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NICOTINE SULPHATE IN A DUST CARRIER AGAINST TRUCK- CROP INSECTS

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NICOTINE SULPHATE IN A DUST CARRIER AGAINST TRUCK-CROP INSECTS.

INTRODUCTION.

The successful use of nicotine sulphate in dust form by Ralph E. Smith, of the University of California, in 1916 in the control of the walnut aphid *Chromaphis juglandicola* Kalt.), a serious pest in the walnut sections of southern California, induced the writer to test this insecticide against insects injurious to truck crops. As first used by Prof. Smith, the dust was made by grinding up stems and refuse tobacco, with the inevitable result of a variation in the nicotine content. To this variation was laid the cause for the diversity of results in different orchards where the amount of material used and methods of application were the same. Since there was no way to regulate the nicotine content in ground tobacco, Prof. Smith decided to use a certain amount of prepared and standardized nicotine sulphate in an inert dust carrier. After extended experiments it was found that kaolin possessed the necessary characteristics for fineness, lightness, and inertness for an ideal carrier. Further experiment showed that a mixture of 2 per cent by weight of 40 per cent nicotine sulphate in kaolin gave a thoroughly satisfactory kill of aphids. It was also found that by using 25 per cent of finely pulverized unslaked lime in the carrier, the slaking and heat therefrom took up the moisture in the nicotine-sulphate solution and that a chemical reaction took place, forming calcium sulphate and free nicotine, which latter proved to be much more toxic to the aphids than the nicotine sulphate.

PROCESS OF MANUFACTURE.

The original process of manufacture was as follows: The material was first run through a sifter and mixing box such as bakers use. The proper amount of kaolin and lime was put in this box, which was about 5 feet long by 2 feet square, and had a capacity of 400 pounds. At one end was a small tank into which the desired amount of nicotine sulphate solution was placed, a 2 per cent mixture requiring 8 pounds, a 5 per cent mixture 20 pounds, etc. So that the mixing would be thorough this solution was blown into the mixing box as a fine spray. From the mixer and sifter the dust went

through an additional sifter, so that when the process was complete the materials would be entirely blended into a fine dust, such as would easily go through a 200-mesh screen.

At present the process is similar, but on a much larger scale.

The use of this dust was so successful and so universally satisfactory that the California Walnut Growers' Association, one of the large cooperative farmers' organizations of California, decided to manufacture it, not only for its own members but also for outsiders. During the 1920 season 10 tons of 40 per cent nicotine sulphate were used in making approximately 450 tons of the dust. During the season when the walnut aphid was at its height the one plant turned out almost 100 tons per week. As a result of the marked success of this method of control, spraying for the walnut aphid has been entirely superseded by dusting.

The dust is easily carried by the wind, and hence the best results are obtained when little or no air is moving, and also when there is a slight amount of moisture on the foliage. Many dusters make a practice of beginning at daylight and continuing up to about 10 o'clock. Since an acre can be covered in about one-half hour, a comparatively large area may be gone over. It is often possible to continue later in the morning, so that if an early start is made an average of 15 to 20 acres per day can be dusted, which is in decided contrast to the 3 or 4 acres which it is possible to spray in the same length of time. Several operators have tried dusting at night, but although this practice was successful, it has not been followed to any extent.

TYPE OF MACHINE USED.

In the commonest type of duster the hopper holds 100 pounds of dust. A mechanical and easily regulated device allows the desired amount of dust to feed into the pipe under the hopper, through which the air is blown from the large, rapidly revolving fan. From the pipe the dust passes into a hose 4 inches in diameter and about 12 feet long. The operator moves about under the tree with this hose, directing the blast of dust, until the tree is covered. Power to run the fan is derived from a gasoline engine. The duster and engine can be mounted on a small wagon or sled. Such an outfit retails at about \$375 complete, while a walnut sprayer would cost not less than \$900. The duster requires a driver and one operator, while the sprayer takes two operators, and sometimes a driver. An extra sack or two of dust can be carried with the outfit and other sacks placed at the ends of the tree rows, so that refilling the hopper is a matter of only a few minutes' time, while with the sprayer it is necessary to stop work and go to the source of water to refill, which often may be some distance.

ACTION OF THE DUST.

The action of this dust on insects and mites is similar to that of the nicotine sulphate in liquid spray, except that it is very much more rapid. Within a minute or two after the application of the dust, aphids or other insects show extreme distress. They become agitated, elevate their abdomens as if they were trying to stand on their heads, and soon fall. When one is standing under an infested walnut tree just after it has been dusted the falling of aphids reminds one of a gentle rain. On other plants the effect is as immediate, but not quite so striking.

The after effect has been observed to be quite lasting also, especially on young aphids. If any young are produced by an adult which was not killed, or by a migrant several days after the application was made, they will immediately be overcome by the dust.

USE AGAINST TRUCK-CROP INSECTS.

When nicotine sulphate applied as a dust became so strikingly successful in controlling the walnut aphid, it was decided to test it against some of the insects, particularly aphids, affecting truck and associated crops.

THE MELON APHIS.

The melon aphid (*Aphis gossypii* Glover) has been a serious enemy of the melon, squash, cucumber, and some other crops in southern California for a number of years, the damage varying from year to year, and in different localities, from slight and scattered infestations of little consequence to severe infestations causing a total loss of the crop. From the fact that the insect feeds almost entirely on the lower surface of the leaves, causing many of the latter to curl, it has been difficult to obtain a satisfactory control with liquid spray. If sufficient time and care are taken to insure the covering of all the leaves, particularly the undersides, the operation is too expensive, and if extreme care is not taken the percentage of aphids killed is too low to make the spraying worth while.

Tests of nicotine sulphate dust did not give very good results at first, but when a mixture containing more nicotine sulphate was used, the results improved accordingly. It was soon discovered that while the walnut aphid was easy to kill with a 2 per cent strength, for practically all other aphids a higher strength was required. When extreme care was taken and a very thorough application made, the weaker strength gave good results, but in commercial practice it was found that a 5 to 7½ per cent strength of 40 per cent nicotine sulphate was very much better.

The most satisfactory type of machine for melons was found to be a hand-operated bellows duster such as is shown in figure 1. With such a machine one man can cover not less than 2 acres of full-grown cassabas or muskmelons a day, using about 50 pounds of dust per acre, costing 12 cents a pound for 5 per cent strength and 15 cents for the 7½ per cent.

It is characteristic of the melon aphid in southern California that it appears early in the season, when the plants are small, and seriously infests scattered portions of the field. If left unchecked the plants will be sufficiently damaged to produce little or no fruit, and often the aphids will spread to all parts of the field. Such infesta-

FIG. 1.—Hand-operated bellows type of duster used in applying nicotine sulphate dust to melons for the melon aphid.

tions are a nuisance to spray with an outfit of any size, while knapsack, or small compressed-air sprayers, are almost equally unsatisfactory. With a duster of the type shown in figure 1, however, it is a simple matter to go over the field as often as necessary, dusting the infested plants and thus stopping the damage and checking the spread.

Figure 2 shows a power-operated fan blower which was used in a badly infested cassaba melon field. This machine killed a large percentage of the aphids, and covered almost an acre per hour, but was somewhat wasteful of material, using from 75 to 100 pounds per acre. It was apparent that this amount could be reduced with

some mechanical changes and by using a smaller exit pipe. This machine would be advantageous for large acreages and where it is desired to get over a field in a very short time. The outfit, with engine, costs about \$150, while the hand duster does not cost over \$20.

Dusting for the aphid was found to be equally successful on all kinds of melons, cassabas, cucumbers, etc.

THE CABBAGE APHIS.

The cabbage aphid (*Aphis brassicae* L.) often does serious damage in California. The bulk of the cabbage crop is grown in the winter.

FIG. 2.—Power-operated fan duster used with success in a badly infested melon field.

and usually the aphids are kept in check by rains and cold weather. For several years, however, the early winter rains have been lacking and the temperature very mild, which has resulted in a serious aphid infestation of thousands of acres of cabbage and cauliflower.

Here, again, because of the fact that the colonies of aphids are usually on the undersides of the leaves, or are protected by the compact foliage of the growing head, it is difficult to get a satisfactory killing by spraying. The difficulty is further accentuated by the fact that the aphid colonies cause the leaves to curl, making it almost impossible to reach them with a spray. When the dust was tried in a badly infested cabbage field, a high percentage of the aphids was killed. The cloud of dust hovering over and about the plant pene-

trated to all parts, and in most cases even reached the aphids in the curled leaves. (Fig. 3.)

A preliminary experiment to determine the effectiveness of the different strengths of nicotine sulphate in the dust gave the following results (Table 1). A careful estimate of the aphids on a number of different plants was made both before and after dusting, and the percentage of killing taken from that.

TABLE 1.—*Effectiveness of different strengths of nicotine sulphate in dust against the cabbage aphid.*

Strength of 40 per cent nicotine sulphate, by weight-----per cent--	2	4	6	8	10	¹ 10
Percentage of aphids killed-----	82.3	92.4	96.7	97	98.3	91.8

FIG. 3.—Dusting for the cabbage aphid. Note cloud of dust hovering about and completely covering all parts of infested plants.

Further experiments confirmed the above, indicating that the percentage of killing rose considerably from 2 to 6 per cent strength, but above that the rise was small and did not justify the additional expense of the extra nicotine sulphate. It was also determined that for ordinary commercial purposes the 5 per cent strength was the most satisfactory, considering both the killing obtained and the cost per pound.

A badly infested cabbage field in Orange County was dusted by hand machines such as that shown in figure 3. Mexican laborers were employed, one man covering an average of 2 acres a day, using 30

¹ This dust was about 9 months old, and, having been kept in a gunny sack, had lost some of its strength.

pounds of dust per acre, on cabbage less than half grown, while on cabbage more than half grown one man averaged $1\frac{3}{4}$ acres a day, using 50 pounds of dust per acre. (See Table 2.) The cost of the dusting with $7\frac{1}{2}$ per cent strength of dust was as follows:

TABLE 2.—*Cost of dusting cabbage for the cabbage aphid.*

On cabbage less than half grown:	
Dust, 30 pounds, at 15 cents-----	\$4.50
Mexican labor, $\frac{1}{2}$ day at \$3.25-----	1.65
Total cost per acre-----	6.15
On cabbage over half grown:	
Dust, 50 pounds at 15 cents-----	7.50
Labor, $1\frac{3}{4}$ acres per day-----	1.85
Total cost per acre-----	9.35

About the same time a field of badly infested cabbage was sprayed with 40 per cent nicotine sulphate and soap by a commercial sprayer. The work was done with a power outfit, two men following behind with short spray rods attached to 25-foot lines of hose. With this outfit it was possible to cover only 3 or 4 acres per day, at an average cost of \$12 per acre, including rent of machine and team. The percentage of aphids killed was low, averaging not over 70 per cent for the entire field. On the other hand, an average killing of 90 per cent or over is easily obtained with the dust when carefully applied.

THE ONION THRIPS.

Extensive plantings of onions in the Coachella Valley have often been severely damaged by the onion thrips (*Thrips tabaci* Lind.).

Control by spraying with a nicotine sulphate and soap solution has been successful from a standpoint of killing efficiency, but the practice was unsatisfactory for the following reason:

Bulb onions are planted in rows 12 to 14 inches apart, and irrigating flumes cross the fields about every 660 feet, with the onion rows reaching up to the flumes. On account of the closeness of the rows and the irrigating flumes across the fields, the operation of horse-drawn spray machines causes considerable damage to the onions. As it is impossible to drive across the flumes, the frequent turning around damages many onions. Practically all cultural work is done with burros or ponies, having small feet, but a spray machine of any size would require large horses, which would cause further damage to the bulbs.

A trial of the nicotine sulphate dust on the onion thrips killed from 87 to 97 per cent. A trial on a commercial scale, using the hand-

operated bellows duster (fig. 4) showed that one man could cover from $2\frac{1}{2}$ to 3 acres a day, using from 40 to 50 pounds per acre, which made a total cost, including labor at \$3.50 per day, of from \$6 to \$7 per acre.

A field of seed onions near by, of similar size but planted in 24-inch rows, was sprayed with a traction sprayer, which had a stationary boom covering five rows at a time. With this outfit it was possible to cover up to 6 acres a day, although this depended on the distance it was necessary to go for water to refill the tank. An average of 150 gallons of spray per acre was used (with a weight of 1,200 pounds). The total average cost per acre, including hire of team and

FIG. 4—Dusting onions with hand-operated bellows duster.

two men, was \$4.40, and this amount would be approximately doubled for the bulb onions, grown in the 12 to 14 inch rows.

A small power-operated duster that could be used in an infested onion field has an arrangement of pipes from the blower so that eight rows can be covered at a time, with one pipe discharging directly over each row. With this outfit from 10 to 12 acres could be covered a day using 50 to 75 pounds of dust per acre, at an average cost of from \$8 to \$9.50 per acre, including material and hire of pony and one man. Here again it was evident that with some mechanical adjustments, so that less dust could be fed into the pipes, and with the speed of the fan increased, the amount of dust used per acre could be lowered, and the cost reduced accordingly.

While the cost per acre with this outfit is higher than with the hand machines, on account of the larger amount of dust used per acre, the chief advantage of the power-operated machine is the large acreage covered. This would be of importance in sudden or severe outbreaks, or on very large plantings. This machine, however, is subject to the same objection as the horse-drawn sprayer, only to a less degree, as it is smaller, much lighter, and can be drawn by a pony or burro.

THE PEA APHIS.

The pea aphis (*Macrosiphum pisi* Kalt.) is present throughout California and during some years causes large losses. In fact, in

FIG. 5.—Hand-operated fan duster used against the pea aphis.

several localities the growing of peas commercially has been largely abandoned because of this pest. This is particularly true of sweet peas grown for seed.

Experiments with the pea aphis have been less extensive than with the other insects mentioned, but it has been conclusively proved that this pest is much more resistant to the action of nicotine dust than any other aphid upon which it has been tested. The low percentages failed absolutely to kill the aphids, but good results were obtained with a 10 per cent strength when carefully applied. Several large seed companies have used this strength of dust for two seasons, and are much better satisfied with these results than with previous control work with liquid sprays. Both hand dusters (fig. 5)

and large power-operated machines, which cover eight rows at a time, are used. The latter use as high as 100 pounds of dust per acre, but can cover the ground very rapidly, averaging 3 or 4 acres an hour.

All of the work mentioned in this paper, except the following on the pea aphid, was done with dust varying from a week to several months old and which had not been kept in tight containers. As will be explained later, dust which has stood for some time after manufacture loses materially in toxicity, particularly if the containers are not tight. It was therefore decided to test on the pea aphid some freshly made material which had been immediately put in tight cans, applied with a bellows duster to a rather badly infested field of peas about a foot high. The results are given in Table 3:

TABLE 3.—Comparative effectiveness of different strengths of freshly made nicotine sulphate dust on the pea aphid at La Habra, Calif., Oct. 28, 1920.

Strength of nicotine sulphate 40 per cent by weight (per cent)-----	2	3	4	6
Percentage of aphids killed-----	60.2	70.2	90.9	98.2

The foregoing experiment showed that the 2 and 3 per cent strengths were effective against the young aphids, but quite ineffective against the adults, unless the latter were literally coated with dust. The application was very liberal, so that, with the present² cost of the 6 per cent dust at 20 cents a pound, it would be impractical to use it except on sweet peas. Later experiments may determine that a smaller amount of dust, or a slightly lower strength, will be satisfactory; but it seems at present that this is the one aphid which requires too great a strength of nicotine sulphate to make dusting as practical a remedy as spraying.

CUCUMBER BEETLES.

Two pests of considerable importance are the western 12-spotted cucumber beetle (*Diabrotica soror* Lec.) and the western striped cucumber beetle (*D. trivittata* Mannh.). The former injures a large number of plants, while the latter feeds chiefly on squash, cucumber, and other cucurbits. While working with nicotine sulphate dust on the melon aphid, it was observed that the dust was very toxic to the occasional specimens of *Diabrotica* feeding on the melons, and plans were made for further experiments against them. A field of young cucumber was later examined and found to be badly damaged by cucumber beetles. Both *D. soror* and *D. trivittata* were present, but the latter was more numerous. Some hills showed little damage, but in the majority the foliage was badly eaten and sometimes all the

² October, 1920.

plants in a hill were killed outright. From two to upward of a dozen beetles were found in practically every hill. Applications of dust were made, using the hand-operated bellows duster. The feed was fairly liberal, so that one puff of dust would be sufficient to cover a hill. The effect was immediate. When struck with the dust many of the beetles were unable to fly away, but crawled about on the ground under the plants in very apparent distress, and in a few minutes succumbed. Some which were able to fly away, on being followed, were found to go only a short distance, and in a very short time were overcome. Several days later the field was examined again and a careful examination revealed only two living adults in the entire field. New leaves had been put out by the injured plants and their recovery from attack was apparent.

The material used was a 10 per cent strength of nicotine sulphate, 40 per cent in kaolin and lime. A 20 per cent strength was found not to be superior to the weaker material. One pound of dust covered from 200 to 300 hills of small plants, at the rate of nearly 1,000 hills per hour.

COMBINATIONS WITH NICOTINE SULPHATE DUST.

It has long been the custom in spraying operations to combine two or more insecticides, or an insecticide and a fungicide, when different types of insects or a disease and an insect are infesting the one plant. This practice can be continued to a large extent with dusting. In fact, some combinations are more satisfactory in the dust form, while others are less so.

In several sections of California the codling moth has become a serious pest of walnuts. It happens that in these same localities, to a large extent, the walnut aphid is present also. Therefore when the nicotine sulphate dust was made, to each 100 pounds was added 10 pounds of arsenate of lead. At first the acid form was used, but as this caused burning of the foliage the basic or neutral form of lead arsenate was substituted.

At first the dusting was not as satisfactory in controlling the codling moth as was desirable. The operation of dusting for the aphid could be done quickly and easily, but for the codling moth the dust had to be more carefully applied. Although the actual percentage of worms killed was a little less with dusting than with spraying, dusting is greatly preferred because of the much greater speed and ease of application, as well as the lesser cost.

On cucumbers the nicotine sulphate dust not only controlled the cucumber beetles but also killed any melon aphids present. Furthermore, with the use of a dust carrier containing from 25 to 40 per cent of powdered sulphur, the development of cucumber mildew can be prevented.

The use of the nicotine sulphate-sulphur dust on peas will control both the pea aphid and powdery mildew, and would be equally satisfactory for the rose aphid and rose mildew.

The same combination has proved successful on citrus trees against the citrus aphid and the red spider. If any thrips are present, they will be controlled by the same dusting.

On cabbage the nicotine sulphate dust has given good success in killing both the aphid and the cabbage worms, but if it is desired, the combination of nicotine sulphate and arsenate of lead can be used.

Such insects as aphids, thrips, and red spiders and other mites reproduce very rapidly. Therefore no matter what method of control is used, whether it be dusting or spraying, under conditions favorable to the insects, a reinfestation may take place even though a high percentage may have been killed. On account of this it is not to be expected that at all times one dusting will be sufficient for an entire season. It is often necessary to dust twice or even three times. In fact, many growers plan on a second application, timing it to get the second infestation before it begins to be serious.

All dusting and spraying should be done with the idea of preventing a serious infestation and the resulting damage, rather than waiting until the infestation is heavy before control measures are undertaken. It is always easier and more satisfactory to prevent an infestation than to stop it after it is well under way.

LOSS OF STRENGTH.

Since the nicotine in this dust is very volatile, some of the strength is apt to be lost if the dust is held for very long in open containers. The walnut aphid dust is put up in burlap sacks with paper liners; but as this dust is practically all used within a short time after it is made, there is little or no loss of strength. To retain the strength, it is now proposed to put up the dust in air-tight drums, cans, and sealed cartons. It is believed and partly borne out by experiments that if these tight containers are used a 3 or 4 per cent strength will do as efficient work as has been done heretofore with the 5 to 7½ per cent strengths put up in sacks, and a 5 or 6 per cent material can be substituted for the 8 to 10 per cent strengths. This will reduce the cost from 3 to 5 cents a pound.

Nicotine sulphate dust, even up to the 20 per cent strength, has not been observed to cause any burning to foliage.

For walnut trees the lightest dust possible was found to be desirable; hence the carrier is mostly kaolin. For low-growing crops, such as cabbage and melons, a heavier dust is more desirable; hence the carrier was composed of about half kaolin and half lime from sugar-beet factories.

ADVANTAGES OF DUST.

Dust can be applied much more easily and quickly than spray; hence larger acreages can be covered in a given time.

Its killing efficiency is always equal to and usually more than that of spraying.

It is easier of application.

Its cost of application is less than that of spraying.

Power dusters cost much less than power sprayers.

Hand dusters are much easier to operate and to carry than hand sprayers.

Very much less weight of dust than of spray is required to cover an acre.

Refilling the duster is much quicker and easier than refilling the sprayer.

It can be combined with arsenate of lead or sulphur and applied dry for insects and certain fungous diseases.

DISADVANTAGES OF DUST.

Its volatility causes it to lose strength unless put up in tight cans or used soon after manufacture.

The dust is sometimes disagreeable to the operator, especially if the latter is inexperienced.

It can not be combined with Bordeaux mixture, except when the latter is dry.

SUMMARY.

Ground tobacco gave good though varied results in controlling the walnut aphid in California. The substitution of a certain amount of 40 per cent nicotine sulphate in a carrier of kaolin and lime eliminated this variation in results.

Dusting requires much less material and may be done in a much shorter time, with a less expensive machine, and at about half the cost of spraying.

The action of the dust is similar to that of nicotine sulphate spray, but much more rapid.

Nicotine sulphate dust has proved superior to spraying for the melon and cabbage aphids, onion thrips, cucumber beetles, and some other insects, giving usually a better killing at a smaller cost and with a greater speed and ease of application.

Nicotine sulphate dust can be combined with arsenate of lead or sulphur for different types of insects, or for insects and fungous diseases.

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