of Colorado.[55] A $50,000 fund was allocated with $25,000 of it made available for "the erection, equipping and maintenance of the insectary at Palisade for a two-year period."[56] The BOC was concerned that the time lost waiting until July 1945 to start construction of the insectary could not be recaptured and would delay the mass production of the Mac, making it too late to liberate parasites into the orchards for the 1946 growing season. In a Memorandum of Agreement dated May 1, 1945, the BOC agreed to put up the money to prepare the insectary, with the provision that the money would be repaid when the state fund came through in July.[57] The BOC made a one-half cent per-bushel, and one-fifth cent per-box assessment on the anticipated 1945 peach crop to get an advance start on the program.[58] This supplemental fund, after reimbursement by the state, would be used to cover any unforseen emergencies not provided for in the budget of state funds.[59] With money in hand, plans for the insectary were made.

The insectary was to be located in the same building occupied by the BOC at First and Main Streets, Palisade, Colorado, which the BOC contracted to purchase for $1700 from H. M. Fuller.[60] The facility was to be shared with the State Entomologist and the BOC was to have a voice in hiring insectary personnel.[61] An addition was built onto the existing building to house the laboratory, an office, two rearing rooms, and a basement. Because of World War II, qualified personnel was in short supply and the state had to look to the Army for a qualified person to head the insectary. Lorin Anderson was hired as the entomologist in charge of the laboratory, but had to receive an early discharge to begin his duties in Palisade.[62] His wage was $200 a month, $18.50 paid by the BOC, and $181.50 paid by the state.[63] The Colorado Insectary started operations on Tuesday, August 14, 1945.[64]

Adapting the rearing process studied in California to Colorado's climate created many problems for the Insectary. Humidity levels and temperatures were critical in the development of the host insects. These problems were addressed and resolved as they arose. Humidity was controlled by modifying a conventional swamp cooler to recirculate air through moisture saturated pads. As soon as the climate was stabilized, host insect material was imported from California in twelve small, spaced shipments to ensure a steady supply of adult tuber moths for continuous egg laying and parasitization. The first moths arrived on January 14, 1946. By the first of March the host insects were well established and producing a level and constant egg supply. Shipments of the Mac parasite were now arranged for over a span of time.



Original Insectary building, Palisade Colorado.

(Photo courtesy of Colorado Department of Agriculture.)

The first Colorado-produced Mac parasite cocoons appeared in the separation washes on April 28, 1946.[65] Soon after, parasitization dropped below hoped for levels. The two life cycles of the insects were out of phase, which meant that the Mac was trying to locate the host larvae during a time when this larvae was not available for parasitization—it had burrowed too deeply in the potato. Changes in time of parasitization of the tuber moth larvae solved this problem. Introduction of the Mac into the rearing cages was made about twenty-four hours after the tuber moth larvae hatched, allowing the Mac to parasitize the host larvae before they burrowed too deeply.[66] Other difficulties were encountered that also caused complications in production.

Once the two insects were brought together and the potato tuber moth larvae became host to the Mac egg, not all tuber larvae were parasitized, the tuber moth larvae would exit the potato and crawl into forty by sixty inch rectangular galvanized trays covered with wax paper and containing sand. Here the tuber larvae would cocoon, some with the Mac parasite egg inside. Solid "sand mats," that could be picked up, were formed from all the larvae cocooning in one tray. In Colorado the potato tuber moth had been a quarantined insect since 1925 and could not be released into the orchard as was done in California.[67] The problem now became finding a way to separate the two insects, the ones with the Mac inside and the ones not parasitized, so that the Mac cocoon could be placed in the orchard at the right time, just before it hatched into the adult Mac. According to Lorin Anderson, the California experimentors did not know how to do this. Somehow the silk and sand mats needed to be dissolved to separate the cocoons. A solution was discovered when the wife of one of the professors working on the project informed them that

Clorox dissolved silk stockings.[68] Experiments began with a 1:1 ratio of 5.25% sodium hyper chlorite bleach and water.

The sand mats were placed in this solution in a screened bucket with a trap door and in a matter of four to five minutes the silk mats dissolved. A fresh water rinse with gentle agitation then followed, allowing the sand to sift down and out leaving the separated tuber moth pupae and Mac cocoons. To further separate the two insects without killing the Mac parasite meant another bath in isopropanol alcohol and water. When placed in this solution, the Mac parasite cocoons floated to the top and the trap door was closed making collection easy. The potato tuber moth pupae, that had not been parasitized, sank to the bottom unharmed, were collected and allowed to hatch and lay the next batch of tuber moth eggs to be used for hosts.[69] The timing of this separation bath process was a critical stage of production. The Clorox solution could break down, producing a free chlorine gas that was very toxic to both insects.[70] Once successfully separated, the liberation process could continue.

Mac cocoons are about the size of a grain of wheat. Paper bags, with a string attached for hanging in trees and an escape hole for the Mac, were prepared, and about one thousand cocoons were placed in each bag, measured out in cups. The bags went to the orchard a day before they were to hatch. This had to be timed carefully to coincide with entry of the OFM larvae into the stems of the peach trees. If placed too soon, the Mac could not locate its host because there would not be any frass piles; if placed too late, the OFM would be too deep in the stem to be stung. The bags were hung in every tenth tree in every tenth row, which amounted to 1000 Macs per acre.[71] Because only the female Mac could parasitize the OFM, emergence tests were performed regularly to see what the sex ratio was. It consistently remained about 50/50. This

Al Merlino hanging bags containing Mac cocoons in peach trees. (circa 1947)

(Photo courtesy of Al Merlino.)

allowed for, with a 50:50 ratio of female to male, five females per tree per acre. Sacks were made up in the lab, ready to go free of charge to any grower who wanted them. The sacks were also distributed by the survey teams going out to the orchards to seek peach mosaic infected trees and examine insect traps.

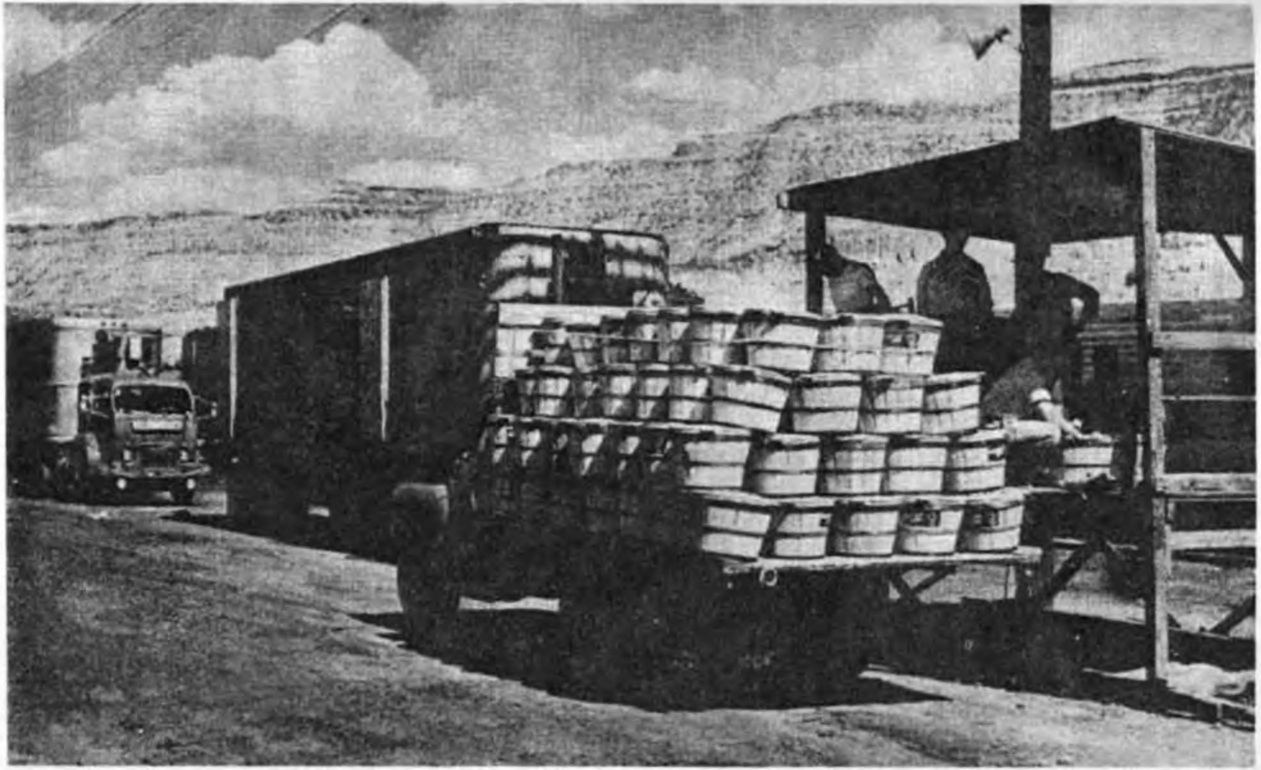
One problem that remained persistent over the many years of production was the condition of the potatoes the Insectary received to host the tuber moth larvae. If the potatoes were not fresh, which was the case most of the time, the tuber moth larvae would not respond well to burrowing into them. Potatoes came from cellar or refrigerated storage, and were often flaccid and dehydrated, or the sugar content had increased due to the cold to a point that the "sweetened" potatoes were of no value as food for the potato tuber moth. Not having adequate nutrition increased host mortality and decreased reproduction capacity. Parasites developing from these weakened hosts lacked vigor and productivity. Observations of production of parasites using fresh and old sweetened potatoes for host food showed dramatically different results. Fresh potatoes produced 16,000 host insects per tray and 10,000 parasites. Old potatoes in poor condition produced only 1,800 hosts and 308 parasites per tray.[72]

Despite the numerous problems encountered during the initial startup, about 250,000 Mac parasites were placed in orchards around Mesa County during the 1946 growing season.[73] By the tenth anniversary of the Mac in Mesa County over 8.1 million had been liberated. The range of liberation was 228,000 in 1946 and 878,000 in 1955.[74] Traps were continually hung to monitor for the OFM. In 1947, 181 traps collected only one OFM. For several years after 1956 the production of the Mac was put on standby, meaning minimal production and releases.[75]

The BOC, thinking that perhaps the OFM could not become established due to Western Colorado's climate extremes, supported this decision. Peach growers were cautioned by Lorin Anderson, Insectary Supervisor, that insects have the innate characteristic to become adapted over time. As a precaution the Insectary decided to keep a small colony, one hundred female Macs, going just in case it was needed. Unfortunately, the fruit shipped in 1964 had been infested and went undetected by shipping inspectors, and the OFM larvae emerged from the fruit after it reached the store shelves. Even home canners were devastated to find worms among their canned peaches.[76] The OFM parasite rearing program was reinitiated starting with the one hundred female Macs that had wisely been kept on hand.

During the Mac rearing standby, the Division of Plant Industry picked up the expenses for the Insectary to continue. Insectary personnel devoted their time to peach mosaic surveys, retail and terminal inspection of nursery stock, greenhouse inspections, collection of seed for testing of purity and germination, survey and removal of barberry bushes that spread stem rust on wheat, survey and spraying of halogeton, a weed that can be toxic to sheep, survey for ash tree borers, and checking pesticides for registration.[77]

The Colorado Department of Agriculture, Division of Plant Industry, had closely observed the success of using this natural predator on the OFM. In 1951 there were no OFMs trapped in Mesa County. However, the strawberry leaf roller had become a problem in the strawberry industry in Colorado. This insect tied leaves together to make its case, feeding and pupating inside, making it very difficult to control with pesticides, which by this time were contact poisons developed during World War II. There had been some testing on the strawberry leaf roller using the Mac parasite that had shown



Peach inspectors, participants unidentified. (circa 1953-1954) (Photo courtesy of Colorado Department of Agriculture.)

some control. The Colorado Insectary sent 6,000 Mac parasites to Larimer County to be liberated in the strawberry fields. Initial indications were that the liberations were "encouraging."[78] This venture eventually proved successful, and the Mac was shipped to the State of Washington for the same purpose.[79]

Biological pest control was beginning to take hold in several parts of the United States and abroad. Trading information and parasites with other countries was deemed necessary to the expansion of this type of control, and this was freely done with no money transaction. The need for precautions to prevent the introduction of injurious insects during these trades was addressed. It was decided that all material would be shipped from point of origin to the Biological Laboratory at Fontana, California, where the insect would be quarantined until the second generation hatched, making it impossible for anything other than the desired insect to be released.[80] This process was decided upon in response to the potential of more requests for trade from other countries and the need for the U.S. not to introduce a new insect that would cause more damage.

The Colorado Insectary received a request from the Commonwealth Institute of Biological Control for *Macrocentrus* parasites. This organization served the British Commonwealth of Nations and its activities were international in scope.[81] The Institute was also willing to furnish the Insectary with beneficial insects developed in their laboratories. Shipping this material afforded the chance to test air transit facilities between the U. S. and Europe. Helping to establish rearing programs in other areas was desirable. Thus, forming a working relationship with this Organization could be of great benefit to Colorado.[82] Non-native insects and plants brought into the United States from other countries, either on purpose for ornamental use or accidentally, usually have no natural enemies here to keep them from reproducing and spreading out of control, as was the case in their native habitat. Going to the country of origin to find and bring back any natural predator could help to control a possibly uncontrollable situation.

The first exchange Palisade received was from the French Ministry of Agriculture in June 1952. It was arranged through the USDA and the University of California, which quarantined the first shipment, and sent the second generation to Colorado. Two parasites were received, the *Coccophagus insidiator* and the *Trichomsthus*. These insects were the natural predators of the European elm scale, which had infested thousands of elm shade trees in Colorado towns and cities. Chemical control was possible, but very expensive, limiting the number of cities that could use this method.[83] The imported parasites became quickly established after liberation, and in 1953 they were collected and propagated at the Colorado Insectary to liberate throughout the Grand Valley.[84]

Another successful biological control project the Insectary became involved in during this time was weed control. The targeted weed, klamath weed, had first appeared in California probably around the turn of the century.[85] This plant is also commonly called: St. Johnswort, goatweed, and tipton weed. Toxic to white faced cattle, it had seriously infested prime rangeland in California, Washington, and Oregon. Entomologists from these states, and the Bureau of Entomology, USDA, began visiting foreign lands where this weed grew, but in a controlled, non-spreading manner. In New Zealand they found that the weed was kept under control by a beetle, *Chrysolina quadrigemina*, that fed only upon this plant, and arrangements were made to bring this insect to the United States to help control the klamath weed in the West.[86]

Lorin Anderson (left) and Al Merlino placing Chinese elm wood in rearing cages for the elm bark beetle to lay eggs on. The predator insect was introduced into the same cage later to parasitize these eggs.

(Photo courtesy of Al Merlino.)

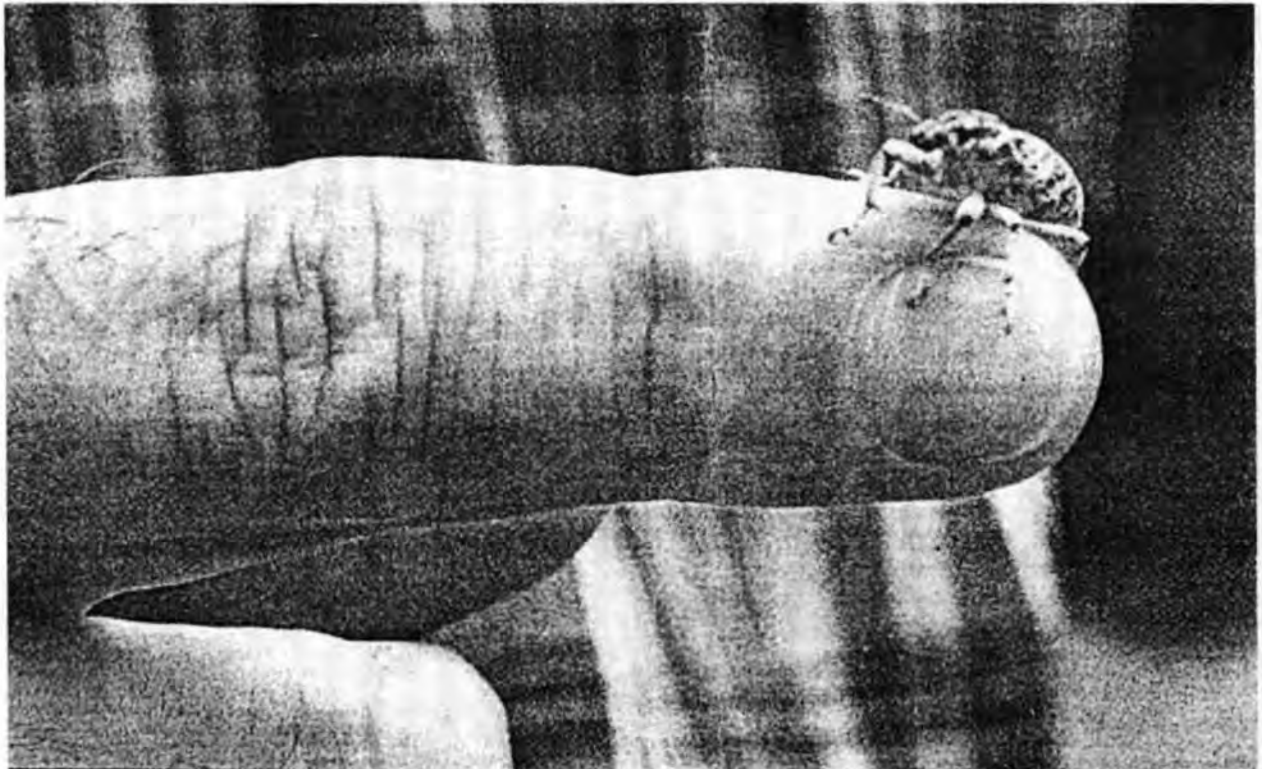
The beetle was brought to the United States in 1943 and placed in quarantine to confirm that it would not feed on any other plant. The Australians had tested the insect on forty-two plants with no cross over. California tested six more plant groups, and concluded that the "leaf-feeding beetles would starve rather than feed or reproduce on other types of plants."[87] With testing complete, the first release was made in California in 1945-1946. Establishment was slow, and at first it was thought that the beetle had died, but it had not and within a few years thousands of acres of klamath weed had come under control.[88] The klamath weed was discovered in Colorado in South Boulder County around Rocky Flats in the early 1950s. A shipment of the predatory beetles was requested from California and propogated at the Colorado Insectary. They were released at points of infestation, observed for several years, and today have become the state's most successful weed control project.[89] Chemicals can also control this weed, and this is the recommendation for small, isolated outbreaks of it, as is the case for most weeds, because there would not be a sufficient density to sustain a beetle population, but, "On large infestations, control by beetles is the most efficient and economical method."[90] Specificity tests have shown that this beetle will not cross over to live on other plants, even if the target plant is no longer available.[91]

Specificity testing is more precise and strict when an insect is being considered for weed control. Biological pest control evolves around protecting plants used to produce agricultural crops. It is easier for an insect predator of plants to cross over to another plant if the plant density the insect was released to kill becomes too low to sustain the insect than it is for the predators of insects to crossover to other insects. It is important to know what plant(s), if any, the insect will or will not crossover to. Strict specificity testing is done before an insect is released. If it crosses over to an agricultural plant, that would disqualify it from the program. Very few released insects have adversely affected people or the ecosystem. Insects will never completely kill all the host plants in a weed location: if weed levels are low, they will adjust their population, or they will feed on other plants to preserve next year's crop of preferred food.[92] Many plants have more than one biological enemy to help control their growth.

Finding and utilizing more than one insect on a weed problem is not unusual, in fact it is desired. Different predator insects attack specific plant parts: flowers, foliage, stems, and roots, at different stages of development in the plant's life. For example, the larvae may feed on the stem, root, or in the flower head destroying seed production, while the adult will feed on leaves, weakening the plant. Other insects can be root-boring with the larvae feeding and overwintering in galled roots, often killing the plant. Larvae that migrate into the main root crown destroy the vascular system, helping to kill small roots. Gall-forming insect larvae feed on the tips of plants, forming a gall around the plant which prevent it from producing flowers and seeds. Establishing these various insects can take years.[93]

Field insectary sites to rear and colonize beneficial insects are established through the cooperation of land managers and owners. There are no guarantees that these sites will remain protected while insect populations are allowed to reach "collectable" levels. Herbicide use and grazing by livestock can severely damage or destroy these sites.[94]

In 1996 the Colorado Insectary received the knapweed crown borer, nicknamed the "pinto bean," which attacks spotted and diffuse knapweed. It was the first insectary in the United States to raise this insect. This toxic weed, found on the Eastern Slope of Colorado, is tenacious and difficult to



(Photo courtesy of Sam Meyer/*The Daily Sentinel*.)

Kent Mowrer, supervisor at the Insectary, holding a knapweed crown borer, nicknamed "pinto bean," a natural predator of spotted and diffuse knapweed control using chemicals. This insect has been successful in bringing the weed under control. Other insects have also been reared and released for control of this plant. The Western Slope is plagued with Russian knapweed and the Insectary has planted a plot at its facilities in anticipation of an insect that could control this plant, sharing information with Wyoming and Montana scientists who also are at work seeking a predator insect to help control this weed.[95] So far they have had success with a gall forming, microscopic nematode, *Subanguina picridis*, which is native to Asia and is being mass reared and released on Russian knapweed in the former USSR.[96]

Musk thistle is another weed that has been brought under control using insect predators, but the insect that attacks this plant will also attack native thistles, and recently was discovered to crossover to artichokes, an agricultural plant, and cannot be used in areas where this crop is raised. The insect's first love is the musk thistle though, and if it is around, that is where the insect will be. Even though the insect could reduce native plant populations, it is not as damaging as letting the musk thistle thrive without control. The musk thistle, if left alone, will completely choke out native plants.[97] Understanding that it is better to lose some native plants to insects as opposed to losing the whole crop to a non-native plant would seem the only logical solution, but some do not agree.

There is an organization found in most states referred to as the Native Plant Society. This group is concerned with protecting an area's native plants from any type of human interference in the plant's evolution. This includes introducing insects or herbicides to control other plants that may unduly threaten native plants. The group believes it is more acceptable to let the native plant be choked out by the intruder, than to introduce an insect into the ecosystem of that plant. There are noxious weed sections in Colorado that cannot be controlled using biological pests or chemicals because of this group's influence.[98]

Raising predator insects for plant and insect control were not the only programs the Insectary worked on. After World War II the Colorado Insectary also became involved in the area of chemical control of insects. For a very long time chemicals have been used to help control plants and insects. Early chemicals were naturally occurring minerals and plant products such as arsenic, copper, lead, manganese, zinc, pyrethrum (from the dried flowers of chrysanthemums), nicotine sulphate, and rotenone from leguminous plants of the East Indies.[99] Arsenic was the most common mineral used in the control of pests in the fruit industry before later manmade chemicals became available. Used for centuries by man as a highly toxic poison that not only caused death if ingested, it is also considered to contain cancer-causing hydrocarbons.[100] The Environmental Protection Agency, established in the United States in 1970, cancelled the last agricultural use of arsenic acid in the United States on December 31, 1993.[101] The chemicals that followed arsenicals were far more deadly.

During World War II, scientists involved in developing chemicals for use in bombs, for killing lice on people and in buildings, and for warfare produced a number of new chemicals that were toxic to insects. These new insecticides fell into two groups: chlorinated hydrocarbons, represented by DDT, and organic phosphorus, represented by malathion and parathion. Both were built on the basis of carbon atoms, the building blocks for all living things on earth. Carbon atoms are capable of forming chains and rings of different configurations in an infinite number of ways with atoms of other substances, creating a diversity in the living world ranging from "bacteria to the great blue whale."[102] One common substance carbon links with is hydrogen and chemists during the war discovered that they could detach one or all of the hydrogen atoms and replace it/them with other elements. This manipulation of the basic ring produced a "battery of poisons of truly extraordinary power."[103] DDT, discovered in 1939, is probably the most familiar synthetic pesticide to be developed using this rearranging process. The person who discovered this insecticide, Paul Muller of Switzerland, won the Nobel Prize.

When DDT, ***d**ichloro-**d**iphenyl-**t**richloro-ethane*, was first used on humans it was not thought to be toxic in the least, and was used to dust soldiers, refugees, and prisoners during the war to kill lice and to control disease-carrying insects like mosquitoes. These people suffered no immediate adverse side effects, and showed no accumulation in the body through monitoring tests.[104] These early reports were wrongly perceived to mean the insecticide was safe. DDT was widely publicized as a "miracle" chemical and its reputation soared when it was credited with the arrest of the Naples typhus epidemic in 1943-1944, where it had been used in the louse powders administered through public health measures. American production of DDT went from two million pounds per month in 1944, to about three million pounds per month by the war's end when it was released by the War Department for general civilian use on August 1, 1945.[105] This was received with joy by farmers, but with concern by the Food and Drug Administration (FDA).

Acute toxicity to humans exposed to DDT in powder form had measured low, but early experiments indicated that it could accumulate in body fats over time and is passed on in milk. The FDA had no control of withholding DDT from the market until more testing could be done on its effects on agricultural crops consumed by the public. The only thing the

FDA could do was set tolerance levels. By 1948, tests, confirmed by the Committee on Medical Research, provided evidence of body accumulation and excretion of DDT in milk. Wartime tests exposing rats to high chronic levels of DDT showed "fatty degeneration of the liver and kidney."[106] The Committee reported that the lack of data created a dangerous gap in public health officials' knowledge, and such fears were shared by other public health groups, including the American Medical Association's Council on Foods and Nutrition. By 1950 the FDA's Division of Pharmacology found DDT in the fat of persons who had not been exposed to occupational uses of it.[107] Public debate on the safety of DDT occurred in 1950-1951. A U.S. House Select Committee held hearings to investigate problems produced by using chemicals in and on food products. There was sharp disagreement on the issue. The USDA argued that existing laws were sufficient, but scientists, the FDA, and private foundations argued more controls needed to be placed on new insecticides and on their introduction and use.

Government regulation of insecticides had begun in 1910 with passage of the Insecticide Act, which established standards and regulations on chemicals sold and used. The Colorado Insecticide Act, passed in 1941, required manufacturers and distributors to register insecticides with administration and enforcement the responsibility of the Bureau of Plant and Insect Control.[108] In 1942, it was noted in the Colorado Division of Agriculture's Bureau of Plant and Insect Control Annual Report that there had been a rapid development of the manufacture and uses of insecticides, especially synthetic ones. These new synthetic chemicals required a "new procedure of analyses, requiring highly trained personnel and specialized equipment...it is not possible for a complete analyses of the exact composition of these complicated insecticides."

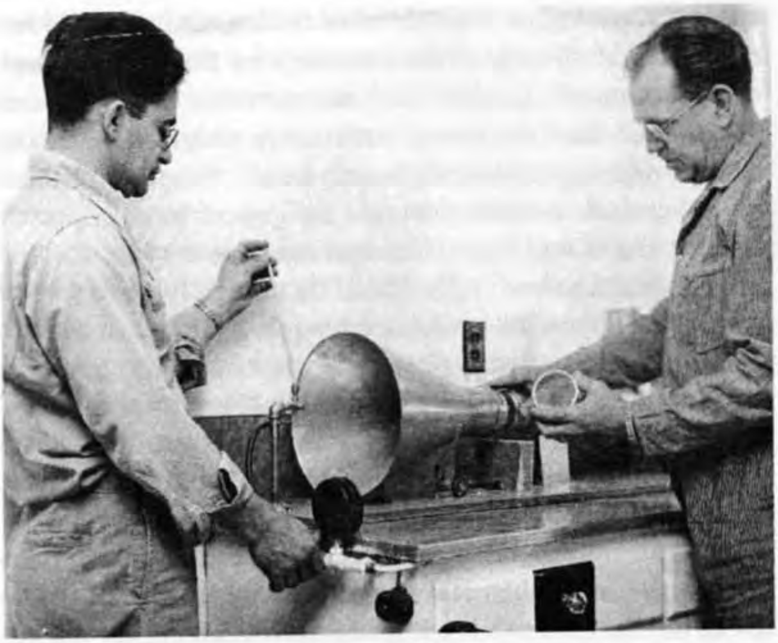
The report also stated that this was not overly serious because manufacturers of these products have experience and knowledge they will offer to the public. During 1942, 143 Manufacturers registered over 625 insecticides.[109] In 1951, when the hearings on the safety of DDT were taking place, the Colorado Bureau of Plant and Insect Control handled registration of about 2,000 formulas sold by 225 companies. The Bureau's report also expressed concerns about public verbal statements being made in regards to the safety of pesticide use. The State Entomologist, F. Herbert Gates, who wrote the report, clearly relayed his feelings about the issue:

> During the past few years, manufacturing and application of insecticides has become near perfect with a greatly increased production and quality. This use and application of insecticides has offered a great opportunity for certain agencies and individuals (who perhaps knew little of the subject) to speculate on the dire results of the use of insecticides even to the point where some magazine writers have gone so far as to indict the use of insecticides as being responsible for all types of human diseases, soil deficiencies and the possible sterilization of future generations. If the nation is to meet its obligations in the production of sufficient insect and disease free foods and fibers, it is necessary that these false profits [sic] be somewhat restricted in their unfounded statements.[110]

Locally, the Colorado Insectary was affected by the sharp increase in new chemicals that were made available to the public; they needed to be inspected first. Legislation passed by the General Assembly in 1952 made funds available for insecticide inspections. Plans were made to establish and maintain a bio-assay laboratory in conjunction with the biological laboratory at the Insectary to evaluate the effectiveness of chemicals in killing insects and weeds as claimed by the manufacturer, and to suggest corrections in formulas found to be deficient in its label recommendations.[111] Testing was to be done on a strain of non-resistant house fly, *Musca domestica*, obtained from Shell Development Corporation. These were the flies Shell used in their testing of chemicals, and Dr. V. P. Sun, employed by Shell Development Corp., helped get the testing procedures for the Insectary up and going.[112] This freely given "help" from the most vigorous defenders of chemical pesticides, the manufacturers, was of great concern to those who wanted more testing, legislative regulations, and information on the potential harm these chemicals were presenting.

Agricultural chemical production had become a big business, with total pesticide sales soaring from $40,000,000 to an astounding $260,000,000 between the years of 1939 to 1954.[113] Fewer than ten companies produced the bulk of DDT, reaping high profits. Many were concerned that the manufacturers' lobbying in Washington and heavy corporate financial support of scientists and university research of the side affects of chemical use influenced reports and helped shape government regulations. The Colorado Insectary was one of many institutions who received this kind of corporate assistance.

Passage of the Miller Bill in 1954 required federal registration of pesticides offered for sale. This bill, an amendment to the 1938 Food, Drug, and Cosmetic Act, placed the burden of proving the safety of new products, in this case pesticides for public use and consumption, in the lap of the applicant. Manufacturers of pesticides were strongly opposed to this requirement because they believed it "vested exces-



Al Merlino (left) and Lorin Anderson making adjustments to the Rohn Kerns Tunnel used in the bio-assay testing of pesticides.

(Photo courtesy of Al Merlino.)

sive power in the FDA, giving it authority arbitrarily to ban the use of agricultural chemicals."[114] This bill impacted the Colorado Division of Plant Industry which checked labels for chemicals, claims of tolerance levels, dosage instruction standards and advertising claims. The bio-assay office at the Insectary became increasingly important in testing and analyzing chemical samples for approval. Such work meant cutting back on the biological control operations of the laboratory as space and personnel were diverted to this new effort. However, in 1955 the use of the Insectary for this type of work was reexamined. Limited facilities, personnel, and the need to continue the bio-control work made progress of testing slower and less economical than expected. Also, tests on these new chemicals needed elaborate equipment run by specialized personnel, and it soon required out-of-state contracts with private laboratories.[115] By 1958, fly production was placed on a standby basis, but available for bio-assay testing, if needed. The Insectary eventually phased out chemical testing, and the development and study of biological pest control continued.

Nationally the debate over chemical control escalated dramatically, with the voice of the general public being heard. By the early 1960s a formerly unconcerned public was beginning to sit up and take notice of reports about the serious consequences of chemical use, especially that of DDT. In 1962, Rachel Carson's book, *Silent Spring*, hit the book stores and sparked an interest in the general public concerning the debates that until now had been fairly quiet and between professional and government agencies. This easy to read and understand book clearly stated how and why chemicals were poisoning the environment, the danger they posed to every living thing, and how they moved from an initial contact point to show up in the environment and animals who had no first hand exposure. Resistance built up in exposed insects was also alarming. A chemical that was initially so deadly to insects was not doing the same damage on later generations of these pests, due to gradual, generational development of a resistance to the toxicity.

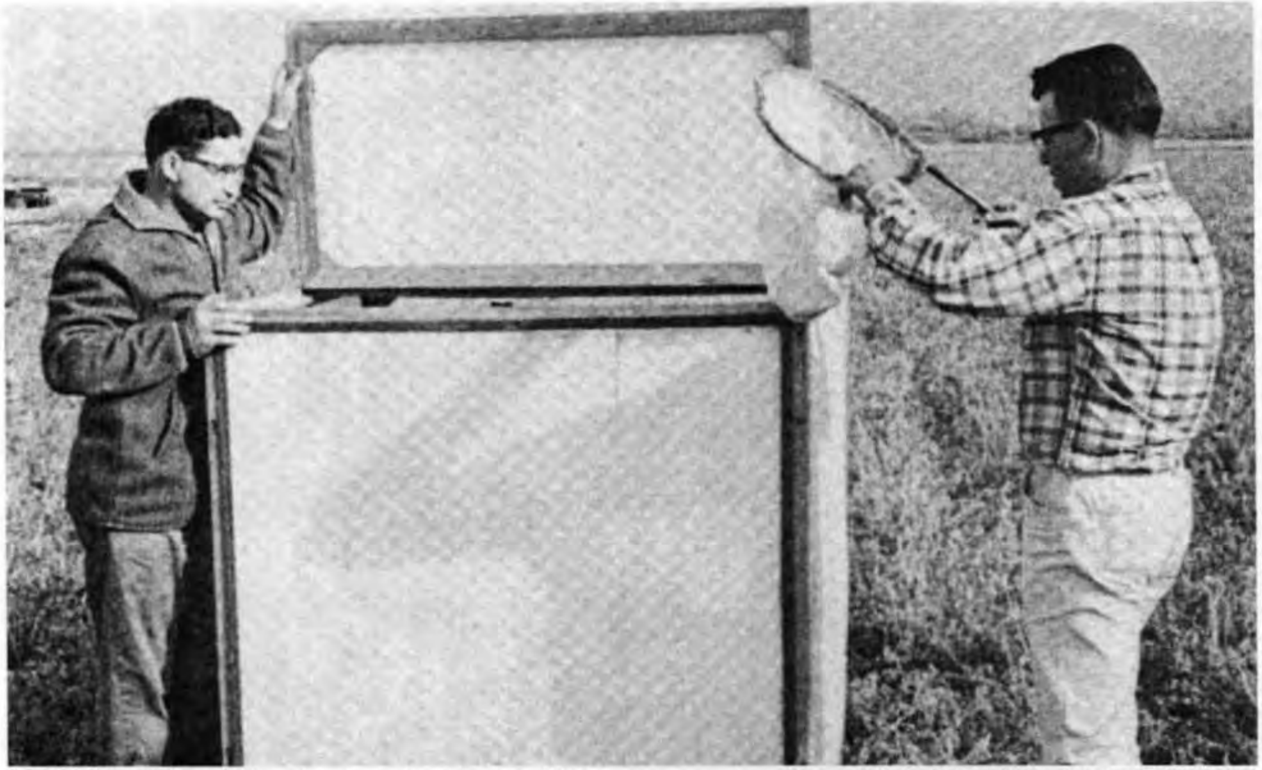
Many growers responded to increased resistance by increasing the concentration of chemicals used, and manufacturers responded by creating even stronger chemicals to control resistant insects. Carson's book was, and still is, very sobering, and the public took what she had to say very seriously. Today, the book is seen as the beginning of the modern environmental movement, and in 1992, was chosen by a panel of distinguished Americans as the most influential book of the last fifty years.[116] The book sparked a fire that culminated in the creation of the Environmental Protection Agency (EPA) in 1970 and the eventual ban of DDT in the United States in 1973. Today, DDT is still used in other parts of the world but work is actively ongoing to have it banned worldwide.[117] The negative reaction to use of chemical insecticides and herbicides made biological pest control methods more viable and the work being done more important. Agriculture still needed effective ways to control weed and insect pests in order to produce the abundance of food that the American public had come to expect on the store shelf.

The Colorado Insectary quietly continued its work in natural pest control throughout this controversial period of chemical use debates, expanding into a new building in 1968, a greenhouse in which to raise plants as a food source for the insect pests being studied, parasitized, and released. The Mac was still being produced in the original building located next door. The first plant raised in the new greenhouse was alfalfa, to feed and propagate the pea aphid, which bears live young and causes serious damage to alfalfa crops. The parasitic insect, *Diaeretiella rapae*, was released into the greenhouse to parasitize the pea aphid. Parasitized aphids look pearly white in color and are about the size of a large pinhead. Employees manually picked these parasitized insects off the alfalfa leaves and liberated them into infested fields, a very tedious job.[118] Work at the Insectary during this time was a seven-day a week job, and employed three people year round: Lorin Anderson, Al Merlino, and Jim Hampton. The current director, Kent Mowrer, was hired in 1975 when the Insectary was working on four specific control projects: OFM, alfalfa weevil, elm bark beetle, and musk thistle weed control.[119] From that time to 2000 the scope and presence of their work has expanded significantly.

1991 was the last year that the Insectary operated out of the original building. During this year it successfully mass-produced and released thirteen beneficial insects, up from three just fifteen years earlier. Employees also did field collections and redistribution of several predators that had previously been established. New methods were, and still are, being developed to accommodate an environment conducive to the mass production of new predator species arriving, which totaled seventeen during 1991 alone. In addition to rearing the insects to be hosts and the parasites to be released, the Insectary was involved in field surveys, tracking thirteen pest species so that timed parasite insect releases could be made at peak benefit periods in the generational cycle of the pest insect.[120]

Capital construction funds were obtained from the Colorado Lottery program in 1992 to build a new Insectary facility.[121] Bob Sullivan, Director of the Division of Plant Industry, was instrumental in bringing this project to fruition.[122] It was anticipated that many new programs would be added to the "rapidly growing arsenal of beneficial organisms" which space at the old Colorado Insectary limited.[123] A post-release

Al Merlino field releasing a parasite to kill alfalfa weevil.
(Photo courtesy of Al Merlino.)



Al Merlino (left) and Jim Hampton checking an alfalfa weevil cage in the field. (circa 1966-1967)

(Photo courtesy of Colorado Department of Agriculture.)

survey done in 1992 to observe the establishment of beneficial species reported six "New County Record[s]" in colonization rate, meaning the natural predators released had successfully overwintered, established themselves and were doing well.[124] Within a year the Insectary had increased from thirteen to eighteen the successful mass production and releases of beneficial predators, which targeted five insect pests and thirteen noxious weeds.[125] Seven new county and five new state records were set for post-survey recovery of beneficial species released earlier. Mass production of the Mac continues to be an important function of the Insectary. During the 2000 growing season, fifty-five years after its inception, 129 releases totaling 2,466,000 Macs were made by eighty growers and covered approximately 1,514 acres,[126] as compared with the original release of 250,000 made the first year the program operated.

By 1999 the Insectary had an annual budget of $450,000, and employed seven full-time people who were paid by the Colorado Division of Agriculture.[127] Operations have expanded to include the open ground next to the building, which has been cultivated and planted with the weeds being targeted for control, one more way to increase production of some important and beneficial insects. In 2000 the Insectary worked with 57 different beneficial predator insects, including the original Mac (see appendix one).

Making these important natural enemies freely available to the public is done through an arrangement with the Colorado State University Extension Service. They advertise the availability of these insects in local newspapers, and a list of interested landowners is compiled at the extension office. Letters are sent to participants explaining the program and when the insects would be available. Insectary personnel then collect, count, package and ship the requested natural preda-

The Colorado Insectary today (2001), showing cultivated ground for growing noxious weeds to help in establishing beneficial insects to kill these weeds. (Photo courtesy of author.)

tors to the extension office for individuals to pick up and release on their weed infestations.[128] Benefits for utilizing this process can be significant not only in a reduction of chemicals going into the environment, but also money saved. In 1984 it was estimated that it cost between forty and fifty dollars per acre to use chemical control on the OFM, as opposed to ten dollars to raise enough Macs to protect the same acre.[129]

Biological pest control has become a very viable alternative to chemical control of both insects and weeds. Locally, nationally, and internationally this is an area of study with information being shared and exchanged as easily and economically as possible. Colorado became involved in this branch of entomology before it was even a state. By 1946, agriculture was such a large part of the economic base of the state that when insects threatened it, the people quickly moved to support this cutting edge science, building a facility to promote it. Through the times when chemical pesticides were new, and seen as the miracle way to end pests once and for all, the Colorado Insectary determinedly kept going. As these chemicals' true nature showed up in environmental and biological damage, it became even more important to develop natural, biological pest control. The Bug House keeps Colorado on the cutting edge, with the benefits increasingly more evident as developments in the realm of biological pest control are made. It is environmentally and economically logical, and while it is not a replacement for pesticide and herbicide use, it is an important tool that fits nicely into the whole picture of the pest control process, helping to ensure healthy and bountiful food crops for a growing world population.

Appendix One*

This list is of the targeted pests and the beneficials that the Colorado Insectary worked on during 1999-2000. A few of them are being surveyed for establishment and are not actively being reared or released.

Weed/Insect Pest	Beneficial Insect
Russian wheat aphid	*Hippodamia variegata*
	Propylea quatuordecimpunctata
	Aphelinus albipodus (Colorado)
	Aphelinus albipodus (Wyoming)
	Aphelinus varipes
	Diaeretiella rapae
	Sphaerophoria scripta
	Scymnus frontalis
Alfalfa weevil	*Tetrastichus incertus*
	Bathyplectes curculionis
	Bathyplectes stenostigma
	Bathyplectes anurus
Oriental fruit moth	*Macrocentrus ancylivorus*
Tall larkspur	*Hoplomachus affiguratus*
Mediteranean sage	*Phrydiuchus tau*
Russian thistle	*Coleophora klimeschiella*
	Coleophora parthenica
Canada thistle	*Urophora cardui*
	Larinus planus
	Cassida rubiginosa

Musk thistle	*Trichosirocalus horridus*
	Rhinocyllus conicus
Bull thistle	*Urophora stylata*
Toadflax, yellow and dalmatian	*Calophasia lunula*
	Mecinus janthinus
	Eteobalea intermediella
	Gymnetron linariae
Punturevine	*Microlarinus lareynii*
	Microlarinus lypiformis
Leafy spurge	*Aphthona nigriscutis*
	A. czwalinae/lacertosa
	A. abdominalis
	A. cyparissiae
	A. flava
	Oberea erythrocephala
	Spurgia esulae
Knapweed, spotted and diffuse	*Urophora affinis*
	Urophora quadrifasciata
	Chaetorellia acrolophi
	Terellia virens
	Larinus obtusus
	Pterolonche inspersa
	Larinus minutus
	Bangasternus fausti
	Sphenoptera jugoslavica
	Agapeta zoegana
	Metzneria paucipunctella
	Cyphocleonus achates

Russian knapweed	*Subanguina picridis*
Purple loosestrife	*Galerucella calmariensis*
	Galerucella pursilla
	Hylobius transversovittatus
	Nanophyes marmoratus
Field bindweed	*Aceria malherbae*
	Tyta luctuosa
Poison hemlock	*Agonopteris alstroemeriana*
St. Johnswort	*Chrysolina quadrigemina*

* List provided by Colorado Insectary, Palisade, Colorado, 7 February 2001.

Notes

[1] Lorin Anderson, interview by Linda Ciavonne, tape recording, 2 Oct. 1984, OH-748 (2 tapes), Mesa County Public Library, Grand Junction, Colorado.

[2] "Meeting of the Board of Control, Mesa County Peach Marketing Order," minutes for 1 December 1944, Peach Action Committee Box, Museum of Western Colorado's Research Center and Special Library Collections, Grand Junction, Colorado. Hereafter cited as BOC minutes.

[3] *Daily Sentinel* (Grand Junction, Colorado), 25 August 1999.

[4] Colorado Division of Agriculture, Bureau of Plant and Insect Control, *Annual Report 1948*, 1. Hereafter, all annual reports will be cited as *Annual Report (date)*. Collection held by Colorado Insectary, Palisade, Colorado.

[5] Ibid.

[6] Ibid., 2.

[7] Ibid.

[8] Ibid.

[9] *Annual Report 1945*, 44.

[10] Ibid.

[11] *Denver Post* (Denver, Colorado), 22 August 1949.

[12] *Annual Report 1945*, 44.

[13] State Entomologist of Colorado, *Seventeenth Annual Report for 1925*, circ. 51, prepared by C. P. Gillette (Fort Collins, CO: Colorado Agricultural College, June 1926), 26. Collection held by Colorado Insectary, Palisade, Colorado.

[14] Ibid., 27.

[15] *Annual Report 1944*, 13.

[16] *Seventeenth Annual Report for 1925*, 29.

[17] Ibid., 30.

[18] Al Merlino, interview with author, Palisade, Colorado, 24 February 2001.

[19] *Seventeenth Annual Report for 1925*, 28.

[20] Ibid., 62.

[21] Ibid.

[22] *Annual Report 1936*, introduction.

[23] Colorado Department of Agriculture, Division of Plant Industry, *(Annual Report 1949-1950*, 3. Hereafter cited *Annual Report (date)*. Collection held by Colorado Insectary, Palisade, Colorado. The Colorado Division of Agriculture was reorganized by an act of the Colorado General Assembly in 1949 and became the Department of Agriculture with the Bureau of Plant and Insect Control becoming the Division of Plant Industry under this new Department.

[24]*Annual Report 1936*, 5.

[25] Ibid., 6.

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[28] BOC minutes, 22 July 1940.

[29] Ibid., 11 August 1939.

[30] *Daily Sentinel*, 6 August 1939.

[31] Ibid.

[32] BOC minutes, 14 August 1939.

[33] Ibid., 16 August 1939.

[34] Ibid., 14 August 1939.

[35] Ibid., 12 August 1940.

[36] R. N. Roberts v. W. C. Sweinhart, no. 9550, District Court, Mesa County, Colorado, 5 May 1941, 1. Attached to BOC minutes, 5 August 1942.

[37] Ibid., 8.

[38] BOC minutes, 19 August 1942.

[39]*Annual Report 1943*, 1.

[40] Ibid., 16.

[41] BOC minutes, 24 September 1942.

[42] Ibid., 2 November, 1942.

[43] *Annual Report 1943*, 15.

[44] Ibid., 14-15.

[45] Merlino, interview, 3 February 2001.

[46] *Annual Report 1944*, 13.

[47] *Annual Report 1946*, 17.

[48] *Annual Report 1944*, 13.

[49] *Annual Report 1946*, 17.

[50] *Annual Report 1944*, 14.

[51] Anderson, interview.

[52] *Annual Report 1946*, 18.

[53] BOC minutes, 27 September 1944.

[54] Ibid., 1 December, 1944.

[55] *Annual report 1945*, 20.

[56] Ibid., 31.

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[58] BOC minutes, 26 March 1945.

[59] *Annual Report 1945*, 31.

[60] BOC minutes, 24 April 1945.

[61] *Memorandum of Agreement*, 1 May 1945, 2.

[62] Anderson, interview.

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[73] *Annual Report 1947*, 8.

[74] *Annual Report 1955-1956*, 116.

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[77] Ibid.

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[79] *Annual Report 1954-1955*, 144.

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[81] "European Elm Scale Parasite Liberations," *Annual Report 1951-1952*, n.p.

[82] "1952 Insectary Activities," Ibid., n.p.

[83] "European Elm Scale Parasite Liberations," Ibid., n.p.

[84] *Annual Report 1953-1954*, 103.

[85] *Annual Report 1954-1955*, 115.

[86] *Annual Report 1952-1953*, 49.

[87] *Annual Report 1954-1955*, 117.

[88] Ibid., 115.

[89] Kent Mowrer, interview by author, Palisade, Colorado, 12 November 1999.

[90] *Annual Report 1954-1955*, 115.

[91] Ibid., 117.

[92] Mowrer, interview.

[93] *Annual Report, 1999-2000*, n.p.

[94] Ibid.

[95] Mowrer, interview.

[96] *Annual Report, 1999-2000*, n.p.

[97] Mowrer, interview.

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Press, 1981), 61.

[105] Ibid.

[106] Ibid., 64.

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[109] Ibid.

[110] *Annual Report 1950-1951*, 47.

[111] *Annual Report 1952-1953*, 54.

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[119] Mowrer, interview.

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