

The Indian Council of Agricultural Research

SAN JOSE SCALE IN INDIA

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CHAPTER I

INTRODUCTION

THE notorious San Jose Scale which entered the Indian Sub-continent about forty years ago has been found, in recent years, to have spread to a number of States. During the past 15 years the Government of India have been undertaking measures to prevent the spread of the pest by notifying it under the Destructive Insects and Pests Act and quarantining areas as soon as the pest is recorded in any locality. The Indian Council of Agricultural Research financed thorough surveys of the pest some years ago and a scheme for the study of the biology and suitable methods for its control in Kashmir was in progress under the auspices of the Council for about ten years. Simultaneously, field control of the pest has also been in progress in Kashmir and all other infested localities. In this bulletin all the more important observations on the distribution, biology and control of the insect, made in India, so far, are summarized. Relevant information from foreign literature is also included.

Distribution of the Scale in the World. San Jose Scale is generally believed to be a native of Northern China. As it was frequently found on plants imported from Japan into the U. S. A., it was, at first, thought to be a native of Japan but it was later proved that the pest had spread into Japan from California on Chinese flowering peach in or about the year 1870. It first attracted the attention of fruit growers at San Jose in Southern California in 1873 which is responsible for the name of the pest. Within the next two decades the insect had spread to all the deciduous fruit growing areas of the U. S. A.

In 1903, Fernald gave the world distribution of the scale as Canada, United States, Chili, Germany, Australia, Japan, China and Hawaiian Islands. But today it has spread to practically all the deciduous fruit growing areas of the world. Besides the countries named above, it is now found in Austria, France, Yugoslavia, Bulgaria, England, Hungary, Portugal, Spain, Russia, Rumania and Italy in Europe; India, Pakistan, Korea, Formosa, Russian Far East, Turkmenistan, Iraq (Mesopotamia) and Manchuria in Asia; New Zealand and Tasmania in Oceania; Union of South Africa, Algeria and other parts bordering the Mediterranean region in Africa, Argentina and Brazil in South America and Mexico in North America.

CHAPTER II

INTRODUCTION AND SPREAD OF THE SCALE IN INDIA

IT is difficult to fix the exact year of its entry into India. But the pest evidently came along with introduced nursery stock from Australia, the U.S.A., or Japan.

The pest is believed to have entered Kashmir State along with flowering plants like *Oydonia japonica* which had been imported to decorate gardens at Srinagar but it became serious about 1922 and the then Imperial Entomologist was invited to advise on the control measure. A detailed survey of Kashmir conducted in 1939-40 under the auspices of the Indian Council of Agricultural Research showed the existence of the pest at Phalgam, Fraslon, Tangmarg, Wodura, Martand, Anantnag and Achhabal, Quazigund and Dasu. In Jammu area the pest was found at Banihal, Batote, Kud and Berthal. On the Kistwar side beyond the Simthan pass, the scale was found scarcely on wild pear trees at Mogul Maidan. At Kistwar and Badrawah proper, the infestation was mild. In 1940-41, the pest was recorded at Ganderbal, Waylu, Margund in the North, Pulwam, Kulgam, Nandimarg, Shupian, Keilar, Nasur, Ahhabal, Taungmarg, Sedau, Kungawattan in South Kashmir State; Banihal, Rambau, Batote, Berthal, Kud, Chenani in South (Jammu area); Pahalgam, Sirhama, Panjura, in the East and at Rampur, Baramula and Tangmarg in the West. Survey showed the existence of the scale from about 3,500 ft. to 7,600 ft. and occurring in pest form between 5,000 ft. to 7,000 ft. In 1941-42, it was also found at Uri, Chenari, Hattian in Kashmir State, Rajauri in Jammu area and at Poonch and Suran in the Poonch Jagir. In 1943-44, the pest was found to be severe from Sopore northwards to all over the Lolab valley. Observations made in Kashmir* on the incidence of San Jose Scale with reference to environmental conditions showed that all places situated near rivers or large bodies of water or with a high subsoil water level, catch the infection in quite an acute form.

In the State of Punjab, it was first recorded in Kulu in 1921 and at Kotagarh in 1924. A detailed survey of N. W. India conducted during the years 1937-40 has shown the existence of the pest in the following localities in the Punjab.

(a) *Simla Hills.* Dagshai, Darora, Dhagi, Dhar, Dhari, Kaithu, Kaliana, Kasauli, Khanog, Kiyar, Kotagarh, Kotkai, Kufri, Loqa, Losth, Marela, Mashobra, Phagu, Rhoga, Sabathu, Sabathu Cantonment, Salogra, Shainan, Simla, Summer Hill, Thandar.

(b) *Kulu Valley.* Ani, Aramgarh, Arsu, Bahu, Bandrol, Bajaura, Jibi, Jagatsukh, Katrain Kasol, Kulu, Manali, Naggar, Niggali, Ohalpur, Palampur, Pati, Raison, Sharar, Trimli, Urthu.

(c) *Gurdaspur District.* Dalhousie.

(d) *Former States.* Balsan, Chamba, Jubbal, Koti, Kumarsain, Madhan, Mandi, Bhaga, Suket.

It is found in all the hilly tracts of the West Punjab, North West Frontier Province and Baluchistan now included in Pakistan.

In the Uttar Pradesh it was first recorded at Chaubattia in Almorah District in 1938 and subsequently at Mussoorie in Dehra Dun District. It is now confined to only two localities in this State, namely Pauri (Garhwal District) and Jilling (Nainital District).

In 1943 this dangerous pest was recorded in Madras State at Kotagiri, Coonoor and Ootacamund in the Nilgiri District, at Masinaikanpet near Salem and in the Shevaroy Hills in Salem District. The pest was recorded for the first time in Assam in July 1945, in West Bengal in September 1945, in Orissa in December 1945 and in Mysore in January 1946.

It was also recorded at Gorapur near Kodaikanal in Madras State during the same year.

In Assam, the pest was recorded at Shillong on apple, plum, peach and pear in several orchards. It was present in the Government Fruit Experimental Station and the Government

*The San Jose Scale and Woolly Aphis Research Schemes in Kashmir. Summary of the *Final Report*.

House Garden at Shillong, Government Farm and in private orchards at Upper Shillong and in an orchard at Sonapani. In the private orchards the pest seems to have come along with the nursery stock obtained from the Fruit Experimental Station. Annual reports of the Department of Agriculture of Assam refer to the importation of host plants of the scale from Australia, England, the United States of America and Kashmir Government Fruit Experimental Station. The pest appears to have come with some of these imported plants and then spread to other orchards.

In West Bengal, the pest was first recorded on plum, peach and pear trees in the Government Agricultural Farm at Kalimpong. It was subsequently recorded in a private orchard on a plum plant obtained from Chandra Nursery, Reynock, Sikkim State. In the Rishi Farm at Kalimpong the scale was obtained on an apple tree which had been imported from Sikkim State. The existence of the pest in Sikkim State, where apple is grown near Gangtok, also appears therefore probable. Various fruit trees had been imported into the Government Agricultural Farm at Kalimpong from Quetta and Bhimtal in 1933, and again from the latter locality in 1940. The pest must have come with these imported trees. Recent reports go to show the existence of the pest in the Bhutan State also.

An examination of the Government Fruit Farm at Pottangi during December 1945 for *Icerya purchasi* revealed the presence of the San Jose Scale in the State of Orissa as well. Here it was recorded on pear, peach, apple and plum. Many of these fruit trees had originally been obtained from Kulu in the Punjab and Chəubattia in the Uttar Pradesh during the years 1939 and 1940.

In 1945 specimens of a scale insect on bush apple which were collected at Panchgani in Bombay State by a horticulturist proved to belong to this notorious species. The apple plants are reported to have been imported from Sikkim from where the infested plants had been imported at Kalimpong also.

San Jose Scale was also noticed for the first time on apple seedlings and stock plants, in the Fruit Research Station at Hesargatta in Mysore State in January 1946. The scale appears to have been introduced along with bud wood and grafting material of apple obtained from Shillong in November 1945.

CHAPTER III.

HOST PLANTS

SAN Jose Scale has a very wide range of host plants. It has been recorded by various workers in the different parts of the world on nearly 200 different varieties of fruit trees, shrubs and ornamental plants. Out of these, on some plants it maintains its number while on others it dies in the course of a few generations. Although its food plants belong to nearly 26 different families of the plant kingdom, it has been found to prefer plants belonging to the Rosaceae.

The most important food plants of the scale in other parts of the world are :

Berberidaceae

Akebia sp.

Akebia quinata

Bignoniaceae

Catalpa speciosa (Juneberry)

Caprifoliaceae

Lonicera xylosteum

Symphoricarpos racemosus (Snowberry)

Celastrineae

Euonymus spp.

Cornaceae

Cornus alba var. *sibirica*

Cornus baileyi

Cornus sangiunea

Cupuliferae

Alnus sp. (Alder)

Castanea sativa (Chestnut)

Fagus sylvaticus (European purple leaved beech)

Juglandaeae

Juglans spp. (English walnut and Black walnut)

Juglans sieboldiana (Japanese walnut)

Leguminosae

Acacia sp.

Myrtaceae

Eucalyptus corynocalyx

Oleaceae

Ligustrum vulgare (Common privet)

Syringa persica (Persian lilac)

Syringa vulgaris

Rosaceae

Amelanchier canadensis

Cotoneaster sp.

Cotoneaster vulgaris

Crataegus sp. (Hawthorn)

C. cordata

C. coccinea

C. crus-galli

C. oxyacantha (English Hawthorn)

Cydonia japonica (Japanese or flowering quince)

Cydonia vulgaris (Common quince)

Eriobotrya japonica (Loquat)

Prunus amygdalus (Almond)

P. armeniaca (Apricot)

P. avium (Sweet cherry)

P. cerasifera var. *altropurpurea* (Purple leaved plum)

P. domestica (European plum)

P. hortulana (Wild goose plum)

P. japonica (Flowering almond)

P. maritima (Beach plum)

P. persica (Peach)

P. pissardi

P. pumila.

P. pumila var. *besseyi* (Sand cherry)

P. serotina

P. triflora (Japanese plum)

P. virginiana (Chokecherry)

Pyrus baccata

P. communis (Pear)

P. malus (Apple)

P. sinensis (Sand pear)

Rosa sp.

Rosa carolina

R. lucida

R. rugosa

Sorbus sp. (Mountain ash)

S. americana (American mountain ash)

S. aucuparia (European mountain ash)

S. melanocarpa (Black chokecherry)

Rutaceae

Poncirus (*Citrus*) *trifoliata*

Ptelea trifoliata (Hop tree)

Salicaceae

Populus sp. (Poplar)

P. deltoides (Carolina poplar)

P. nigra var. *italica* (Lambardy poplar)

Salix sp. (Willow)

- S. lucida*
- S. babylonica* (Weeping willow)
- S. humilis*
- S. incana*
- S. pentandra* (Laurel leaved willow)
- S. vitellina*

Saxifragaceae

- Ribes aureum* (Flowering currant)
- R. nigrum* (Black currant)
- R. rubrum* (Currant)
- R. oxycanthoides* (Gooseberry)

Styraceae

- Diospyros* sp. (Oriental persimmon)

Ternstroemiaceae

- Actinidia* sp.

Tiliaceae

- Tilia* sp. (Basswood, Linden)
- Tilia americana* (American basswood)

Urticaceae

- Ulmus* sp. (Elm)
- Ulmus americana* (American Elm)
- Ulmus campestris* (English or European Elm)

The scale is generally listed as attacking citrus but according to Quayle [1941] it must be considered as only a very minor pest on it. In Florida, U. S. A., the pest has been recorded on *Poncirus (Citrus) trifoliata* (Family : Rutaceae). This plant is used as a stock mostly of the Satsuma orange in Japan and in the Gulf States of the U. S. A. and hence the scale is not considered as actually attacking a citrus variety grown for fruits. Gerasimova's [1937] experiments on artificial infestation of different plants have shown that the scale develops successfully on *Prunus laurocerasus* (Family : Rosaceae) and *Aleurites fordii* (Family : Euphorbiaceae) besides persimmon and *Poncirus trifoliata*.

In North West India, its host plants are :

Caprifoliaceae

- Viburnum faetans*

Compositae

- Aster* sp.
- Erigeron canadensis*
- Rudbeckia* sp.

Cupuliferae

- Alnus nepalensis* (Alder)
- Castanea sativa* (Chestnut)
- Quercus* spp. (Oak)

Iridaeae

- Irisensata*

Juglandaceae

Juglans regia (Walnut)

Leguminosae

Astragalus sp.

Liliaceae

Asparagus

Malvaceae

*Hibiscus mutabilis**Hollyhock**Malva* sp.

Oleaceae

*Ligustrum**Syringa vulgaris* (English lilac)

Ranunculaceae

Actaea spicata

Rosaceae

Cerasus vulgaris (Cherry)*Crataegus oxyacantha* (Hawthorn)*Cotoneaster nummularia**Cydonia japonica* (Japanese quince)*Cydonia vulgaris* (Quince)*Kerria japonica* (Gooseberry)*Prunus* sp. (Greengage)*Prunus* sp. (Wild almond)*Prunus* sp. (Cherai, parachinar local plum)*Prunus* sp. (Wild apricot)*Prunus* sp. (wild plum)*Prunus amygdalus* (Almond)*Prunus armeniaca* (Apricot)*Prunus communis* (Plum)*Prunus divaricata* (Alubukhara)*Prunus japonica* (Japan plum)*Prunus persica* (Peach)*Pyrus* sp. (Wild pear)*Pyrus* sp. (Crab apple)*Pyrus communis* (Pear)*Pyrus malus* (Apple)*Pyrus pashia* (Wild pear)*Rosa* spp. (Roses)*Rosa* sp. (Persian rose)*Rosa macrophylla*

Salicineae

Populus sp. (Poplar)

Salix babylonica (Weeping willow)

Salix sp. (Willow)

Scitamineae

Canna indica

Urticaceae

Canabis sativa

Morus alba

Ulmus sp. (Elm)

Urtica dioica

Vitaceae

Vitis vinifera

CHAPTER IV

LIFE-HISTORY AND BIOLOGY

THE life-history and biology of the scale has been studied in different parts of the world. In the following pages are given the more important details on these subjects, as observed in different parts of the world.

Larva

San Jose Scale is an ovo-viviparous species, i.e., gives birth to living young from the eggs developed within the body of the female. The newly born larva appears like a minute yellow speck, elliptical in shape. Crawling out of the body of the parent and escaping out from under its parent scale, it moves about for 12 to 24 hours in search of a suitable place for settling down. When it finds a favourable spot, it thrusts its mouth parts into the plant tissues and begins to feed by sucking out the plant sap. From now on it is stationary. Within 48 hours after its fixation, white waxy secretion is formed on the back of the larva to form a scale-like covering and in about two to four days the larva becomes invisible.

Post embryonic development of the female

The larva continues to grow, its scale becoming gradually greyish slaty in colour in about seven to nine days. A central nipple-like elevation is formed which becomes quite prominent in most cases. After about twelve days it moults to enter the second nymphal stage, the moulted skin of the first larval stage remaining on the top of the scale as the first pellicle. In Kashmir the first moult was found to take place 16 to 18 days after emergence in the first generation of the scale; while it was 13 to 15 days in the second generation and 21 to 28 days in the third generation. The second stage nymph has neither legs nor antennae. The second stage moults ordinarily again after another 8 or 9 days to enter into the adult stage of the female. In Kashmir, however, in 1940 this period was found to be as long as 32 to 35 days in the first generation, 27 to 30 days in the second generation and 47 to 54 days in the third. The second nymphal skin also remains on the top of the scale and is termed the second pellicle. The growth of the insect and the scale now becomes fairly rapid and when fully formed, the latter is more or less circular in shape and having diameter of 2 to 3 mm. The scale becomes darker and the nipple when exposed, slightly golden in colour. The female proper is a curious, legless, segmented, yellowish insect somewhat circular in form. She never leaves the protection of the scale. In about 30 days after birth, the female becomes fully grown and 10 to 14 days later she begins to give birth to young ones. In Kashmir the overwintering female commences giving birth to crawlers a month after the emergence of males. In the first generation gravid mothers give birth to nymphs for 50 to 53 days and in the second generation for 47 to 50 days.

Post embryonic development of the male

The male-producing larva after birth settles down on the twig like the female-producing larva but generally prefers the under side of the leaf to do so. In a couple of days the elliptical or oval scale is secreted. After about twelve days, the nymph moults to get into the second nymphal stage. This stage has a functional beak and, therefore, sucks plant sap as in the first stage. It has, however, neither legs nor antennae. This stage lasts six days. After this, as in other coccids it passes through two pupal stages during which the eyes, limbs, antennae, wings and the reproductory organs are developed. The third instar or the first pupal stage lasts for two days. In this stage, the rostrum is lost and, therefore, it cannot suck plant sap; developing eyes become gradually prominent, wing pads, developing antennae and legs are external and free; this stage is, however, inactive. In the fourth instar which lasts for four to six days, the eyes, antennae, legs, wing pads, and style are well formed; rostrum is lacking as in third instar. The final moult and emergence of the adult male or the fifth instar takes place after about 24 to 30 days. It varies according to the climatic conditions of the

country. It is a month after fixation of the male producing larva according to Rahaman [1947] in the Punjab and the North West Frontier Province ; 24 days in the U. S. A. according to Howard [1895] ; 26 to 28 days according to Newman [1926] in Australia and 26 days in Italy as stated by Melis [1943]. In Kashmir, the life of the males of the overwintering generation was found to be about 21 weeks, of which atleast 16 weeks were severe cold weather; but in the first summer generation, emergence of the male has been found to take place in 28 to 31 days while in the second generation it was 25 to 28 days and in the third 38 to 44 days.

The male emerges out by backing out from the rear end of the scale. He is of a light amber colour with brownish markings, has two wings, prominent pair of ten segmented functional antennae, three pairs of legs, conspicuous purple eyes and an anal style. He lives only for a short time usually 24 to 32 hours at the most.

In Kashmir, observations made in 1941-42 showed that there is considerable difference in the sex ratio of the scale at certain times of the year in the scale population on stem, branches and leaves. In Spring, both the sexes were found to confine themselves to older growths where the males were found to be about 30 per cent. In the subsequent generations, the male population on the leaves increased considerably and varied from 58 to 80.5 per cent with the result that on stem and branches their population decreased to a minimum of about 17 per cent. On the apple fruits the sexes were found to be represented almost in the same proportion as on young shoots.

Fecundity and reproduction

Fotidar and Raina [1936] found, in Kashmir State, each female of the scale producing on an average 200 to 400 nymphs. More detailed observations, however, made in Kashmir in 1940-41 showed that the female of the first generation gives birth to about 196 nymphs whereas a female of the second generation produced on an average only 70 nymphs. In 1941-42, the third generation scales produced on an average 95 nymphs, the maximum being 181 and in the second generation the number was 69. In Kashmir during 1941-42, the overwintering females gave rise to crawlers in the last week of May, completed reproduction in 40 days and died soon afterwards. In the case of the first summer generation females which started giving birth to young ones in the second week of July, the crawlers emerged briskly for the first 25 or 30 days, but for the later 25 days the rate decreased considerably ; on the whole this generation gave rise to largest number of nymphs as mentioned already. Reproduction continued for about 57 days at the maximum, resulting in overlapping of generations. In the second generation, the emergence of crawlers extended over 67 days. The fecundity of the scale appears to be varying in different countries. For example in Australia, Jarvis [1927] found each female producing about 400 youngs. Females of the late summer generations on apple and pear in Italy according to Melis [1943] produced 39 to 190 crawlers each, the period of reproduction lasting four to five weeks. Timofeeva [1937] in East Georgia of the Russian Union has found the average number of larvae produced by the female of the overwintered and first generations to be 57 and 85 respectively as compared with only six in the case of the second generation. In Adjaristan, Gerasimova [1937] observed maximum fecundity in the case of the females of the second generation which produced as many as 165 larvae on peach and 194 on plum. Breeding experiments and life-history study of the insect conducted by Forbes [1915] in the U.S.A. have shown that under optimum conditions the possible rate of multiplication of one female in one year as 32,791,472. Similar observations made in Kashmir during the San Jose Scale showed the progeny of a single female after the third generation would be 3,65,526 provided there was no environmental resistance such as predators, parasites, inability to find suitable food plants, inclement temperatures, etc.

Number of generations per year

The number of generations of the scale per year has been found to vary according to the climatic conditions of the country wherein it exists. For example, it has been found in Australia by Watzl [1938] and in the North Western U.S.A. by Regan [1926] to have two

generations. In British Columbia, Heriot [1944] found the scale having four or six generations, while in Yugoslavia, Kovacevic [1937] found it has three generations of which the last is not completed in some years. Popova [1938] found in Sochi, the scale having usually three generations a year but sometimes a partial fourth is produced; while in Maikop and Slavyansk Districts there are two complete generations and a partial third. Bruneteau [1939] mentions the number of generations of the scale as three. In Georgia, U.S.A. as many as five or six generations on peach have been noticed by Chase [1916]. In Italy, Melis [1943] found that there are five main overlapping generations, the crawlers appearing in June, mid-July, August and mid-September and November, though some were produced even during winter which he considered may constitute a sixth generation. In Kashmir State, India, Fotidar and Raina [1936] have found the pest having four or five generations, the overwintered nymphs becoming active in mid-March. More detailed observations carried out in Kashmir have shown that there are two complete summer generations and a partial third which overwinters. At constant temperature of 25°C. (77°F.) and 90 per cent humidity, four generations of the scale have been raised in Kashmir, the average duration of each generation being 43 days. The males took on an average 25 days to emerge from the time of settling.

Low temperature and its effects on the insect

That very low temperatures are generally destructive to the insect has been observed by several workers in the U.S.A. and Canada. Ross and Ceasar [1919] report that large numbers of the scales were destroyed by the severe Winter of 1917-18 in Ontario. Similar observations have been made by Felt [1935] in 1934-35 in Long Island and by Flint *et al.* [1937] in 1935-36 in Illinois in U. S. A. According to the latter authors destruction of the scale was so high as to render spray unnecessary. Snapp and Thomson [1933] opined that young scales are more susceptible to low temperatures than half grown ones and that majority of the scales on peach trees are not killed by usually low temperatures in the Southern latitudes. Earlier observations made by Snapp and Alden [1923] show that San Jose Scale frequently passes the winter or parts of the winter as full grown adult. During these months the crawlers are noted to settle down and start the formation of the scale covering a few hours after emergence in the same manner as those that emerge during summer months. But according to Watzl [1938] in Austria severe winter frosts kill all stages except the first instar larvae and heavy infestation has been noticed only in the districts with mild climate. Korchagin's [1936] more detailed observations have shown that mortality due to cold among the larvae hibernating on trees was about 50 per cent of those on the lower parts of the trunks under a cover of snow and debris and 92.7 per cent of those in exposed situations. On the Black Sea Coast of Russia, Popova [1936] found the scale to be not affected by such high temperatures as 35.2°C. to 46°C. (95.3°F. to 114.8°F.) and a frost of -32°C. (-25.6°F.) caused about 93 per cent mortality. Even in the Spring, sharp fluctuations of temperature were found to kill about 30 per cent of the scales. Rains also effected the number of generations in the year, there being only three of them while in dry years a partial fourth was found to occur. Popova [1938] also found isolated females continuing to reproduce in winter and surviving temperature as low as -7.3°C. isolated (18.86°F.).

During winter in Kashmir, the scale enters into hibernation in all stages of its life-history but only the first instar nymphs which have reached a size of about 1/8cm. and have secreted dark grey scales survive the low temperatures. The rest of the scales including the newly settled nymphs, distinguishable male scales and gravid females almost perish by the end of cold weather. Mortality of hibernating nymphs is appreciable. Nearly 27.4 per cent of the scales died as a result of cold weather in 1939-40. In 1940-41, the mortality of the scale was 18.23 per cent in winter. A comparative study of the mortality of the first instar nymphs and those of the subsequent stages during hibernation showed that none of the subsequent stages survive. About 35 per cent of the living nymphs of first instar developed into males and females; the latter gave birth to nymphs about the end of May the next year. In 1941-42 the hibernation period lasted from the end of November to the beginning of March, when 40.6 per cent of the entire scale population died on account of excessive cold. The first instar scales under a grey covering only survived but even these suffered mortality to an extent of 36.6 per cent. All the scales in the other stages of development died. In 1942-43, 31.0 per cent of the scales died while in 1943-44, 41.3 per cent died in winter.

Diapause

The occurrence of diapause or arrestation of development has been noticed in several species of insects. In the case of San Jose Scale it was first noticed by Timofeeva [1937] and Gerasimova [1937] in the Russian Union. In East Georgia, Timofeeva found 30 per cent of the larvae of the first generation that appear at end of July or beginning of August undergo a summer diapause and that about 39 per cent of the first instar larvae of the second generation produced in August also undergo diapause. In Adjaristan, Gerasimova found more than 40 per cent of the first instar larvae of both the first and second generations diapause. This checks the increase of the scale to a certain extent. In Kashmir, it was noticed that a small percentage of the scale population was slow in its development and remained in the first instar under a dark grey covering from mid-July onwards till mid-March and developed along with other overwintering population ; 3 to 8 per cent of the first generation was estimated doing so in 1942-43, thus adopting a long life cycle or summer diapause and contributing to the overwintering population. Observations made in 1943-44 showed that the percentage of diapausing scales varied from about 15 to 55 under field conditions in Srinagar. Observations made in 1944-45 showed, for the two complete summer generations and partial third generation, that the diapausing scales ranged between 0 to 8, 21.0 to 61.0 and 84.4 to 100 per cent respectively.

CHAPTER V

NATURE AND EXTENT OF DAMAGE

ALL parts of the host plants, above the ground, are attacked by the scale and injury is due to the extraction of the juices of the plant. In the beginning only the growth is checked but as the insects increase in number most of the attacked trees die due to large quantities of plant sap drawn by millions of scales on them. According to Chase [1916], death is more due to the effect of poisons introduced into the plant by the insect while sucking, rather than the loss of sap itself. Heriot [1944] has compared the injury caused to apple by San Jose Scale with that by aphids. The puncturing of the bark by the sucking mouth parts of the scale results in a diseased condition. The damage caused by the San Jose Scale is not usually realized, unlike other insects that cause visible injury immediately. In estimating the damage caused by the scale, one has to keep in view the weakening or killing of the tree, spotting of the fruit so as to make it unmarketable and subjection of the trees to further insect and disease attacks following the weakening effect of the scale. Smirnov [1937] in the Azov Black Sea Province of Russia found 40 per cent of fruits with scales in slightly attacked trees and 85 per cent to 100 per cent on severely attacked ones. The market value of the fruit was found to have decreased according to the degree of infestation. Even as early as 1924, Davis estimated the monetary loss as £200 per acre of apples even if the scale is ultimately controlled and the trees are brought back into normal produce, the weakened effect before and after control being assumed to result in four years of unproductiveness. To-day, the loss must be very much more than that.

Rekk [1937] who made special observations on the injury caused by San Jose Scale to young apple, cherry and plum trees in Georgia (Russia) found that the scale severely injures the bark on the stem and main branches. This was responsible for checking the expansion of the stem, for the dying of the tissues outside the cambium and the formation of cracks. Consequently the growth of the tree is stopped, the crown becomes thinner, fewer shoots are formed, the yield of fruits is decreased and the commercial quality lowered. Similar observations were also made by Snitko [1937] in the Azov Black Sea Province. On apples and plums he found the feeding of the scale producing a disturbance in the normal function of the conducting system of the tree as a result of which there is a decrease in the growth of the crown branches. Sometimes there is decrease in the size of the leaves. Curiously enough, as a result of infestation, he found some of the branches bear fruit, the yield of the fruit increasing temporarily and then decreasing. Then the life of the tree is shortened. Nepveu [1943], basing his study on a comparison of peach trees on which the scale was controlled by spraying with untreated ones, concluded that in the Mediterranean region, infestation of peach by the scale caused a decrease in the length of the branches and in the total leaf area and corresponding reduction in the ratio of leaf surface to bark surface. He found that if this ratio drops to about a fifth of its normal value in the course of the year, the tree dies. Quaintance [1915] found peach trees were usually killed in two or three seasons.

Varietal resistance to San Jose Scale

A marked selection of varieties of the host plant by the scale has been noticed by a number of workers. Howard [1895] states that in the U.S.A. varieties of pear, the 'Bartlett' and 'Duchesse d'Angouleme' are almost invariably seriously affected while the 'Kieffer' is practically exempt from attack of the scale. In New Jersey, the varieties of pear attacked by the insect range in approximately the following order: 'Idaho', 'Madame Van Garper', 'Lawson', 'Sackel', and 'Lawrence'. 'Bartlett' and 'Kieffer' have been found to be absolutely exempt and the 'Leconte' nearly so. In cases where 'Lawson' and 'Kieffer' are grafted on the same tree, the 'Lawson' branch and the fruit have been found covered with scales while the 'Kieffer' found to be entirely free. According to Metcalf and Flint [1939] 'Mature Kieffer' and 'Garber' pears are seldom seriously injured by San Jose Scale and rarely need to be sprayed for the control of the insect.

Preliminary trials made in 1942-43 and 1943-44 on the comparative susceptibility of 23 different varieties of apple commonly grown in Kashmir showed that no variety is immune but

on varieties called 'Queen Apple', 'French Red', 'Cox's Orange Pippin', 'King of Tomkin's', 'French Large Radish', 'Behi Saharanpuri', the scale Tom-found to multiply rapidly. The varieties 'Jonathan', 'Lady Pippin', 'Emperor', 'Blood Red', 'Esopus' ('Spitzenburg') 'Saharanpuri No. 1' and 'White Cedar' were found to offer a fair degree of resistance during the period under trial. Amongst all varieties of plums under trial in 1943-44, 'White Plum', 'Tragedy' and 'Black Plum' proved fairly resistant. In 1944-45 'Wickson' showed some resistance. 'California' and 'Sugarprune' came next while 'Satsuma', 'Misry' and a variety of wild plum were fairly attacked and showed signs of damage specially on the young shoots. In 1944-45 'Misry' and wild plum showed signs of severe damage. 'Burbank', 'Victoria' and '2A Plum' suffered the most, resulting in the death of many plants and showing heavy encrustations of scales after the third season of inoculation. More detailed and extended observations are necessary before any definite conclusions can be arrived at. The real cause of this variation has also to be studied.

CHAPTER VI

MODES OF SPREAD OF SAN JOSE SCALE

THE scale is principally distributed from one region to another on nursery stock, scions or budding and grafting material. During the crawling stage, the insect is also able to pass from one tree to another when their limbs are in contact, but in this stage, it is by agencies independent of itself that it is principally distributed. These principal agents of transference are insects, squirrels, birds, bats, domestic animals, man and wind. Prominent amongst these factors, are birds which may alight upon infested trees where the young insects may crawl upon their feet and subsequently be deposited on other trees where the birds may alight. Observations made near Madison in U.S.A. on the habits of the English sparrow showed that this bird is the chief carrier of the San Jose Scale in closely settled residential areas. In the Punjab, nymphs of San Jose Scale were found on the following six species of passerine birds by Rahaman and Kalra [1940]:—*Urocissa flavirostris flavirostris* Blyth (Yellow billed wagpie), *Corvus macrorhynchus levailanti* Less (Indian jungle crow), *Corvus splendens splendens* Vieill. (Indian house crow), *Acridotheres tristis tristis* Linn. (Common myna), *Trochalopterum lineatum griseicentior* Hartert (Simla streaked laughing thrush), *Molpastes leucogenys* Gray (White cheeked bulbul). These authors have also found the nymphs on the bat, *Pteropus giganteus* Brun. The nymphs of San Jose Scale are carried by insects such as grasshoppers, ladybird beetles and ants. They may be transported on clothing of man, on vehicles, and on horses, or other livestock which may be in the other orchards. Wind plays a very important part in the dispersal of the tiny larvae. This has been found in the case of several species of scale insects and is true of the San Jose Scale also. Often the nymphs may be blown to very great distances.

Infested fruits as possible carriers of the scale

There has been considerable difference of opinion on this point in various parts of the world. While some workers believe that there is little risk of infestation from transported fruits or their discarded skins, others believe that the spread of the scale through infested fruit cannot wholly be discounted. Several countries like France, Germany and Switzerland have therefore, placed restrictions in some form or other on the importation of fresh fruit.

Experiments made by Forbes [1915] with infested ripe apples show that the San Jose Scale can live and reproduce freely on such fruits plucked from the tree and kept at ordinary temperatures and that living young may continue to be born under such conditions during the period of eight weeks. Infested apples taken from cold storage in December gave similar results, young being produced on these apples, for twenty five days. Skorkin [1937] working in Russia showed the existence of a direct correlation between the infestation on the tree and its fruit. Although under natural condition its rate of mortality on apples is high, it not only maintains itself and reproduces on stored apples in summer and autumn but infestation also spreads to healthy apples kept with them. In cooler stores, the viability of the scales was found lowered and very few survive the winter, so that there is little danger of distribution on apples transported in spring. The risk was found to be the greatest when greater number of females are producing young in September and October in Sukhum District. In various observations made, although the crawling larvae were found to be unable to survive without food for longer than 24 hours and were unable to migrate more than 2 ft., trees became infested from apples, placed at a distance of 18 in. or less. As on apples the scale occurs chiefly in the hollows at the stem and calyx ends which are usually discarded when the fruit is eaten and might be thrown close to uninfested trees, the chances of the spread of the scale are, therefore, considered very great. Kirichenko [1937] therefore, recommended fumigation of infested apple fruits to prevent dissemination of the scale in Russia.

Observations made by the authors of this paper also have an important bearing on this subject. A visit to any fruit market in any important town in India will show to what extent fruits infested by the scale are kept for sale to the public. The authors have seen such infested fruits at Shillong, in Assam, at Siliguri, Kurseong, Darjeeling, Kalimpong and Calcutta in West Bengal, at Coimbatore and Madras in Madras State and at Bangalore in Mysore

State. In most cases the fruit is imported from Kashmir and Kulu. Sometimes apples are found veritably covered by gravid scales. They are specially abundant in the depressions near the attachment of the stalk and in the calyx region of the fruit where they are not easily rubbed off. As found by Forbes [1915], we have also observed the San Jose Scale reproducing on infested fruit kept under room temperature. The peelings of such a fruit, dropped in a garden having any favourite host plants of the scale such as rose, might well be responsible for its spread. Rahaman's [1947] observations in the Punjab have shown that nymphs from an infested fruit can crawl up to a distance of 12 ft. on the ground to infest a plant. The possibility of spread of the insect in this manner is specially great in localities having a cooler climate permitting the gravid female or the freshly emerged larvae to live a longer time and allowing the latter sufficient interval to be blown over to a suitable plant and get a proper foothold, as wind plays an important part in the spread of the scale. The presence of the insect in such places where it establishes itself cannot be detected till it attains a pest status several years later. The chances for the insect to spread along with fruit is so great that it is not surprising that some countries as stated below have even laid an embargo on the importation of fruit while other countries realizing that this embargo will seriously interfere with trade, fumigate imported fruit or have placed other restrictions.

Germany was the first to realize the importance of this subject. As early as 1898, San Jose Scale was found in numbers in living and developing condition upon pears imported from California at the port of Hamburg and Germany from that year restricted importation of fresh fruit from the U.S.A. In 1914, a detailed statistical study on the incidence of San Jose Scale on introduced fruit from Australia, America and Japan was made at the port of Hamburg. The revised regulations restricting importation of fresh fruit into Germany as a precaution against the San Jose Scale were published in 1928, 1930 and 1932. In the Union of South Africa, the danger and spread of the scale with imported fresh fruit had also been realized sufficiently early and restriction had been placed on their importation from overseas and Lounsbury in 1917 reports that these regulations were to remain. Furthermore, the sending of apples, pears, and quinces from infested areas into certain defined areas was prohibited as an added safeguard. In Argentina, to prevent the spread of the pest from the infested areas of San Rafael, Lahille [1924] suggested that a fumigation chamber be erected at all railway stations from where the fruit is exported. To prevent the entry of the scale with imported fruit into Spain, the import of all kinds of fresh fruits as well as living plants from Portugal, Argentina, Brazil, Mexico, South Africa, U.S.A. and other countries where the pest is found was prohibited from 1934. Balachowsky reported in 1932 of his record of the scale on apples from the U.S.A. and New Zealand bought in Paris and warned about the danger of the establishment of the scale in France as an apple peeling thrown down in a favourable spot can easily start an infestation. A decree and connected regulations were subsequently promulgated in France prohibiting import into France of all fresh fruit other than oranges originating from countries where San Jose Scale is known to occur, unless certified to be free from infestation as described by Balachowsky [1932]. According to Schneider [1946] strong steps were taken to prevent the entry of the scale along with infested fruit into Switzerland from Austria, France or Italy and specially from South Tyrol where the pest has established itself. All imported apples were fumigated at the frontier with methyl bromide but it was later found that this is inadequate owing to the low temperature. A federal decree was issued in December 1945 which temporarily forbade the import of all fresh, pip fruits from countries where the scale is known to exist, hand sorting of fruit on the frontier was instituted and only the uninfested were allowed entry. The more recent regulations in Switzerland according to Schneider and Bovey [1947] required all fresh pip, stone and berry fruits to be accompanied by a certificate stating that they are free from infestation of the scale and originate from an uninfested area. They are subject to inspection at the frontier and any material found to be infested is refused entry. Only fruits that have passed the inspection are admitted without fumigation, but plant material, excepting a few specified plants, must be fumigated. According to Blattny [1932], in Czechoslovakia there is a prohibition to import from countries having San Jose Scale, of all plant or parts of plants liable to carry infestation. Fresh fruit, however, may be imported only if found free from infestation.

CHAPTER VII

NATURAL ENEMIES AND BIOLOGICAL CONTROL

NATURAL enemies of San Jose Scale consist of (i) hymenopterous parasites, (ii) predaceous insects, (iii) a predaceous mite, (iv) predaceous birds and (v) parasitic fungi. The extent to which they control the pest varies considerably but some of them exert a considerable check on it. It appears that these natural enemies have not been used as much as they ought to be for the biological control of this noxious insect. The following account is given to enable one to know the different natural enemies of the pest recorded in various parts of the world.

Parasites

At least a total of twenty-nine important species of hymenopterous parasites have been reared from San Jose Scale from different parts of the world. Some of them have been incompletely identified and are known only under the generic names.

- Ablerus clisiocampae* Fitch
- Anagrus spiritus* Girault
- Anaphes gracilis* Howard
- Aphelinus diaspidis* Howard
- Aphelinus fuscipennis* Howard
- Aphidencyrthus aspidioti* Girault
- Arrhenophagus chionaspidis* Auriv
- Aphytis mytilaspidis* Le B.
- Aspidiotiphagus australiensis* Girault
- Aspidiotiphagus citrinus* Crawford
- Coccidencyrthus ensifer* Howard
- Coccophagus clariscutellum* Girault
- Coccophagus clariscutellum* var. *fasciifacies* Girault
- Coccophagus immaculatus* Howard
- Coccophagus lecanii* Fitch
- Habrolepis zetterstedti* Howard
- Perrisopterus pulchellus* Howard
- Physcus varicornis* Howard
- Prophyscus laticepus* Desantis
- Prospaltella aurantii* Howard
- Prospaltella perniciosi* Tower
- Prospaltella fasciiventris* Girault
- Rhopoideus citrinus* Howard
- Signiphora nigrita* Ashmead
- Signiphora pulchra* Girault
- Anagyrus* sp.
- Chaetostricha* sp.
- Chiloneurus* sp.
- Elasmus* sp.
- Microterys* sp.
- Mymarilla* sp.

Psyllaephagus sp.

A mymarid

A Proctotruipoid

A number of parasites have been found parasitising San Jose Scale in the U. S. A., but the only species found in sufficiently large numbers is *Prospaltella perniciosi* which was first described by Tower [1914]. He found that although large numbers of the scales may have eggs laid on them by the parasite, only one parasite ultimately matures in a single scale. Since the parasites pass the winter as undeveloped and partially developed eggs in the bodies of first and second stage scales, winter spraying was found to kill both the scale and the parasite. Fernald [1914] found the parasite abundant in the State of Massachusetts during 1913 and on many infested branches which were examined, over 90 per cent of the scales were found to be parasitized. Hodgkiss and Parrott [1914] found it to be the most numerous species amongst those reared by them in New York State. In 1915 large number of the parasites had also been reared from the scale in the State of Connecticut. Since then the parasite was reported as occurring in several parts of the U. S.A. In 1924 Siegler and Baker made a detailed study of parasitism of San Jose Scale from infested twigs received from various localities in the U. S. A. and found *Prospaltella perniciosi* to be the only species present in appreciable numbers. The parasite was reported by Wakeland [1937] as having been introduced into Idaho and that it had established itself there. Into California it was introduced from the Atlantic sea board in 1943. A method for mass multiplication of the parasite was developed by Flanders [1944] and about 200,000 females were produced for liberation by the end of the year. The scales for parasitization in the laboratory were reared on Citron melons (*Citrullus vulgaris*) at about 80° F. the scale maturing in about 37 days after hatching on fruits 6—8 in. in diameter. All post-embryonic stages of the scale were found to be attacked, the parasite maturing in a minimum of about 19 days but its development was found to be prolonged sometimes if the host was in its first stage of development when parasitized. In the course of mass production on *Citrullus*, Flanders saw that the male sex disappeared from the cultures.

We have found *Aspidiotiphagus citrinus* (Crawford) parasitising the scale at Kotagiri and Coonoor in India in small numbers.

Predaceous insects

Predaceous on the San Jose Scale are a number of species of insects belonging to the Order *Coleoptera*, a single species of *Lepidoptera*, a single species of ant; and another species of *Orthoptera*. A species of mite (belonging to the order *Acarina* of Class *Arachnida*) has been found feeding on the pest. Two species of birds have also been recorded as feeding on the pest.

Coccinellid beetles are important natural enemies of scale insects, in some cases controlling them very efficiently. Out of several species found feeding on the San Jose Scale in various countries the following fifteen are the most important :

Chilocorus bipustulatus Linnæus

Chilocorus bivulnerus Mulsant (*C. stigma* Say)

Chilocorus kuwanae Silvestri

Chilocorus renipustulatus inornatus Weise

Chilocorus renipustulatus Scriba

Chilocorus rubidus Hope

Chilocorus similis Rossi

Chilocorus bijugus S. sp. *infernalis* Mulsant

Chilocorus tristis Pald.

Microweisia misella Lec.

Orcus australiae Boisd.

Orcus chalybaeus Boisd.

Rhizobius ventralis Erich.

Rhizobius histellus Crotch

Scymnillus aterrimus Horn

In the U. S. A. the coccinellid predators are *Scymnillus aterrimus* Horn, *Rhizobius ventralis* Erich. *Chilocorus bivulnerus* Mulsant (*C. stigma* Say) and *Microweisia misella* Lec. *Chilocorus similis* Rossi was introduced into California from Japan for the control of the scale. Although it is said to feed on San Jose Scale, it has been found by Smith [1916] to feed on all coccids but has a preference for Diaspines. *Chilocorus bivulnerus* is an important predator of the scale throughout the year in Georgia State, U. S. A. according to Alden [1930]. *Scymnillus aterrimus* Horn was recorded by Wakeland [1938] as a natural enemy of the scale in Idaho State. Headlee [1914] found *Microweisia misella* Lec. feeding on the scale in New Jersey State. *Rhizobius ventralis* and *Chilocorus bivulnerus* have been found attacking San Jose Scale in New York State by Parrott [1914] while Quaintance [1915] recorded *Microweisia misella* Lec. and *Chilocorus bivulnerus* as predators of the pest in U. S. A. In Ontario, Canada, *Microweisia (Pentilia) misella* and *Chilocorus bivulnerus* are the natural enemies of the insect. These records are of Caesar [1914]. In France, *Microweisia misella* and *Chilocorus similis* have been found feeding on the insect by Feytaud [1913]. In Japan, Ishii [1937] noticed *Chilocorus kuwanai* Silv. feeding on the scale. In Queensland, Australia, Jarvis [1925] found *Orcus australiae*, *O. chalybaeus* and *Rhizobius histellus* feeding on the insect. The use of *Orcus chalybaeus* and other coccinellids and their limitations in the control of San Jose Scale have been discussed by Berlese [1916].

Considerable work on coccinellids predaceous on San Jose Scale has been done in Russia where it is reported that large numbers of the pest are destroyed by the local species, *Chilocorus renipustulatus* Scriba and *C. bipustulatus* L. while *Chilocorus rubidus* Hope has been considered by Maslovskii [1936] to be useful in the control of the insect in the Caucasus and some other parts of Russia. This last named species has been found by Telenga and Bogunova [1936] readily attacking the scale in the Far East of Russia. In the Slavyansk District of the region of Krasnader, amongst the predators attacking San Jose Scale, Popova [1936] found the chief one to be *Chilocorus renipustulatus* Scriba. Under experimental conditions one individual of this beetle was found to have destroyed a mean of 182 females and 9.5 larvae of the scale in 24 hours. Peaks of activity of the beetle exist during the year. The reduction of the scale is chiefly due to the activity of this predator but unfortunately its efficiency is considerably checked by parasites. In 1936 upto 52 per cent of the pupae were found parasitized. In the Sukhum area of Caucasus, *Chilocorus renipustulatus* ab. *inornatus* Weise was brought from the Russian Far East and released. Observations made here by Bogunova and Telenga [1938] have shown that this species has three generations a year. An adult of the beetle was found to devour on an average of 22½ scales daily while a larva destroyed 334 during its development. In this region, the indigenous coccinellids *C. renipustulatus* and *C. bipustulatus* which have two full generations and partial third during a year are also found to feed on San Jose Scale but 85 to 99.6 per cent of the larvae, pupae and adults of these beetles are destroyed by parasites of which *Tetrastichus coccinellae* Kurdj is the most important. In the Sochi region and Slavyansk (northern Caucasus), *C. renipustulatus inornatus* was liberated and was found to occur throughout summer. It is believed to be of importance as it appears in the field earlier than the two indigenous coccinellid and is, therefore, able to attack overwintered scales and to complete a generation before it is liable to attack by the parasites. As a result of four year's work by Telenga reported by Meier [1940] on the value of releasing *Chilocorus* spp. against San Jose Scale in the Russian Union, it was found that liberation of the beetles in spring reduces the abundance of the overwintered coccids. Mass breeding of the coccinellids in winter was, however, found to be difficult. It was also found that as larvae, pupae and adults are attacked by parasites, the efficiency of the predators is very much reduced.

In the Adjaristan region, Gerasimova [1937] found the ant, *Solenopsis fugax* Latr. along with *Chilocorus bipustulatus* and *C. renipustulatus* destroying 10 to 80 per cent of the insect.

Chilocorus spp. have been recorded by Rahaman [1947] feeding on the scale in the North West Frontier Province now in Pakistan but the exact names of the species do not appear to have been determined. *Coccinella septumpunctata* L. was also recorded by Rahaman [1947] preying on the scale during July to October in Alizai and Parachinar regions of the Kurram valley in the North West Frontier Province.

In Kashmir, the chief coccinellid predators of the scale are *Jauravia* sp., *Chilocorus bijugus* S. sp. *infernalis* Muls. and *Chilocorus tristis* Pald. *Jauravia* sp. has low feeding capacity and, therefore, cannot cope with the rapidly increasing population of the San Jose Scale. But

it is the first to appear in spring and last to disappear in autumn. Counts of the scales eaten by adult beetles of *Chilocorus bijugus* S. sp. in *infernalis* Muls. gave an average of 217 per beetle per day under insectary conditions. It does pretty good work against the pest in early months of summer but is heavily parasitized by a number of Chalcid and Eulophid parasites from the end of July. *Exochomus nigripennis* which is mainly aphidivorous also feeds on the crawlers of the scale. *Brumus suturalis*, *Coccinella septempunctata* and *Exochomus nigripennis* have been found feeding on the pest at Jammu and Udampur on infected seedlings.

The Tenebrionid beetle, *Epitragus mucidus* Berg has been observed to feed voraciously on San Jose Scale in Brazil *so much so that it is not a dangerous pest in that country.

In Italy, Melis [1943] found Nitidulids of the genus *Cybocephalus* and coccinellids to be active predators of the scale but their total effect was slight. A *Cybocephalus* sp. was recorded by Rahaman [1947] feeding on the pest in the Kurram valley of North West Frontier Province. Two species have been recorded in Kashmir State feeding on the scale.

A *Chrysopa* sp. was recorded by Rahaman [1947] feeding on the scale in the North West Frontier Province, now in Pakistan.

Although ordinarily the snow tree cricket, *Oecanthus niveus* De Geer, is a pest of various fruit trees like apple, prune, plum, cherry, raspberry, etc., under certain conditions according to Parrott and Fulton [1914] and Fulton [1915], San Jose Scale forms a large part of its diet in the U. S. A.

Newman [1924] and Jarvis [1927] have recorded small Tineid larvae of the genus *Batrachedra* preying in numbers on San Jose Scale in Australia.

Predaceous mite

The predaceous mite, *Hemisarocptes malus* Shimer, is an important natural enemy of the scale in Canada and the U. S. A. according to Tothill [1918] and Buckell [1931]. It has also been recorded in France by Andre [1942]. In these countries it has also been found feeding on *Lepidosaphes ulmi* Linnaeus. The latter scale is probably its principal host in its native home in Europe. The mite is widely distributed in orchards through the medium of birds and tree visiting animals. In Canada and in France it is able to hibernate in any or all of its stages and to maintain its activity at comparatively low temperatures which accounts for its usefulness to a great extent. Though chiefly a predator on the eggs, it has been recorded in both France and New Brunswick as feeding in summer time upon the growing and even full grown scales. Its value on apples is unfortunately lessened by its susceptibility to the sprays applied against the scale.

Predaceous birds

Some of the smaller birds particularly *Acanthiza pusilla* and *Smicronis brevirostris* feed on the insect in Australia.

Entomogenous fungi

Entomogenous fungi are known to attack a number of scale insects. A few have also been recorded on San Jose Scale in various parts of the world. Petch [1921] recorded *Fusarium coccophilum* (*Nectria coccophila* and *Sphaerostilbe coccophila*) on San Jose scale and according to Feytaud [1917], Berger [1921], Quaintance [1915], Alden [1930], and Chase [1922], this fungus commonly called the Red headed fungus controls the pest in the U.S. A. Berger [1942] who calls this fungus as *Sphaerostilbe aurantiicola* has found it very effective in Florida. He states that it can destroy large number of coccid without any sign of its presence. It has also been recorded in France and in Queensland, Australia. We have recorded it at Kalimpong in India. *Myriangiium duriaei* commonly known as the Black fungus has been found to control the pest in the U.S.A. by Chase [1922], Berger [1921] and Alden [1930]. This species along with *Peziotrichum saccardinum* has been recorded on the scale in Argentina by Marchionatto [1934]. The latter

*Esta' descoberto a inimigo natural do 'piolho' de S. Jose' chacaras Quintaes, XXVIII, (4), 304, S. Paulo.

fungus is a true parasite but its rapid development sometimes injures the branches of the fruit trees on which the scale occurs. It is believed by the author that these fungi give satisfactory control only when the pest is found in large numbers and the atmospheric humidity is high. In France, Feytaud [1917] found along with *Fusarium coccophilum* another parasitic fungus, *Hyalopus (Cephalosporium) yvonis* controlling the scale. The latter has also been recorded in Martinique by Petch [1925]. Wollenweber and Reinking [1935] have referred to the occurrence of (a) *Fusarium coccophilum* (b) *Fusarium juruanum* (c) *F. larvarum* (d) *F. lateritium* var *longum* (e) *F. sambucinum* and (f) *F. stilboides* on *Aspidiotus perniciosus*. Pichler [1938] has mentioned six species of *Fusarium* that have been recorded in literature as infesting the coccid. One individual of the scale collected in Styria was found by him also to be attacked by a fungus of the same genus.

Although the above mentioned fungi have been found in nature controlling the pest under certain conditions, none of them have been actually used in large scale biological control projects against the insect. It may be worth while trying them in India against this noxious pest.

CHAPTER VIII

CHEMICAL CONTROL

THE chemical control of San Jose Scale is principally with (a) sulphur compounds—particularly lime sulphur, (b) oil sprays, (c) miscellaneous sprays, and (d) modern chemicals like dinitro compounds, Parathion, etc., (e) disinsectization by fumigation with gases like HCN, methyl bromide, etc., and (f) hot water treatment.

(a) Sulphur compounds

Considerable research on different aspects of sulphur compounds for control of San Jose Scale has been carried out in various parts of the world. The important compounds of sulphur investigated are the polysulphides of calcium (known as lime sulphur), barium, sodium, potassium and ammonium.

Lime sulphur being one of the easiest and cheapest to prepare has received considerable attention. Taking first into consideration the method of preparation and proportions of lime and sulphur to be used, the following information has been collected. Four different methods of preparing lime sulphur have been tried :

- (i) Boiled liquid lime sulphur
- (ii) Dry lime sulphur
- (iii) Self-boiled lime sulphur
- (iv) Dry mix lime sulphur

(i) *Boiled liquid lime sulphur.* Among the four methods of preparation of lime sulphur, the boiled liquid lime sulphur has received favourable general consensus of opinion for ordinary spraying.

Metcalf and Flint [1939] give a standard formula and method of preparing boiled liquid lime sulphur in the U. S. A.

*Lump or stone lime	100 lb.
Commercial ground sulphur	200 lb.
Water enough to make	100 lb.

Heat about one-third of the required amount of water and to this add the lime. As soon as the lime starts slaking, add the sulphur which should have been previously mixed thoroughly with enough water to make a thick paste. Then add the remainder of the water and boil for from 45 minutes to one hour, adding more water as necessary to keep up the original level. If cooked by steam as is usually done, a mechanical agitator should be provided. When the free sulphur has all disappeared, the mixture should be strained and may be stored in barrels, tanks or cisterns.

In order to use lime-sulphur solutions intelligently, their strength or concentration must be tested using a hydrometer with a graduated stem to enable the reading to be made easily. Two standard scales of graduation are used, the specific gravity scale, which begins at 1 for water at 70°C. and the Baume (Be') scale which begins at 0 for water at 70°C.

The concentrated home boiled and commercial lime sulphur must always be diluted. Different batches of the home boiled preparations will vary somewhat in strength but the commercial brands of lime sulphur usually test about 33° Be'. The 33° Be' material should be diluted one part to seven or eight of water, for use as a dormant or winter spray on fruit trees ; and about 1 to 40 or 49 of water for summer sprays. Lime sulphur which has been drawn from different levels in storage tanks or barrels will give varying readings on the hydrometer. It is therefore best to test the diluted spray mixture when ready to be applied when the application is to be made to dormant trees, the diluted lime sulphur should give a reading of about 5° Be' or 1.035 specific gravity. For summer spraying the reading should be about 1.005 specific gravity.'

In Kashmir the lime sulphur that gave best results had the following formula :

Unslaked lime	3 lb.
Ground sulphur	5 lb.
Water	2½ lb.

The lime sulphur tested 25° Be' to 29° Be'.

Harukawa [1922] studied two kinds of lime sulphur in which the ratios of unslaked lime and sulphur were kept 1 : 1 and 1 : 2 respectively. No difference was found in their effectiveness.

Dilution ratio for stock lime sulphur. The lime sulphur described above is called the stock solution. It is too strong to be sprayed before dilution. Experimental work on the optimum dilution ratio of stock lime sulphur has been done in the U. S. A. by Houser [1916], Parrott [1921] Herrick [1926], Talbert [1919], Crowley [1937], Childs [1917] and Baerg [1921] ; in Australia by Newman [1933], and Ward [1933] ; in Germany by Molz [1913] ; in Canada by Caesar [1917] and Ross *et al.* [1933] and in Rumania by Bruneteau [1939]. On the whole it appears that several factors have got to be taken into consideration. They are (a) the polysulphide content of the stock lime sulphur as conveniently measured by the Baume degree ; (b) the type of spray whether dormant, late dormant or summer spray ; (c) the climatic conditions of the locality, (d) the species of the plants to be sprayed.

Stock solutions of lime sulphur which read 33° Be' require optimum dilution ratio of 1 : 7 to 1 : 8 of water for dormant sprays. A large number of experiments conducted in the U. S. A., Canada and Australia have repeatedly confirmed the ratio.

Ratios of 1 : 10 to 1 : 15 have also been tried and found efficient for late dormant sprays and more delicate plants.

Bruneteau [1939] who experimented with stock solutions of 20° Be' to 25° Be' in Rumania found 1 : 4 ratio as the optimum for lime sulphur of low polysulphide content.

On the effect of climate, Ruth [1922] finds the diluted spray should contain 15 lb. of sulphur in 50 U. S. gallons*, in southern Illinois, while weaker applications have been found effective in northern Illinois for effective control of the scale.

List [1929] who has studied the optimum sulphur content recommends 3.35 per cent sulphide sulphur in diluted sprays to control San Jose Scale.

Yetter [1923] finds calcium caseinate which is generally used as a wetting and spreading agent, does not increase the killing power of lime sulphur.

(ii) *Dry lime sulphur.* The obvious economic advantages of a dry material over a liquid have led to the development of a dry lime sulphur. This material is prepared by the evaporation of lime sulphur concentrate with sucrose as a stabiliser. Abbott, Culver and Morgan [1926] find this product less effective than liquid lime sulphur. Talbert and Swartwout [1931] state that the value of dry lime sulphur is doubtful in San Jose Scale control ; but, it is an efficient substitute for liquid lime sulphur in the case of apple giving the higher finish to the fruit and avoiding injury. In Idaho State in U. S. A. its use has been advocated at the rate of 33 lb. to 50 U. S. gallons water.

(iii) *Self boiled lime sulphur.* This form of lime sulphur is produced without the use of external heat, the temperature rise of the solution caused by the slaking of calcium oxide being used to accelerate the reaction between the calcium hydroxide produced from this reaction with the sulphur present in suspension. This process was first described by Scott [1908] who used 15 lb. of calcium oxide and 10 lb. of flower of sulphur to 50 gallons of water. This form was mainly used for sensitive plants, particularly on peach trees. It is rarely used at present.

*One U.S. gallon of water at 15°C. (62°F.) weighs 3.7820 Kg. or 8.337 lb. as compared with 1 British gallon weighing 4.535 Kg. or 10 lb.

(iv) *Dry mix sulphur lime.* This combination known also as 'New Jersey Mix' is a substitute for self boiled lime sulphur for use on plants susceptible to injury. The original formula was sulphur 8 lb., hydrated lime 4 lb., calcium caseinate 4 oz.

Polysulphides of barium and alkalies. Efficacy of calcium polysulphide in lime sulphur has drawn attention to the aspect of how far alkaline earths and alkalies can replace lime in polysulphides. The elements tried are barium, sodium, potassium and ammonium. Soluble sulphurs have been advocated by Caesar [1917, 1926] but Edmundson [1918] prefers lime sulphur to them. Parrott [1914] making a comparative study of barium, sodium and potassium polysulphides finds their effectiveness in the order stated. For average conditions liquid lime sulphur can scarcely be substituted by the other polysulphides. Soda sulphur has been substituted as a dormant spray in place of lime sulphur by Haywood [1907] but according to Shephard [1947] it can be used only as a dormant spray. Dusts of barium and sodium polysulphides with talc as diluent have been tried in Tasmania, Ontario and other places. They have been found to be less effective than liquid lime sulphur, by Abbott *et al.* [1926], Parrott [1922] and Baerg [1921].

Action of polysulphides on San Jose Scale. Observations on this subject have been made by Shafer, [1911], Harukawa [1922], O'Kane and Conklin [1930], Young [1922], and Hartzell and Lathrop [1925]. Investigations on the exact nature of action of polysulphides on scale insects, especially action of lime sulphur have brought out some remarkable results. Polysulphides when sprayed on plants in contact with atmosphere have been shown to precipitate elemental sulphur in a superfine state. This sulphur is volatile under ordinary atmospheric temperatures. When sulphur volatilizes and is inhaled by the scale, hydrogen sulphide is evolved due to certain enzymatic action of insect tissues. This hydrogen sulphide is deadly to scale insects.

Some remarkable discoveries have been made by Newcomer and Yothers [1929], and Yothers [1940] on the effect of lime sulphur on San Jose Scale. They find that lime sulphur causes sterility of the female San Jose Scale. They also found that the spray was repellent or lethal to the males. The unproductivity of the females was probably also due to the lack of fertilization owing to the death of males.

Melander [1914, 1915, 1923] has discovered that continuous spraying with lime sulphur for long periods develop new strains of the scale resistant to lime sulphur. This subject has been reviewed by Webster [1933] and Quayle [1938]. The latter author states that it is difficult to explain the development of resistance, although the figures of Melander are significant in suggesting this.

Injuries caused by lime sulphur on plants. At times, lime sulphur sprays have been known to burn foliage and injure the appearance of fruit. How exactly the damage develops is still not clear. The cause has been variously ascribed either to polysulphides, thiosulphates or due to hydrogen sulphide produced during the breakdown of the polysulphides.

(b) Oil sprays

Oils used in San Jose Scale control are divided into two classes; (a) Oils derived from mineral sources, viz., petroleum oils and coal tar oils. (b) Oils derived from vegetable and animal kingdom, viz., vegetable oils and fish oils.

Petroleum oils. Much research data on the use of petroleum oils against San Jose Scale in field conditions has gathered in various parts of the world. Some of the aspects worked out are (i) the physical characters of oil to be used; (ii) best methods of preparations of oil emulsions and miscible oils; (iii) dilution ratios to be used for winter dormant sprays and summer sprays; (iv) comparative studies of oil spray *versus* lime sulphur; (v) use of combination sprays viz., oil and lime sulphur (vi) use of blended oils; (vii) use of alkaloids like pyrethrum; (viii) use of Bordeaux with oil sprays, etc.

Physical properties of petroleum oils for use in San Jose Scale control. A review of experimental work in the U. S. A., Canada and Austria shows that viscosity, volatility, degree of refining as measured by sulphonation test and specific gravity of the oils are the factors which influence toxicity and limit the use of particular grades of oil in San Jose Scale control work. Trial

conducted in the U. S. A. and Canada show that oils between widely differing physical constants are found toxic to scales but the lower and higher margins of the physical constants have been more or less defined. A special committee* of the U. S. A. and Canada which examined the issues in 1925 recommended petroleum oils with the following physical constants ;

Viscosity—90 to 250 seconds Saybolt at 100°F.

Specific gravity—0.87 to 0.93 at 68°F.

Volatility—Less than 2 per cent.

For scale control, oils bearing the following physical constants were recommended.

Viscosity—180 to 220 seconds Saybolt at 100°F.

Specific gravity—0.88 to 0.91 at 68°F.

Volatility—Less than 1 per cent.

Melander, Spuler and Green [1926] in Washington correlate toxicity of petroleum oils with boiling points of the distillation fractions. They find oils which distil slightly over 50 per cent between 240° C. and 300° C. at 40 mm. pressure and slightly over 25 per cent below 240° C. are the best. Viscosity, specific gravity and source—they find to have only incidental effects on the insecticidal value.

Some experimental work on correlation of physical constants *versus* toxicity deviate to a considerable extent from the recommendations laid by the Special Committee which sat in sessions in 1925.

Beran's (1942) observations in Austria show that oils with the highest viscosity, highest boiling point, lowest unsulphonated residue and lowest volatility are the most effective—quite an unusual observation deviating from the results obtained in the U. S. A. and Canada.

Oil emulsions and miscible oils. Paraffin oils as such cannot be sprayed on plants, as they damage them. They have got to be diluted by neutral materials like water. As oil and water do not mix readily much research work on preparation of oil emulsions and their applications to plant life has been carried out. One of the first problems to be solved was how to emulsify oil in water. Different types of emulsifiers have been tried. The emulsifying agents fall into several groups ; soaps of animal and vegetable oils, proteins (albumen and gelatine), salts of proteins (casein ammonia, casein lime), saponines, alcohols, fine clays like bentonite, phenols, cresols, cyclo-hexanols and freshly made Bordeaux.

Two different methods of preparing oil emulsions have been tried : boiled emulsions and cold emulsions. A comparative study of these methods of preparing oil emulsions show that they are practically equal with slight difference in favour of boiled emulsions which are generally more stable. Boiled emulsions have been found to be the most reliable for home made use. Boiled emulsions mix satisfactorily with Bordeaux. On the other hand cold emulsions have to be prepared just prior to spraying. Cold emulsions are compatible with lime sulphur, and a little cheaper than the boiled emulsions.

Oil emulsions and miscible oil formulae. A detailed account of the various formulae tried for oil emulsions and miscible oils would fill several pages ; suffice it to give a resume of a few important ones to indicate on one hand the general principles involved and on the other to give some important formulae found efficient to control San Jose Scale in other parts of the world and which may be successfully tried in India. Some of the early attempts to use miscible oils against the scale were those by Parrott *et al.* [1906], Jarvis [1907], Penny [1908] and Ball and Fracker [1918].

* Special Reports prepared under the direction of the Sub Committee of insecticides and appliances, Committee on policy. *J. econ. Ent.*, (1925) XVIII, (2), 410-420.

The following are a few formulæ for oil emulsions with potash fish oil soaps as emulsifying agent :

Haseman and Sullivan [1923] recommended oil emulsion prepared with 1 U.S. gallon lubricating oil, 1 lb. potash fish oil soap and $1\frac{1}{2}$ U. S. gallons of soft water. These are boiled and while still hot passed through a force pump at least twice under a minimum pressure of 60 lb. This emulsion keeps indefinitely if it is not allowed to freeze which occurs at 18°F. The addition of $\frac{1}{2}$ U.S. gallon of water containing $\frac{1}{4}$ lb. of copper sulphate and $\frac{1}{2}$ lb. lime has been found to be sufficient to soften 50 gallons of water and prevent breakdown of the emulsion. A 2 per cent oil spray has been found to give good results.

Yothers' [1918] formula. Lubricating oil 2 U.S. gallons, potash fish oil soap 2 lb., water 1 U.S. gallon. The ingredients are mixed together brought to a boil and while still hot pumped together through spray pump. The stock emulsion is diluted to 200 U. S. gallons for spraying.

Huber's [1925] formula. One U.S. gallon oil, $\frac{1}{2}$ U.S. gallon water and 2 lb. soap. At strength of 6 gallons of emulsion to 100 gallons of water, he observed a hundred per cent kill of San Jose Scale.

The best formula of stock emulsion recommended by Chandler, Flint and Huber [1926] against San Jose Scale is 1 U.S. gallon oil, 1 lb. to 2 lb. potash fish oil soap and $\frac{1}{4}$ U.S. gallon water. The materials are boiled together and pumped twice at pressure of 75 lb. or more. A 2.4 per cent oil spray has been found to be effective.

Newcomer and Yothers [1931] use an oil emulsion containing coconut fatty acid (a commercial mixture containing crude lauric acid). Nine ounces of commercial caustic potash is dissolved in 2 U.S. gallons of water. $2\frac{3}{4}$ lb. of coconut fatty acid is melted and is poured into the caustic solution; 2 U.S. gallons of oil and entire mixture is heated to boiling point. Two U.S. pints of kerosene are added to it after removing from fire; the mixture is then emulsified by pumping twice through a hand pump.

A few formulæ for cold oil emulsions with Bordeaux as emulsifying agent. Macrum [1919] developed the following spray :

200 U.S. gallons tank is filled with three quarters with water and 24 U. S. gallons of copper sulphate solution (1 lb. to 1 U.S. gallon of water) are added. Milk of lime made with 12 lb. slaked lime is then added until litmus paper shows the solution neutral and $1\frac{1}{2}$ gallons of glue solution ($1\frac{1}{2}$ lb. glue in water) are then added. 12 U.S. gallons of the General Chemical Company's No. 1 oil poured into the tank and the entire fluid is made to 200 U.S. gallons.

Ross [1923] uses the following formula. Three gallons of lubricating oil; copper sulphate 6 oz., fresh hydrated lime 6 oz., water 3 gallons. A 3 per cent oil emulsion proved to be the best. Metcalf and Flint [1939] suggest equal parts of oil and 4-4-50 Bordeaux mixture pumped through a pump at least three times for emulsification. A 2 per cent emulsion has been found to be very effective.

Mills and Dewey [1947] recommended 2 gallons of lubricating oil and 2-4-100 Bordeaux mixture as an emulsifier. A 2 per cent oil is recommended.

Cold emulsions with calcium caseinate as emulsifier. Burroughs [1923] uses the following formula successfully : Two U.S. gallons engine oil, 1 U.S. gallon of water with 4 oz. calcium caseinate. A 2 per cent emulsion seems to be efficient and could be used without injury upto the cluster-bud stage.

Flint [1926] and Metcalf and Flint [1939] suggest 2 U.S. gallons lubricating oil, 1 U.S. gallon water, 4 oz. calcium caseinate. Eight per cent of this stock has been found effective against the fruit tree leaf roller and the San Jose Scale.

Cold emulsions with cresoap as emulsifier. Melander, Spuler and Green [1924, 1926] give a formula for making oil emulsions and miscible oils with Cresoap. Cresoap is prepared by dissolving $5\frac{1}{2}$ lb. of potash fish oil soap in $4\frac{1}{2}$ lb. of cresol. This product is used in the proportion of 10 per cent. by weight to 90 per cent weight of lubricating oil. Emulsions prepared with this product give the most concentrated miscible oils—only $4\frac{1}{2}$ gallons of the stock being needed

to make 100 gallons of 4 per cent spray. Another advantage is that this stock requires no boiling or pumping nor does it freeze. But this oil is not recommended where water is very hard. This oil has been found effective with 4 per cent spray. It has also been found that alcohol can be used as a substitute for cresoap. For this purpose 8 lb. caustic potash are dissolved in 51 lb. of water and then the solution is mixed with 20 lb. of denatured alcohol and 25 lb. of red oil. As the reaction of the mixture is violent and heat is generated, the emulsifier should be allowed to cool slightly before being mixed with lubricating oil.

Cold emulsions with blood albumen as emulsifier. Two gallons of lubricating oil with half pound of commercial blood albumen as emulsifier was found to be the cheapest spray against the scale that could be made by the grower, when sprayed at the rate of 2 per cent of oil.

Miscible oil formulae. Eddy [1936] suggests the following :

Oleic acid — 8.5 parts by weight

Phenol or cresol — 1 part by weight

Isoamyl alcohol or amyl alcohol — 3 parts by weight

Caustic potash—3.5 parts by weight

Ethylene glycol or mono ethyl ether—1.5 parts by weight

Mix above ingredients and add mineral oil 82.5 parts by weight.

Another formula used commercially is :

Fish oil soap—5 per cent

Water — 2 per cent

Cresylic acid — 3 per cent

Red engine oil (unsulphonated residue 50 to 70 per cent)— 90 per cent

First the fish oil soap and water are mixed together. Then the cresylic acid and lastly the red engine oil are added.

Dilution ratios of petroleum oil emulsions. Stock emulsions are too concentrated to spray on plants. Optimum dilution ratios for stock emulsions with water have been worked out in various parts of the world against San Jose Scale. Dilution ratios depend on a number of factors ; whether the oil has got to be used for winter dormant spraying or late dormant spraying or summer spraying, climatic conditions of the locality and the type of plants to be sprayed.

Experience in the United States as mentioned by Howard [1924] and Wakeland [1925] suggests two to four per cent of a good lubricating oil or a miscible oil in water for dormant spraying of apples. The optimum percentage of dilution depends on the latitude and climate of the place. In the North West U.S.A. a 4 per cent oil, in the Middle West, Southern Idaho and New York States a 3 per cent oil and in Georgia State a 2 per cent oil are recommended. Howard [1924] recommends only a 2 per cent oil for peach as a dormant application. Experience in Australia and Argentina suggests a higher percentage of oil, viz., 4 to 6 per cent. In Western Australia, regulations demand 5 per cent petroleum sprays for dormant spraying on apple. Popova [1938] and Kraiter [1940] working in Krasnovdarsky and Eastern Georgia regions of Soviet Russia recommend 4 per cent and 2 per cent lubricating oil sprays for the respective localities. On the other hand Italian recommendations go to the extreme of 7 per cent oil for dormant sprays for apple. In British Columbia, Ruhmann [1937] states that a 4 per cent oil emulsion is a standard recommendation.

For late dormant sprays at 'Green tip' stage of apples Herrick [1926] working in New York State advises 2 per cent to 3 per cent oil. Popova [1938] recommends a 4 per cent oil spray at bud swelling stage of apples.

Summer spraying against San Jose Scale. Summer oil sprays are not generally recommended for San Jose Scale control unless the infestation is very severe because they have a tendency to injure the foliage and fruit. If summer sprays are deemed necessary, highly refined oils, the so called white oils have got to be used the dilution ratio being $1\frac{1}{2}$ per cent to 2 per cent

of the oil. Chandler, Flint and Huber [1926] advise boiled potash fish oil soap emulsion for apples, but not for peach.

Boiled and cold mixed emulsions. In the foregoing pages the formulæ for both the boiled and cold mixed emulsions have been given. Boiled and cold mixed emulsions are considered practically equally effective against the San Jose Scale with a slight difference in favour of the boiled which is generally recognised as the more stable. Cold mixed emulsions should be made up only as needed. Amongst the home made emulsions boiled soap emulsions have been found to be the most reliable. Both are very adhesive and this property is increased when Bordeaux is mixed with them. The boiled emulsions satisfactorily mix with Bordeaux but not with lime sulphur. The cold mixed emulsions are compatible with lime sulphur as well as with others. The use of a weak ($\frac{1}{2}$ — $\frac{1}{3}$ —50) Bordeaux with the emulsions permits satisfactory mixing in most hard waters. The boiled emulsions probably cost slightly more than the cold mixed but are considered to be cheaper than any of the commercial and about half the cost of lime sulphur.

Spray trials against San Jose Scale in India. Diesel oil emulsion with the following formula has been used in Kashmir. Diesel oil : $1\frac{1}{2}$ gallons, soft soap : 1 lb., water : $1\frac{1}{2}$ gallons. The water is heated and the soap is dissolved in it ; the solution is then brought to a clear boil. Then the oil is added, gently heating the solution for a few minutes and stirring it very well. Care should be taken not to boil the contents after adding the oil as there is danger of oil catching fire. The mixture is then taken off and pumped thrice from one can to another, diluting the stock solution thus prepared.

In the Punjab, the Diesel oil emulsion is prepared with chemicals used in the following proportion : Diesel oil : 5 seers, potash vegetable oil soap or potash fish oil soap : 2 seers and water 14 seers. One part of this stock solution is diluted with 33 parts of water and then sprayed.

In Kashmir* cold Diesel oil emulsions, emulsified with calcium caseinate or Bordeaux mixture have also been used. The formulæ in the latter case was — Diesel oil : 2 gallons, water 1 gallon, calcium caseinate : 1 oz. Calcium caseinate was prepared by adding 4 parts of slaked lime to 1 part of pure calcium casein. It was then dissolved first in water; the oil was then added and the whole mixture thoroughly pumped with a hand pump. Usually three to four pumpings gave a good creamy emulsion which was diluted with ten parts of water to give a spray with six per cent oil contents. For emulsification with Bordeaux mixture, the following proportions were used : Diesel oil : 12 gallons, lime : 2 oz., copper sulphate : 2 oz., water 1 gallon. Bordeaux mixture was prepared first and soon emulsified with oil. A few pumpings usually gave a thick bush green stock solution which was diluted with ten parts of water before spraying. Diesel oil emulsion, emulsified with white of egg was also used in Kashmir. One egg was used to emulsify a gallon of Diesel oil and half a gallon of water. This did not make a thick and white emulsion and quickly separated. It was, therefore, diluted (1 : 10) and sprayed soon after preparation.

A home made miscible oil was also tried in Kashmir. The following formula was adopted for this : Diesel oil : 750 c.c., soft soap : 1 oz., superior phenyle : 2 oz. Soap and phenyle were thoroughly mixed together with pestle and mortar and the Diesel oil added slowly and mixed well. A homogenous liquid was formed which on dilution with water formed a strongly smelling phenyle emulsion.

In 1939-40 comparative tests were made in Kashmir with (a) Burmah Shell Diesel oil 'A' emulsified with rosin-fish oil soap diluted in 5, 7, 10 and 15 parts of water, as well as with local soft soap diluted in 7 parts of water, (b) Texaco 'New Light' Diesel oil emulsified with local soft soap diluted in 7 parts of water, (c) 'Whiz' a proprietary ready made mineral oil emulsion in dilutions of 1 : 24, 1 : 32, 1 : 48 and (d) lime sulphur in the dilutions of 1 : 8 and 1 : 10. Oil emulsion sprays were found to be superior to lime sulphur, best results being obtained with Burmah Shell 'A' Diesel oil 1 : 5 with 8.33 per cent oil contents. This was recommended for

*The Progress report on the San Jose Scale and Woolly Aphis Research Scheme in Kashmir for the year ending March 1940.

heavy infestations. Diesel oil emulsions in dilutions of 1 : 7 and 1 : 10 with 6½ per cent oil contents respectively gave very good results, these being recommended for heavy to moderate infestations. 'Whiz' in dilutions of 1 : 24 was found to be equivalent to 1 : 10 Diesel oil emulsion but is costlier than the latter.

In 1940-41* small scale as well as field scale spraying experiments were carried out with (a) common bus oil (lubricating) emulsified with soap, (b) Diesel oil emulsified separately with soap, Bordeaux and calcium caseinate, (c) light kerosene oil emulsified with calcium caseinate, (d) 'Whiz', (e) 'Wintrol', (f) home made miscible oil, and (g) lime sulphur. In the hot emulsions used, lubricating oil emulsified with soap and containing 6.25 per cent oil, 12° Be, although it gave 100 per cent mortality, injured the plants fatally. Similarly kerosene oil emulsified with six per cent oil contents and emulsified with calcium caseinate injured the plants fatally. Diesel oil emulsified with soft soap and sprayed with 6.25 per cent oil contents gave good results. A proportion of 4.5 per cent oil contents though reduced the oil efficiency of the spray, could be recommended in case of light infestation only. 'Whiz' proved to be equivalent to the Diesel oil emulsion with 6.25 per cent oil contents. Amongst cold emulsions, Diesel oil emulsified either with calcium caseinate, Bordeaux mixture or white of an egg was found easy to prepare and cheaper than the hot emulsions. It was quick breaking and acted immediately. Diesel oil emulsified with calcium caseinate gave better results than the emulsions made either with Bordeaux mixture or white of an egg. Of the latter two, the one made with Bordeaux mixture was better than the one made with white of an egg. (3) As regards miscible oils tried, 'Wintrol' used in dilution of 1 : 20, i.e., with 4.2 per cent oil contents gave 98 per cent kill and in dilution of 1 : 15 with 5.6 per cent oil contents, nearly 100 per cent control was obtained. Home made miscible oil gave slightly poorer results than the hot or cold emulsion spray. As in the previous year, lime sulphur, 1 : 8 gave results inferior to oil spray.

Trial with mineral oil sprays were continued in 1941-42.† 8.3 per cent oil strength of the Attock (Burmah Shell) and Caltex Diesel oils gave best allround results. An oil strength of 6.6 per cent was also effective in the dormant season, while for medium infection a still lower strength of 4.5 per cent could be recommended. Caltex Diesel oil in various dilutions also gave satisfactory results, although the Attock Diesel oil proved superior to it in all dilutions. The heavier lubricating oil, Caltex S.A.E. 30 with 4.5 per cent strength in the spray gave satisfactory results and also left a greasy surface on the plants without injury to them. As regards different emulsifiers tried, 6.6 per cent Diesel oil emulsions prepared with calcium caseinate, saponin and Bordeaux mixture were cheaper and gave as good results, on the whole, as hot (soap) emulsions, when the oil strength was kept constant. Miscible oil was found to be costlier, difficult to prepare and manipulate and gave no better results than the sprays mentioned above. It was also found that 1½ per cent resin fish oil soap solution did not even kill half the number of live scales on the trees. Its value as an insecticide was, therefore, almost nil.

In trials of different sprays continued in 1942-43‡ it was found that a normal 6.0 to 6.6 per cent of Diesel oil in the emulsion gives 99 to 100 per cent control. In cases of heavier infestation, the oil percentage may be increased to 7.4 while for lower infestation the oil may be reduced to 5.0. Heavier lubricating oil SAE 30 gave good results with lower oil percentage (4.5 to 5.0) in spray liquid. Caltex Diesel oil being less refined in quality than the Attock Diesel oil showed slightly inferior results than the latter. Cold emulsions prepared with calcium caseinate, Bordeaux mixture or bentonite were found to be cheaper and equally efficacious on the whole, but the problem of using them on large scale specially for big orchards when the spray solution had invariably to be left over for the night, remained unsolved as these emulsions were found to separate out quickly unless emulsified and applied by a high

*Progress Report of the San Jose Scale and Woolly Aphis Research in Kashmir for the year ending March, 1941.

†Progressive Report on the San Jose Scale and Woolly Aphis Research Scheme in Kashmir from 1 April 1941 to 30 June 1942.

‡The San Jose Scale and Woolly Aphis Research Scheme in Kashmir. The Fourth Progress Report from 1 July 1942 to 30 June 1943.

pressure machinery in which continued stirring keeps the emulsions in condition during operations. As regards use of emulsifying agents, Diesel oil with (1) Bordeaux mixture, (2) local soap, (3) local potash soap, (4) bentonite, (5) calcium caseinate, and (6) soap nuts were tried. Soap nut decoction used as emulsifying agent formed a very stable emulsion but the difference between this treatment and others was not at all significant.

A comparative study of the use of various sprays with different types of machinery was also made in Kashmir in 1943-44.* The following were the important items under study (1) Attock Diesel oil 6.6 per cent emulsified with 1 seer, $\frac{1}{2}$ seer, $\frac{1}{4}$ seer and $\frac{1}{8}$ seer local soap and sprayed with bucket pump. (2) Diesel oil 6.6 per cent emulsified with double dose, normal, half, quarter and one eighth dose of rosin fish oil soap sprayed with bucket pump. (3) Caltex Diesel oil 7.4 per cent, 6.6 per cent and 6 per cent with half the dose of local soap and sprayed with bucket pump. (4) Attock Diesel oil 7.4 per cent, 6.6 per cent and 6 per cent with half the dose of local soap and sprayed (a) with bucket pump and (b) with high pressure pump. (5) Diesel oil 6.6 per cent emulsified with (a) calcium caseinate (b) bentonite, and (c) Bordeaux mixture sprayed with bucket pump. (6) Diesel oil 6.6 per cent emulsified with Bordeaux mixture and sprayed with Bucket pump and high pressure pump. All the above sprays excepting lime sulphur gave nearly 100 per cent control. Trials made since 1939 also indicated that Diesel oil Attock A brand at about 6 to 6.6 per cent in the spray emulsion provided an efficient and economical measure of control. Severer infestations needed heavier dose of oil to an extent of about 9 per cent which gave complete mortality of the scale without injury to the plants. Lubricating oil S.A.E. 30 emulsified with soft soap and at about 6.6 per cent oil strength gave 99.8 per cent control.

In 1944-45†, the spraying trials conducted in Kashmir gave results which were in conformity with those of the previous year. Diesel oil 'A' at about 6.6 per cent strength in the spray emulsion provided an efficient and economical control measure but severer infestations required heavier doses of oil, about 9.10 per cent oil strength having been tried without injury to the plant tissue. As regards trials with various emulsifiers, spraying with cold emulsion prepared with calcium caseinate as an emulsifier, proved as satisfactory as the hot emulsion. Bentonite as an emulsifier did not prove quite satisfactory and gave poorer results of mortality. Bordeaux mixture as an emulsifier proved quite efficacious. Lime sulphur gave poorer results than oil sprays.

Coal tar and wood tar oils. During destructive distillation of coal for various industrial uses, several grades of oil are recovered as fractional distillates. These oils resemble petroleum oils in physical properties but are chemically different. These oils are mixtures of different types of aromatic compounds. Oil grades known as middle oil, heavy oil and anthracene oil are collectively known in the U.S.A. as creosote oils. They have been favourably reported from Continental Europe, especially from Germany and Holland, for insecticidal purposes. Trials conducted with these chemicals are still in their preliminary stages; some aspects of their use have been worked out. But opinion is still conflicting on their significant place in the group of insecticides used against scale insects and particularly against the San Jose Scale. In the U.S.A., Australia, Vienna and Russia coal tar oils distilling between 200° to 350°C. have been generally used. Hartzell and Pearce [1934] recommend oils distilling between 200° C. to 350°C. with not more than 15 per cent fraction distilling between 200°C. to 230°C., and the tar acid content not exceeding five per cent. Chernova as reported by Kraiter [1940] worked with anthracene oil in the province of Krasnodar (Russia).

On the subject of emulsifiers used, sodium caseinate and lignin pitch have been favourably reported. Hough [1933] recommends sodium caseinate as an emulsifier. Three U.S. gallons of tar oil, one U.S. gallon of lubricating oil and two U.S. gallons of water are taken. Seven ounces of powdered Casein is dissolved in one U.S. gallons of boiling water in which $1\frac{1}{2}$ oz. sodium metasilicate has been dissolved. The solution is diluted to two U.S. gallons. The

*The San Jose Scale and Woolly Aphis Research Scheme, Jammu and Kashmir. The *fifth Annual Report* for the year 1st July to 30th June 1944.

†The San Jose Scale and Woolly Aphis Research Scheme, Kashmir. Summary of the *sixth Annual Report* for the year 1st July 1944 to 30th June 1945.

one U.S. gallon of lubricating oil which facilitates emulsification of tar oil is next added and the mixture pumped through the nozzle until emulsified. As the mixture is pumped back on itself the tar oil is gradually added and pumping continued until it is completely emulsified. The stock solution contains 50 per cent of tar oil. Stanley, Marcovitch and Andes [1934] find powdered lignin pitch better than a soft soap as an emulsifier. Powdered lignin pitch 3.6 lb. is dissolved in $1\frac{1}{2}$ U.S. gallons of hot water. Three U.S. gallons of the coal tar oil is slowly added while the solution is being forced through a hand-pump. A fine stable emulsion which does not break when exposed to freezing temperatures is formed.

A number of comparative studies between petroleum and coal tar oil emulsions and their blends have been made. Hough [1932] who compared five coal tar distillates with lubricating oils opines that coal tar concentrates of 1 to 15 and possibly 1 to 10 with water have got to be used to get results comparable to a three per cent lubricating oil emulsion. Hartzell, Parrott and Harman [1933] find that in severe infestations tar distillate sprays are not as effective as lubricating oil emulsions. On the other hand Hartzell and Pearce [1934] found 1.6 per cent to 4.5 per cent coal tar sprays comparable to lubricating oil sprays of 2.5 per cent to 6 per cent. Hartzell, Harman and Reed [1935] found three per cent sprays were equally effective on moderately weakened trees. According to another report coal tar oils applied to fruit tree during dormant stage were not as effective as 2.5 per cent of lubricating oils. On the whole coal tar products have not yet proved their worth in competition with petroleum sprays.

On the subject of dilution ratios of coal tar emulsions with water, Hartzell, Parrott and Streeter [1932], and Ginsburg and Driggers [1938] recommend not more than 4 to 4.5 per cent of oil in water. On the other hand Hurt [1932], Hartzell, Harman and Reed [1935] and Kraiter [1940] who worked with heavy redistilled tar oil and anthracene oils recommend only two per cent to three per cent oil—the maximum limit being four per cent. Most of the proprietary coal tar oil blends in the U.S.A. blend 37 per cent coal tar oil to 46 per cent lubricating oils.

Wood tar oil. Stanley, Marcovitch and Andes [1934] tried wood tar oil of hardwoods for control of San Jose Scale on peach trees. They found blends of wood tar oil and lubricating oils more efficient than either wood tar oil or lubricating oil sprays used alone. Four per cent of blend consisting of 1 per cent wood tar oil and three per cent lubricating oil gave 99.08 per cent control of San Jose Scale. On the other hand Hough [1939], and Snapp and Thomson [1943] proved that wood tar oils are as efficient as lubricating oils.

Mode of action of tar oils. Little is known of the action of tar oil on insects. Toxicity has been correlated with the rise in boiling point of the tar oils. Toxicity has been ascribed to physical properties of the oil, asphyxiation being caused by the film of oil. Chemical properties are also believed to be involved as the tar oils are more effective than mineral oils on aphid and psyllid eggs. Beran [1939] who worked with medium and heavy coal tar oils and combinations of both types, believes that no marked difference in the influence of atmospheric temperature exists on these two grades in the field. He also finds that coal tar oils are not effective against San Jose Scale at low freezing temperatures.

Vegetable oils. Viel [1946] in the Alpes Maritimes of France conducted comparative experiments with vegetable oils and white mineral oil. He found groundnut oil emulsions among the vegetable oils at 3.75 per cent more effective than white oil emulsion at 1.6 per cent. In Kashmir (1944-45), rape seed (*sarsoon*) and raw linseed oil emulsified with soft soap and sprayed at 6.6 per cent gave excellent results. Turpentine oil emulsion with soft soap at 6.6 per cent oil strength gave only very negligible control in winter.

Pre-requisites for effective control of San Jose Scale by oil sprays. Works of Hough [1938] and Popova [1939] indicate that certain amount of orchard sanitation is essential for good results with oil sprays against San Jose Scale. They find that the trunks and large limbs of the trees should be scraped and the loose dead bark, moss, lichen, etc. which shelter the scales, removed. Woody undergrowth between the rows and the edges of orchards should be destroyed.

Determination of spray effectiveness against San Jose Scale. Spray effectiveness against San Jose Scale judged generally by comparing the percentage dead upon the sprayed plants

and unsprayed plants one month after the application of the spray, is misleading. Spray results may also be checked by taking subsequent counts of the number of new scales on a given length of a new twig and fruits at harvest as suggested by Abbott [1926]. By using these check counts Abbott concludes that mortality counts made 30 days after treatment are accurate enough. Swingle and Snapp [1931] believe that one month interval between the time of spraying and taking counts to be too wide as results may be vitiated by deaths from natural causes. Houser [1926] warns that counts should not be taken immediately after rains as dead scales which become plumpy and juicy, look like live ones. Abbott [1925] has developed a method of computing results in algebraical terms. A laboratory method of comparing toxicity of an oil to San Jose Scale has been developed by Kagy [1936].

(c) Miscellaneous sprays

Use of alkaloids of Larkspur and Stavesacre. Alkaloids obtained from the seeds of Larkspur (*Delphinium consolida*) and Stavesacre (*Delphinium staphisagria*) have been found by Davidson [1929] to possess insecticidal properties. A two per cent soap emulsion gave him fair results against San Jose Scale.

Nicotine oleate and sulphate sprays. Nicotine oleate at 1 oz. to 1 U.S. gallon; or 1 oz. nicotine sulphate to 5 U.S. gallons of water containing 1 lb. fish oil soap has been tried by Davis [1922]. He found the latter mixture superior to the first. Wahl [1932] reports that a summer spray of nicotine is more effective than a coal tar or lime sulphur spray. Brunteau [1939] records the use of nicotine sprays during June, July and September in Rumania. Herbert and Leonard [1929] found a combination of nicotine and oil giving a successful commercial control of San Jose Scale, besides other insects like the codling moth.

Pyrethrum in oil. In Idaho State, U.S.A. a combination of one part of kerosene extract of pyrethrum and 400 parts of dilute dormant oil emulsion controlled San Jose Scale on prune when applied at the time the buds were beginning to show white.

Some proprietary dormant oils. 'San. U. Zay Scale Oil' is a proprietary petroleum miscible oil preparation used for San Jose Scale Control. It has been tried by Forbes [1915] who found it practically equal in value to the solutions of lime sulphur. 'Scalecide' is another proprietary miscible dormant spray. It is a miscible oil composed of both vegetable and mineral oils. The manufacturer's instructions are that it should be used at the rate of 1 to 15 for deciduous trees. It has been used by Forbes [1915] and Flint [1923]. The former who diluted 1 part of it with 20 parts of water found it somewhat less effective than lime sulphur but Flint who used the dilution 1:15 found less than 0.5 percentage of scales alive after treatment. Fracker [1918] has suggested the use of this insecticide, one gallon of it being diluted with 12 gallons of water. Baerg [1921] has found it next best to lime sulphur. In Ontario, Canada, it has been found effective at the 1:15 strength recommended by manufacturers. The latter state that a large part of this miscible oil consists of vegetable oils which are high in growth promoting harmones. Spraying is advised every time after the foliage is off in autumn or before the buds show $\frac{1}{4}$ in. to $\frac{1}{2}$ in. of green tips in the spring provided the temperature is warmer than 40°F.

Some of the other important proprietary oil emulsion containing oils used in the U.S.A are 'Spra cream', 'Superior oil', 'Security brand oil emulsion', 'Free emulsion', 'Spra-emulsion' and 'Liquicide'.

Oil sprays vs. lime sulphur. About the time Parrott *et al* [1906] and Jarvis [1907, 1908] were making a study of petroleum emulsions and miscible oils against the San Jose Scale, lime sulphur became suddenly popular in the U.S.A. and the use of oil sprays was checked till about 1922. There was also difference of opinion as to which was superior. Experiments made by Flint [1923] confirmed that a much higher degree of control could be obtained with lubricating oil emulsions than with the best grades of liquid lime sulphur. He reported the use of thousands of gallons of home made lubricating oil emulsions with very satisfactory results and at or rather less than half the cost of the dilute commercial liquid lime sulphur. As liquid lime sulphur did not prove effective against the San Jose Scale in all places, Haseman and Sullivan [1923] also recommended an oil emulsion in the State of Missouri. However in the subsequent year, Parrott [1924] stated that though oil emulsions are very effective against the

San Jose Scale, their emulsions should be limited to particularly heavily infested orchards, lime sulphur solutions being of more general practical value under ordinary circumstances. But four years of experiments carried out by Chandler, Flint and Huber [1926] in Illinois with lubricating oil emulsions against the pest showed again the superiority of oil sprays over lime sulphur, the mortality being 98 per cent with the former and 89 per cent with the latter. Regan [1926] in a more detailed discussion on the respective advantages of a standard oil spray and liquid lime sulphur showed that if properly applied they are both equally effective against the pest. According to him, lime sulphur is less likely to injure trees but oil is cheaper and more agreeable to handle and apply. It was, therefore, suggested by him that the use of oil as dormant spray, alternated with lime sulphur every second or third year, would give satisfactory results and be more economical. Owing to gradual increase of San Jose Scale on peach trees in the Southern States of the U.S.A. in spite of annual dormant treatment with lime sulphur, Alden [1925] used two per cent lubricating oil emulsion and found it not only giving excellent control but also causing no injury to the tree even when used twice in one dormant season. He also found this spray to be more effective than lime sulphur. Regan [1926] found that a dormant oil spray with from $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent actual oil content was an effective control for the San Jose Scale and cheaper and more agreeable to use than lime sulphur. In experiments conducted in Virginia, U.S.A., Hough [1938] also obtained higher mortality with a two to three per cent oil spray than with lime sulphur. It is, therefore, but natural that oil sprays should be generally more popular than lime sulphur sprays. Work conducted in Kashmir has also shown the superiority of oil sprays over lime sulphur sprays.

Oil-lime sulphur mixtures. As already described various lime sulphur mixtures have been used for San Jose Scale control. Cold mixed emulsions have been found to combine readily with lime sulphur and these have, therefore, been preferred by some workers. According to Porter [1927], however, these mixtures cause injury to plant tissue than when either component is used alone. But Rolfe [1933] in his winter spraying experiments against the San Jose Scale in Australia obtained good commercial control of the scale on pears with two gallons of commercial white oil and $5\frac{1}{2}$ gallons lime sulphur in $72\frac{1}{2}$ gallons of water. Experiments conducted by Hough [1938, 39], in Virginia have also shown that the addition of a two per cent lime sulphur to the dormant oils sprays increases their effectiveness to a slight extent. Webster and others [1944] found dormant sprays with one per cent or two per cent oil with three per cent lime sulphur applied to San Jose Scale giving excellent results. These workers had earlier in 1941 also obtained increased mortality of the scale by adding one per cent mineral oil to dilute sprays of lime sulphur. But according to Shepard [1939] oil sprays should not be mixed with sulphur sprays nor allowed to follow the latter within a month because severe burning may result. The use of oil sprays combined with lime sulphur is, discouraged by some at present.

Use of oil emulsions in combination with Bordeaux mixtures. These combinations have been in use specially where soap is rendered insoluble on account of the hardness of water and in areas where the sprays are intended against the peach leaf curl besides the control of the San Jose Scale. Ordinarily a Bordeaux mixture of the formula $\frac{1}{2}$ lb. blue stone or copper sulphate, $\frac{1}{2}$ lb. lime and 50 U.S. gallons water is suggested as a substitute for soap for emulsification in the case of hard water. By pumping the lubricating oil directly with the Bordeaux in the tank when it is one third full, a uniform distribution of oil can be secured. These mixtures are in common use in the North Western part of the U.S.A. on account of the peach leaf curl present there. In Kashmir, they have been successfully used by Kapur [1946]. Unfortunately as at low concentrations the oil in combination with Bordeaux loses some of its efficiency, greater strength than 1 per cent or $1\frac{1}{2}$ per cent combinations of these emulsions have to be used. According to Marlatt [1928] the use of Bordeaux mixture, with highly refined white oil emulsions at low concentrations, for summer spraying of peach trees for the simultaneous control of peach leaf curl and San Jose Scale, tends to reduce the efficiency of the oil spray materially at a concentration upto 1.5 per cent of actual oil, although at higher strengths under experimental conditions no difference was found to exist. Porter and Sazama [1930] who undertook detailed investigations to test the comparative efficiency of oil emulsions in combination with Bordeaux mixture against San Jose Scale in summer treatment of apple and

dormant season treatment of peach trees, found lubricating oil emulsion to be reduced in efficiency when Bordeaux mixture was added at the usual strength, i.e. 2 : 3 : 50 or 4 : 6 : 50. This reduction as reported earlier by Marlatt appeared with dormant sprays of low concentrations of oil and practically disappeared when the oil content reached 1.5 per cent. In summer spraying this reduction in efficiency was found to be very marked with oil concentrations up to 2 per cent. It was believed by the authors that the Bordeaux mixture acts in a mechanical way by absorbing a certain volume of oil and thus prevent its penetration into the insect. They, therefore, recommended that the oil content of an emulsion for dormant spraying should be moderately increased whenever Bordeaux mixture at full strength is to be added and that oil applications in summer for emergency control should be made separately and not in combination with one of the sprays. That the efficiency of oil spray is reduced when it is mixed with Bordeaux mixture has been shown also by the work carried out by Ross *et al.* [1933] in Ontario in Canada. The scales were killed within 12 days by a spray of three per cent or 4 per cent lubricating oil emulsion while it took 31 days by the same concentrations in Bordeaux mixture (3 : 6 : 40).

The effect of winter spraying with oil emulsions on the vegetative growth of deciduous fruit trees attacked by San Jose Scale. By strict dormant spraying with approved dosages and even carried out for successive seasons, injury to the fruit trees has hardly occurred. Discussing the effect of mineral oils on plants Swingle and Snapp [1931] state that in Georgia State, sprays containing 25 per cent or more of oil injured dormant peach trees while lower concentrations had no effect. On peach trees in foliage they found oils with high percentage of unsulphonated residue safer than those with a lower residue. The blossoming period of peaches was neither retarded nor advanced; neither was there evidence of cumulative injury from yearly applications of oil sprays as mentioned above. Three weekly applications of a six per cent spray could be made upon one year old dormant peach trees without causing injury while older trees could withstand even a larger number of applications. Spuler, Overley and Green [1931] found miscible oil emulsions of a four per cent strength not injuring trees even during the critical period, i.e. between the time the buds first show green and cluster buds separate.

This subject received the attention of Eidel'man and Lesnikovski [1939] in Russia in connection with the control of San Jose Scale. In experiments carried out by them six year old trees were sprayed once each in the months of January, February and March with a four per cent emulsion of machine oil prepared with ferrous sulphate. Observations on the treated trees in March and April showed that not only were there no injuries caused but also the swelling and the opening of the fruit buds, and in one variety of apples even the appearance of the first leaves occurred surprisingly three days earlier on them than on the untreated ones. They also found that the sharp fall in temperature in February had no effect on the general condition and further development of sprayed trees. To determine the effect of frost on trees which had received spraying treatment, special experiments were also carried out by these authors in which three year old apple seedlings were sprayed at the beginning of December with four per cent emulsions of solar or refined machine oil while others were smeared with non-emulsified oil. The trees were outdoors, where the temperature fell as low as -26°C . and -28°C . (-14.8°F . and -18.4°F .). At the end of January and in February they were shifted to a green house to accelerate their development. In the sprayed seedlings no injury either to the twig, buds or trunk was seen; but in those that was smeared with oils many of the buds and tips were damaged. The bark of the trunk on the other hand was not affected and the seedling produced abundant foliage from the buds. Injuries to the smeared branches appeared to be caused by the particles of the solar oil penetrating into the tissues of the twigs and buds.

Detailed surveys made by Snapp and Thomson [1943] for a number of years showed no sign of injury to the tree given a spray of three per cent emulsions. Retarded brooming was observed in one year from six per cent emulsions and only slight injury in two years. Retarded brooming was also noticed in one from eight per cent emulsion. A certain amount of damage was caused by 10 and 12 per cent emulsions though no trees were killed and severe injury was caused by 15, 20 and 25 per cent emulsions. Inspections made by them for

cumulative injury also indicated that there is no danger from the application of three per cent lubricating oil emulsion once a year; and, applying two 3 per cent sprays during the dormant period where necessary is considered probably safe.

Blended oils. Snapp and Thomson [1943] have made investigations on the control of the scale on dormant peach trees in Georgia, U.S.A., using concentrations of two per cent and three per cent of blended oils prepared in the laboratory in trial tests until mixtures of the desired characteristics were obtained and found them as effective as the single oils.

Use of used oils for sprays. Used crank-case oil has been tried by Melander, Spuler and Green [1924] against the scale. They found it too uncertain in composition to be dependable. The use of worn-out motor oil for the control of San Jose Scale on peach trees has been tried by Snapp and Thomson [1933]. They have found it giving excellent control provided it is completely emulsified and the emulsion is fairly stable. They have also suggested the use of more calcium caseinate than is ordinarily required for emulsification of new lubricating oil and that the oils should be diluted to a four per cent strength. There is no injury to the trees from the use of these oils. In Kashmir, only as a trial to see if any injury to plants is caused by a heavier dose of oil used, motor engine oil emulsion with 33 per cent oil strength was sprayed on apple grafts during the coldest week of winter. No injury to bark was observed while sprouting buds were affected to an extent of 20 per cent but on the sprayed plants the sprouting buds produced leaves more profusely probably to make up the loss than the buds on the control plants.

(d) Some modern chemicals used in San Jose Scale control

(i) *Dinitro-ortho-cyclohexylphenol.* In the United States in 1930, a number of Government agencies became interested in the work of America's chemical industries to find spray materials that did not contain arsenic. At this time Dow's Organic Research Laboratory developed Dinitro-ortho-cyclohexylphenol, one of the first synthetic agricultural spray materials of organic origin which contained neither arsenic nor lead. It is a yellowish white crystalline substance practically insoluble in water, soluble in petroleum oil and having melting point of 106°C. Subsequently its value as an ovicide and contact insecticide was established and the tolerance of host plants was determined. It has been found that when this chemical is added to dormant sprays it increases their toxicity thus permitting a reduction in oil deposit and at the same time maintaining a satisfactory insect control. Such mixtures have been studied by Kagy and Richardson [1936], Dutton [1936], Hartzell and Moore [1937]. Boyce *et al.* [1939] have made an extensive study of the properties of the chemical specially with reference to its use and effect on plants. Dutton in his orchard trials of Dinitro-ortho-cyclohexylphenol in petroleum oil obtained complete control of the scale by dormant applications by an oil solution of the compound emulsified with calcium caseinate. In more extensive trials made by this author the dinitro compound was used in sodium caseinate emulsions, tank mixtures (with blood albumen emulsifier) and miscible oil preparations. The scale was satisfactorily controlled by dilute sprays containing from 1.2 per cent oil and 0.05 per cent of the compound to 2.4 per cent oil and 0.1 per cent of the compound without injury to the trees. The percentage control was 99 with the weaker of these formulae in a caseinate emulsion and 99 and 100 per cent for the stronger. Kagy and Richardson [1936] in their studies on scalcidal properties of the chemical against San Jose Scale obtained 98 to 100 per cent mortality using 1 per cent emulsions having 1.5 or 3 per cent of the dinitro compound.

Hartzell and Moore [1937] as a result of their tests with tar oils, tar lubricating oils and lubricating oils containing dinitro-ortho-cyclohexylphenol suggest their application before the buds reach the silver tip stage.

Hrenoff and Leake [1939] commented on the 1 per cent petroleum oil solution of this 2-4 dinitro-o-cyclohexylphenol which is strong enough to kill San Jose Scale without damage to trees or fruits. They consider that there is no danger to consumers eating fruits from trees sprayed with preparation containing one per cent of the chemical.

Experiments made by Hartzell [1939] in Western New York have shown that minimum concentrations of certain dormant sprays give effective control of insect pests like San Jose

Scale and against it he obtained cent per cent mortality on apple by using three per cent lubricating oil, two per cent DN—oil (oil containing four per cent, dinitro-ortho-cyclohexylphenol).

Dormant sprays applied in March containing approximately 2 per cent—2·2 per cent oil and dinitro-ortho-cyclohexylphenol and dissolved in the oil or mixed with the emulsifier and used at the rate of about 7½ to 11½ oz. per 100 U.S. gallons diluted spray, were found effective against San Jose Scale in experiments conducted by Hough [1939] in Virginia, U.S.A.

In France, Raucourt and Begue [1947] using in Winter, a three per cent emulsion of groundnut oil containing two per cent dinitro-ortho-cyclohexylphenol obtained 99·8 per cent mortality of the scale.

A number of proprietary insecticides containing dinitro-ortho-cyclohexylphenol are now available in the market. Amongst these 'Dowspray Dormant No. 3' (DN oil) is an important one. Its advantages are: (a) it is easily prepared for application, (b) is flowable at all temperatures being non-freezing, (c) it is non caustic, and (d) does not deteriorate in storage. Ordinarily two gallons Dowspray Dormant No. 3 (DN oil) in each 100 gallons of spray would suffice. The mode of preparation of the spraying solution is as follows:

A small quantity of about five to ten gallons of water is placed in the sprayer tank sufficient to permit the agitator blades to work in it to a depth of 2 in. or 3 in. The agitator is started and kept running. The required quantity of emulsifier is added. The recommended amount of DN oil is then added. The mixture is thoroughly circulated through pump, spray gun or nozzles back into the tank until a smooth creamy emulsion is formed. The tank is then filled with required quantity of water and it is circulated through the nozzles to clear the pump, hose and nozzles. At least 100 lb. pressure is required in preparing the emulsion. Another proprietary product containing dinitro-ortho-cyclohexylphenol is DN—Dry mixture No. 2. This is a dry product for use alone in water or in combination with oil emulsion, emulsible oil or miscible oil. The addition of DN—Dry mixture to oil increases toxicity of the spray to scale insects. This chemical is easily handled and its use permits variations in the amount of this material and oil to control one pest or combinations of pest. Against San Jose Scale one pound of the chemical in 100 gallons of two per cent oil in a 'heavy depositing' emulsion or 2½ per cent in a 'light depositing' emulsion is recommended. Soap and Bordeaux are not recommended as emulsifiers for these emulsions to be used with this chemical.

'Nitro-Kleenup' is a proprietary prepared oil emulsion containing 75 per cent oil and a dinitrophenolic compound which can be used as a dormant spray against scale insects including the pernicious San Jose scale.

(ii) *Dinitro-sec-butylphenol*. DN-289. This proprietary insecticide contains the triethanolamine salt of dinitro-sec-butylphenol which was first used in orchard trials in the spring of 1942. Promising insect control in many experiments obtained since that time led to limited release of the product for commercial use in 1947 under the trade name of DN-289 by the Dow Chemical Co. of U.S.A. The composition is a stable solution which contains eight ounces actual dinitro-sec-butylphenol per quart and is readily miscible with water. It has given promising results in the control of the San Jose Scale. The amount of the compound required to obtain good control ranges from one quart to two quarts in 100 gallons of water according to the intensity of the infestation. DN-289 is a clear solution mixing readily with water in the spraying tank. It is stable even in freezing temperatures and does not deteriorate in storage. It is not recommended for use with oil. It should be used only with water, the application being made during the spring dormant period. It should not be used on peaches but can be successfully used on apples, pears, cherries, plums, prunes and currants.

Another proprietary product containing dinitro-ortho, secondary butylphenol is 'Elgetol 318' produced by the Standard Agricultural Chemicals. This is also a water soluble dormant spray and has been tried by various experiment stations in the U.S.A. As in the case of DN-289 it cannot be used with oil. It mixes readily with water in the spray tank and does not deteriorate in storage. It is a clear yellow solution. For use against San Jose Scale two quarts of the chemical is used with 100 gallons of water. It should not be used after green tips appear

on apple, cherry, plum, prune and currant. If used for early dormant treatment, a delayed dormant application can be made only after an interval of two weeks. 'Elgetol 318' cannot be used against peaches.

(iii) *Dinitro-ortho-cresol*. Products of dinitro cresol contain 40 per cent active ingredients the balance being usually talc and a wetting agent and are used in combination with dormant oils against aphid eggs, leafrollers, San Jose Scale, red mite and oyster shell scale. Crosby *et al.* [1941] have described their use against various orchard crops. Beran [1942], who made a study of a commercial preparation containing 50 per cent dinitro-ortho-cresol found it giving complete mortality against San Jose Scale at strength of not less than two percent but considered it to be expensive. Sodium salt of dinitro-ortho-cresol which is an example of cresolate form of dinitrols is also used against various insects as contact insecticides. On account of the presence of sodium materials these insecticides form water soluble compounds. One of the prominent amongst these is 'Elgetol' which controls San Jose Scale when used in combination with the dormant oils. 'Elgetol' contains 28 oz. of DNOC per gallon and is packed in one gallon pails. The inert is water and a penetrant. For use one quart of 'Elgetol' has to be added to 100 gallons of dormant oil spray. The manufacturers state that it has a fungicidal action also.

Another proprietary product is Du Pont's 'Krenite' which is designed for use on trees and other plants when they are in a dormant condition. It is an effective liquid formulation and contains as its active ingredients sodium dinitro-ortho-cresylate which readily goes into solution in water in the spray tank. In the concentrated form it is not entirely in solution and has therefore to be well mixed before using. When preparing 'Krenite' for spraying, the tank is filled three fourth of the required amount of water. Then with the agitator running the required quantity of well mixed 'Krenite' is added. When this is dissolved the remaining quantity of water is added and completely dissolved. For scale insects, up to 1 gallon 'Krenite' in water 100 gallons has to be used. 'Krenite' can be combined with spray oils satisfactorily for killing a number of insects like San Jose Scale than can be accomplished with either material alone. The oil emulsion has to be prepared in the normal manner in the spray tank. When the tank is almost filled the 'Krenite' is added and the tank is filled with water. In general, one third less is needed in combination with oil than when used alone in water. In the case of tank-mixed emulsions the amount of emulsifier such as blood albumen has to be reduced to one-half of the usual strength to prevent foaming. 'Krenite' is toxic and has to be handled carefully. Its contact with skin causes temporary yellow discolouration of the skin. Its spray drift should not be inhaled. When taken internally the doctor has to be sent for immediately. The recommended antidote is diluted alcohol, 4 oz. or 1 oz. of Epsom salt followed immediately with emetic mustard. This will have to be repeated three or four times and lastly albuminous drinks or milk or white of egg have to be given.

'Orthozol' is another commercial product containing dinitro-ortho-cresol used for San Jose Scale control work. It is available in powder or oil emulsion form. For use, one lb. Orthozol dinitro powder has to be mixed with 100 gallons of dormant spray containing three per cent actual mineral oil. The 'Orthozol' dinitro oil emulsion is a combination oil spray and dinitro emulsified together. It has, therefore, only to be diluted with water for application. Against San Jose Scale 3 gallons Orthozol oil to 100 gallons of spray have to be used.

Ioline Standard DNOC petroleum winter wash is a British proprietary product which is a combined wash of particular value to growers who cannot undertake the separate application of tar and petroleum oil washes. In this product the dinitro-ortho-cresol is incorporated in the oil phase. The normal rate of use against scale insects is $7\frac{1}{2}$ per cent. At this concentration it provides more than five per cent oil and 0.1 per cent dinitro-ortho-cresol in the spray.

'Dinitrol' is a proprietary product of American manufacture containing dinitro-ortho-cresol. It is a dry yellow powder derived in the dye industry and is manufactured from coal tar products. It is recommended for use with any properly made oil emulsion, emulsifiable oil, or miscible oil as a dormant spray. Dinitrol can be used only when the trees are completely dormant and spraying should, therefore, be completed before any signs of leaf growth appear. Dinitrol should never be used in combination with lime sulphur, Bordeaux mixture, copper

sulphate or any other copper compound. For control of San Jose Scale a three per cent oil emulsion and 1 lb. of Dinitrol in 100 gallons of water have to be used. For mixing, the spray tank has to be filled three quarter with water ; the agitator running the required amount of Dinitrol is added and the tank, filled with water.

' Dinitrosol ' is a sodium salt of dinitro-ortho-cresol, which is non-corrosive, water soluble, economical and effective insecticide for use as a dormant spray. Against San Jose Scale it has to be mixed with a high quality oil emulsion at the dilution of three gallons per 100 gallons of water. It has to be applied in early spring and when the temperature is above 40°F.

(iv) *Diethyl p-nitrophenyl thiophosphate.*—This chemical commonly known as ' Parathion ' can be used against crawlers of San Jose Scale at the rate of 2 lb. in 100 gallons of water per acre. A single spray would suffice.

As Dinitro-compounds and Parathion have been found to be readily absorbed through the skin and the vapours are also highly toxic, all prescribed precautions, such as wearing of gloves, gas masks and protective clothing and extreme care in all operations involving the handling or application of these chemicals, should be adopted.

CHAPTER IX

FUMIGATION

DISINFESTATION of nursery stock infested by San Jose Scale by fumigating it with various poisonous gases and particularly HCN has been done from early times since the destructive nature of the pest was known.

Fumigation with HCN. The stock to be fumigated was kept in an air-tight box and subjected for an hour to the gas generated in it by the combination of 3 oz. of water, a little more than one fluid oz. of H_2SO_4 and 1 oz. of 60 per cent cyanide of potassium placed in a glazed earthen ware vessel of the capacity of at least a gallon, in the order named, these amounts being for 15 c.ft. of space. On account of the poisonous nature of the gas, care had to be taken to avoid breathing of the gas. The formula KCN 1 oz. by weight, H_2SO_4 1 oz. by weight and water 2 fluid oz. was also in use.

Fumigation of living trees attacked by San Jose Scale has also been tried using canvas tents for this purpose. Some of these early attempts are reported by Lintner [1895] and Howard [1895] to have been not entirely successful. But Ross [1916] found fumigation of young apple trees with HCN just before or shortly after buds commence to swell, controlling the scale. The dosage he used was 1 oz. KCN to 100 c. ft. for 45 minutes.

Subsequently, sodium cyanide was substituted for KCN, 1 oz. of this with $1\frac{1}{2}$ fluid oz. of H_2SO_4 and 2 fluid oz. of water were generally used, the gas being generated by the pot method. Portable HCN generators also gradually came into use. The development of liquid HCN and its packing in cylinders also made fumigation of San Jose Scale infested trees, easier. About 1916, Cyanogen combined with calcium and called calcium cyanide became available. This is in form of thin flakes or powder containing 27 to 30 per cent HCN. Another form is called Calcid which comes in the form of tablets or discs in which HCN has been absorbed. A special machine grinds the tablets and the ground material is blown into the chamber or tent in which the plants to be fumigated are present. Another form of dust cyanide called Zyklon B also came into use subsequently. This consists of HCN incorporated in diatomaceous earth, HCN absorbed in an inert, porous and absorptive material like wood or paper pulp cut out in the form of discs and packed in cans also come into use. These cans have to be opened with special openers and operators using them have to wear gas masks.

Preliminary experiments made by Sullivan [1924] showed that nursery stock infested with San Jose Scale can be fumigated with calcium cyanide. He found this fumigant effective when used at the rate of 1 oz. to 100 c. ft. The results after 30 minutes exposure to the above strength were found to be equal to those after two hours exposure. The weaker concentrations require a longer exposure, 1 oz. to 200 c. ft. or 400 c. ft. requiring $1\frac{1}{2}$ and 2 hours period respectively.

In Austria according to Wahl [1932] regulations have been made which require all seedlings leaving a nursery to be fumigated for about an hour with HCN acid gas (Zyklon B, 0.2 to 0.5 volume per cent) at a temperature above $10^\circ C.$ ($50^\circ F.$).

Experiments have been made by Watzl [1938] in Austria on fumigation of nursery stock infested by the scale using HCN in tents, boxes, and a brick chamber. All the scale on small fruit trees could be killed by fumigation for an hour with 0.3 to 0.5 volumes per cent of HCN released from Calcid tablets or Zyklon. Plants in leaf were only slightly injured if fumigated by night at $15^\circ C.$ to $20^\circ C.$ ($59^\circ F.$ to $68^\circ F.$). He obtained complete control without injury by fumigating dormant plants in the chamber with 0.5 volumes per cent. for one hour at $11^\circ C.$ ($51.8^\circ F.$).

Beran [1940] who made fumigation experiments using calcium cyanide in the form of briquettes which generate an amount of HCN gas equal to half their weight, came to the conclusion that in the case of currant bushes infested by the scale a 20 oz. per 1000 c. ft. dosage was effective in one hour, if an air-tight fumigation chamber is used.

In Kashmir* fumigation experiments were carried out both in the field using fumigation tents and in the laboratory using fumigation box or chamber with the dosages H_2SO_4 , 2.5 oz. H_2O , 3.34 oz. and NaCN or KCN, 1.67 oz. per 100 c. ft. Liquid HCN was also tried. With exposure period of one hour, cent per cent kill was obtained.

Care required in fumigating trees sprayed with Bordeaux mixture. Fumigation of trees which have been sprayed with Bordeaux mixture, has to be done with great care allowing atleast about a fortnight interval between the spraying and fumigating. This has been shown by the work of Nepveu [1944]. Fumigation of the trees was done by this author under tents in the evening at temperatures of 10°C. to 15°C. (50° F. to 59°F.), the gas being generated by the pot method using a mixture of 1 part sodium cyanide, 2.5 parts water and one part sulphuric acid and applied according to the normal schedule. Although the fumigation apparently did not interfere with fungicidal action of the Bordeaux mixture, when the interval between spraying and fumigation was only one day, extensive scorching occurred and most of the buds were found to be destroyed but the growth of those that remained was extremely vigorous. When it was six days, only the ends of branches and some buds in the axils on which the deposit was thick were scorched but no harmful effects were noticed on trees fumigated 10 to 14 days after spraying or on others bearing older deposits that had been exposed to rain though some of the latter were fumigated at twice the normal concentration.

Fumigation with methyl bromide. Work conducted in the U.S.A. in recent years, has shown that methyl bromide is a better fumigant than HCN for use against live plants. Mackie [1938] found this gas to be very toxic to San Jose Scale. Larvae were found by him to be very susceptible to the gas succumbing to dosages of 8 oz. and 4 oz. per 1000 c. ft., the latter for 16 hours.

In California deciduous fruit trees, ornamental trees and shrubs infested by San Jose Scale are at first warmed for two hours at 80°F. when atmospheric temperature is below 80°F. during the day. The humidity is maintained at 75 per cent. The dosage of methyl bromide for fumigation is at the rate of 2½ lb. per 1000 c. ft. exposure being for 120 minutes at 80°F. The humidity during fumigation is maintained at 75 per cent or over. Plant material fumigated with the gas has to be protected from sunlight and wind for 48 hours. It has been found that deciduous fruit trees can be treated with greater safety during the dormant season.

Fumigation of fruit. Considerable progress has been made in the methods to be adopted for the fumigation of the fruit using methyl bromide. This gas is commonly used in the U.S.A. for fumigating fruit. Lepigre [1945] has used this gas in Algeria for destroying San Jose Scale on fruit. The dosage used by him is 5 oz. per 1000 c. ft. of free space along with 20 oz. CO_2 , the mixture and air being introduced into a container with a vacuum of 670 mm. mercury until vacuum fell to 20 mm. This has some effect on the ripening of fruits like plums. Apricots exposed to 5 oz. methyl bromide per 100 c. ft. for one hour at 28.5°C. (83.3°F.) showed no damage and acceleration to ripening. Apples from France fumigated with the gas with a dosage of 8 oz. per 100 c. ft. without CO_2 for 100 minutes and then kept at 25°C. were found to be slightly sweeter and appetising in appearance a month after exposure. Examination six days after fumigation showed that a dosage of 5 oz. of the gas and 20 oz. CO_2 per 100 c. ft. for 30 minutes at about 25°C. was found to give complete mortality of all stages of the San Jose Scale on plums.

The same author also found exposure of the fruit to HCN gas for 45 minutes to a dosage of 0.5 oz. per 100 c. ft. at 26°C. (78.8°F.) not having any adverse effect on plums of two varieties. There was also no trace of the gas in the fruit one day after treatment. The author recommends the HCN gas for fumigation of fruit intended for export as it is cheaper. This gas also gave complete mortality of the scale on apple and pear twigs, at a dosage of 0.125 oz. per 100 c. ft. total space for 25 minutes at 22.5°C.

*The San Jose Scale and Woolly Aphis Research Scheme, Kashmir. Summary of the Final Report,

Weismann as reported by Meier [1936] has obtained 100 per cent mortality of San Jose Scale on imported apples in barrels and boxes fumigated for four hours with hydrocyanic acid gas at the rate of 0.4 to 0.5 volumes per cent. He also found that this concentration did not injure apples or pears. HCN gas was also used by Belyavskaya [1937] in her experiments on fumigation of fresh fruits with a view to destroy San Jose Scale. The gas was generated from 85 per cent to 96 per cent sodium cyanide used at the rate of 1 part by weight to $1\frac{1}{4}$ parts of H_2SO_4 and 3 parts of water. Cent per cent mortality of the scales on apples wrapped in paper and packed in boxes was obtained by fumigating for one hour with 1.4 oz. at 22° C. (71.6°F.) or 1.7 oz. at 10° C. (50°F.). The quality of the apples was not affected even when sodium cyanide was used at the rate of 4.5 oz. to 4.4 oz. per 100 c. ft. Fumigation at the rate of 2.2 oz. per 100 c. ft. for one hour did not affect the ripening or keeping qualities of apples. Pears on the other hand could not stand HCN fumigation. Three of the varieties tried were all scorched when the rate was 4 oz. and in one case even when it was 1.8 oz. It was also found that after being aired for two hours, apples, pears and plums retained such negligible traces of HCN as not to constitute danger to man. But, as cherries, straw berries and currants were found to absorb and retain considerable amounts of HCN, the use of this gas for these fruits is not recommended.

Large brick chambers with cemented walls and ceiling and concrete floor were used for fumigating apples and in these chambers the effective dosage was found to be 15 oz. to 17 oz. Sodium cyanide per 1000 c. ft. at temperatures in the open air 20°C. to 25°C. (68°F. to 77°F.) and 15°C. to 20°C. (50°F. to 68°F.) respectively exposure being for one hour. The fruit and the packing material ought to be dry for HCN fumigation.

Fumigation with hydrogen sulphide. The use of hydrogen sulphide as a fumigant in San Jose Scale control was first tried by Shteinberg [1936]. In laboratory experiments he found this gas to be effective for fumigating seedlings, slips, and fruit, if the dosage was high and the exposure short. He obtained complete mortality in spring, summer and autumn at temperatures ranging from 13°C. to 29°C. (55.4°F. to 84.2°F.) by using a dosage of 32.5 oz. per 100 c. ft. for 30 minutes. This fumigation did not cause any injuries to the plants. Another report* says that 100 per cent mortality was secured in 30 to 60 minutes with 6 per cent to 8 per cent H_2S and the plants were unaffected. Fumigation with hydrogen sulphide was also conducted by Nekrasova [1937] in Northern Caucasus. She obtained cent per cent mortality of the insect on slips of apple, pear, plum and sloe using dosages of 1 oz. to 10 c. ft. space at 17°C. (62.6°F.) for 60 minutes or 2 oz. and $3\frac{1}{4}$ oz. at 16°C. and 14°C. (60.8°F. to 57.2°F.) respectively for 30 minutes in April. In another series of tests in August all the scales were killed with dosages of 1, $1\frac{1}{4}$ or 2 oz. to 10 c. ft. at 25°C. or 26°C. (77°F. or 78.8°F.) and an exposure of 30 minutes. In one more series of experiments she obtained only 99.8 per cent mortality, using a dosage of 1 oz. to 10 c. ft. at 25°C. exposures for 30 to 60 minutes. The slips were uninjured. All the scales on three year old trees of apple, pear, plums and apricots were killed with dosages of 2 oz. or 3 oz. to 10 c. ft. at 12°C. and an exposure of 30 minutes and even a dosage of 1 oz. killed 99 per cent of the scales, in both cases the trees being uninjured.

Fumigation with ethylene oxide. This gas is reported by Vayssiere [1936] to be commonly used at Bordeaux, Le Havre and Marseilles for fumigation purposes, nearly 10,000 tons of fresh fruit imported from abroad being treated annually on account of the danger of infestation by San Jose Scale. This gas has now been replaced by methyl bromide.

Fumigation with HCN as compared with phosphine, methyl bromide and ethylene oxide. According to Beran [1947] who conducted his experiments in Austria, fumigation with HCN is superior to that with gases like phosphine, methyl bromide and ethylene oxide. With HCN he obtained complete mortality of the San Jose Scale using 0.25, 0.5 and 1.4 oz. per 100 c. ft. in 4.2, 5 and 48 minutes. He states that ethylene oxide, methyl bromide and phosphine could not be used as a substitute for HCN as duration of exposure was longer and greater concentration of fumigant necessary to achieve results. His dosage of these chemicals were 1.5, 2.5 and 9.2 oz. per 100 c. ft. respectively and required exposure periods of 2, 1 and 15 hours.

*Hydrogen sulphide and its application in controlling pests and diseases of crop plants. *Bull. Pl. Prot. Leningr.* No. 6, (1935), 99.

CHAPTER X

HOT WATER TREATMENT

IMMERSION of nursery stock bulbs in hot water to disinsectize them has been tried and used successfully several times against pests like Japanese beetle, grape phylloxera, nematodes, various flies attacking bulbs, etc. Similar methods have also been adopted against the San Jose Scale infested nursery stock. According to Marlatt [1930], experiments with hot water treatment for fruit stock infested with San Jose Scale have shown that the insect is not killed at 112°F., but succumbed at 120°F., the dipping being for 20 minutes. Apple, peach and pear stocks have been immersed successfully while dormant for periods of time sufficient to kill insects but plum, quince and cherry stocks were found to be severely damaged. Ivanova's [1935] experiments carried out in Russia also showed that immersing nursery stock in hot water at 50°C. (122°F.) for ten minutes gives complete mortality in the case of San Jose Scale. Peaches were checked in their growth but pears were not affected by immersion even at 53°C. She also found that plants whose above ground parts were dipped were found to be less affected than those which were dipped completely along with their roots. Experiments carried out in Kashmir have shown that the pest on apple plants can be killed by immersion in hot water for five minutes at a temperature of 44°C. (111.2°F.) without injury to the plants. Apple plants could also withstand a dip in hot water of 48°C. (118.4°F.) but pear and plum plants could not withstand this temperature, although the scale was killed at this temperature.

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