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ARSENATE OF LEAD AS AN INSECTICIDE  
AGAINST THE TOBACCO HORNWORMS.

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#### INTRODUCTORY.

During the past five years the Bureau of Entomology has been conducting an investigation of tobacco insects in Tennessee and Kentucky and in some of the adjoining States. In Tennessee the bureau has been very materially assisted by Prof. H. A. Morgan, director of the Tennessee Agricultural Experiment Station.

In the dark-tobacco districts of Kentucky and Tennessee tobacco hornworms are the ever-present and most serious problem of the tobacco grower. Ten to twelve years ago, when labor was plentiful, cheap, and efficient, "hand-worming" was found to be economical and effective in combating this pest. However, during the last six or eight years hand-worming has become too costly, because of the great scarcity of labor, and too inefficient, and the growers have been forced to employ an insecticide. At the time insecticides were first used Paris green was found to be the safest and most efficient. Nevertheless, there has always been complaint of frequent serious burning of tobacco as a result of its use. To find a safe and effective insecticide has been one of the main lines of investigation by the writers during the past five years. Di-plumbic arsenate of lead has been found to meet the requirements. In the further discussion of this subject the use and action of Paris green will be rather thoroughly discussed in connection with the use and action of arsenate of lead, for the reason that since the insecticidal results of the use of Paris green are so well known it will be easier to explain the value of arsenate of lead if it be compared with this well-known poison.

## NECESSITY AND ADVANTAGES OF THE USE OF AN INSECTICIDE.

The way in which the scarcity of labor tended to bring about the use of an insecticide upon tobacco has already been explained. In addition to this necessity of using insecticides, the much greater efficiency of a good application of an insecticide is another strong argument in its favor. Hand-worming, even of the best, has many objections; for instance, eggs are not picked off, many small worms are overlooked on account of their small size, and, lastly, during the hot hours of the day large worms crawl down into the "ruffles" near the bases of the leaves and a considerable number are thus overlooked. On the other hand, a thorough application of an insecticide will kill practically every hornworm—except those very nearly full grown—within two or three days, and will also continue to kill the young worms that hatch several days after the application. In short, hand-picking has only an immediate effect in lessening the worms, whereas the application of an insecticide usually continues to kill over a period of several days. Cheapness is another point very greatly in favor of an insecticide as compared with hand-picking. The cost of keeping an acre of tobacco hand-wormed in a year when worms are plentiful is variously estimated at from \$6 to \$10. A like number of worms can be killed with an insecticide at a cost of not more than \$2 or \$3 an acre—sometimes less.

## THE USE OF PARIS GREEN.

In some districts of Kentucky Paris green has been in use for over a decade. In the dark-tobacco districts of Kentucky and Tennessee it certainly was used to some extent 10 years ago and at the present time is in very general use. On account of the frequent injury to tobacco by the use of this insecticide many farmers would not use it if labor could be secured to do the hand-picking. On the whole, the cost of the Paris green plus the cost of application, plus the loss due to damaged tobacco, is much less than the cost of hand-worming. In this district the use of insecticides has come to stay. It is a necessity.

Paris green is applied with a dust gun and without a carrier. From 1 to 2 pounds per acre is the usual application; 1 pound when worms are small (i. e., less than half grown) and 2 pounds when there are many worms over half grown. Success with the application depends upon the judgment of the farmer in choosing the time of application and upon the thoroughness with which the application is made. Much of the tobacco that is injured by Paris green is injured because of unevenness of application, or, what is too frequently the case, because the grower has delayed the application until half-



grown or two-thirds grown worms have become dangerously numerous, and has then put on a large and uneven application with the hope that he would kill all the large worms. This is an example of poor judgment. Two applications should have been made. The first should have been smaller and at an earlier date in order to kill the worms while small, and also to lessen the danger of burning the tobacco. The second application should follow as soon as worms begin to increase in numbers after the first application.

#### OBJECTIONS TO THE USE OF PARIS GREEN.

##### DANGER TO THE OPERATOR.

There is occasionally some injury or irritation to the operator in applying Paris green. Wherever Paris green strikes the tender parts of the body irritation soon occurs unless a thorough bath be taken promptly. Bleeding at the nose sometimes occurs as a result of the irritation to the mucous membranes. For these reasons many people dislike to apply Paris green. However, if care is taken to work in a direction quartering the breeze and upon the windward side of the row while making an application, a thick sack around the body and a sponge over the nose will be found to be excellent preventives of irritation, particularly if followed by a bath.

##### INJURY BY PARIS GREEN TO TOBACCO.

The very general complaint of loss due to Paris-green-burned tobacco has been found to be justified. Under favorable weather conditions 2 pounds of Paris green per acre, sometimes more, may be applied without noticeable injury. On the other hand, unfavorable weather conditions will frequently cause injury to follow an application of only 1 pound per acre. Very hot suns and low humidity for an extended period will produce a condition of the tobacco plant very susceptible to Paris-green burn. Light rains or very heavy dews immediately following an application will wash the Paris green down into the axils of the leaves or into the furrows along the mid-ribs, and serious injury is likely to result.

In the Clarksville district of the dark-tobacco belt of Kentucky and Tennessee Paris-green burn was quite severe during 1911 and 1912, particularly so in 1912. Previous to these years one of the most careful growers in this district informed the writers that his loss on a 6-acre field of tobacco, due to Paris-green burn, amounted to 8 per cent gross, which was a loss of at least 16 per cent of the net profit, and that many other growers suffered a similar loss in 1912. In 1911 the writers observed many fields in which the loss equaled or exceeded that quoted above. In 1912, however, the injury by Paris green was more widespread than for several years, notwithstanding

the fact that many growers who suffered loss the year before were extremely careful in making applications.

On January 4, 1913, the senior writer interviewed several tobacco buyers employed by the Italian Government. He was informed that several crops of tobacco the grade of which was especially suitable for the Italian Government were not bid upon because of the large percentage of tobacco injured by Paris green. The buyer stated that for one crop, had it been in average condition in regard to Paris-green injury, he would have bid  $8\frac{1}{2}$  cents per pound. In its damaged condition, however, he did not believe the crop was worth over 5 cents per pound—a gross loss of  $3\frac{1}{2}$  cents per pound, or of \$25 to \$30 per acre. Another crop would have received an offer of 8 cents per pound from the Italian buyers, but on account of Paris-green burn no offer was made. This buyer thought the crop worth not more than  $5\frac{1}{2}$  cents—a gross loss of  $2\frac{1}{2}$  cents per pound, or about \$20 per acre. A third crop had its value reduced by one-half, a fourth crop was apparently worth about 5 cents per pound, and would ordinarily have brought 9 cents. This is the report of buyers of the heavier types of tobacco grown in this district. The lighter-bodied tobaccos undoubtedly suffered as severely and probably more severely than the heavier tobaccos, because the lighter tobaccos are ordinarily more susceptible to Paris-green injury.

Paris green injures tobacco in two ways: First, by causing dead, burned areas upon the leaves, where the powder has been collected by the dews or washed down by the rains; second, by weakening the leaf at the stalk. Light rains wash the insecticide into the axils of the leaves, and the result is that many leaves drop off before cutting time or become so weakened that they drop off when the plant is cut. Such leaves are not a total loss, for they are collected and cured, but they are a partial loss. They are light in weight and lack gloss and elasticity.

#### THE USE OF ARSENATE OF LEAD.

Arsenate of lead causes none of the injury mentioned above. Experiments performed under the direction of the senior writer showed that powdered arsenate of lead may be put on a fresh sucker wound in large quantities without causing any noticeable injury, and that when applied to a torn or bruised leaf it produces no injury. Paris green can not be applied to tobacco in the "graining" stage (i. e., when nearly ripe) in sufficient quantities to do good insecticidal work without too grave danger of burning the plant. Arsenate of lead, on the other hand, can be safely applied to tobacco in the "graining" stage in quantities sufficient to produce satisfactory insecticidal results. Furthermore, arsenate of lead will cause no irritation to the

operator as will Paris green; in fact, thus far it has produced no noticeable injurious effects upon the operators.

Since arsenate of lead can be applied to tobacco without injuring the plant, and since it is very much less objectionable from the operator's standpoint, its insecticidal properties should next be discussed. As the dosage and action of Paris green are very widely known, the value of arsenate of lead as an insecticide can the more easily be explained by comparing it with Paris green. The following tables will serve to show the relative values of the two insecticides under different conditions.

TABLE I.—Comparison of the insecticidal effects against hornworms of arsenate of lead and Paris green in fair weather.

Experiment No.	Date of application.	Number of pounds per acre.	Poison used.	Examinations to show number of worms killed.												Number of plants examined.	
				On day applied.		On first day after.		On second day after.		On third day after.		On fourth day after.		On fifth day after.			
				Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.		
1	Aug. 25, 1910	5	Lead arsenate.	134	0	46	56	24	22	.....	.....	1	2	.....	.....	.....	50
2	.....do.....	3½	.....do.....	130	0	73	61	35	31	.....	.....	1	4	.....	.....	.....	50
3	Aug. 24, 1910	1½	Paris green....	106	0	35	49	14	17	5	7	.....	.....	(?)	(?)	.....	100
4	Aug. 21, 1911	½	Lead arsenate.	135	5	92	45	70	20	35	23	31	26	.....	.....	.....	100
5	Aug. 23, 1911	1½	Paris green....	107	7	86	17	61	16	50	15	32	8	.....	.....	.....	100

<sup>1</sup> Taken on 200 plants by ordinary hand-worming.  
<sup>2</sup> Many small worms alive.

Arsenate-of-lead experiments Nos. 1 and 2 were applied under very favorable conditions, i. e., there was dew upon the plants and no breeze. Paris-green application No. 3 was applied under equally favorable conditions. These three experiments killed worms very satisfactorily. The records in Table I were made by counting the worms on 50 plants of tobacco on each succeeding day after the application. No. 1, 5-pound dosage of arsenate of lead, gave the best results, for on the fourth day after the application only 2 live worms were found in hand-worming 200 hills. The 3½-pound dosage of arsenate of lead was not quite so good, although only 14 live worms were found on 200 plants the fourth day after the application. The Paris-green application No. 3 killed more quickly than either of the applications of arsenate of lead, but on the fifth day after the application numerous small worms were noticed in worming 200 plants.<sup>1</sup> It was thus apparent that the Paris green was losing its effect, owing to heavy dews which tended to puddle it, and to heavy drying winds during the day, which blew some of it from the plants.

The application in experiment No. 4 was not made under the most favorable conditions. There was a slight breeze during the appli-

cation; in addition, there were a large number of eggs on the plants, and many of the young worms hatching from these eggs were not killed until they wandered from the place of hatching. The same is true of experiment No. 5, the 1½-pound dosage of Paris green. It will be seen, however, that experiment No. 4, the arsenate-of-lead application, was more effective than the Paris-green application, for on the day of application there were at least 140 worms in experiment No. 4, the arsenate-of-lead application, and only 114 worms in experiment No. 5, the Paris-green application, while on the fourth day after the applications there were only 31 live worms in experiment No. 4, but 52 in experiment No. 5.

The poisons were applied in the following series of tests in the morning from 6.30 to 9 o'clock. The arsenate of lead was mixed with an equal weight of dry wood ashes. All applications were made with fan dust guns. The mixture of ashes and lead arsenate made a very good dust and compared favorably in evenness with the application of Paris green. Rain began to fall at 11.30 a. m. and continued intermittently until 2 p. m. Part of the rain was dashing. About one-third of an inch fell. The first examination of the plats was made after 3 p. m. of the same day. The tobacco on these plats was nearly full grown and lapped in the rows considerably.

TABLE II.—A comparison of the insecticidal effects against hornworms of arsenate of lead and Paris green in rainy weather.

Experiment No.	Date of application.	Dosage.	Poison used.	Examinations to show number of worms killed.										Size of worms left.
				On day applied.		On first day after.		On second day after.		On third day after.		On fourth day after.		
				Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	
1	Aug. 28, 1911	5	Lead arsenate.	59	49	15	41	10	8	.....	.....	6	2	Small. Small and medium. Small to large.
2	..... do.....	4	.....do.....	102	21	48	27	21	13	.....	.....	33	8	
3	..... do.....	2½	Paris green....	87	15	54	29	34	14	.....	.....	36	9	

The three experiments recorded in Table II are very interesting. They show, first, that arsenate of lead was far more effective during rainy weather than was Paris green (see number of live worms on the fourth day), even though a very heavy dosage of Paris green was used; second, that to be very effective during rainy weather an application of at least 5 pounds of arsenate of lead per acre is re-

quired. Experiment No. 2, 4 pounds of arsenate of lead per acre, was more effective than the  $2\frac{1}{2}$  pounds of Paris green. Although a considerable number of worms were left on plat 2, we find that fewer were alive in this experiment on the fourth day than were alive in the Paris green experiment, notwithstanding the fact that there were practically 20 per cent more worms on No. 2, the arsenate of lead plat, at the time of application of the poison than there were on the Paris green plat. Fortunately for the effect upon the tobacco plants, the rain washed off nearly all the Paris green, so that there was very little burning. There was no burning of plants on the arsenate of lead plats.

TABLE III.—*Comparison of insecticidal effect of good and poor applications of arsenate of lead.*

Experiment No.	Date of application.	Pounds per acre.	Examinations to find number of worms killed.										
			Day applied.		First day after.		Second day after.		Third day after.			Fourth day after.	
			Alive.	Dead.	Alive.	Dead.	Alive.	Dead.	Alive.	Dead.		Alive.	Dead.
1	Aug. 16, 1910	$4\frac{1}{2}$	33	0	49	24	44	13	48	13	.....	.....	Lime as carrier, 50 plants counted. Ashes as carrier, 50 plants counted.
2	Aug. 25, 1910	$3\frac{1}{2}$	130	0	73	61	35	31	.....	.....	14	.....	

<sup>1</sup> On 200 plants.

In Table III, which gives a comparison of a good and a poor application of arsenate of lead, application No. 1,  $4\frac{1}{2}$  pounds arsenate of lead per acre, was from the same keg as application No. 2,  $3\frac{1}{2}$  pounds per acre. Counts were made on 50 hills in each instance. On August 16, 1910, many eggs were noticed on the plants, so that most of the worms appearing on this plat were small. It will be noticed that the application did not keep down the increase of worms due to hatching. In experiment No. 2 there were very few eggs on the plants and the worms were therefore larger than on plat 1 and harder to kill. Practically a clean sweep was made on No. 2, only 14 worms being found on 200 plants on the fourth day after the application. Favorable weather prevailed after both applications, and the conditions at the time of application to both plats were equally favorable. What, then, is the explanation of the poor results on plat 1 and of the very excellent results on plat 2? The explanation is found in the carrier. In No. 1 the arsenate of lead was mixed thoroughly with an equal weight of finely sifted air-slaked lime, while in No. 2 it was thoroughly mixed with an equal weight of finely sifted dry wood ashes. Notwithstanding the dryness of the

lime the mixture lumped out of the gun considerably. On the other hand, the arsenate of lead and ashes made a very even dust, with scarcely any lumping. These two experiments are here shown to emphasize the necessity of applying a thoroughly even dust. A lumpy application is a waste of time and material and will be no more effective than would a perfect application which had been rained upon immediately following the application.

#### HOW TO APPLY ARSENATE OF LEAD TO TOBACCO.

Paris green is generally applied to tobacco by means of a dust gun and without the admixture of a carrier. On the other hand, arsenate of lead must be mixed with a carrier in order to secure an even and thorough distribution. Several carriers have been tested with this insecticide. Finely sifted air-slaked lime, to our surprise, did not dust evenly. Road dust and land plaster proved to be too heavy. The best results were obtained with finely sifted, freshly burned wood ashes. At least an equal bulk of the wood ashes should be used. Mix the arsenate of lead and ashes very thoroughly and apply while there is dew upon the tobacco and when there is no breeze. Even if very dry and finely sifted ashes are used, unsatisfactory results will be obtained unless the application is made with a powerful dust gun. The hand-power dust guns now in general use do not furnish sufficient power to make anything like a satisfactory and effective application. Special guns that will perform satisfactory work are gradually coming on the market. The new guns have a fan with a diameter of 8 inches, whereas the old guns have a fan diameter of only 6 inches. The new guns have also an auxiliary dust chamber, which is very essential, because the dust containers of the old guns are so small that they have to be refilled five or six times for each acre dusted. Two refillings of the new guns will be sufficient for dusting an acre.

To secure the best results dust the tobacco when dew is upon the plants and when there is no breeze. By reference to Table III we see the comparative results of a good and a poor application of arsenate of lead. The use of a carrier that does not dust evenly, the application of the insecticide when there is too much breeze, and the use of too small a dust gun are all certain to give unsatisfactory results. Avoid these mistakes, and satisfactory results will be secured.

Thoroughness of application can not be too strongly recommended. When tobacco worms are numerous a poor application of an insecticide will miss worms enough to ruin in two days more than enough tobacco to pay for the whole application. Make the application thorough.

## THE GRADE OF ARSENATE OF LEAD TO USE AGAINST THE TOBACCO HORNWORMS.

Arsenates of lead, theoretically, are either triplumbic or diplumbic, although many of the grades and brands are undoubtedly a mixture of the two. Numerous experiments by agents of the bureau have proved that triplumbic arsenate of lead is a very unsatisfactory insecticide for use against tobacco hornworms; in fact the insecticidal action of this grade is so slow that very few growers would accept an application as a gift. On the other hand, an arsenate of lead composed almost entirely of the diplumbic form produces very satisfactory insecticidal results when used against this insect.

In both the triplumbic and diplumbic forms the arsenic is present as arsenic acid. Theoretically triplumbic arsenate of lead in powdered form contains 25.58 per cent of arsenic acid, while the diplumbic, in powdered form, contains theoretically 33.15 per cent of arsenic acid. Tobacco growers should demand a powdered arsenate of lead that is composed largely of the diplumbic form. In order to be certain that the diplumbic form is predominant buy only those powdered arsenates of lead which the manufacturers will guarantee to contain at least 30 per cent of arsenic acid; also insist upon a guaranty of not more than 1 per cent of free, or water-soluble, arsenious acid, in order to be sure that the applications will not burn the tobacco. The writers advise growers and dealers who may use or handle powdered arsenate of lead for use against tobacco worms to demand a written guaranty that the composition of the products is as recommended above.

## WHEN TO APPLY ARSENATE OF LEAD.

The first application of arsenate of lead should be made when tobacco worms become too numerous to be kept off tobacco by the hand-picking that is usually done while hoeing, suckering, or topping tobacco. In some years a second and even a third application may be necessary. The time for making these applications will be indicated by the numbers of eggs and young worms appearing on the tobacco.

## DOSAGE OF ARSENATE OF LEAD REQUIRED.

When tobacco is small and has not begun to lap in the row an application of  $3\frac{1}{2}$  pounds of arsenate of lead per acre will be efficient. Full-grown tobacco should receive not less than 5 pounds per acre. In water spray use 3 to 4 pounds of powdered arsenate of lead per 100 gallons of water.

## COST OF ARSENATE OF LEAD.

The special grade of powdered arsenate of lead recommended for use on tobacco will cost about 22 cents per pound at the factory in 100-pound kegs. The freight will be about 1 cent per pound, making the total cost 23 cents per pound to the grower. Therefore a 3½-pound dosage will cost about 80 cents, while a 5-pound dosage will cost \$1.15. A 2-pound dosage of Paris green costs from 50 to 55 cents, while a dosage of 1¼ pounds, which is the smallest which should be applied, will cost about 31 to 35 cents. If the comparative cost of Paris green and arsenate of lead were the only question to be considered, it would be useless to recommend arsenate of lead. The cost, however, for the careful grower should be a matter of strictly secondary consideration. The certainty of not burning the tobacco should more than compensate for the extra cost of this insecticide.

## SUMMARY.

Paris green frequently burns tobacco very severely, and may reduce the value of the crop as much as 50 per cent in exceptional cases.

It is impossible to apply an effective dosage of Paris green without risk of burning tobacco.

Paris green, which is applied in dust form, is used at a dosage of from 1 to 2 pounds per acre.

Arsenate of lead is safe and effective during rainy weather, while Paris green is dangerous and ineffective.

It is recommended that arsenate of lead be used against the tobacco hornworms, and that it be applied as a dust or powder.

The dosage of arsenate of lead in powdered form varies from 3½ pounds per acre to 5 pounds per acre. If applied as a spray, use 3 to 4 pounds in 100 gallons of water.

Arsenate of lead applied in powdered form, as here recommended, must be mixed with a carrier. The best carrier found so far is dry wood ashes, used in a bulk at least equal to the arsenate of lead.

In applying arsenate of lead use a dust gun having a fan diameter of at least 8 inches.

Apply arsenate of lead when there is no breeze and when dew is on the plants.

Approved:

JAMES WILSON,  
*Secretary of Agriculture.*

WASHINGTON, D. C., February 6, 1913.























