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Title **The Hop Aphis, Phorodon humuli (Schrank), and its control in the Willamette Valley**

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A general discussion of the hop aphis as it affects hop growing in the Willamette Valley is given, including its life history, habits, and economic importance.

Results of field investigations on the cost and effectiveness of control measures now in use in the Willamette Valley are given, including the use of nicotine-lime dust, which is new to hop aphis control.

Means of application of control measures are illustrated. There are also numerous other illustrations.

THE HOP APHIS, PHORODON HUMULI (SCHRANK), AND ITS CONTROL IN THE WILLAMETTE VALLEY

by

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INTRODUCTION

This thesis is a report on a study of the hop aphis and its control in the Willamette Valley with special reference to the cost and efficiency of field control methods.

The Oregon hop crop

Oregon produces about two-thirds of the nation's hop crop. The acreage in this state in 1934 was 22,000 acres, almost all of which was in the Willamette Valley. The yield was nearly 19,000,000 pounds or over 90,000 bales. The value of the 1934 crop was nearly $3,000,000, and was the fifth most valuable crop in the state. In 1933, however, the crop was second in the state, having a value of $6,470,000. (12)*

Recent losses due to aphis

In the 1933 season, Oregon hop growers suffered losses amounting to over $600,000. In 1934, laborers in Washington lost almost $100,000 in wages when one-fifth of the state's crop went unharvested because of aphis attack. This loss is due to mold following serious aphis infestation and will be discussed later.

Hop culture

Hop fields contain about 640 hills per acre. The plants are of different sexes, the female flower heads,

* Figures in parenthesis refer to literature cited, page 44.

commonly called cones or "hops", being the part that is picked. The vines are trained to trellis wires usually about 14 feet high but which may vary from 6 to 16 feet. For cultural reasons the lower part of the vine, up to about 4 feet, is usually stripped of suckers and leaves, and this contributes to aphis control by facilitating spraying.

Training of the vines is done by hand. During the growing season, soil moisture is conserved by continued cultivation and dragging. Irrigation is practiced in many fields. Pipes are moved about in the field as needed. The water is usually pumped from wells or sloughs.

Hops are hand picked. Then they are dried in kilns or dryers, cooled, and are put up in 200 pound bales. A pound of dry hops is produced by the drying of 3 pounds of green hops as picked.

The hop harvest in Oregon begins in August and continues for two or three weeks in September, sometimes lasting until the end of September.

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THE HOP APHIS

Historical

The earliest mention of the hop aphis found in the literature (10) is in 1752 by J. G. Orth, a German priest. The original description of the species was published in Bavaria in 1801 and placed in the genus Aphis. In 1860, Passerini (9) erected the genus Phorodon for this species, and this is the now-accepted genus. The species was reported present in England in 1807. In 1843, English writers suspected that the overwintering form lived in the poles on which the hops were grown, and the charring and treating of poles was suggested. Three years later it was suggested that the soil be changed as well as treating the poles.

Francis Walker, in 1848, was first to suggest a host plant other than hop. He claimed the primary host was sloe, a fence-row species of Prunus found in England, and hop was only the summer host. The following year he involved other species of Prunus as well. The first American appearance of the hop aphis was in New York state in 1863. The year 1886 brought great disaster to the hop yards of New York and Wisconsin. This resulted in an investigation by the Division of Entomology of the United States Department of Agriculture, and the investigation was carried on under the direction of

Entomologist C. V. Riley by W. B. Alwood, Springer Goes, and Theodor Pergande.

The first appearance of the hop aphis on the Pacific Coast was in 1890, according to Parker. (7)

The federal plant quarantine law of 1905 which prohibited interstate shipment of pests mentions the hop plant-louse by name as being one of the destructive insects to be guarded against.

<u>Distribution</u>

In distribution, the hop aphis is quite cosmopolitan. The following records for the species have been found in the literature: Japan, Canada, the United States, Formosa, India, and the following countries of Europe: Germany, France, England, Italy, Poland, Russia, Denmark, Hungary, Latvia, Belgium, Jugoslavia, and Czechoslovakia.

In the United States it occurs in at least the following states: Washington, Oregon, California, Idaho, Colorado, Wisconsin, Ohio, New York, Connecticut, Maine, Illinois, and Vermont.

<u>Original Description</u>

The original description of the hop aphis appeared in Fauna Boica, published in 1801 by Franz von Paula Schrank at Ingolstadt, Bavaria. The description of this species appears in part one of the second volume, on page 110. It follows:

> Hopfen B. 1199 Weislichtgrün, einfärbig; zwey Hornchen am Vorende: die Fühlhörner am Grunde mit einem Zahne.
> Aphis Humuli
> Wohnort: an der Unterseite der Hopfenblätter.
> Anm. Die Saftspizen fast parallel, ein wenig einwärts geneigt.
> Diess ist der Mehlthau des Hopfens; in der That eine Anzeige, dass der Stock krank sey, aber nicht die Ursache der Krankheit.

Translated into English the literal interpretation of this description follows:

> Whitish-green, unicolorous; two little horns at the anterior end; antennae at base with a tooth.
> Aphis humuli
> Habitat: On the underside of the hop leaves.
> Note: The honey tubes nearly parallel, a little inwardly inclined.
> This is the mildew of the hop; in fact an indication that the plant is diseased, but not the cause of the disease.

Taxonomic Position

Literature on the Aphididae shows lack of uniformity in the classification of that family. Below is given the taxonomic position of the hop aphis modified from Baker. (1)

Genus PHORODON

Sub-tribe MACROSIPHINA

Tribe APHIDINI

Sub-family APHIDINAE

Family APHIDIDAE

KEY FOR THE IDENTIFICATION OF THE HOP APHIS

By reference to the following key, adapted from Baker, hop aphis may readily be correctly identified:

Superfamily APHIDOIDEA, order HOMOPTERA:

1. Summer parthenogenetic oviparous forms produced: Stigma formed by the radial sector. . . (Phylloxeridae)

1. Only sexual oviparous forms produced: Stigma formed by radius.. . . . . (APHIDIDAE) 2

2. Sexual forms small with functioning mouth parts absent. Oviparous female with all the egg tubes present or indicated in the embryo but the adult possessing only one tube and maturing one cell so that one egg only is laid. Cornicles much reduced or absent. Wax glands abundantly developed. Wing veins usually reduced. Antennal sensoria prominent.. . . . . . (Eriosomatinae)

2. Sexual forms with functioning mouth parts. Nearly all the ovarian tubes developed in the adult oviparous female. 3

3. Radial sector of forewing inserted mesad of the stigma. Sexes small. Oviparous female laying several eggs. (Mindarinae)

3. Radial sector not so inserted but arising from the stigma. 4

4. Forms usually gall makers. Wing veins much reduced so that the media is usually simple. Wax glands usual. Antennal sensoria annular. Aleyrodiform stages common. Sexes wingless as a rule and small. . . (Hormaphidinae)

4. Forms not usually gall makers. Wing veins often not reduced. Wax glands not abundant. Antennal sensoria oval or subcircular. Aleyrodiform stages rare. Cornicles often little reduced. Winged males common. APHIDINAE 5

5. Cornicles situated on broad flat cones. (Lachnini and Setaphidini)

5. Cornicles truncate, or more or less elongate. . . . 6

6. Cornicles clothed with long hairs . . . . (Greenideini)

6. Cornicles never with long hairs 7

7. Thorax of alate form with the lobes not prominently developed; oviparous form small, often laying one egg. Large wax plates present. . . . . (Thelaxini)

7. Thorax of alate form with the lobes prominently developed; oviparous female laying several eggs. Large wax plates usually absent. 8

8. Cornicles truncate or elongate; when elongate the cauda knobbed, and the anal plate bilobed, or the antennae prominently hairy . . . .(Callipterini)

8. Cornicles not truncate, usually elongate. Cauda never knobbed. Antennae with only a few spinelike hairs. APHIDINI 9

9. Body covered with long projections. . . .(Cervaphidina)

9. Body naked with the exception of a few hairs. . . . 10

10. Head without prominent antennal tubercules. .(Aphidina)

10. Head with prominent antennal tubercules 11

11. Wings with the radial sector more or less united with the upper branch of the media or hing wings reduced. (Pentalonina)

11. Wings with the radial sector normal . . MACROSIPHINA 12

12. Cornicles swollen . . . . .(Rhopalosiphoninus, Francoa, Megoura, Capitophorus, Amphophora)

12. Cornicles cylindrical or tapering, scarcely swollen 13

13. Cornicles very small, much smaller than long, broad cauda.. . . . .(Hyalopteroides)

13. Cornicles as long as or longer than the cauda . . . 14

14. Head without prominent, elongate projections to the antennal tubercules. . . . . . (Myzus, Macrosiphonella, Macrosiphum, Acanthaphis, Illinoia)

14. Head with prominent, elongate projections to the antennal tubercules, particularly evident in the

apterous form . . . . PHORODON 15

15. Summer form common on hops. . . . . . . humuli Schrank

15. Summer form not common on hops. . . . . (other species)

Forms of hop aphis

Aphids of a given species take up several forms during the year. The hop aphis is a typical two-host aphis and the following forms of that species appear: stem mother, spring apters, spring alates, summer apters, fall alates, alate males, and females, the latter laying eggs. As these forms differ in appearance each will be characterized. All the descriptions except the stem mother and egg are from Theobald. (15)

STEM MOTHER or FUNDATRIX on Prunus

Alate viviparous female. (First migrant.) Pale green to apple green, paler beneath. Head dark brownish; a dark line or band on pronotum; dark brown thoracic lobes. Abdomen with dark transverse bars and 3 to 4 black lateral spots. Anal plate black. Cauda green. Cornicles green. Legs green, apices of femora and tibia brown; tarsi black. Eyes reddish-brown. Wings large, the cubitus and stigma greenish-yellow. Antennae about as long as body; green to dusky-green, especially at apex; segments i. and ii. darkened, base of iii. palest; segment i. larger than ii., with a blunt apical process on the inner side; iii. longer than iv. and not quite so long as vi., with 27 to 33 sensoria over its whole length; iv. very slightly longer than v., with 3 to 6 irregularly disposed sensoria; v. less than half length of vi.; the flagellum long. Head with small lateral processes and the median ocellus on a prominent process. Rostrum reaching nearly to second coxae, which are close to the third and some way from the first. Cornicles shorter and thicker than segment iii. of antennae, darker green in some than others, imbricated, projecting well beyond the cauda. Cauda one third to less the length of the cornicles, spinose, bluntly acuminate, expanded basally, with 5 or more pairs of rather long hairs.

<u>Apterous</u> <u>viviparous</u> <u>female</u> (on Prunus). Yellowish-green, with 3 deeper green irregular lines on the body, the median one more regular than the lateral, the latter frequently zig-zag. Elongated oval in form. Head rather narrow. Eyes small and red. Legs and antennae green, reaching the second coxae. Legs nearly equidistant apart. Frontal tubercles porrected, prominent, not quite reaching the level of the apex of antennal segment i. Segment i. of antennae much larger than ii., with a blunt apical process on inner side; iii. longer than iv., and equal to or rather longer than vi.; v. about as long as iv.; basal area of vi. about one-third of flagellum. Cornicles green, as long as or slightly longer than antennal segment iii. and thicker; faintly imbricated. Cauda green, much shorter than cornicles; spinose, with 3 pale hairs each side. Anal plate green. Tibia with short hairs. Length 2.7 to 3 mm.

<u>Apterous</u> <u>viviparous</u> <u>female</u> (on Hop). Somewhat similar to the former, but narrower, more shiny and transparent; the three dorsal stripes not so well developed; body rather narrower. Frontal tubercles large and somewhat different in form to the former. Segment i. of antenna larger than ii., with a well-defined blunt tooth on its inner margin towards the apex; otherwise very similar. Cornicles and cauda similar in colour, but the former not so straight and longer than antennal segment iii. Rostrum reaching to second coxae. Length 1.3 to 2 mm.

<u>Alate</u> <u>viviparous</u> <u>female</u> (Return migrant on Hops). Very similar to spring migrant. Antennal segment iii. with 23 to 30 sensoria; iv. with 3 to 8. Abdomen with 3 to 4 lateral dark spots, as well as the usual transverse dark bars. Cornicles, cauda and legs much as in former. Anal plate dark. Femora dark, except at base; tibia green, except just at apices;

tarsi dark. Length 1.7 to 1.9 mm.

Male. Alate. Green; head and thorax dark. Abdomen with 3 large dark lateral spots, a dark dorsal patch and one at base of each cornicle, caudad; anal plate dark. Cauda and cornicles dark. Antennae dark green. Legs green, except apices of femora, tibia and the tarsi. Antennae longer than body; segment i. larger than ii., with a dentate process apically; iii. longer than iv., with 23 to 25 sensoria; iv. slightly longer than v., with a few sensoria. Eyes large, dark. Rostrum not reaching to second coxae. Sternal plate dark. Cornicles thin, cylindrical, much shorter than antennal segment iii. Cauda much thicker and shorter than cornicles. Claspers dark. Wings much longer than body. Length 1.5 to 1.8 mm.

Oviparous female. Apterous. Yellowish-green; antennae green at base, dusky at apex. Legs green, except hind tibiæ which are dusky. Cornicles, cauda and rostrum yellowish-green. Antennae shorter than body; segment i. much larger than ii., with a large dentate process near apex of inner edge; iii. a little longer than iv. and a little shorter than vi.; iv. and v. about equal; flagellum of vi. rather short. Frontal processes of head very prominent. Cornicles cylindrical, somewhat curved inwards, about as long and slightly thicker than segment iii. of antennae. Cauda broad, about half length of cornicles. Legs rather short and thick; many sensoria on hind tibiæ except just near apices. Length .8 to 1.0 mm.

EGG, on Prunus. Color: greenish at first, turning to black. Size, .4 x .7 mm.

Seasonal History and Hosts

Observations on the life history were carried out during the summer and fall of 1934 and during the spring, summer, and fall of 1935. Most of the observations were made in the field at Corvallis or at Independence, although some observations were made in the vicinity of Forest Grove, Coburg, and Harrisburg.

Laboratory studies on life history were made at Independence during the summer of 1934. The method used in this investigation was to observe and record data regarding aphids isolated in petri dishes. The dishes were supplied with fresh hop leaves daily and the aphids moved to the new leaf. The data thus obtained are included under the topic of summer forms.

The SEASONAL HISTORY and HOSTS of this species in the Willamette Valley is briefly as follows: Wingless aphis on hop throughout the summer, a migration to prune or other hosts in the fall and the deposition of eggs and passing the winter as eggs on that plant. In the spring after a short time on prune there is a migration to hop where the summer is passed. (See Plate 1.)

HOSTS: The typical life cycle of the hop aphis includes the prune as the primary host, and the hop as the secondary host. The terms primary and secondary hosts of aphis refer to winter and summer hosts, respectively, rather than to the importance of the hosts. The list of hosts of this species, both from observations by the writer (starred) and from literature on the subject, follows:

Hop (Humulus lupulus,* H. japonica)
Common prune and plum (Prunus domestica)*
Damson or bullace plums (Prunus insititia)
Cherry plum (Prunus cerasifera pissardi)
Mahaleb cherry (Prunus mahaleb)
Blackthorn (Prunus spinosa)
Cherry (Prunus cerasus)*
Apple (Malus malus)*
Hawthorn (Crataegus douglasii)*
Asparagus (Asparagus officinalis)
Rose (Rosa spp.)
Nettle (Urtica dioica)

SPRING: Only a very small number of overwintering eggs were found in the spring of 1935, which might indicate a high winter mortality. The earliest spring aphid record is of a stem mother on prune April 15, 1935. She was surrounded by 58 offspring so she probably hatched late in March. On May 8, 1935, a stem mother with 34 young was taken. Some of the offspring had already matured and were depositing young, an indication of 3 generations on prune before the spring migration. Alate spring migrants were found on prune about the middle of May. The earliest collection of aphis on hops was May 22, 1935, when several small apterous aphis were taken. Parker (7) found spring migrants in California on May 15.

SUMMER: The summer is spent on the hop foliage. The earliest I have seen aphis on hops was May 22, 1935. From this time until winter frosts kill the hops there is a succession of generations of aphis on the hops. From the latter part of May to the fore part of September, when fall migrants leave to go to the winter host, it is estimated that there are 11 generations of aphis on the hops. The males appear as an estimated twelfth generation about the middle of September. Some of the wingless agamic summer forms remain on hop throughout the fall and migrants are constantly produced during that season.

The following information was obtained from laboratory studies: The time taken to reach maturity is about 10 days. Four instars are passed through in reaching maturity. A single aphid was kept for 39 days and one aphid produced 61 offspring in a month.

Table I shows the number of young produced by four females over a period of several days.

<u>FALL</u>: In the fall there is a migration to the prune from hops. The earliest fall migrant was found on August 12, 1934, when wing pads appeared on a specimen reared in the laboratory at Independence. This specimen matured with wings on August 17. On September 10, 1934, wing pads were first seen in the field, and on September 17, 1934, the first winged specimens were taken. In 1935, the first migrants were taken September 26. Parker found migrants in the field in California on August 28, but reported that at Independence they were found on September 22, 1912.

Table I

NUMBER OF OFFSPRING PRODUCED BY APTEROUS FEMALES OF THE SUMMER GENERATION

Day	Aphid No. 1	Aphid No. 2	Aphid No. 3	Aphid No. 4
1	1	1	1	1
2	1	1		1
3	2	1	2	2
4	3	1	1	1
5	5		1	1
6	1	3	1	4
7		2	3	1
8		2	5	2
9	4	1	2	3
10	3	2	2	2
11	1		1	3
12		3	1	1
13		2	2	4
14	1	Dead	1	1
15	4			4
16			Dead	4
17				1
18	1			2
19	2			5
20	1			4
21				1
22				2
23	1			4
24	Dead			2
25				Dead
Totals	31	19	23	56

On October 19, 1934, both sexes were found on prune, and on October 27, 1934, specimens were found in copula. Eggs were found on prune and wild apple in 1934 beginning October 31 and in 1935 after November 10. In the latter year the aphids survived a severe freeze on October 30 and 31.

The eggs are deposited on the twigs, usually near a bud or on a roughened spot. They are shiny green when deposited but turn black in a few days. See plate 2.

WINTER: The winter is passed in the egg stage on the primary host, usually prune.

Notes on habits of the hop aphis

Observations on habits of the hop aphis were made in the field and in the laboratory.

Aphis feed chiefly on the underside of the hop leaves and quite commonly near a vein or rib of the leaf, perhaps for protection from mechanical injuries, although other aphids may be found on the upper surface of the same leaf, especially when the infestation is heavy.

Aphids do not remain on the same leaf all the time but travel occasionally to other leaves. They remain in one position when feeding with the beak inserted in the leaf tissue. The following record, Table 2, shows the variations of aphids on individual leaves during a period of 8 days.

Table 2

VARIATIONS IN APHIS POPULATION ON INDIVIDUAL LEAVES

Date	Leaf No. 1 Number of aphis		Leaf No. 2 Number of aphis	
	Mature	Immature	Mature	Immature
June 8		1	1	
9		6	1	
10	1	2	1	6
11		5	1	12
12		4		13
13		4		7
14		4		7
15	1	6		7

The table shows that both mature and immature aphis wandered to and from the leaves under observation.

There is often a variation in the distribution of aphis on the plants, and many times the chief infestation is high on the plant, around the trellis wire.

Wingless aphis may or may not migrate from one hop hill to another but those knocked on the ground are killed instantly, if the ground is not shielded from the hot summer sun. Those falling on shady soil were not killed.

The distance flown by migrating forms was not determined, but specimens were taken in a prune orchard on a hill near Forest Grove more than a mile from the nearest hop yard, which too was well below the orchard. This does not dismiss the possibility of isolated hop plants nearer to the prune orchard, but suggests that aphids may fly at least a mile.

There is variation in the occurrence of aphis within hop fields. Surveys pointing this out were made in typical fields of the Horst yard near Independence, and it was found that in a hop field adjacent to a forest the aphis infestation was heavier at the edge nearest the timber. See chart 1, figure 3. Likewise, there is increased infestation near bodies of water, as a slough, and near brush and a slough. See chart 1, figures 4 and 5.

Injury to hops caused by hop aphis

The most serious injury to hops due to aphis is the permanent discoloration of the hop cones caused by a mold, *Cladosporium* spp., which settles on honeydew excreted by the aphis. Slightly moldy hops sell at a decreased price, while those more affected cannot be sold. Such a devaluation gives a partial figure of the crop loss as a result of aphis infestation.

Heavy aphis infestations devitalize the plants and probably decrease the yield in following years. The feeding injury of the hop aphis consists of sucking up the plant juices. Great numbers of aphis are also annoying to hop pickers, who will not pick clean under such conditions.

FIELD CONTROL OF THE HOP APHIS IN THE WILLAMETTE VALLEY

MATERIALS

QUASSIA

Quassia is reported by McIndoo and Sievers (6) as efficient against certain species of insects when properly prepared and used.

Quassia, as used in the control of the hop aphis, is the chipped wood of the Jamaica quassia, Picrasma excelsa (Swz.), a tree native to the West Indies. Logs of this wood are shipped to hop growing districts and chipped locally. The cost of the chips varies with the year and with the amount purchased, but usually is about 5 cents per pound.

The quassia wood contains various constituents, but the one to which its insecticidal properties are attributed is quassiin, $C_{32}H_{42}O_{10}$. The wood contains about 0.75 per cent of quassiin. The quassiin content is variable, however, and methods of extraction vary in the ability to extract the entire amount. Quassiin may be obtained fairly pure by treatment of the hot water extract. Purification of the quassiin is not necessary in making aphis sprays, since a hot water solution is readily adaptable to spray purposes.

In taste quassiin is intensely bitter and persistent. It is soluble in hot water but only sparingly soluble in cold water.

Uses of quassiin include: insecticide, anthelminthic, and brewers' substitute for hops (3). The hop aphis is the only insect against which it is used extensively.

Varying quantities of ingredients are used in different hop aphis spray formulas. The formula in use by hop growers of the Willamette Valley calls for 10 pounds of quassia chips with each 200 gallons of water, soaked about 12 hours in the first hundred gallons and boiled 2 or 3 hours in the second hundred gallons. The sacked chips are put in the vat and in this way the chips are kept out of the spray solution, though the solution is usually strained to prevent clogging of the spray nozzles. To this amount of quassia 5 or 6 pounds of whale oil soap per hundred gallons of spray are added.

Parker (8) experimented with various concentrations of quassiin and determined that the following formula would give effective and cheap control, at least for the vicinity of Sacramento, California:

For 100 gallons of spray:

Quassia chips (0.75 per cent quassiin)	3 lbs.
Whale oil soap	3 "

The chips were boiled 3 hours.

If this formula could be proved to be effective in the Willamette Valley considerable saving to the growers would be effected. The common formula here is:

For 100 gallons of spray:

Quassia chips	5 lbs.
Whale oil soap	5 "

The exact way in which quassia kills the aphis is not definitely known. McIndoo and Sievers (5) state:

> "By the process of elimination it is concluded that death occurs as a result of some of the fine spray being breathed into the respiratory system while the aphids are being sprayed."

Experimental tests carried on in the field during the summer of 1935 (see chart 3) indicate that the immediate kill of aphis by quassia isn't very high, but that the aphis decreased for as long as 3½ weeks after being sprayed with quassia. This would hardly be possible were the foregoing speculation true.

An objection often raised against quassia is that it affects the flavor of the hops. This complaint is invalid apparently, for quassia is sometimes used by brewers as a substitute for hops (3). A second objection is that the concentration of the sprays varies, due to variation in chips and extraction.

NICOTINE

Nicotine, a plant alkaloid, is an effective insecticide. Nicotine occurs in various species of

Nicotiana, commercially chiefly in N. rustica where it occurs in amounts up to about 7% in the leaves. Sulfate of nicotine is the form commonly used as an insecticide. It is made commercially by treating nicotine (obtained by steam distillation of leaves and stems of the tobacco plant) with sulfuric acid. Nicotine ($C_{10}H_{14}N_2$) has been synthesized but not commercially.

The toxic effect of nicotine is due to paralysis after being breathed into the trachea, according to McIndoo (4), who further states the paralysis passes along the ventral nerve cord to the brain.

As an insecticide nicotine may be a fumigant, contact poison, or stomach poison, though in all cases the lethal effect is due to paralysis of the nerve cord and brain.

Black Leaf 40 and nicotine sulfate 40 per cent are commercial nicotine preparations and are the forms most commonly used in hop aphis sprays containing nicotine. These contain 40% of nicotine.

Alkali breaks up the nicotine sulfate, liberating nicotine. Whale oil soap in sprays serves this purpose, besides spreading the spray over the surface of the plant.

The common nicotine spray for hop aphis in the Willamette Valley contains:

Black Leaf 40	1/3 pint
Whale oil soap	4 to 5 gals.
Water	100 gals.

The cost of materials for such a spray is $2.90 per acre.

NICOTINE-LIME DUST

Nicotine may be used as a dust by mixing with a good carrier. In such a dust most of the nicotine is liberated within 3 hours at 70°F. and all is liberated in 9 hours.

The dust used at the Horst hop yard and the one referred to when dust is spoken of in this paper contained:

Black Leaf 40	10 lbs.
Lime	50 lbs.
Filler	40 lbs.

The filler was developed by the Niagara Sprayer and Chemical company, and its function was to assist in the liberation of the nicotine. The dust is mixed in large quantities by a large mixer, shown in plates 7 and 8.

The cost of the materials in the above dust is $2.39 per acre, the application being about 30 pounds.

Successful dusting is limited by several factors: (1) Air currents, (2) still air is usually found in the early morning just after daylight, (3) failure to dust the edges of the field, (4) low temperature at time of application. The temperature should be at least 60°F. within a few hours after the dust application. Besides these, other limitations will appear locally when the dust is applied. In spite of these limitations, very good results may be obtained with dust if the operations are carefully planned and properly executed.

MEANS OF APPLICATION OF CONTROLS FOR THE HOP APHIS

There are two methods of application of insecticides for the control of the hop aphis; those that apply liquids and those that broadcast dust. The former type is much more numerous in this state and will be discussed first.

SPRAYING

In the Willamette Valley two main types of hop sprayers are in use, the automatic sprayer and the orchard type of power sprayer.

<u>AUTOMATIC SPRAYERS</u> are those having stationary spray nozzles. Several of these nozzles are mounted on a verticle pipe and adjusted so that a heavy mist of spray is shot upward into the foliage of the plants on either side of the sprayer. This mist is composed of spray from 5 to 7 nozzles on each side. Details of such a plan may be seen in a picture of the sprayer which is used at the Mitoma yard near Independence,

shown on plate 12, figure b.

Automatic sprayers are of several general types, many being made locally from material available. Types in use in the Willamette Valley include:

(1) Those in which the tractor pulls the spray tank and also provides the power for the operation of the spray pump. Two kinds of machines in this class are common: (a) A tractor take-off operates a spray pump on the spray rig. This type of take-off is illustrated on plate 11, figure a, which is a picture of the sprayer used on the Titus yard near Independence. (In this instance the nozzles were not automatic, however.) (b) The spray pump is located on the tractor and is operated by power from the tractor engine. In this case the trailer serves only as a tank for carrying the spray materials and does not function as a sprayer. The Seavy yard near Corvallis uses this type of machine. It is pictured on plate 10, figure b.

(2) Those in which the spray pump is operated by a motor separate from the motor which furnishes traction. At the Mitoma yard near Independence a Star automobile motor is mounted on a tank to make the sprayer. This motor is run full speed to give enough pressure to the spray. The pump and nozzles complete the outfit, which is drawn by a tractor. Pictures of this machine may be

seen on plate 10, figure a; plate 11, figure b; and plate 12, figure b.

Automatic sprayers use fewer men while in operation than do the orchard type sprayers. Besides the mixing and refilling crews, the automatic sprayer type uses only one man, the tractor operator. The orchard type sprayer crew consists of a driver and two hose operators.

Automatic sprayers apply much more spray in a given area than do the orchard type sprayers. An example of this was found at Independence in 1934 when two neighboring yards sprayed at the same time. One used spray guns and applied 522 gallons per acre, while the other used an automatic sprayer and applied about 800 gallons per acre. Automatic sprayers are driven down every row of hops so that each plant is sprayed twice, once from each side, while the wielders of spray guns walk around each plant, spraying it from all sides. Automatic sprayers continue throughout the row, regardless of missing hills, but men with spray guns shut off the spray when they come to missing hills, thus conserving the spray.

The factors of labor and amount of materials used nearly balance, however, for the cost of spraying by these two methods is about the same: automatic sprayer, \$2.67 per acre; spray applied by orchard type sprayer, \$2.54. Figures are for both the cost of application and materials. The difference between the two is 13¢. This is not unchangeable, but may vary in different yards and in different seasons.

NON-AUTOMATIC or orchard type sprayers are those in which operators spray the plants using a hand spray nozzle. Such machines may be variable. (1) Those pulled by horses present one type. An illustration of this type is found on plate 9 which is a picture of the Bean sprayer formerly used at the Horst yard near Independence. The machine used in the experimental control tests was also a horse-drawn machine with a spray gun, though much smaller. (See plate 13, figures a. and b.) (2) Non-automatic machines also may be tractor-drawn. They may be powered by the tractor, as the Titus sprayer plate 11, figure a. and plate 12, figure a., or they may be powered by a separate motor. This type is used at the Wigrich yard near Independence, but is not illustrated herein, though the machine was the same kind as the Horst machine pictured on plate 9, differing only in that it was tractor-drawn rather than horse-drawn.

DUSTING

The first commercial use of nicotine dust on hops in this section was probably in the summer of 1933 when a yard near Salem tried airplane dusting with nicotine-lime dust. This method of application was found unsatisfactory so a ground machine was developed. This machine, the Horst Auto-duster, is shown in plate 4.

This machine was made from a Star car, stripped to the chassis and with the length reduced 15 inches and the width decreased 10 inches. A Niagara dust blower, model F-27-I, was fastened onto the bed of the car, and dust pipes and nozzles were also fitted into position. A Star transmission placed alongside the one already on the car powered the dust blower by means of belts. Much of the detail can be made out in the illustration.

The cost of the machine such as described and illustrated is approximately $350, according to the makers and owners. The company in 1934 made 4 such machines for the local use and later made others for use elsewhere.

The cost of operating this type of machine is less than the per acre cost of operating a spray rig. See chart 6. Each duster requires almost a gallon of gas each hour of operation. Horst Company machinists estimate one gallon of gas (18½¢) an hour is sufficient to include the cost of oil and greasing, as well as minor adjustments.

One man operates each duster and a trucker and truck is needed to haul the dust to the field for the various dusters. The truck and duster drivers are skilled labor and are usually paid 35 cents an hour.

The dusters described usually dust 5 acres of hops each hour. This is done by driving down every other lane with both the car and the dust blower in high gear.

With 4 dusters and one trucker working, the crew can dust 40 acres in a two-hour run. The labor cost is $3.50. The operating expense for the dusters during this period is $1.48 and the truck 16¢ (at 8¢ per hour, as when spraying). The total cost is $5.14 for the 40 acres or 12¢ per acre.

Figuring the depreciation at 5% as with the sprayers, this item would come to $17.50 a year. This company dusts approximately 1,000 acres in a year so the per acre cost of depreciation is 1.75¢.

The total cost of dusting on a small tract is, therefore, approximately 14¢ per acre. In a whole season the cost is more, 16¢ an acre, because the dusters do not always cover the allotted 5 acres per hour. The cost of the material applied is not included here, but is given elsewhere.

EFFECTIVENESS

METHOD OF MAKING EFFICIENCY COUNTS

It was realized early in the investigation that a standard with which to compare various aphis infestations was necessary. After considerable investigation the following standard was adopted.

A representative row (or a large number of random plants) was selected and 4 leaves were taken at random on each hill and examined, and the number of leaves having aphis on the under side was recorded for each hill. This gives the number of hills represented and the number of infested and uninfested leaves. The index of infestation was the per cent of leaves found bearing aphis. For example: if a plot of 10 plants be examined, 40 leaves are counted. If 2 of these leaves have aphis the infestation is 5%.

EFFECTIVENESS AND COSTS

Efficiency data are drawn from the examination of nearly 15,000 leaves which were taken from several hop yards. The counts were all made during the 1935 season. The results obtained are not final, but will serve as an indication of the true relationships. Reasons why the data are not entirely conclusive include: the counts were made at different dates, and in different localities under different conditions; the counts before spraying were not made at the same time nor were the counts after spraying; the same number of leaves was not taken in each case; the infestation was naturally heavier in some localities than in others; quassia-soap and nicotine-lime dust efficiency counts were made under commercial conditions, nicotine-soap under experimental conditions, etc. The results are given as obtained, however.

Table 3

EFFECTIVENESS OF SPRAY MATERIALS

Material	Before spray		After spray	
	No. Leaves	% Infested	No. Leaves	% Infested
Quassia-soap	907	41%	2780	16%
Nicotine-soap	316	65%	396	3%
Nicotine-lime dust	1592	12%	2104	7%

These data show the nicotine-lime dust to be quite an effective means of control, and the quassia-soap spray to be fairly effective. Observations on the nicotine-soap spray were not extensive enough to be a source of conclusions.

Table 4

EFFECTIVENESS OF APPLICATION METHODS

Method of Applic.	Before spray		After spray	
	No. Leaves	% Infested	No. Leaves	% Infested
Auto duster	1592	12%	2104	7%
Spray: orchard type	24	12%	456	53%
Spray: automatic	252	23%	1856	10%

Table 4 shows the dusting method and the automatic spray method to be quite effective. The orchard type sprayer method of application cannot be considered ineffective on the basis of the above figures, for those figures were not obtained under very favorable conditions, nor were they very extensive.

The cost of these methods of application and materials is shown in charts 5 and 6. Brief summaries of the costs are given in tables 5 and 6.

Table 5

COST OF SPRAY MATERIALS

Material	Cost per acre
Quassia-soap	$2.70
Nicotine-soap	2.90
Nicotine-lime dust	2.39

Table 5 shows average costs per acre of materials used in aphis control operations in several yards including over 1,500 acres, or approximately 5% of the state's crop. These costs have been obtained from hop growers. The quassia-soap cost was figured from costs of materials (stated by growers) at an application rate of 600 gallons per acre. The cost of the nicotine-lime dust was figured by the writer from information made available by the Horst Company, users of the dust and developers of the auto duster. The cost of the nicotine-soap spray is from a summary of costs given by two growers spraying a total of 354 acres.

Table 6

COST OF APPLICATION METHODS

Method	Cost per acre
Auto duster	$0.16
Spray: orchard type	2.67
Spray: automatic	2.54

Table 6 gives spray operating costs per acre in several yards. It shows that the Horst auto duster is a much less expensive means of application of hop aphicides than either of the spraying methods. The sprayers using automatic nozzles operate for a few cents below the cost to spray with the orchard type sprayer.

Table 7

DATA USED IN COST STUDIES

Acres	Man Value	Horse Value	Material	Operating Cost	Interest Depreciation, Repairs	Total Cost	Cost Per Acre
70	$108	$29	(1) $42	(1) $ 8	$ 41	$228	$3.26
175	216		(2) 602	(3) 144	297	1316	7.52
15	23	10	(3) 42	(1) 2			
				(2) 8		85	5.67
50	68		(3) 168	(3) 70	77	383	7.66
80	33		(3) 100	(3) 45	50	228	2.85
40	35	6	(3) 30	(3) 9	25	105	2.62
53	46	7	(3) 39	(3) 11	30	133	2.51
14	7		(1) 13	(2) 12		32	2.29
10	5	1	(1) 10	(1) 1			
				(2) 5		22	2.20
10½	9	2	(3) 10	(2) 12		33	3.14
20	29		(3) 20	(2) 10		79	3.95
31	16		(1) 40	(2) 40		96	3.10
17	12		(1) 9	(3) 5	61	87	5.12
6½	13	2	(3) 12	(1) 1	40	68	10.46
17½	22	4	(1) 23	(1) 3	32	84	4.79
500	2640*		(2) 1500			4140	8.28
179	488**		(2) 425			913	5.10
732	84		(4) 1754	(1) 30	18	1886	2.57
7			(1) 14				

* Horses used, cost with labor.

** Includes horses, gas and oil.

Material:
(1) Quassia-soap
(2) Nicotine-soap
(3) Not specified
(4) Nicotine-lime dust

Operating cost:
(1) Gas and oil
(2) Rent of sprayer
(3) Tractor

Data in table 7 are from records taken from growers by Selby, Smith, and Kuhlman (14).

COST OF APHIS CONTROL IN CALIFORNIA: A study of the cost to produce hops in Sonoma County, California, during the 1934 season has come under my observation. This mimeographed report gives itemized costs of operations on 13 different yards. (17) This material has beenggone over and the items of value in the present study are included in the following table.

Table 8

PER ACRE COST OF HOP APHIS CONTROL IN SONOMA COUNTY

Serial	Acres	Labor Cost	Material and Overhead	Total Cost
1	120	$1.16	$3.12	$4.28
3	52	3.25	7.13	10.38
4	43		1.83	1.83
5	40	.30	1.51	1.81
6	68	.20	2.87	3.07
10	46	1.29	.23	1.52
11	35	.43	1.14	1.57
12	5	1.30	.20	1.50
13	12	2.50	4.17	6.67
Average		$1.05	$2.80	$3.85

After the data on aphis control costs were tabulated and discussed two more records were received. They are given below:

(1) Year: 1931
Number of acres: 140
Sprayer: automatic
Cost of materials (Not named) per acre: $4.20
Cost of labor per acre: $1.30
Total: $5.50 per acre. This does not include cost of interest and depreciation.

(2) Year: 1935
Number of acres: 233
Sprayer: automatic
Cost of materials (quassia, common formula) per acre: $4.20
Cost of labor per acre: $.70
Cost of gas and oil per acre: $.25
Total: $5.15 per acre. This does not include cost of interest and depreciation.

EXPERIMENTAL CONTROL TESTS

The purpose of the experimental sprays was to observe the kill of aphis by the various insecticides under test conditions.

THE SPRAY PLOTS

The experimental sprays were made in part of a $5\frac{1}{2}$ acre hop yard under study by the farm crops department. It is located near the Willamette River east of Corvallis. The hills are 8 feet apart and the vines are trained straight up 14 feet to trellis wires. The sprays were applied only to the common varieties of hops, namely: late clusters, early clusters, and fuggles. A map of the field, chart 2, shows the location of the plots and of the varieties within the plots. It will be noted that all the spray plots but number 6 included each of the 3 hop varieties.

THE SPRAY EQUIPMENT

The spraying machine used was a Hardie Duplex 100 gallon sprayer, pictured on plate 13, figures a and b. The nozzle used ejected a cone-shaped mist, but this nozzle is of a type not used in large hop yards. The foliage was sprayed from all sides to assure complete coverage.

APHIS POPULATION

Before application of the spray an average infestation of 60% existed in the plots. The varieties were similarly infested; the late clusters were 63% infested, the early clusters 59%, and the fuggles 61%.

TIME OF APPLICATION OF THE SPRAY

The sprays were applied July 12 and July 13, 1935. For several days the weather had been fairly cool, but July 12 was the beginning of a 5-day hot spell. The official temperatures recorded at the college for those days follows:

	July 12	July 13
Maximum	99.2	106
Minimum	56	62
Mean	95	96

A slight northeast wind did not interfere with the application of the spray.

THE MATERIALS TESTED

The following insecticides were tested:

Black Leaf 40	Pyrocide 20
Quassia	Lethane 440
Derris	Cubor

The following spreaders or wetters were used:

Whale oil soap	Kayso
Liquid soap spreader	Vatsol

A larger quantity of each spray was prepared than was needed, to permit overspraying to assure coverage. The sprays contained 50, 75, or 100 gallons of spray solution.

BLACK LEAF 40 and QUASSIA have been described above.

DERRIS is a powdered insecticide prepared from the roots of the tropical plants Deguilia elliptica and D. ulginosa. The chief insecticidal constituent of derris is rotenone. The rotenone content of the derris used herein was 5%. Derris is slow acting against insects and is fatal when taken into the digestive tract or when absorbed through the body wall. (16) Death is apparently due to inability to utilize oxygen. Derris is non-toxic to higher animals, and is thus qualified as a spray on plants that are to be eaten. Exposure breaks down the derris so it does not have a very lasting effect as an insecticide. Derris was used in two plots, numbers 9 and 10. In plot 9, called Derris 2½%, the rotenone content was approximately .03%. In plot 10, called Derris 1%, the rotenone content was approximately .01%.

CUBOR, a commercial rotenone-containing spray material, contains 2.5% rotenone and 5% cube extract. This material was used in two plots, numbers 3 and 8. In plot 3 the rotenone content was approximately .025%, while in plot 8 the rotenone content was approximately .037%.

The only one of these four sprays that shows up very promising is the so-called 1% Derris, in plot 10. This was less efficient than nicotine or quassia, but was less expensive. The other three derris sprays were not very effective and were costly.

PYROCIDE 20 is a pyrethrum insecticide. Pyrethrum is from powdered flower heads of _Chrysanthemum cinerariaefolium_ and related species. The pyrocide 20 is a kerosene solution of a petroleum ether extract of the pyrethrum containing 2.4% of pyrethrins. In plot 2 pyrocide 20 was used with liquid soap spreader (a cocoanut oil soap) and was ineffective as well as very expensive.

LETHANE 440 is a synthetic insecticide produced by the Rohm and Haas Company of Philadelphia. The descriptive chemical name of this compound is butoxy thiocyano diethyl ether. The control obtained at one gallon to 200 gallons of water, (double the recommendation for aphis) was slight and the cost was prohibitive.

Table number 9 shows the sprays used in each plot as well as the cost of the materials used in each and the cost per acre with an application of 600 gallons of spray.

Table 9

SPRAYS APPLIED IN EXPERIMENTAL PLOTS

Plot & No.Plants	Per Acre Materials, rate (water, 600 gal.)	Per Acre Cost of Materials	Rel. Eff. after 3½ weeks
1-43	Black Leaf 40 2 lbs Whale oil soap 32 lbs	$2.78	5
2-45	Pyrocide 20 2 gal Liquid soap 2 gal		9
3-44	Cubor 3/4 lb	4.80	8
4-65	Quassia 10 lbs, soaked Whale oil soap 36 lbs	2.94	2
5-66	Soaked quassia 10 lbs, boiled Whale oil soap 36 lbs	2.94	1
6-18	Lethane 440 3 gal	25.50	10
7-36	Black Leaf 40 6 lbs Whale oil soap 48 lbs	6.42	3
8-27	Cubor 9 lbs, Kayso 6 lbs	15.60	7
9-26	5% Derris 3¼ lb, Vatsol 1½ lb	2.38	6
10-27	5% Derris 1 3/4 lb, Vatsol 1½ lb	1.56	4

CONCLUSIONS

Taking cost and effectiveness into consideration it appears that the most satisfactory of the sprays tried are: quassia, derris, and nicotine. Further experimentation with these insecticides for hop aphis control is advisable.

SUMMARY

The importance of the hop aphis, Phorodon humuli (Schrank), to the Oregon hop crop is discussed.

The hop aphis is treated from the standpoint of life history, classification, and habits.

Field controls of the hop aphis in the Willamette Valley are discussed both in the matter of materials and methods of application. Cost and effectiveness is given in most cases.

Various types of spraying apparatus are illustrated.

The results of an experiment in hop aphis control are given.

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Chart 1

Aphis Distribution Under Varying Field Conditions

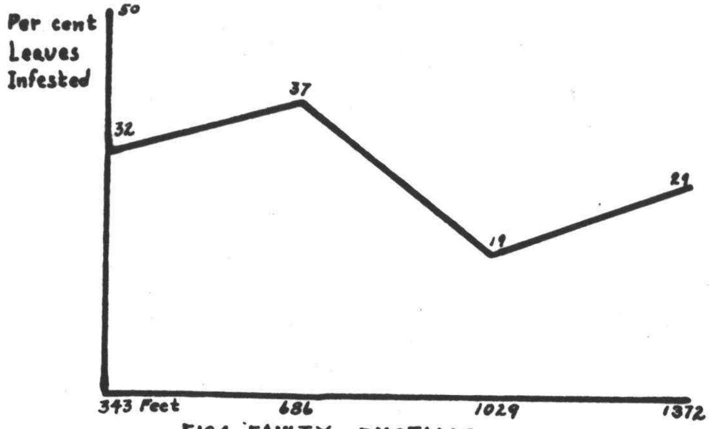


FIG. 1. FAULTY DUSTING

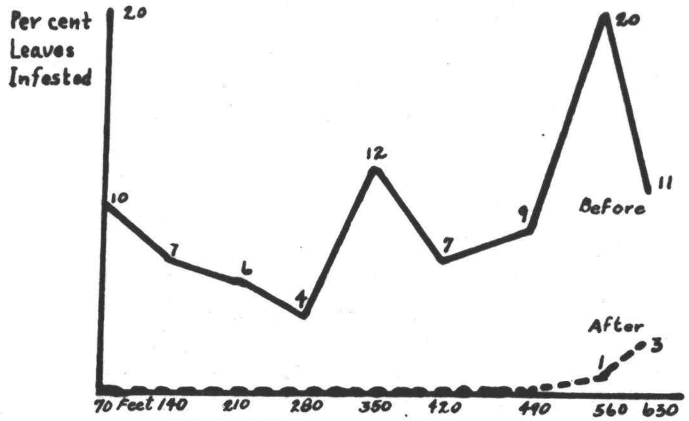


FIG. 2. BEFORE and AFTER DUSTING

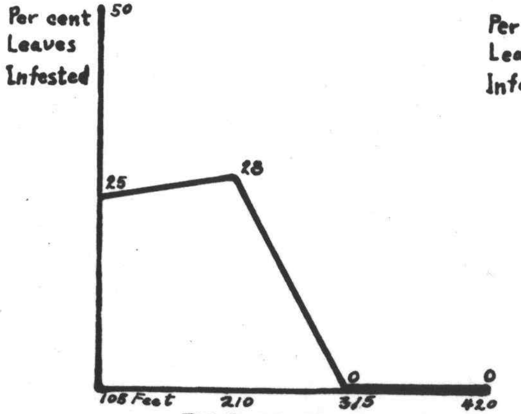


FIG. 3. RELATION TO TIMBER

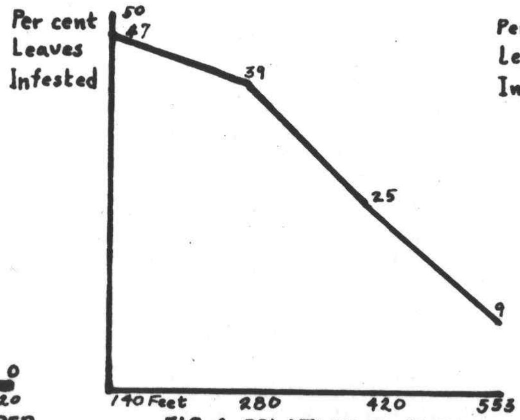


FIG. 4. RELATION TO SLOUGH

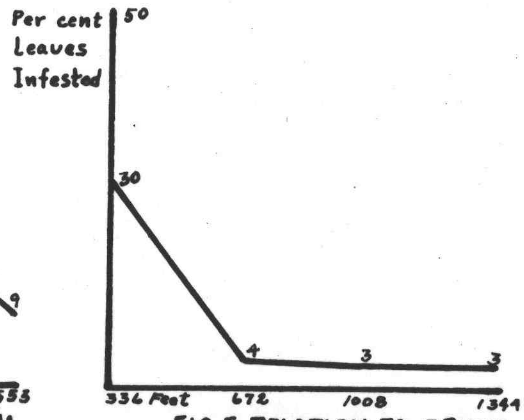


FIG. 5. RELATION TO BRUSH AND SLOUGH

Chart 2

Map of Experimental Spray Plots

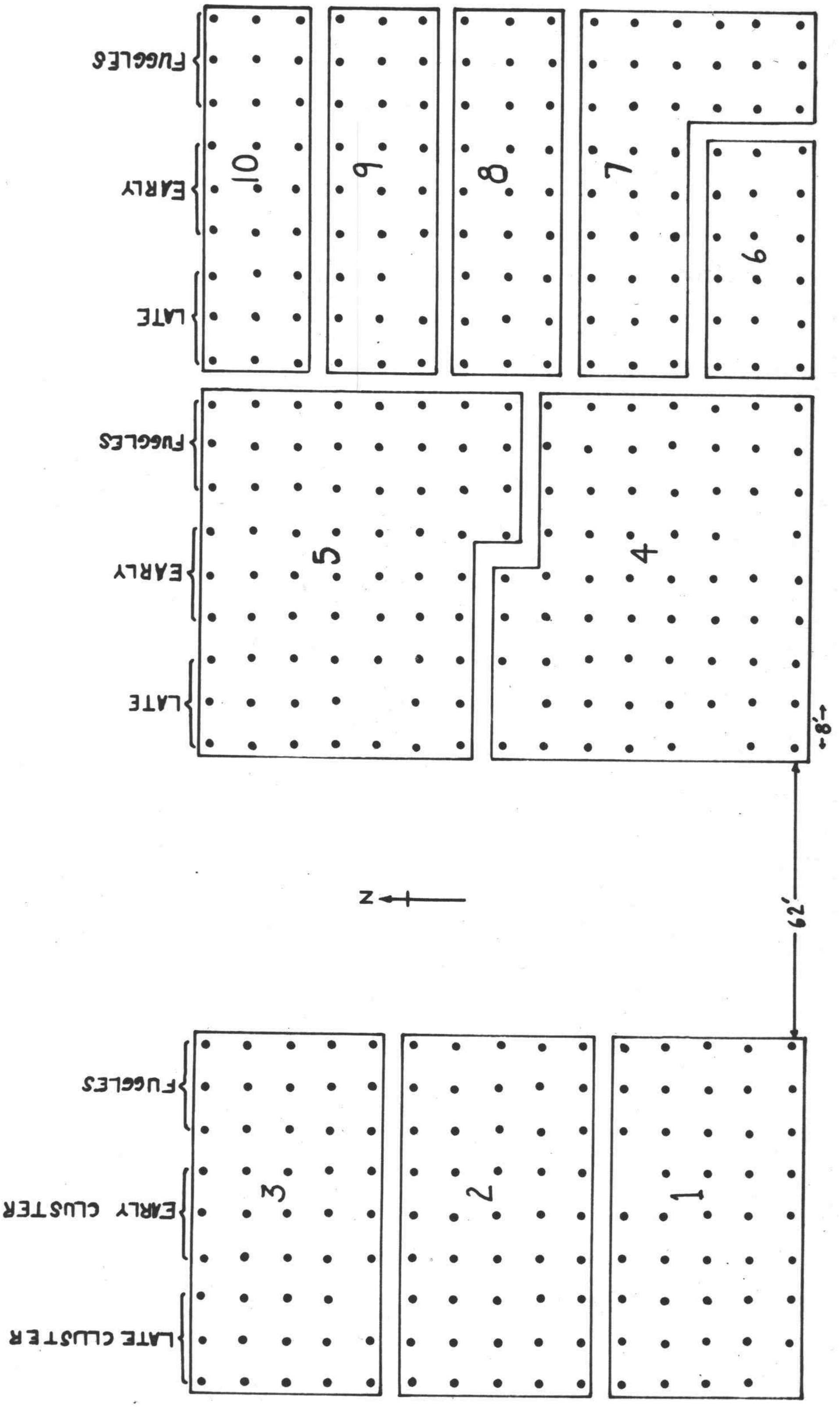


Chart 3

Results of Experimental Sprays - A

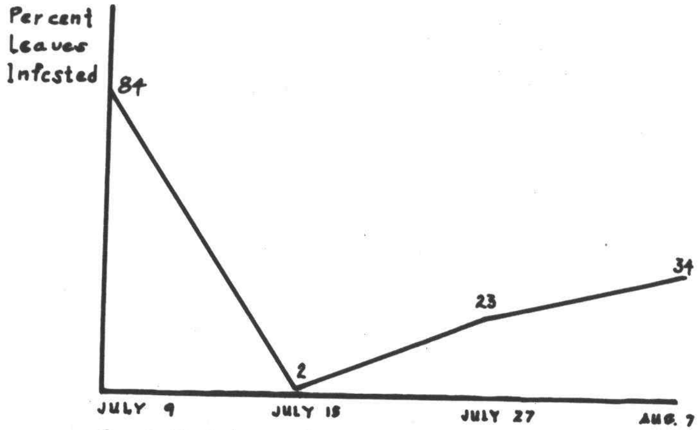


Fig. 1. Plot 1 · NICOTINE ⅓ pint

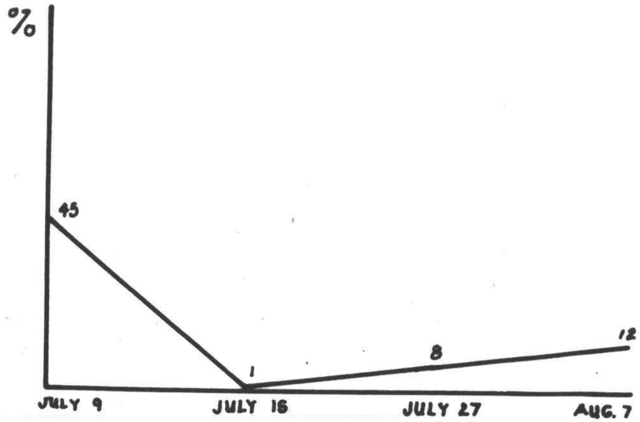


Fig. 2. Plot 7 · NICOTINE 1 pint

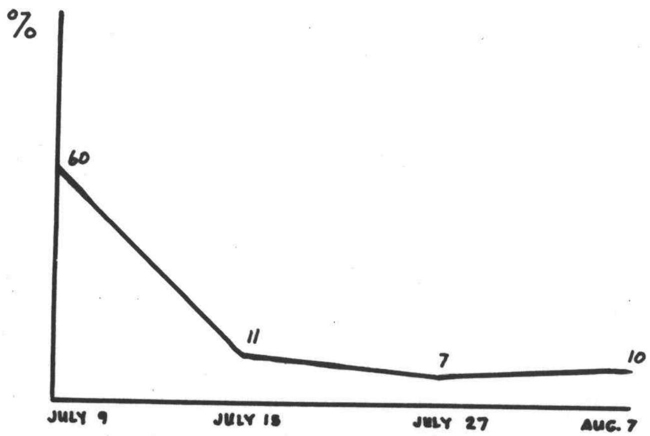


Fig. 3. Plot 4 · QUASSIA, SOAKED

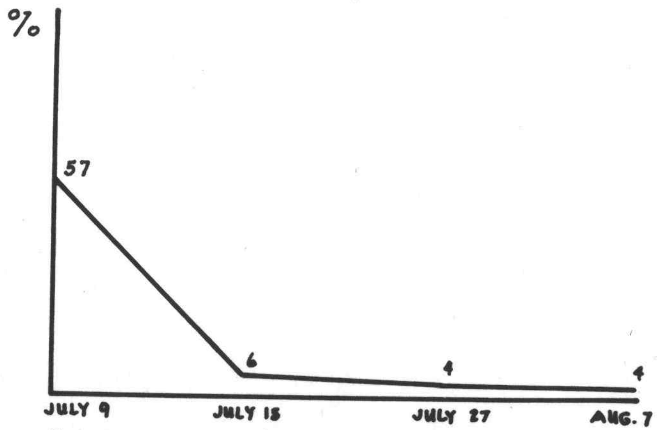


Fig. 4. Plot 5 · QUASSIA, BOILED

Chart 4

Results of Experimental Sprays - B

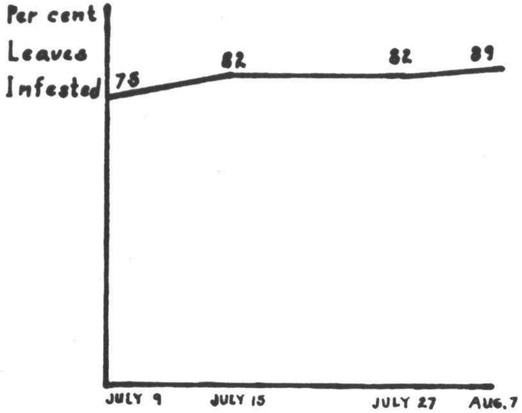


Fig. 1. Plot 2 · Pyrethrum

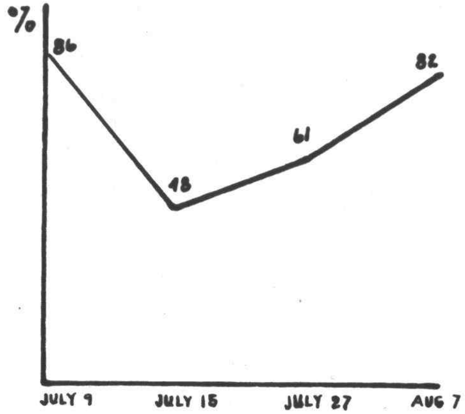


Fig. 2. Plot 3 · Cuber

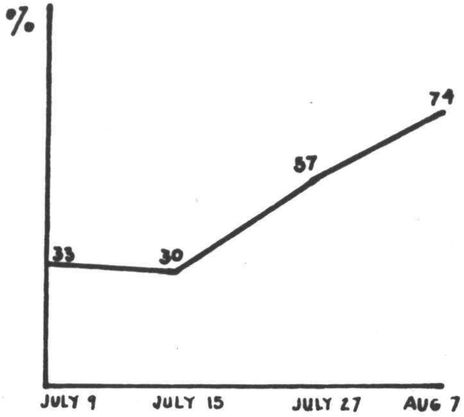


Fig. 3. Plot 6 · Lethane

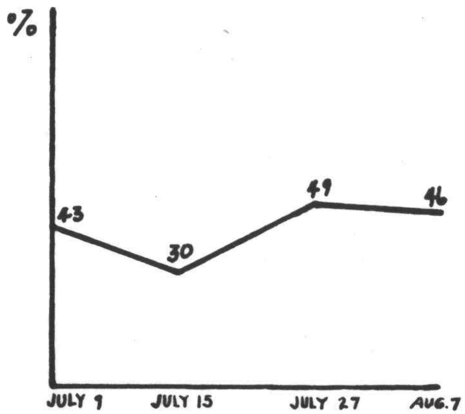


Fig 4. Plot 8 · Cuber, Kayso

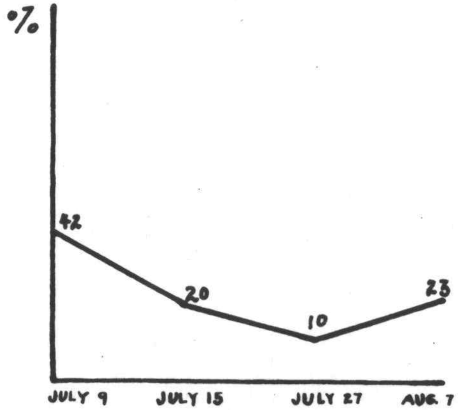


Fig. 5. Plot 9 · Derris 2½ %

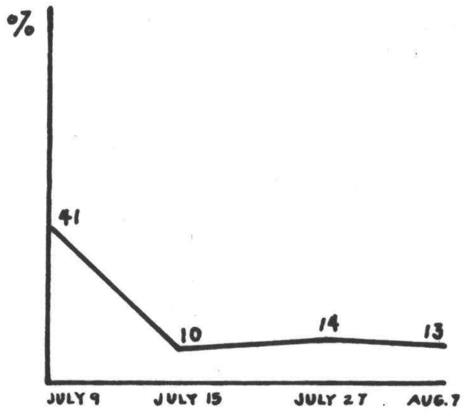
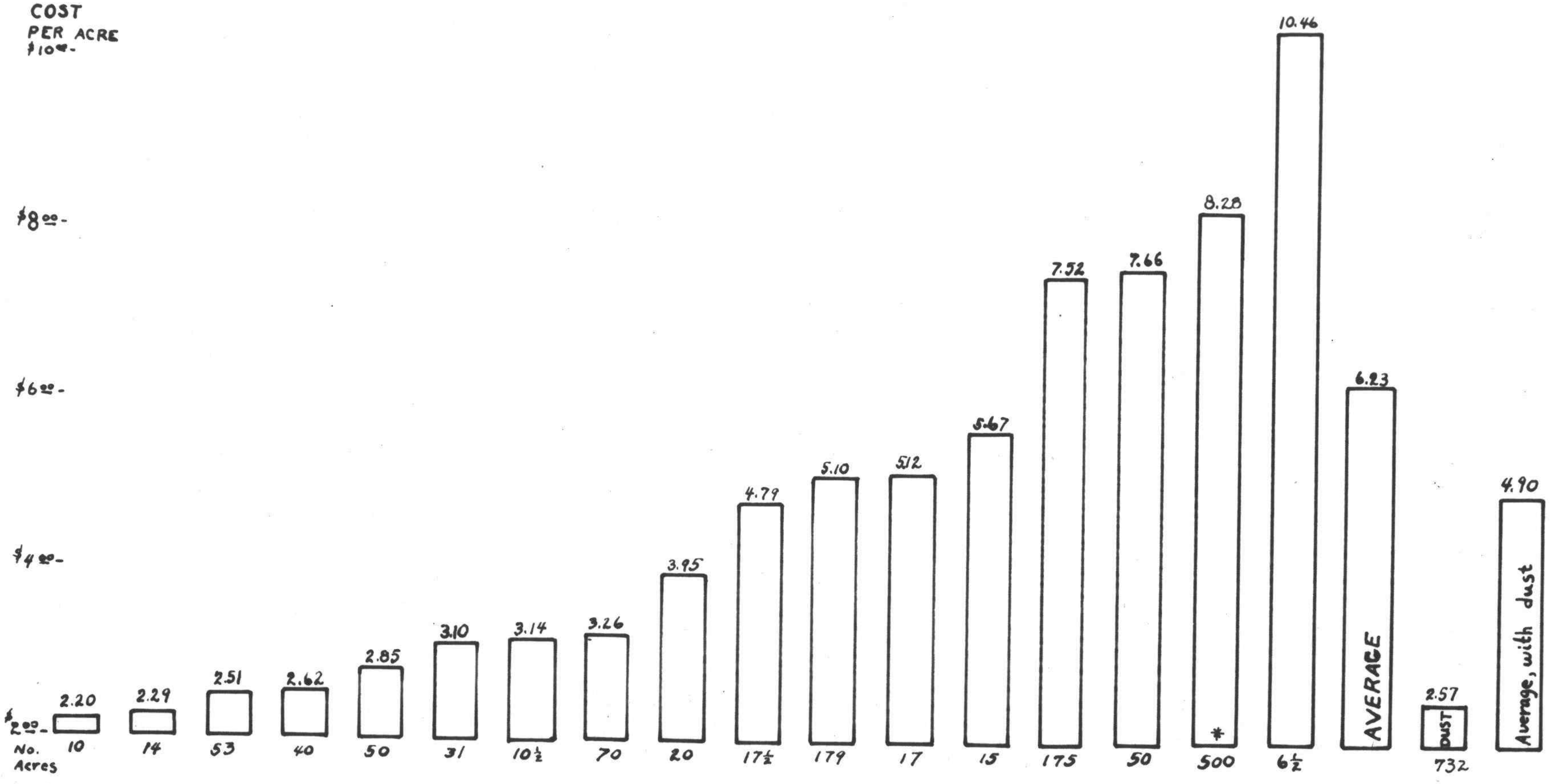


Fig. 6. Plot 10 · Derris 1 %

Chart 5

Total Spraying Costs Per Acre

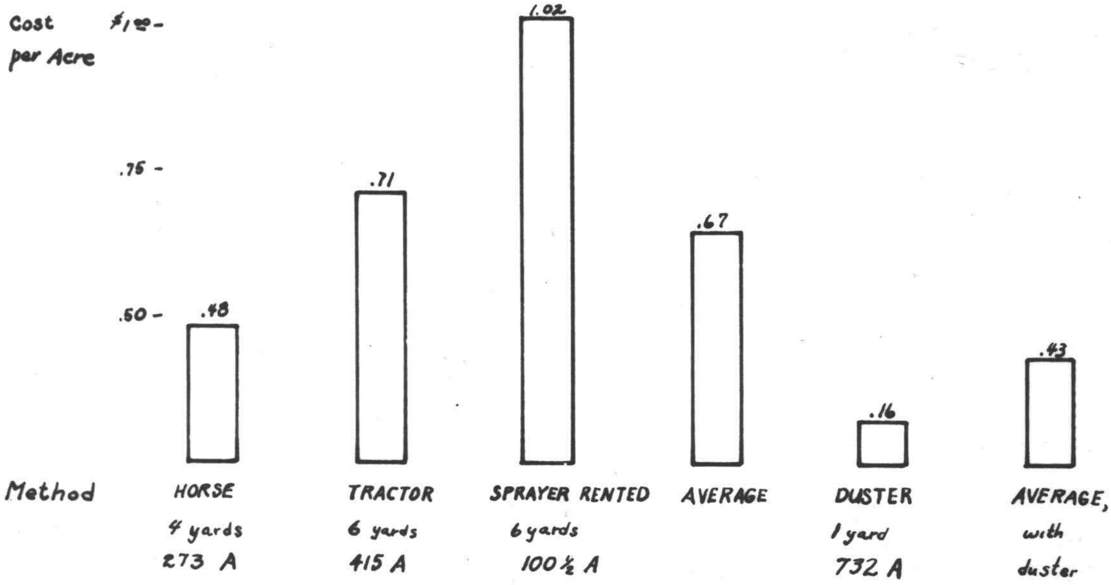


Number of acres	2020 ½
Total cost	$ 9918
Per Acre cost	$ 4.90

* Sprayed, 1932
All others, 1934

Chart 6

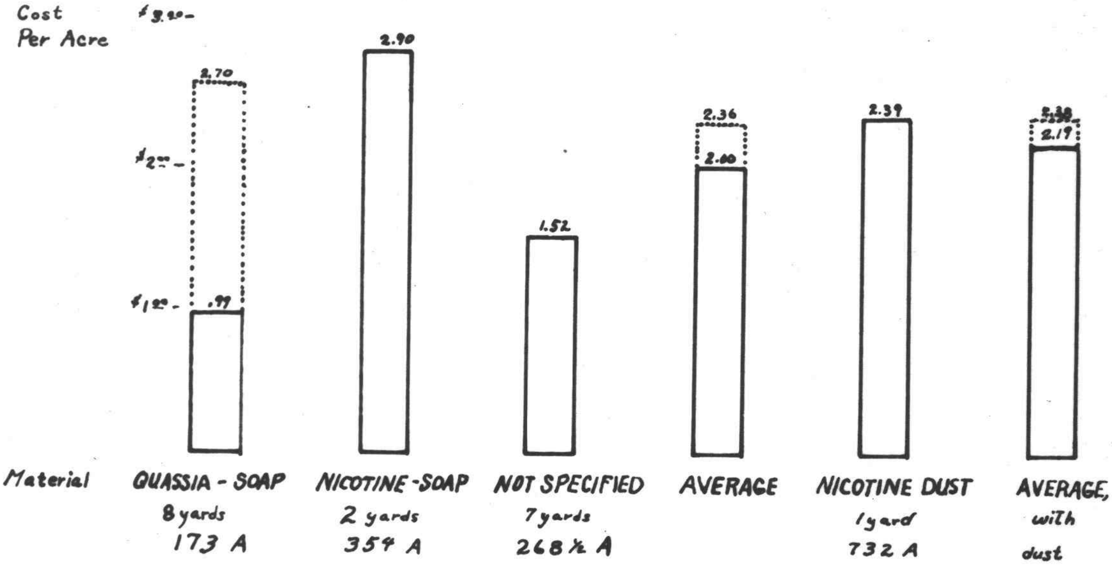
Costs of Spray Application Methods



Number of Acres 1520½
Total cost $654
Per Acre Cost $0.43

Chart 7

Costs of Spray Materials

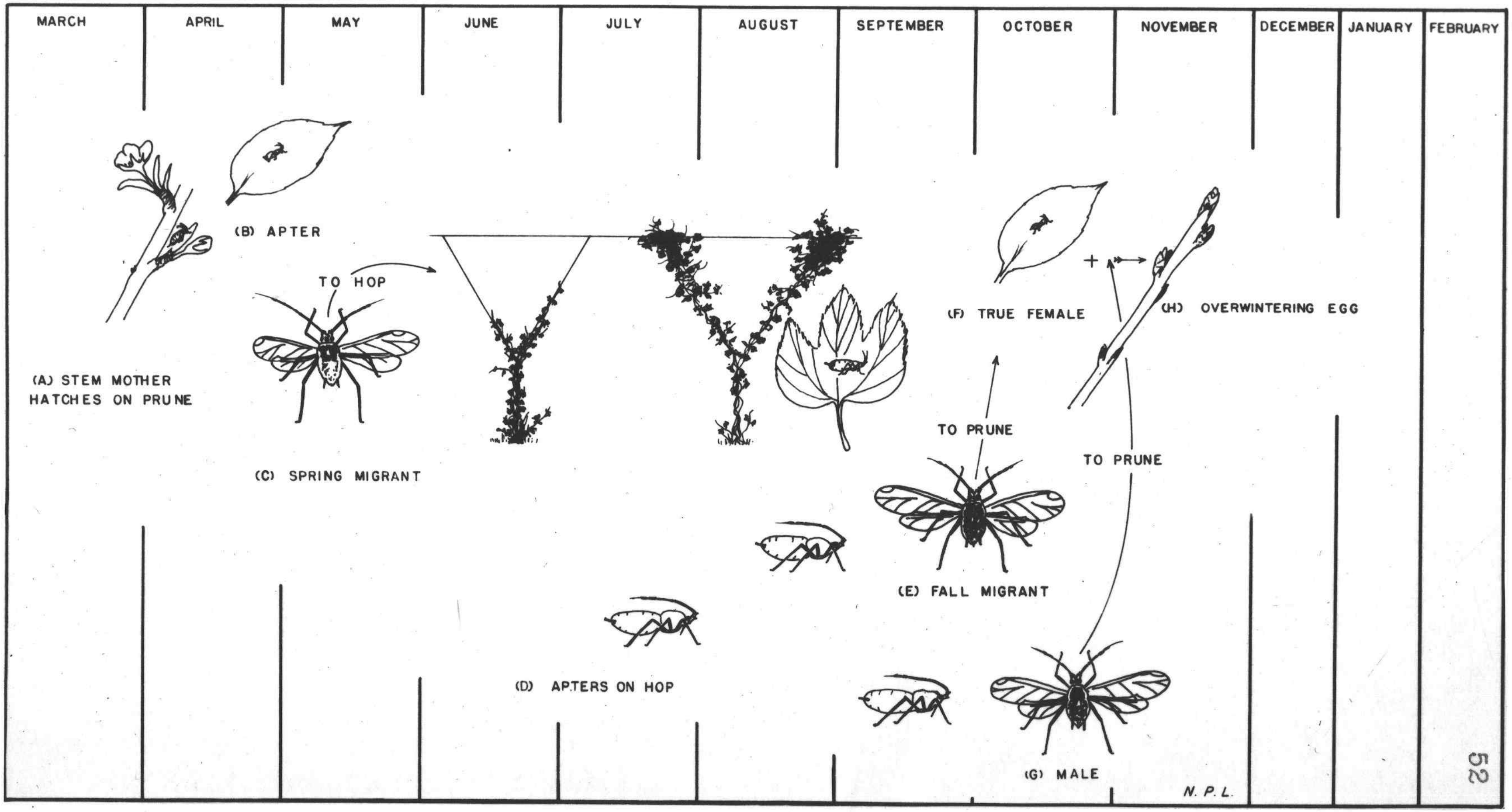


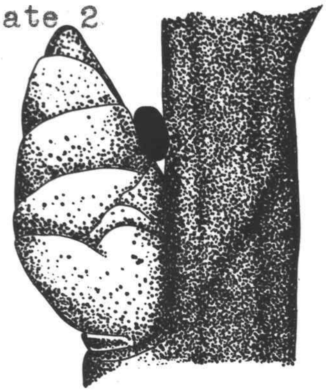
Number of Acres 1527½
Total cost $3351
Per Acre Cost $2.19

Dotted lines represent cost of quassia, (calculated).

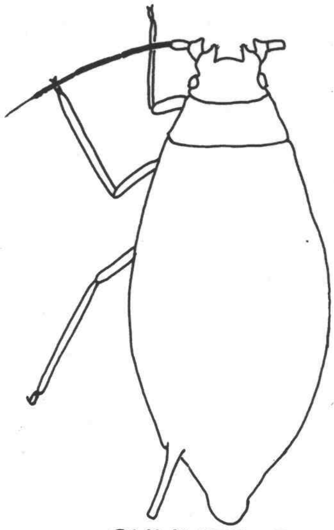
Plate 1

SEASONAL HISTORY OF THE HOP APHIS



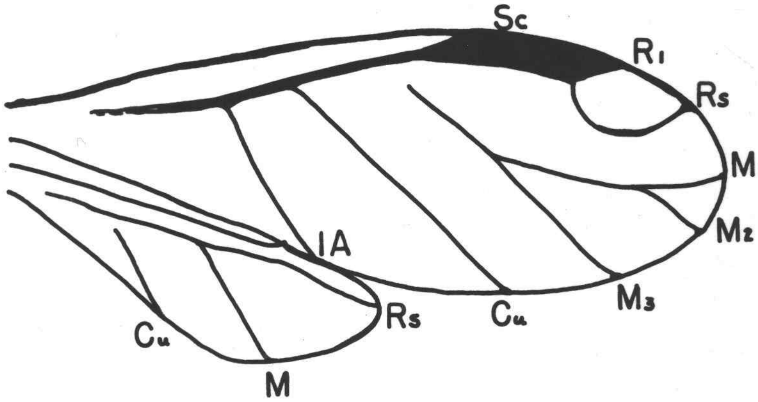


EGG ON PRUNE

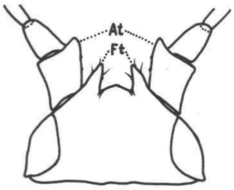


SUMMER FORM

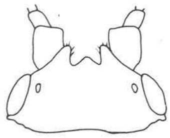
STEM MOTHER



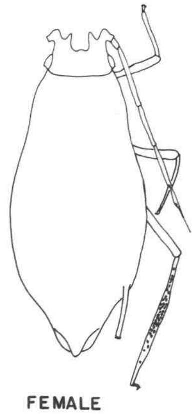
WINGS



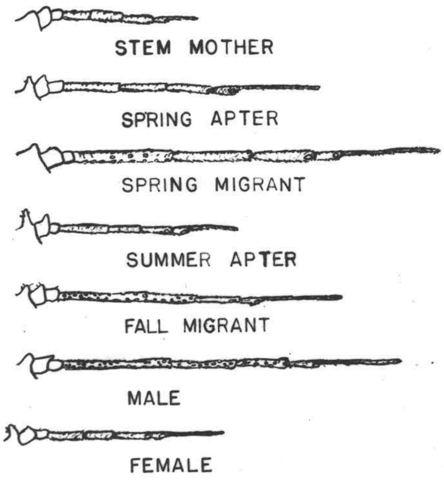
HEAD, FALL MIGRANT



HEAD, MALE

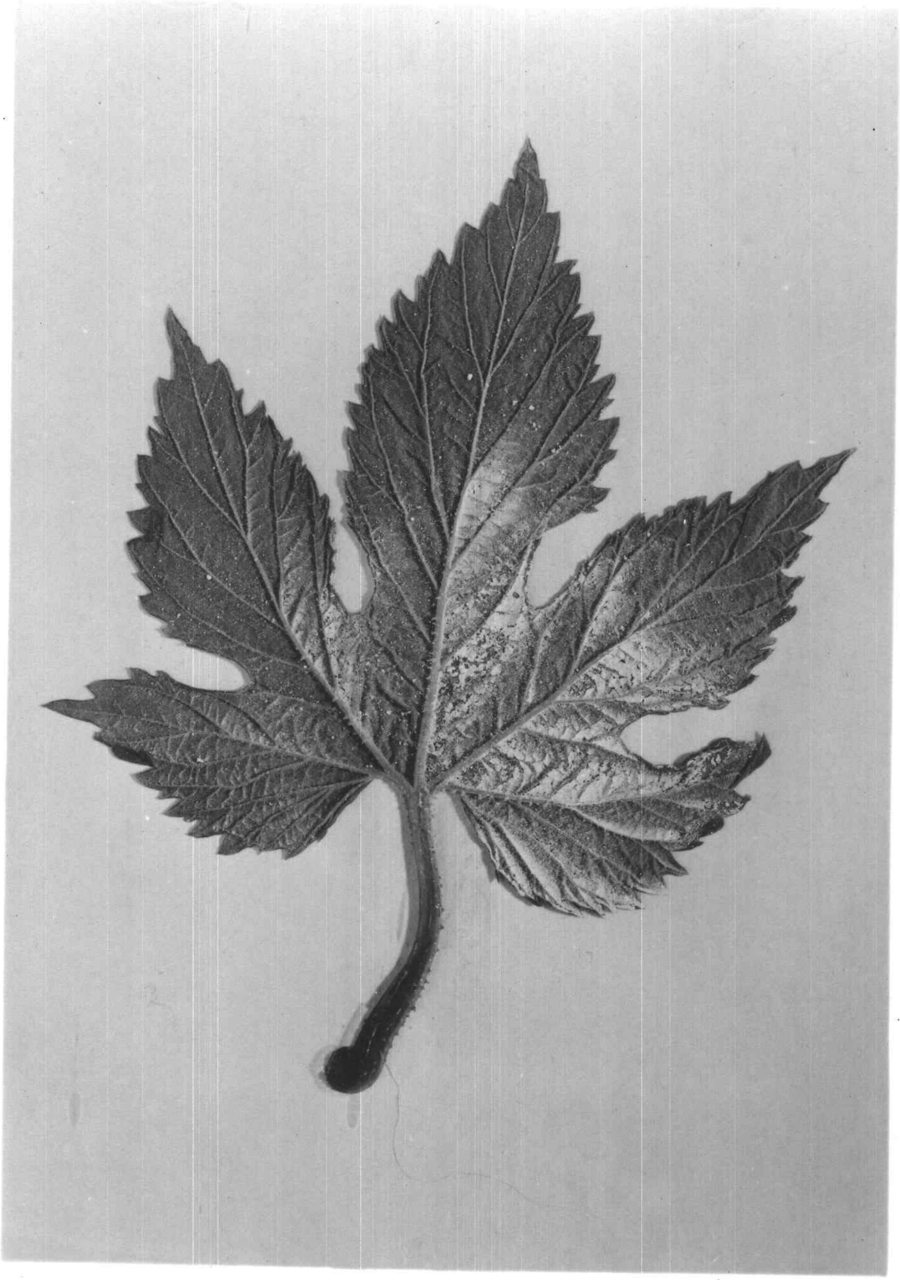


FEMALE

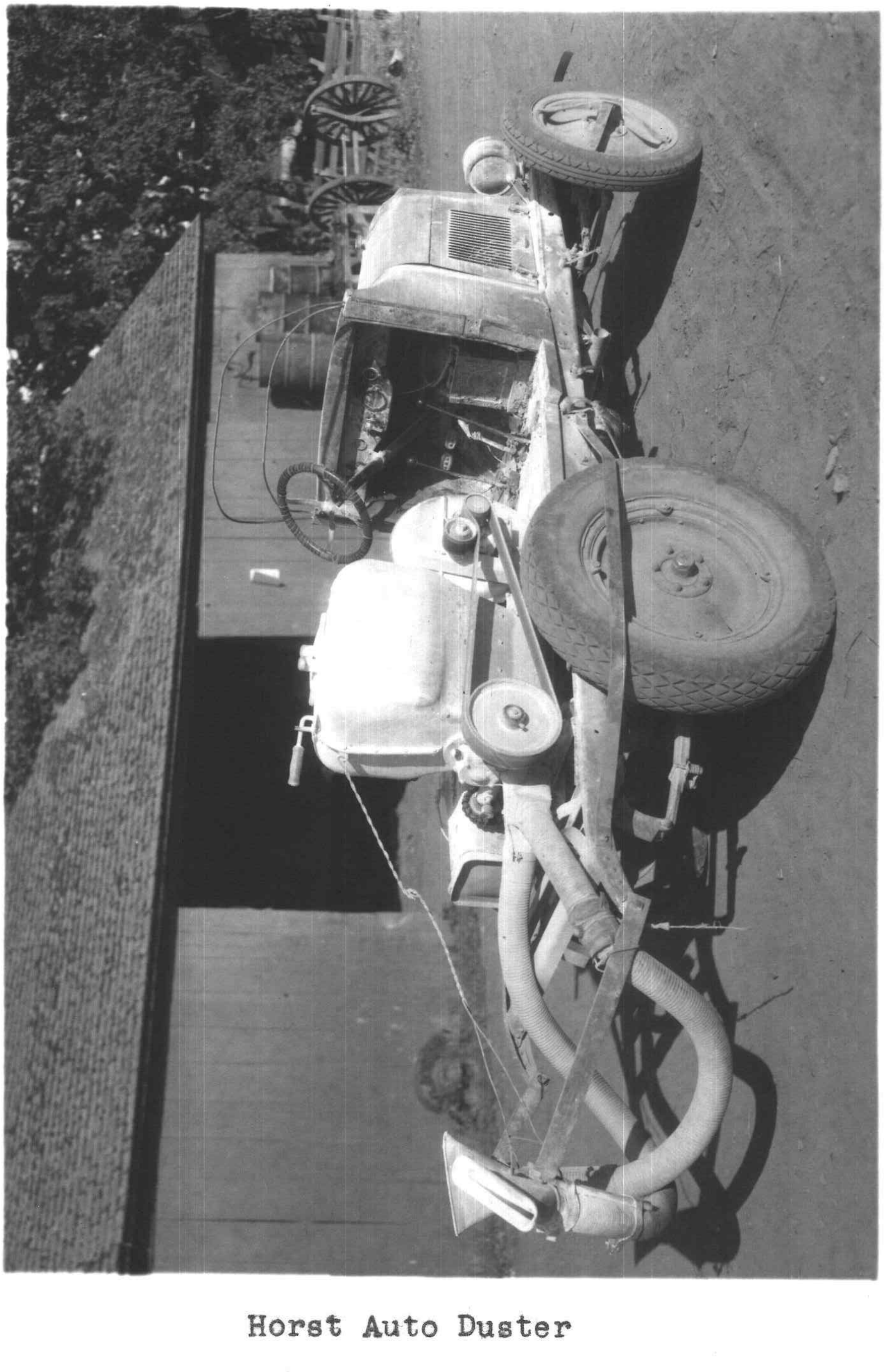


The Hop Aphis

ANTENNAE



Under Side of Hop Leaf Covered With Dust

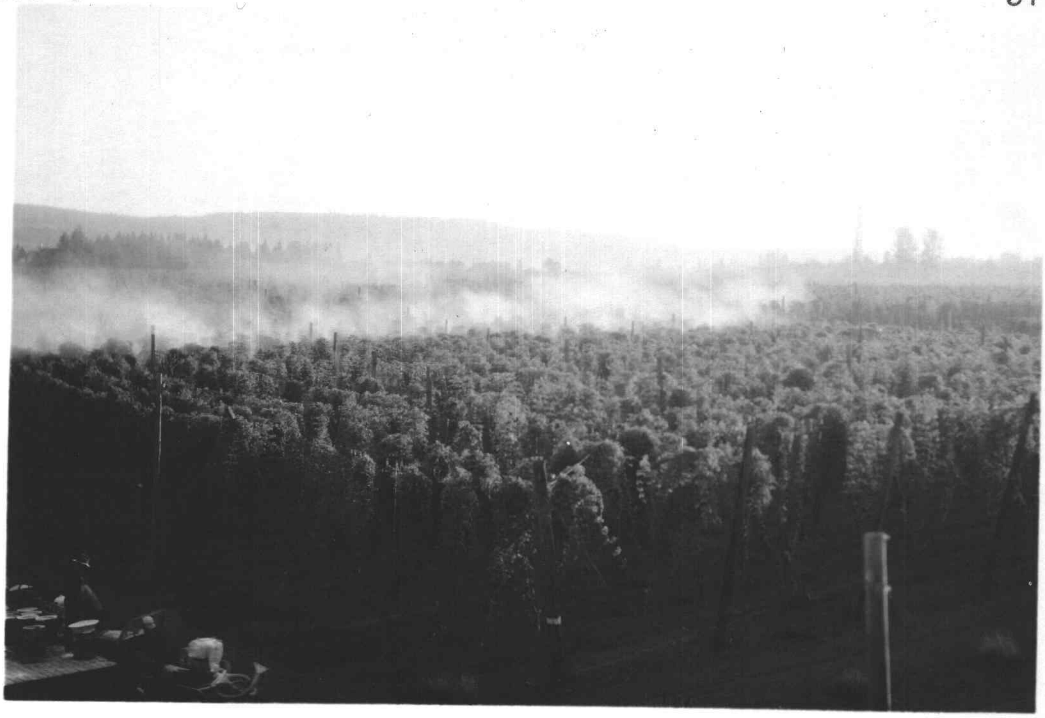


Horst Auto Duster

Plate 5

(a.) Dust in Hop Field

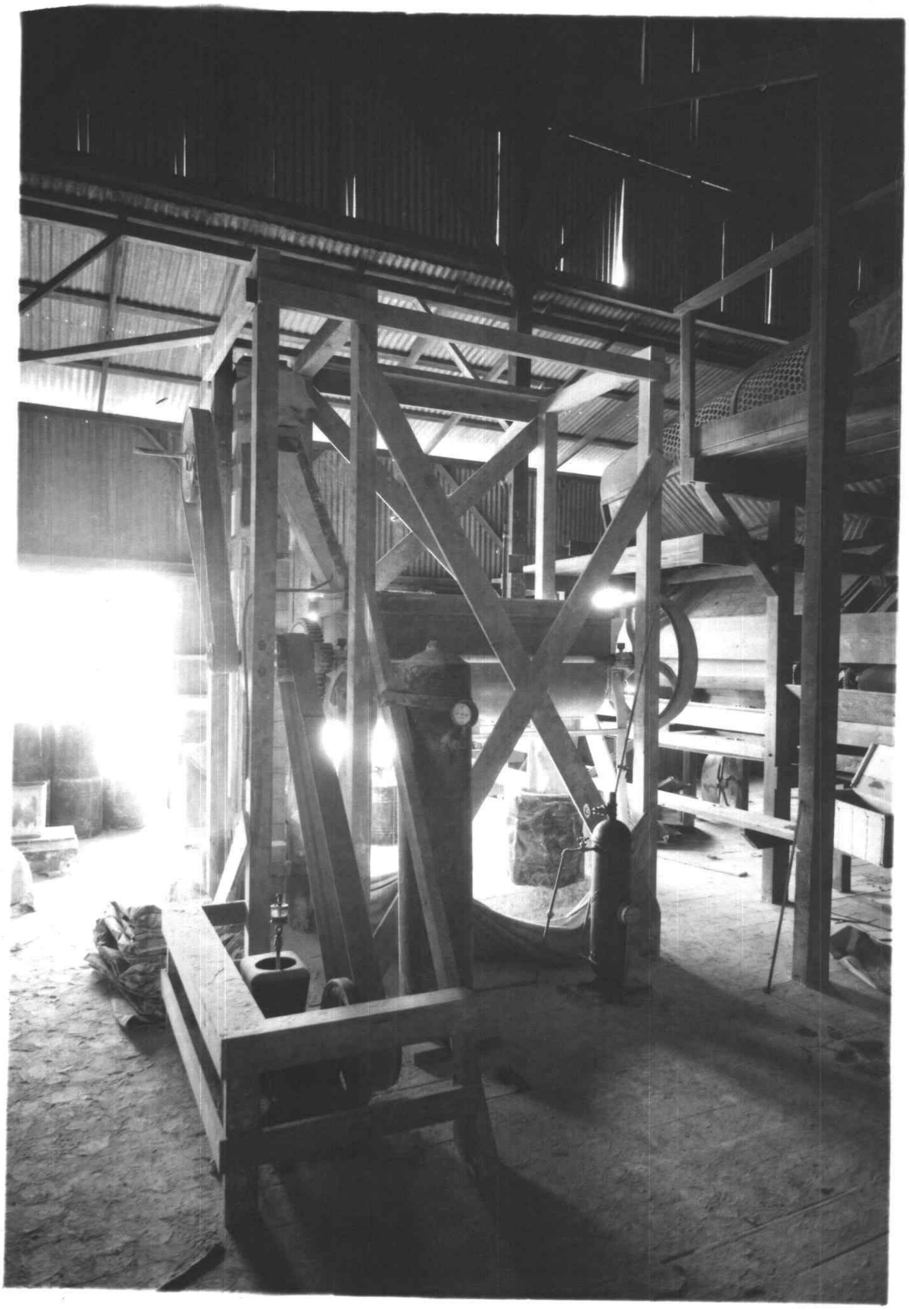
(b.) Dust in Hop Field



(a.) Duster Loading

(b.) Duster Starting

Front View of Dust Mixing Plant

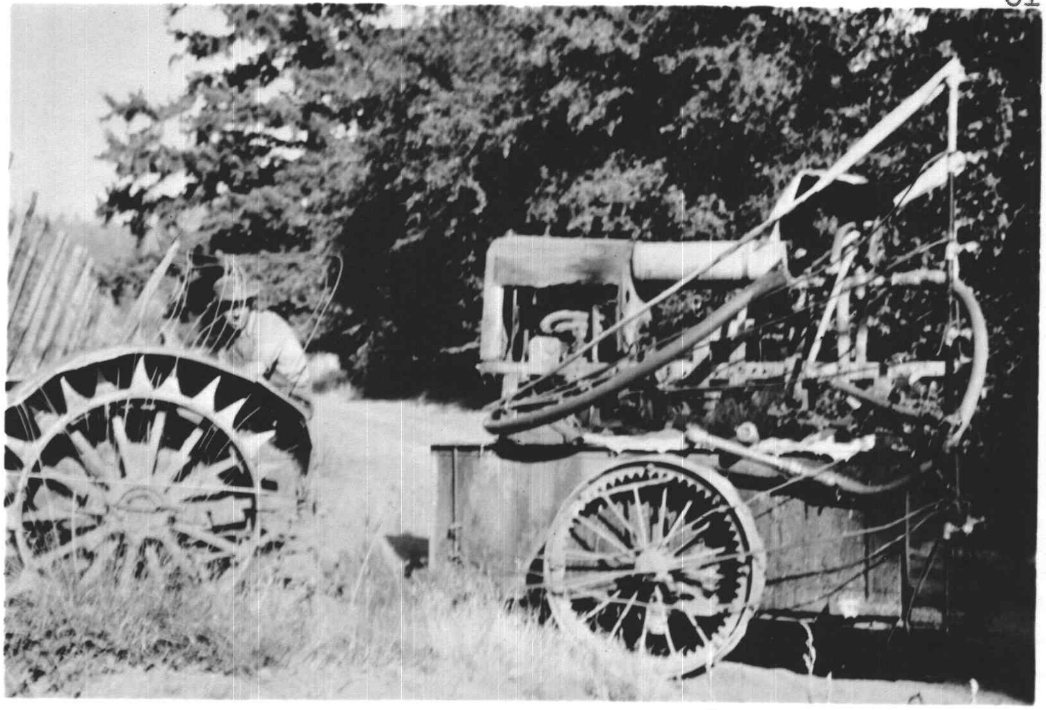


Rear View of Dust Mixing Plant

Plate 9

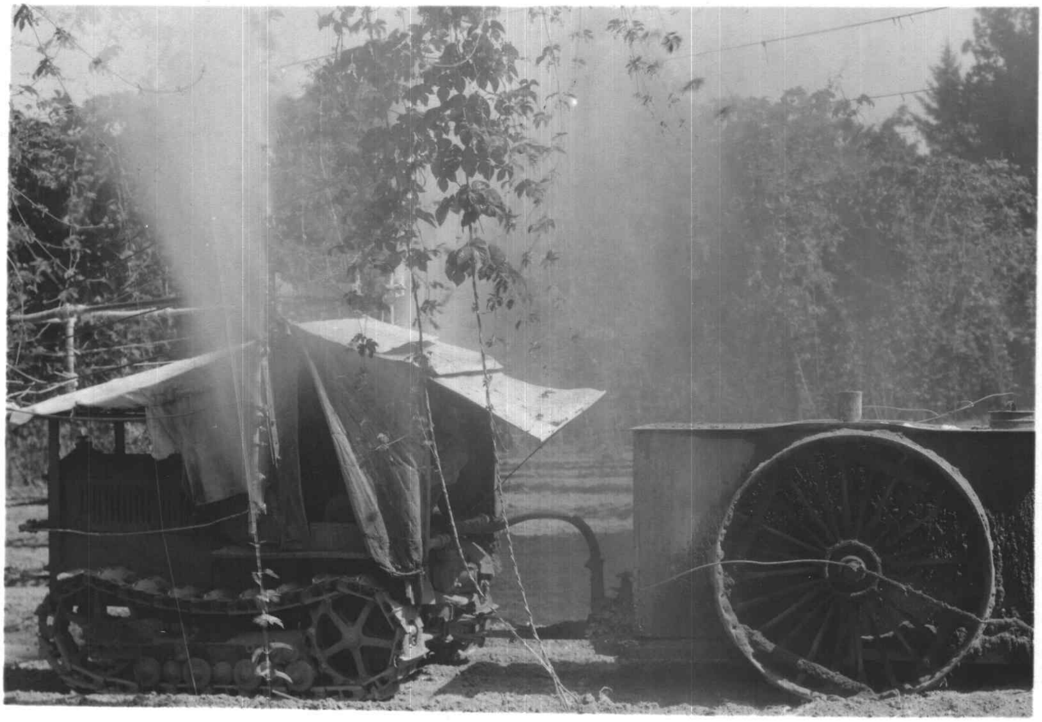
Horst's Bean Sprayer

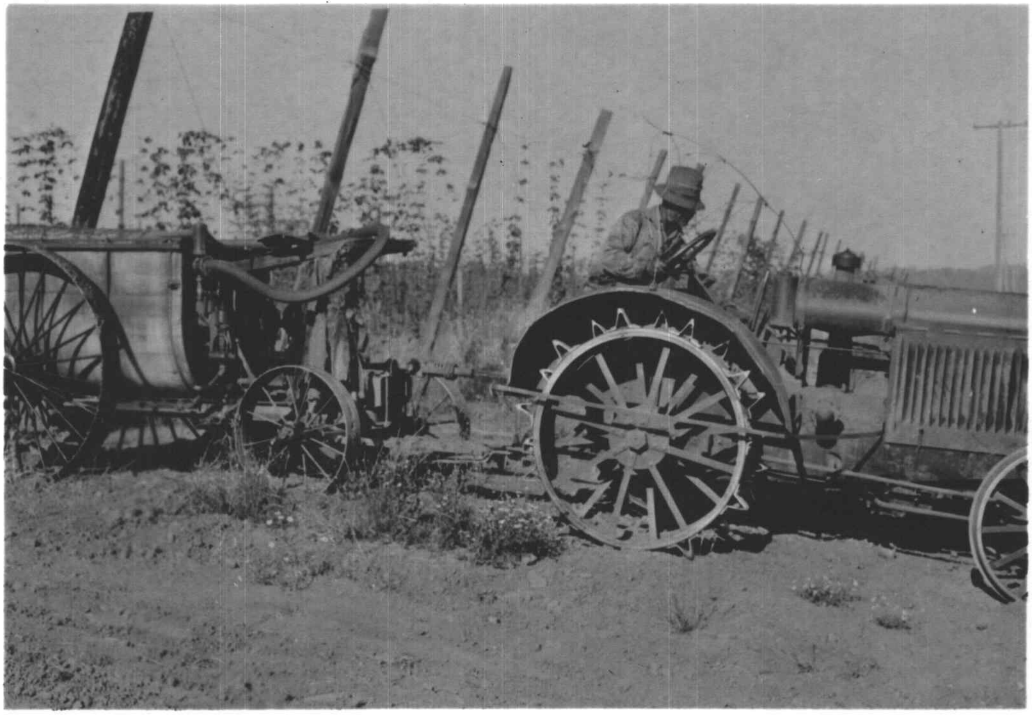
Plate 10



(a.) Side View of Mitoma Sprayer

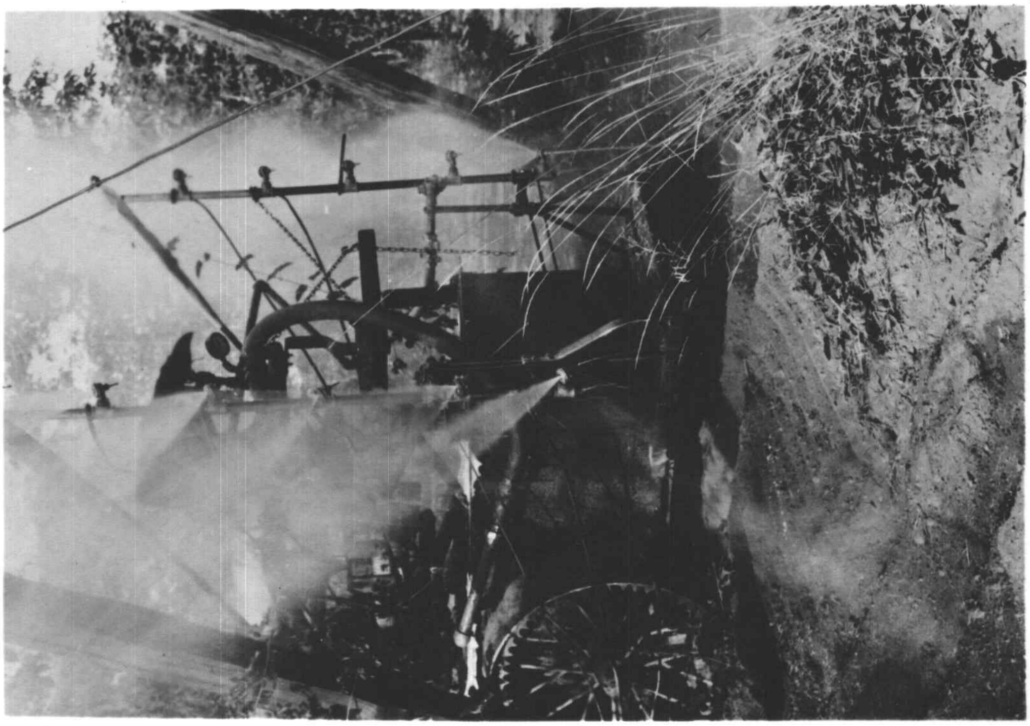
(b.) Seavy Automatic Sprayer

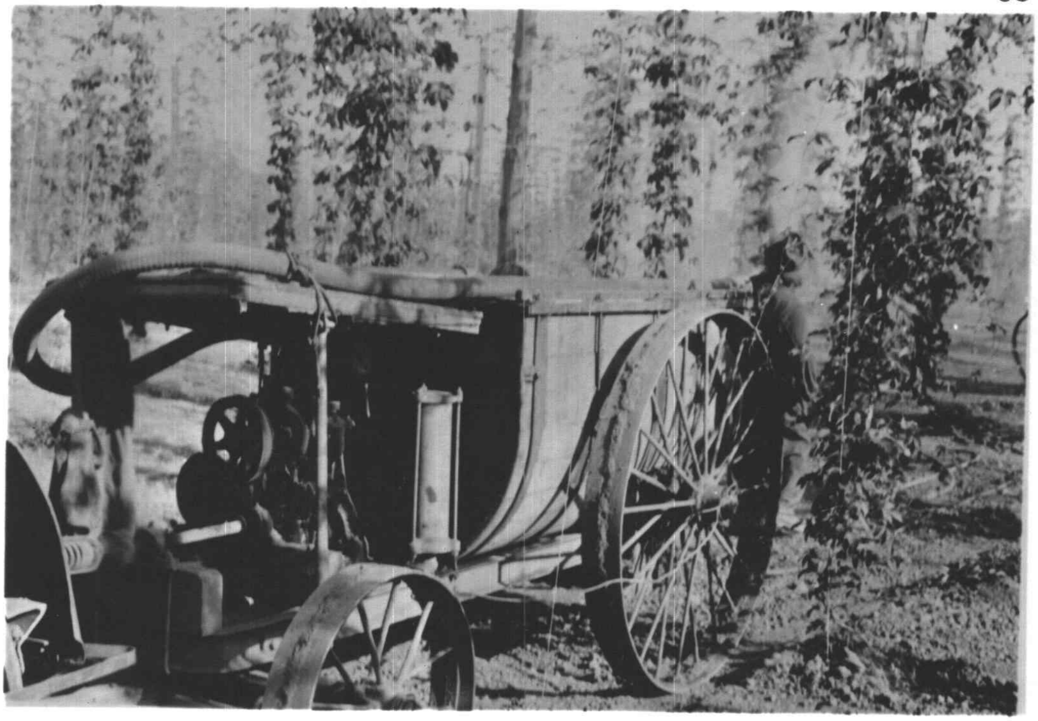




(a.) Side View of Titus Sprayer

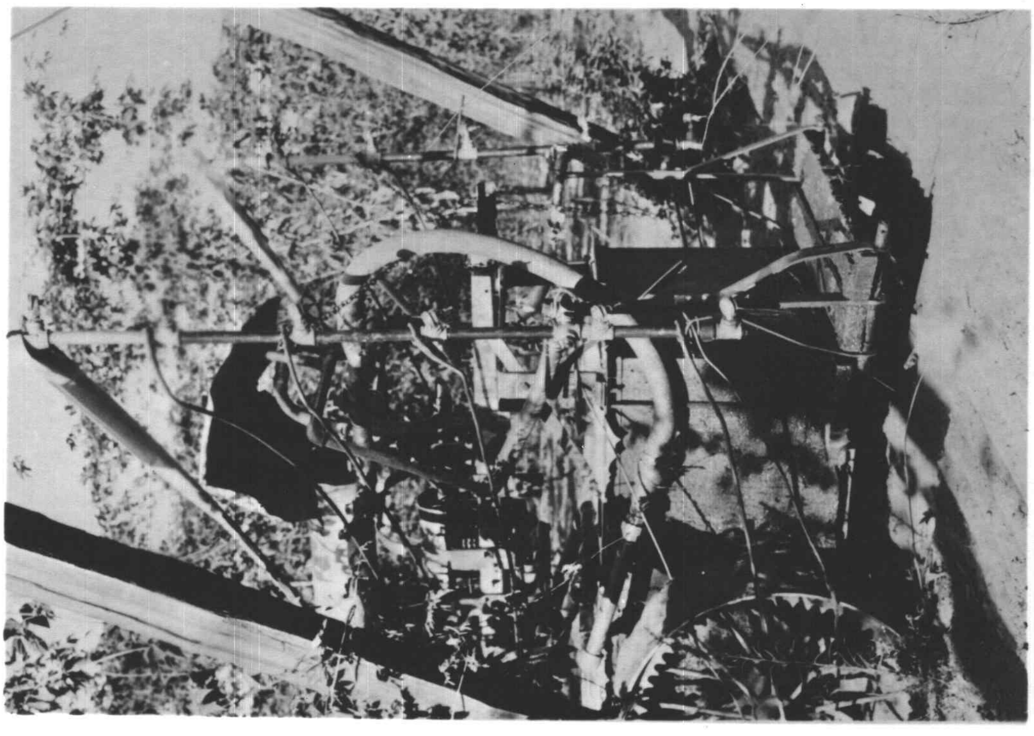
(b.) Mitoma Sprayer in Operation

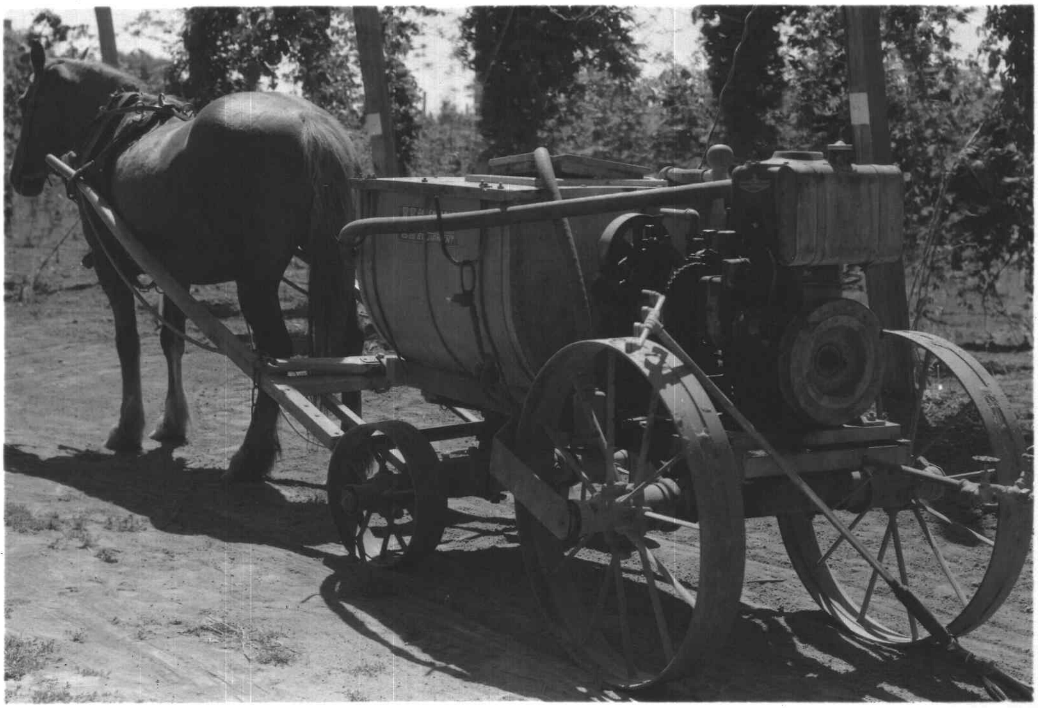




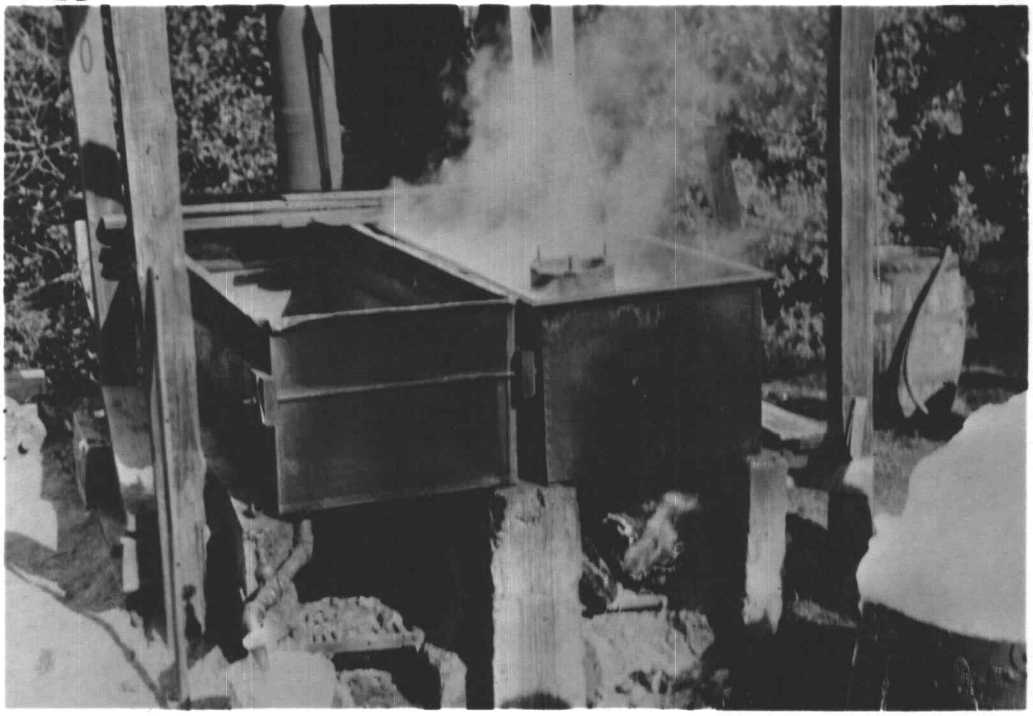
(a.) Near View of Titus Sprayer

(b.) Mitoma Sprayer



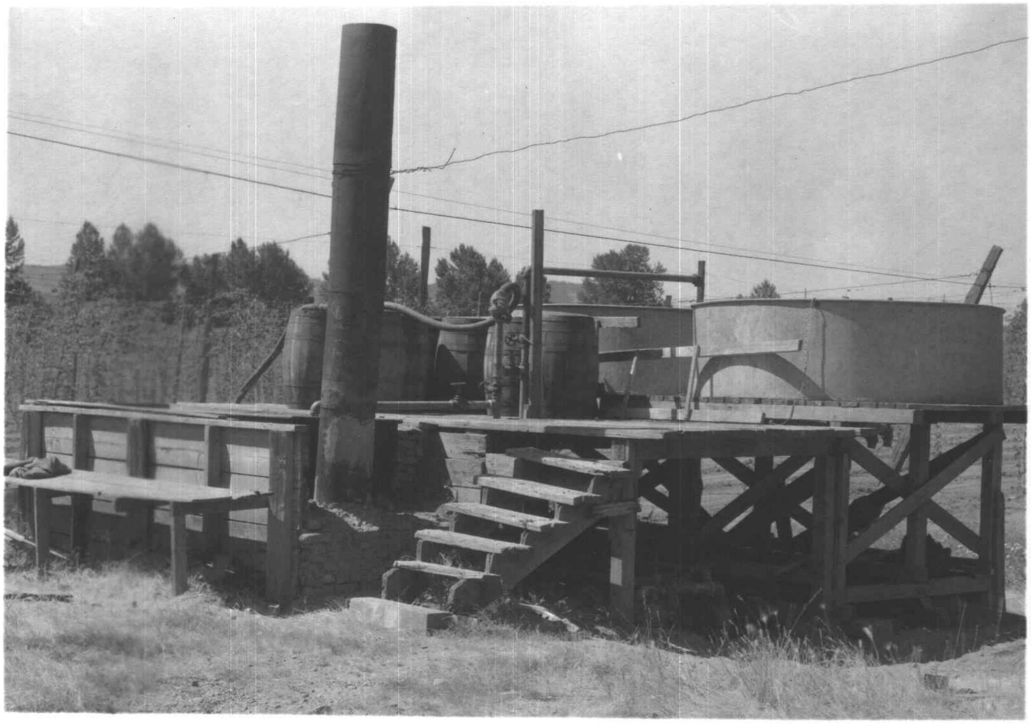


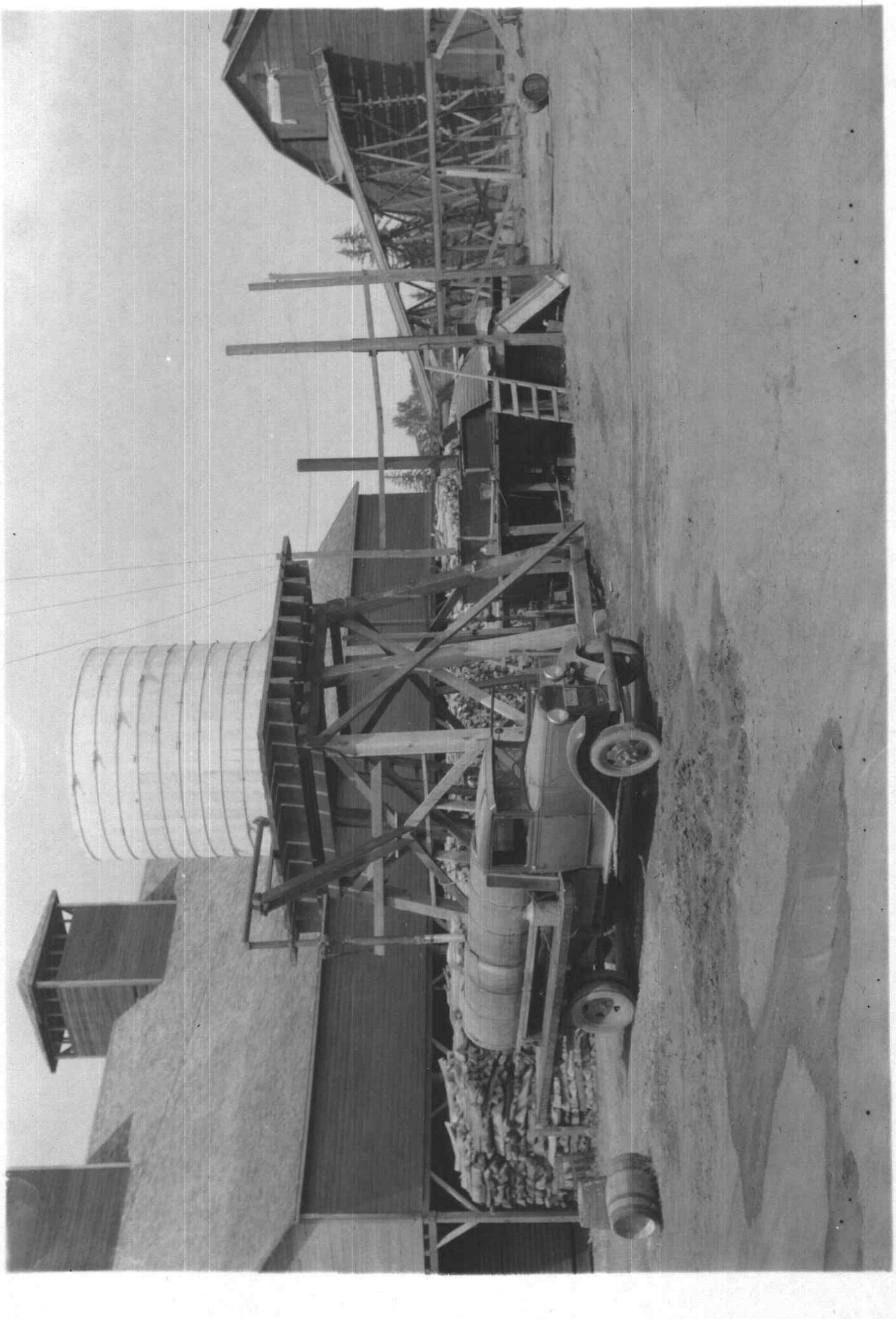
Two Views of the Hardie Duplex Sprayer
Used in the Experimental Sprays



(a.) Mitoma Spray Mixing Plant

(b.) Seavy Spray Mixing Plant





Horst Spray Mixing Plant