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HONOLULU.

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Killing Weeds With Arsenite of Soda

BY

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INTRODUCTION.

Weeds and pests of insect or fungus nature are naturally among the important problems with which the farmer has to contend in all agricultural regions. In controlling these drawbacks to successful production, hand methods were first used but the use of chemicals was early adopted in combating insect and fungus disease. Somewhat later, sprays for the destruction of weeds received attention and chemicals for weed destruction have gradually assumed a greater importance. Many of the facts which are now known regarding the destruction of weeds by means of chemicals were first discovered in connection with spraying for insects and fungus diseases. In order to destroy insects and pathogenic fungi by applications of chemicals to living plants it is necessary to use solutions or mixtures of a strength sufficient to be fatal to the insects and fungi but not injurious to the plants which are to be protected. In the extensive and long-continued spraying experiments which have been carried on in farm practice, it was soon found that certain forms of chemicals used in such operations were more injurious to

plants than other forms. Attention, therefore, was required on this point in order to avoid injury to the plants.

In the use of arsenicals for the destruction of insects it is necessary to get a finely divided condition of the arsenical, which is at the same time relatively insoluble. The small undissolved particles then remain on the surface of the leaves until washed off or eaten by insects. Soluble arsenicals are extremely injurious to vegetation and, therefore, have to be avoided in spraying useful plants. There is thus a complete contrast in the ideas aimed at in spraying for insects and in spraying to kill vegetation. Arsenical insecticides must be as insoluble as it is possible to obtain them, while for killing weeds the most soluble form of arsenic is desired.

CHEMICALS USED FOR WEED DESTRUCTION.

In experiments previously carried on at this Station[1] carbon bisulphide was applied to a number of weeds which grow in the garden and fields. This chemical was found to be very effective in the destruction of some of our hardiest weeds, both of herbaceous and shrubby nature. When applied on a large scale, however, and in long-continued operations, there is some danger from the injurious effects of the fumes of carbon bisulphide upon the workmen and the chemical itself is rather expensive. It seemed, therefore, desirable to carry on experiments with other chemicals which could be applied more easily and at less expense. Arsenite of soda has been extensively used on the mainland of the United States, in Australia and elsewhere for the destruction of a variety of weed plants. Stone[2] found arsenite of soda exceedingly effective against herbaceous weeds when used at the rate of one part in 66 parts of water. Gillette[3] in using arsenicals against insects found that the soluble portion of the insecticides exercised a much greater burning effect upon the foliage in the presence of dew and direct sunlight. Kilgore[4]

1 Haw. Sta. Press Bul. No. 25.
2 Mass. Rept. 1908, pt. I, pp. 62-72.
3 Iowa Sta. Bul. 10, p. 419.
4 N. C. Sta. Bul. 77b.

observed that arsenites are more soluble in solutions containing sulphate of copper and sulphate of iron than in water alone. Jones[1] used arsenite of soda on herbaceous weeds and found the effect produced by this chemical to be slow but lasting. The formula used called for one pound sal soda and two pounds of water diluted before using so as to make nine gallons. In Australia the common practice is to buy arsenite of soda already prepared and simply dilute in water at the rate of one pound to five to ten gallons of water. This solution has proven effective in the destruction of the prickly-pear, wild blackberry and various herbaceous and semi-shrubby weeds.

Asenate of soda has in experiments proven even more effective than the arsenite. For example, Stone in the article cited above found that the mixture of arsenate of soda and corrosive sublimate in equal parts caused a very rapid destruction of the foliage and stems of weeds. Likewise, Morgan[2] found that arsenate of soda alone caused a rapid and destructive burning on foliage upon which this chemical was applied, and Jones in the article referred to above reports arsenate of soda when used at the rate of one pound to eight gallons of water, to be rather quicker and more effective in its action than arsenite of soda.

Iron sulphate. In various processes involved in the commercial handling of iron ores, iron sulphate is obtained as a by-product and costs about one cent per pound in most cities on the mainland. This chemical has been widely tested in Wisconsin, Iowa, Maine, South Dakota, Rhode Island and other states, as well as in foreign countries, and upon a large variety of weeds, but chiefly upon wild mustard. For this purpose it has been found particularly effective and has the further advantage of not destroying cereal grains. For this reason it is commonly sprayed over grain fields infested with wild mustard, and when thus used gives excellent results. Iron sulphate has been used in different strengths, but where the herbage is quite tender a 20 per cent solution is the one commonly recommended to kill weeds and not injure cereals. Iron sulphate is readily soluble in water,

1 Vt. Sta. Rpt. 1901, p. 248.
2 Agric. Education, 6 (1903) p. 11.

and no other manipulation is required for the spray than simply to dissolve the chemical in water. At the Station iron sulphate has been used upon spurge, cockle-bur, lantana, oi, pig-weed, Japanese nut-grass and other weeds. When used at the rate of three pounds per gallon of water, iron sulphate killed all these weeds except lantana and Japanese nut-grass. The leaves were destroyed on lantana but the new buds were sent out, showing that the stems were not killed. The portion of Japanese nut-grass above ground soon turned brown and died after being sprayed with iron sulphate, but fresh shoots came up from the under-ground bulbs. This chemical can be used effectively against most weeds except lantana and Japanese nut-grass, and has the advantage of not being poisonous or in any way injurious to the soil.

Carbolic Acid. When diluted at the rate of 1 quart in 8 gallons of water, Jones[1] observed little effect on common weeds from spraying with carbolic acid. On the other hand, Voelcker[2] obtained satisfactory results from spraying wild onion with a 5 per cent solution of carbolic acid, and the same chemical proved effective in experiments on miscellaneous weeds at the Massachusetts Experiment Station.

Benzine. This substance has been tested on a small scale in destroying weeds in gardens in various localities. Stone[3] reports that a 50 per cent mixture of equal parts benzine and gasoline in water was effective against the less hardy weeds.

Kerosene. In preparing kerosene mixture as a spray for sucking insects, it is always recommended that care be taken not to leave any of the kerosene uncombined with the soap in the mixture, for the reason that if uncombined the kerosene may burn the foliage. Kerosene has a slight burning effect on the foliage of various trees. It was tried by Wilson[4] as a spray for weeds at the rate of 6½ gallons per square rod. When thus

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1 Vt. Sta. Rept. 1901, p. 248.
2 Jour. R. Agr. Soc. Eng. 63 (1902) p. 360.
3 Mass. Rept. 1908, Pt. I, pp. 62-72.
4 Minn. Sta. Bul. 95.

used it was not efficient enough to warrant its application on a commercial scale.

Salt. The injurious effect of salt upon vegetation is a matter of common knowledge. Plants show some variation in their resisting power to salt, but a maximum salt content is soon reached in the moisture of the soil, after which the plants die or can not thrive. Salt has been applied for killing weeds, either dissolved in water or sprinkled upon the ground about the weeds to be destroyed. Salt is chiefly valuable for this purpose in sidewalks or roadsides where it is not desired to grow cultivated crops after the weeds are destroyed. In such places there is no harm from the presence of large quantities of salt in the soil. As a spray it has been found that salt applied at the rate of 80 barrels is inefficient for the destruction of field weeds. It is, therefore, scarcely to be recommended in the list of commercial weed destroyers in field practice.

Sulphuric acid. On account of its great oxidizing and burning power, sulphuric acid has frequently been thought of as a weed destroyer. When used in a 15 per cent solution in water, Wilson[1] found sulphuric acid to be very efficient for destroying weeds but rather too expensive. Similar results have been obtained in Maine and elsewhere. Sulphuric acid is objectionable on account of the danger connected with its use by ordinary laborers, and its destructive effect on spraying apparatus. At the Station sulphuric acid was tried as a means of destroying guava, but without satisfactory results.

Copper sulphate. Copper, both in the form of sulphate and nitrate, but particularly the former, has been widely used in killing various kinds of weeds, especially wild mustard. The effectiveness of copper sulphate for this purpose has been thoroughly demonstrated, both in Europe and the United States. A 3 to 5 per cent solution is commonly recommended to be applied as a spray. Hitier[2] had excellent results in destroying wild mustard from spraying with a 4 per cent solution of copper

1 Minn. Sta. Bul. 95.
2 Jour. Agr. Prat. 5 (1905) pp. 65-8.

sulphate or a 3 per cent solution of copper nitrate. Copper sulphate may be added with a slight advantage to a solution of arsenite of soda, since, when thus used, it increases the solubility and burning effect of the arsenite.

Ammonia. Ammonia has also been used as a spray for the destruction of weeds but cannot be recommended for general use on account of its slight burning power and the disagreeable fumes which annoy the laborers.

Arsenite of soda. This chemical is usually prepared by boiling together common white arsenic and washing soda or sal soda. Theoretically these chemicals combine in such a proportion that if about 1½ pounds of soda be used for each pound of white arsenic, the proper combination will take place to render all of the arsenic soluble by the formation of arsenite of soda. In practice a considerably larger proportion of soda has been used, up to 4 pounds per pound of white arsenic. It seems unnecessary, however, to use more than 2 pounds of soda per pound of white arsenic. In preparing arsenite of soda we have had good results from boiling a mixture of one pound white arsenic and two pounds sal soda per gallon of water for from 15 to 20 minutes. The exact length of time to continue the boiling can not be stated beforehand with any certainty but the boiling should be continued until the solution becomes clear. The clearing of the solution indicates that the proper chemical combination has taken place. In Australia, where arsenite of soda has been widely used for killing weeds, the common practice is to buy the arsenite of soda as such on the market, but in the spraying thus far done in Hawaii with arsenite of soda, it has been prepared by boiling white arsenic and sal soda as just described. The stock solution obtained by boiling together the sal soda and white arsenic is to be diluted before spraying with 15 to 24 parts of water, depending on the hardiness of the weeds to be destroyed.

Arsenate of soda. This chemical is about equally soluble with arsenite and where obtainable on the market at a reasonable price may be substituted for the latter. In experiments with miscellaneous weeds, Jones[1] found arsenate of soda very

effective when used at the rate of 1 pound to 8 gallons of water. Similarly in Massachusetts arsenate of soda gave good results as a weed destroyer, either when used alone or when mixed with corrosive sublimate in equal parts.

EXPERIMENTS WITH ARSENITE OF SODA.

Before giving an account of the experiments with arsenite of soda at this Station and elsewhere in Hawaii, it may be well to refer briefly to other experiments with the same chemical. In Australia this spray has been widely used for the destruction of prickly-pear, wild blackberry and other shrubby and herbaceous weeds. For this purpose it has proven so effective as to make a wide field for itself in the programme of weed destruction. Maiden,[2] on the basis of a number of experiments, recommends for destroying prickly-pear a solution of arsenite of soda containing 1 pound to from 5 to 9 gallons of water. In other experiments more concentrated solutions were used, particularly for the destruction of wild blackberry and other shrubby weeds. Likewise in Iowa, North Carolina, Vermont, Massachusetts and elsewhere on the mainland, as well as in Europe, arsenite of soda has been used with good success in destroying miscellaneous herbaceous weeds. In Massachusetts it proved effective when used at the rate of 1 part to 66 parts of water. Kilgore[3] found that when an attempt was made to combine arsenical insecticides containing soluble arsenic with fungicides containing copperas, copper sulphate or iron chloride, the burning effect of the arsenite was considerably increased by the presence of the other mineral salts. In spraying experiments for the destruction of insects Gillette[4] observed that soluble arsenites in arsenical sprays produced a greater burning effect in the presence of dew and direct sunlight. These points are worth considering as indicating the conditions under which applications of arsenite of soda should be made in order to obtain a maximum effect.

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1 Vt. Sta. Rept. 1901, p. 248.
2 Agr. Gaz. N. S. W. 9 (1898), p. 984.
3 N. C. Bul. 77b.
4 Iowa Sta. Bul. 10, p. 419.

At this Station experiments have been carried on with arsenite of soda in testing the effect of this chemical upon a number of weeds, including oi (*Stachytarpheta dichotoma*), lantana, spurge (*Euphorbia peplus*), pualele or sow thistle, pig-weed, purslane, cockle-bur (*Xanthium strumarium*), glue (*Acacia farnesiana*), dodder, Japanese nut-grass, honohono (*Commelina nudiflora*), crotalaria and other weeds. In these experiments the stock solution, as described above, was dissolved in from 15 to 20 parts of water. The effect of the spray was manifest in most instances within 2 or 3 hours, but on Japanese nut-grass the leaves did not turn brown until the second day. On all of these weeds the leaves and stems ultimately died as a result of a single application.

In spraying alfalfa infested with dodder the alfalfa was killed as well as the dodder. In this respect the results were the same as those obtained with spraying with iron sulphate. The leaves and small stems of lantana were destroyed by a single application, but for the complete destruction of the plant a second, third or even fourth treatment was found necessary. With sow thistle, although apparently destroyed, it seemed to recover rather promptly and grew up again from the base of the plant. Similar results have been had in Nahiku in spraying this plant. Some difficulty is likely to be experienced in destroying honohono on account of the fact that in dense patches it is hard to reach all portions of the plant with the spray and two or three applications may be necessary. Japanese nut-grass, although entirely destroyed above ground by the arsenite of soda spray, promptly grew up again from the underground bulbs without showing any serious diminution of vigor. In previous experiments of the Station it was found possible to destroy this plant with carbon bisulphide, but this chemical is too expensive for use on a large scale. Judging from the experiments which have thus far been made, the best way to destroy this weed economically is to shade it out by using pigeon-peas and allowing them to occupy the ground for a year or more.

In the practical application of arsenite of soda on a large

scale in Hawaii, the chief credit is due to Mr. W. A. Anderson, Manager of the Nahiku Rubber Company. In consequence of the satisfactory results which he has obtained, the method has been generally adopted by all of the other rubber companies. More than 500 acres of land covered with miscellaneous shrubby and herbaceous weeds have already been cleaned by means of the spray, and ultimately the whole area now planted to rubber will be treated in this way. Some of the experience of Mr. Anderson is stated as follows in a letter from him:

"We use it for all troublesome grasses according to the following formula: 2 pounds crystal sal soda, 1 pound arsenic, boiled in 1 gal. water until clear. This is diluted in about 24 gals. of water in the field and applied at the rate, roughly, of about 100 gals. of the diluted mixture per acre, more or less according to the length and thickness of the growth.

"We find this effective for all the grasses we have to deal with, and for the Hitchcock berry and for the general run of weeds, excepting pualele (milkweed), ginger, and wild taro. For best results on honohono a little stronger solution, perhaps one gallon of stock mixture to 20 of water, is necessary. Diluted 1 to 24, it is partially effective with the three exceptions given above, and I feel sure that used slightly stronger, it would dry them up, as it does the grasses and ordinary weeds.

"In a complete list of the plants affected, lantana could not be omitted, as it burns the leaves off, and I have in mind a patch treated over a year ago which has not grown yet. It is unquestionably safe to say lantana can be kept in check with it, the fact having been demonstrated that the growth above ground can be killed, the conclusion would be natural that by keeping at it, the roots in time might be starved out.

"Hilo grass is actually disappearing from our fields that have been plowed, and thereafter treated with the spray. Considerable areas are entirely free from it, and it has been thinned out everywhere."

For several years the Hitchcock berry or thimble berry, and German ivy (*Senecio mikanioides*) have been encroaching on the grass lands of some of the ranches on Hawaii, particularly the Parker Ranch. The method of eradication at first adopted was that of digging out by hand. In this way about $1500 per month was being expended on these weeds and the financial burden seemed an excessively heavy one for the single item of weed eradication. As soon as the experiments with arsenite of soda had been carried far enough to warrant a specific recommenda-

tion it was urged that this spray be adopted for the weeds on ranch land. An extensive test was at once begun with results which have justified the general application of arsenite of soda. Not only the Hitchcock berry and German ivy are destroyed by this spray but also the nettle (*Hesperocnide sandwichensis*). These are the very worst weeds on ranch land. The use of arsenite of soda as a spray seems to be a practical solution of the problem of their eradication. Large bushes of Hitchcock berry are destroyed by a single application. At any rate the roots have been found to be dead for a distance of 18 inches from the base of the trunk and, of course, the leaves and the stems were all killed by the same treatment.

The method of application of arsenite of soda on rough ranch land or in rubber plantations is a simple one. The most of these lands do not admit of horse-drawn spraying apparatus on account of the junglelike nature of the weeds and the roughness of the lands. A knapsack spray holding about 5 gallons of solution may be carried on the backs of laborers, who can readily make their way through the bushes and grass, covering the vegetation with the spray as they walk along. One laborer can spray from one to two acres per day, depending upon the height and density of the weeds to be sprayed and the character of the land. The total cost of a single application, including materials and labor, varies from $1.25 to $2.25 per acre. The flowers and tender foliage of all weeds are destroyed by a single application and this effectively prevents the immediate spread of the weeds. As a rule the stems and roots of the weeds are destroyed by the first application. Hilo grass, however, lantana and certain other of the hardy weeds may require two or three applications for their complete destruction. About 100 gallons of the diluted spray is usually sufficient for an acre of ground.

In spraying with arsenite of soda it should be remembered that the effect is produced by contact with the aerial portions of the plant. The spray should be applied in the form of a fine mist so as merely to cover the surface of the leaves and the stems. Care should be exercised not to drench the plants, since

no more effect would be thus obtained, and the risk would be run of introducing too much arsenic into the soil.

At Ulupalakua some losses have been experienced in the death of cattle from eating a poisonous passion vine which has gradually spread over a small area of the ranch land. The arsenite of soda is now being used for destruction of this plant and also to kill the air plant (*Bryophyllum calycinum*), a useless weed which covers some of the range and prevents other plants from growing. It is commonly considered that red sage (*Salvia coccinea*) causes abortion in cows and mares. The evidence for this belief is quite conclusive and has come from a number of ranches. The arsenite of soda is now being used on Lanai for the destruction of this weed.

The chemical method for the destruction of weeds as described in this bulletin is capable of a much wider application, particularly for killing weeds along roadways and in waste places where cultivation is at present out of the question. It should, of course, be remembered that the arsenite is poisonous and stock animals should not be allowed to browse upon sprayed vegetation until after sufficient rain has fallen to wash off what may remain on the foliage. As a rule the effect of the spray begins to be manifested within a few hours in the withering and browning in the leaves of sprayed plants. They are thus rendered unpalatable as feed for animals. The spray must remain in contact with the foliage for at least two hours, in order to have the desired effect. In applying arsenite, therefore, a clear day should be chosen, or at least one in which it is not likely to rain soon after the application of the pray.

POSSIBLE DANGER FROM THE USE OF ARSENITE OF SODA.

In addition to the danger of stock becoming poisoned from grazing on sprayed vegetation, it seems desirable to consider the possible injurious effect of arsenic upon the soil and cultivated crops which may be growing in the soil at the time, or which may

be subsequently planted in it. This matter has already received some attention, particularly by the Colorado Experiment Station. There is still some difference of opinion as to the possible harmfulness of continued spraying with arsenic. Bishop[1] made analyses of potatoes after the vines had been sprayed with Paris green and found that they contained .0002 per cent of arsenic. Breteau[2] made an examination of wine obtained from grapes picked from vines which had been sprayed with arsenicals and found .003 to .2 mg of arsenic per liter of wine. Comere[3] cultivated algæ in solutions of potasium arsenate. This investigator found that algæ not only grew well in nutritive solutions containing arsenate but that arsenic acid could replace phosphoric acid in such plants. Hyslop[4] found that in cattle which had been sprayed with arsenical solutions, arsenic was present in urine but not in meat or milk. Collins[5] made cultures with barley in which arsenic was added at the rate of 11 pounds per acre normally. The grain of barley grown in the pots contained arsenic to the extent only of 4 oz. per acre and the straw 1¼ oz. per acre. Arsenic has been found in minute quantities in the fruit and in all parts of fruit trees which have been continuously sprayed with arsenic. It is well known that plants readily absorb arsenic from the soil but a considerable variation exists in their sensitiveness to this chemical. In the long-continued litigation between the smelters and cattlemen in Deer Lodge Valley, Montana, an excellent opportunity was had of studying the effect of arsenic upon vegetation and live stock. Unfortunately, too little attention was given in this extensive investigation to the effect of arsenic upon plants when absorbed into their tissues. The arsenic in this case was deposited largely upon the surface of the plants in dust which settled from smelter fumes and which contained arsenic in large quantities. In all cases, how-

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1 Jour. Am. Chem. Soc. 28 (1906), p. 184.
2 Jour. Pharm. Chim. 28 (1908), p. 156.
3 Bul. Soc. Bot. France 56 (1909), p. 147.
4 Natal Agr. Jour. 15 (1910), pp. 693-697.
5 Jour. Soc. Chem. Ind. 21 (1902), pp. 221-222.

ever, in which careful analyses were made, arsenic was found to have been absorbed into the substance of grasses.[6]

The most extensive study of the effect of the absorption of arsenic upon plants has been carried out by Headden.[1] Many fruit trees, both apple and pear, were observed to be in a sickly condition or dying in the orchards of Colorado which had received arsenical sprays for from 20 to 40 years. An examination of the soil under such trees showed the presence of arsenic in varying quantities, the highest being 138 parts per million. In some cases where sickness or death of the trees was observed the arsenic content of the soil was at least ten times that of normal soils in that locality. The orchardists were found to have been applying for years what must be considered as excessive amounts of arsenic. In some cases as much as 0.9 of a pound per tree. In a period of six years this would amount to 432 pounds per acre or about 108 parts per million in the first foot of soil. The first symptom of poisoning in the orchard trees was a premature yellowing of the leaves. If the application of the arsenicals was repeated the next year the trees died the second year. Serious injuries were also produced in these orchards from the corrosive effect of the arsenic which ran down the trunks of the trees. The bad effects were most noticeable at the collar of the trunk near the surface of the ground.

In view of the somewhat divergent opinions which have thus far been expressed relative to the effect of arsenic upon plants, we may well inquire what may be considered the outlook from the continued use of arsenite of soda as a weed destroyer in Hawaii. The results announced by Headden and referred to above have been called in question by other writers but without substantial evidence to disprove his position. Our experience in Hawaii is of only two years' duration. In a letter from Mr. W. A. Anderson of Nahiku, Maui, the following statement is made on the point under consideration:

"As you know, we have been using the spray for nearly two years

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6 Jour. Am. Chem. Soc. 30 (1908), pp. 915-946.

1 Colo. Sta. Buls. 131 and 157.

now, in quantities, and have not been able yet to observe any injurious effects on the trees. Where it has been applied frequently enough to keep the ground in a measure free from weeds, a marked improvement is noticed in the appearance of the soil, as I suppose might be expected from exposing it to the air."

In applying the arsenite spray on the rubber plantation of the Pacific Development Company a considerable quantity of the solution was accidentally upset near two rubber trees and the leaves fell from these trees within two days apparently from the poisonous effects of the arsenite. The trees, however, are recovering.

The conditions under which arsenite of soda has been applied in Hawaii differ greatly from those which prevail in apple orchards in Colorado. In the first place we are applying only five pounds of arsenic per acre and to soils which normally contain no arsenic. Then, too, the rainfall in rubber plantations is very high (160 to 200 inches per year). In the spraying experiments in the Colorado apple orchards the most insoluble form of arsenic was used. When washed down into the soil it, therefore, remains for a long time, gradually becoming soluble and being absorbed by the roots of the trees. Arsenite of soda is an extremely soluble form of arsenic. It is not known whether a considerable quantity of the arsenite of soda may subsequently be fixed in the soil by interaction with other chemicals found in the soil. The soils in the rubber plantations, however, are extremely porous and are underlaid with a-a to such an extent that running streams are rare. It is highly probable, therefore, that the most of the arsenite of soda washed into the soil by rains is carried away by the water passing through the soil. It seems very doubtful whether any serious accumulation of arsenic can take place in the soils of the rubber plantations so long as the conditions remain as at present. It can not be questioned, however, that arsenic in excessive quantities in the soil is injurious to nearly all forms of vegetation, and, therefore, some care should be observed in not using unnecessarily large quantities of the arsenical spray. No harmful results have thus far been observed upon rubber or other cultivated plants in Hawaii from

arsenicals and it is not likely that harm will result, at least in porous soils such as prevail in rubber plantations, particularly with the very small quantities of arsenic which are being used. The effects of arsenic will be closely observed and if any injury should manifest itself in years to come, the danger may be avoided by adopting for a year or so the harmless but somewhat less effective method of spraying with sulphate of iron.