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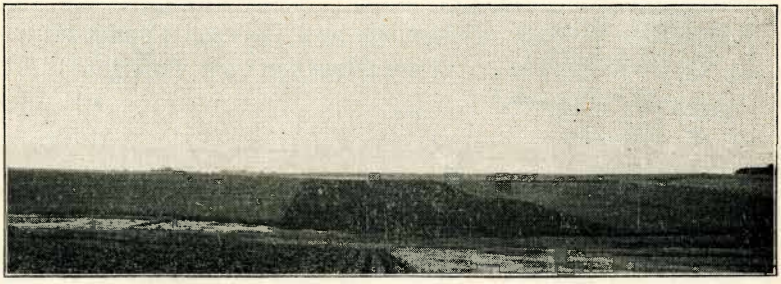

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THE KILLING OF MUSTARD AND OTHER NOXIOUS WEEDS IN GRAIN FIELDS BY THE USE OF IRON SULPHATE.

E. W. Olive.

During the summer of 1908 experiments were carried on in various parts of South Dakota in order to determine the effectiveness of spraying with iron sulphate and other chemicals for the killing of weeds. Arrangements were made with the American Steel and Wire Company of Chicago, Ill., who manufacture the iron sulphate, to co-operate with this Station in the work. The company consequently furnished the services of an expert, together with spraying machines and ample quantities of the sulphate. The writer desires thus to acknowledge his indebtedness to Dr. H. E. Horton, Mr. C. V. Ruzek and other officials of the company; also to Mr. John Messerschmidt of Brookings, Mr. Isaac Lincoln and Mr. E. M. McConnell of Aberdeen, Mr. H. R. Mitchell of Castlewood and others who have kindly co-operated in various ways toward making these experiments possible.

In order to obtain some variety in soil and climatic conditions, as well as to stimulate interest in the killing of weeds in various localities about the state, the work was carried on at Castlewood, on Keator Brothers' ranch; at Milbank ,on the farm of Mr. O. B. Slentz; at Aberdeen, on a ranch of Mr. Isaac Lincoln; at Arlington; and finally, at Brookings.

No one need be told in this age of intelligent farming how it is that mustard and other weedy growths do harm. Nearly all farmers, especially those of the northwest, unite in regarding mustard in particular as a sort of "yellow peril." But occasionally we come

across an individual who holds the opinion that the yellow-flowered plants in his grain fields do no particular damage; in fact, one man claimed that he knew how to gain much benefit from a crop of mustard—simply by plowing it under as a green manure. No one would attempt, of course, to dispute this obvious statement; but there are few who could afford to grow mustard just for a green manure crop, and thus lose for a whole year the income from their field. Still others try to apologize for the abundance of mustard on their farms by pointing out that a little mustard seed ground with grain for milch cows acts as a pleasant and beneficial stimulant.

Weeds are harmful in various ways. In the first place, they grow where there ought to be more grain growing. They crowd the legitimate crop and rob it of moisture, sunshine and soil food. Professor Bolley of North Dakota, found in his experiments that a field of oats from which the weeds had been eradicated by spraying showed one-third increase in yield over a similar unsprayed field. Others have reached somewhat similar conclusions; all agreeing that the yield from the sprayed fields showed considerable increase over the crop from those fields where the weeds were allowed to grow undisturbed. Unfortunately the particular experiments which we had planned in our series for yield tests over large areas were spoiled by drowning out of the crop in one instance, and by heavy damage from oat rust in another case, by which the grain was prevented from proper ripening. There can be no doubt, however, that the crowding from weedy growths in grain fields cuts out and prevents a considerable amount of grain from maturing; and, secondly, that through partial shading by weeds and robbing of the moisture which legitimately belongs to the crop, much of the latter is prevented from proper filling and ripen-

ing. Further, rank growths of weeds keep the leaves of the grain moist so that rust and other fungous diseases can thus readily gain an entrance. A crop clean from weeds growing on a well drained soil, will often largely escape serious damage from rust epidemics which sweep over and destroy large areas of weedy fields.

The majority of progressive farmers of course fully appreciate these facts. Many spend much time and energy as well as money in trying to keep down mustard and other weeds. One large landholder, for instance, says that in his effort to rid his ranch of mustard, he two years ago spent $84.00 in hand-pulling the weed; a year ago he doubled his expenditures in this work; but had to acknowledge finally that it seemed as though no matter how careful and clean his methods of farming, for years to come he might have to keep on increasing in geometrical ratio his expenditure for this purpose, before he could ultimately hope to conquer the pest.

Until the farms of South Dakota become smaller and more intensively cultivated, the weed problem will remain a serious menace to every grain grower. Careful cultivation of smaller fields will of course generally hold well in check troublesome weeds. In the meanwhile, we must in some way keep down the weeds in our extensive grain fields; and the writer is fully convinced that in spraying by means of iron sulphate, we have an efficient help in this work.

The method of spraying for weed killing in grain fields is already familiar to many. Similar experiments have already been carried on in various other states. Apparently the first experiments in this line were carried on in North Dakota in 1896 by Professor H. L. Bolley, who has consistently followed up this preliminary work, especially within the past few years, by extensive investigations. Recently Professor Moore of Wisconsin has carried on extensive spraying with iron sulphate in various western states. In Canada and Minnesota also these methods have been tried through a number of years. Our results in South Dakota agree

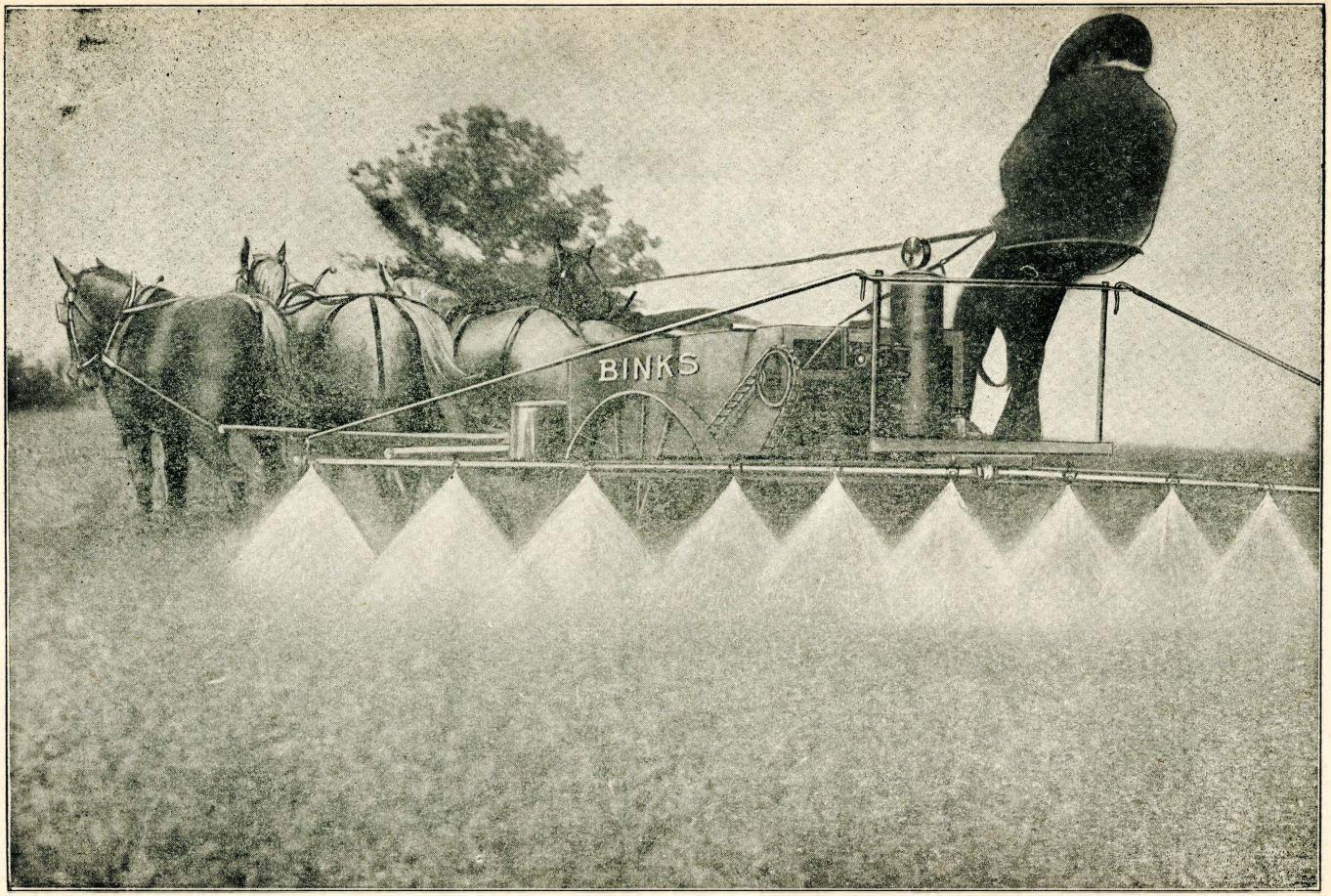

FIG. 11.—A successful type of traction sprayer, built for the purpose of spraying mustard and other weeds in grain fields.

in the main with the results obtained by other investigators.

The machine (Fig. 2) which gave the best satisfaction in our experiments covered a swathe about twenty-five feet wide and threw a very fine and powerful spray, under a pressure of from eighty to a hundred and twenty pounds, directly down on the young mustard and grain. Such a powerful pressure as this has been found to be absolutely necessary in order to develop the proper fineness of spray, as the solution is vented from the nozzle. One sack of a hundred pounds of the iron sulphate is first dissolved in one barrel of water, or about fifty gallons. This makes a very strong solution of about twenty per cent strength. The solution should be stirred vigorously with a hoe for three or four minutes until all the chemical is dissolved. It is then ready to pour into the tank of the machine through several thicknesses of cheese-cloth tacked over the manhole in order to strain out the fibers and undissolved substances.

As has been borne out in the experiments in other states, the best results from spraying are obtained when the grain and weeds are from six to ten inches high; or just before the mustard plants begin to bloom. However, in one of our expriments, fair results were obtained by spraying after the mustard had been blooming for some time. Also it is highly important that the work be done during favorable weather. The necessity of this will be understood when we come to consider the physiological reasons for the killing of the weeds. The best time for the most successful work is just after the dew is off, on a bright, sunshiny day. A little wind will also help the drying process; but if a rain follows too soon, the iron salt is washed off and all the work comes to naught. In several of our experiments, we easily covered twenty-five acres in five hours so that under favorable conditions forty to fifty acres could be readily sprayed in one day with a 160 gallon machine.

Now if one keeps close watch of the sprayed weeds, the various steps of the destructive action of the salt can be readily followed. First, the sulphate

dries on the leaves, leaving minute whitish flakes on the surface. This drying of the salt on the leaves is apparently an absolutely necessary step in the process; if by reason of cloudy weather, or through other unfavorable conditions, evaporation from the leaf surface is prevented, the weeds may not be killed at all or at least only partially destroyed. The next step may be noticed in about two or three hours. If we now examine such succulent weeds as mustard, we see on close examination that the leaves show many scattered, more or less translucent, *sunken* areas, some as much as a quarter of an inch in diameter, others quite small. The leaves by this time appear to be somewhat wilted and the whole plant looks sick. Two or three hours later, comes the next change. The sunken areas by this time have nearly all turned gradually blackish, and on examining these spots with a microscope, we see it is the contents of the shrunken cells which turn black. The leaves from now on wilt rapidly and dry up, so that in twenty-four hours or so, they seem to be about dead. In a few days to a week, most of the mustard leaves fall off, or else remain as dry, withered remnants on the dead stems. Occasionally a leaf may make a weak attempt at revival; or a plant here and there may make a futile effort at flowering and seed production. But if the work be thoroughly done, but few weeds survive the treatment. I have seen mustard so thick as to approximate one hundred plants to the square foot, all totally destroyed by effective spraying.

From the above description of the successive steps in the appearance of a sprayed leaf, the interpretation of the physiological action of the sulphate seems clear. The main action involved seems to be that the water in the leaf is drawn out of the cells by the flakes of salt dried on the surface. Common salt, also, when sprayed on mustard or ragweed or most other weeds in the form of a very strong solution of about 20 per cent strength, apparently acts in a manner precisely like that noticed as a result of spraying with sulphate of iron, only its action is even quicker. Plasmolysis and consequent wilting of the leaves results in from ten to fifteen minutes after the first application of the

FIG. III.—A field of flax near Arlington. Note the distinct line between the sprayed and unsprayed portions. showing blooming mustard plants on the left, in the unsprayed area. Ten acres sprayed in the middle of the field (see figure on title page) were entirely cleared of mustard and other weeds.

salt spray. It follows of necessity that the plants wilt and die if practically all the water is drawn out of their leaves. It is quite probable also that after the drawing out of much of the water from the leaves, some of the chemical itself may be absorbed; but, in my opinion, this action is not the primary cause of the death of the plant; death is due to osmotic properties, rather than to absorption of the chemical into the leaves. The subsequent blackening following the iron sulphate spray probably comes from the formation of sulphides in the cells of the leaves due to the union of some of the absorbed sulphate with the living substance. After the use of common salt, on the other hand, the shrunken spots turn reddish brown; probably chlorides of some sort are formed in this instance in the killed protoplasm.

Now the most interesting question of all remains to be answered: Why are the weeds killed and the grain uninjured? Anyone may answer this question for himself if he will only examine the sprayed plants closely, a few days after the spraying has been done. It will be seen, of course, that the grain does not entirely escape injury. The tips of the young leaves of wheat or rye or oats, as the case may be, are nearly all blackened and killed; but it will be remembered that when the grain is only six inches to a foot in height, the bases of most of the leaves are well protected, wrapped within the sheaths and lower leaves. Therefore the spray strikes only a small part of each leaf, toward the tip.

While the grasses and grains thus suffer a little setback, they soon pick up again. They undoubtedly owe their freedom from permanent injury to their habit of indeterminate growth, their young leaves pushing out and growing from the base, as well perhaps as to the fact that their smooth surfaces largely shed the water. The minute droplets of the iron sulphate or salt do not adhere readily to the surface of flax, for example, on account of the whitish, waxy bloom which covers the plants; and many other grains (and some weeds, too, for that matter) are likewise provided with such a protective covering.

It is thus seen that iron sulphate does not inflict more than a slight, temporary injury to the sprayed grain. In fact, it is claimed that, instead of causing injury, the spraying may be of great benefit to the latter. It is well known that soluble iron compounds are necessary for the formation of the green chlorophyll in plants; and sulphur, also, is a necessary mineral in the life of plants.. There can be no doubt, however, that the minute amount of iron required by plants is readily available in most soils.

It is true that in our spraying experiments, we could readily see that the grain, after the lapse of a week or more, turned a darker, richer green. It is extremely difficult to say, however, whether this general darkening of the sprayed field was due to the general effect of the blackened tips of the grain and dead stalks of the mustard, or whether it resulted from the darkening of the green coloring matter, due to the iron of the sulphate. I am not yet prepared to contribute definitely toward this important question.

It is well known that most of our worst weeds have been imported. It is probable that wild mustard was first introduced into the Dakotas in flax seed. It would seem to be an easy matter to separate the round seeds of mustard from the flat seeds of flax but the fact remains that flax seed even to this day is sometimes foul with mustard. Farmers quite often plant many noxious weeds, unintentionally of course, with the grain. Another method in which mustard and other weeds may be sown is through the application of manure; or, grazing animals, such, as sheep, horses, etc., may scatter the seed by means of their droppings. A farmer near Brookings, for example, sowed his oat field thick with mustard through manure brought from the city. It is quite evident that composting the fertilizer is the only method of killing the weed seeds in such cases.

Professor Bolley has some interesting data concerning buried weed seeds, planted at varying depths ranging from one inch to ten inches. I will note a few of his conclusions. "Small weed seeds the size of naked timothy seed will not come up ordinarily

through two inches of soil. Wild mustard comes up most abundantly through one inch of soil, very abundantly through two inches, abundantly enough through three inches and not at all through five inches. Wild mustard has good germination after being buried fifty-six months. The deeper buried seeds are better preserved." The claim appears to have been many times well authenticated that mustard seed may remain buried for many years—at least ten or fifteen—and still retain the power of germination when finally turned up, and thus exposed to the air and warmth.

In our experiments observations were made on the effect of iron sulphate on many different kinds of weeds. The following list includes those which under favorable conditions of spraying were entirely killed: wild mustard (*Brassica arvensis*); ragweed *Ambrosia artemisifolia*); king-head or greater ragweed (*Ambrosia trifida*); bind weed (*Convolvulus sepium*); marsh elder (*Iva xanthifolia*); milkweed (*Asclepias sp.*); peppergrass (*Lepidium virginicum*); pigweed (*Amarantus sp.*); sweet clover (*Melilotus alba and M. officinalis*). Those which were more or less badly injured: Russian thistle, (*Salsola Kali*); sunflower (*Helianthus sp.*); dandelion; dock (*Rumex Crispus*) thistle (*Carduus sp.*); white clover (*Trifolium repens*); red clover (*Trifolium pratense*); alfalfa (*Medicago sativa*). The following were but slightly injured: plantain (*Plantago major*); sheep sorrel (*Oxalis violacea*); prairie rose; lamb's quarters (*Chenopodium album*). Grasses in general, including the grains (wheat, oats, corn, barley, and speltz were sprayed in our experiments) were none of them seriously injured.

A few observations were also made on eradication of dandelions. The results in general were not so favorable as those reported by other experimenters. Young plants with a small root were generally entirely killed with only one application of the iron sulphate spray applied by means of a hand sprayer. Large, strong plants, on the other hand, required three and even more applications of the spray at intervals of three or four weeks. Even under those conditions some plants persisted in coming up. Probably con-

tinued use of the spray once a month for two seasons would accomplish the desired result.

It should be remembered that a freshly mown lawn is liable to be badly injured by spraying. Further, as was noted above, the white clover common in most lawns is almost invariably injured by sulphate of iron. Since iron sulphate stains clothing and cement walks and is at the same time irritating to the eyes and skin, caution should be exercised in throwing the spray. Those who work with the field sprayer, in particular the driver of the machine, would do well to smear the face and hands with vaseline, in order to prevent the spray from causing irritation of the skin.

A few experiments were also made on killing dandelions by means of acids, etc. Practically all plants treated with per cents of sulphuric acid as strong as 20 per cent strength died. The method of treatment in every case was simply to cut off the crown and apply the solution to the cut top. Kerosene applied in a similar manner also successfully killed the plants and caused the roots to decay. Gasoline, on the other hand, failed to kill the plants completely since the cut roots all commenced to sprout in two or three weeks. The failure in this latter instance was due probably to the rapidity with which the gasoline evaporated.

Those who plan to purchase field sprayers and to try what the writer believes to be one of the most efficient means for aiding the grain grower to eradicate weeds, should be exceedingly cautious about the selection of a machine. A remodeled orchard sprayer will not do the work satisfactorily. Neither will a watering-can serve to produce the misty spray absolutely necessary in this work. The main difficulty encountered in our experiments arose from defective machines. Only one of the four types of traction sprayers employed in our work gave anything like a satisfactory account of itself; and this machine was specially made for field spraying. There have been put on the market during the past year, however, a half dozen types of field sprayers, all manufactured for this special purpose by reputable manufacturers, and it is

quite probable that any one of these would prove satisfactory. I am inclined to think that for the conditions which confront us here in South Dakota, it is better to have a machine of large capacity, with wide tires, since it is absolutely necessary for us to work fast when the right conditions for spraying present themselves. The most favorable season for spraying grain for the eradication of weeds lasts less than two weeks; and in that critical time the weather or the season may prove for the most part unfavorable. Probably for large ranches a machine holding four or five barrels of liquid, capable of spraying ninety to a hundred acres a day and designed to be pulled by four horses would prove to be the most economical. A smaller machine, however, of about one hundred and sixty gallons capacity which can be readily pulled over ground not too soft by two horses, will go across a field about a hundred and sixty rods wide and return on one filling of the tank. For operating such a machine requires besides a driver one helper to mix and pour the sulphate and also a tank man to haul the water. It has been found in our experience that three men thus working with a machine of one hundred sixty gallons capacity can spray twenty-five acres easily in five hours.

A folding spray boom has several advantages over a solid boom, since it can be folded up in order to pass through gates. But, on the other hand, the rubber tubing usually employed in such construction offers many obvious difficulties since it readily decays and becomes leaky. From my own experience I should much prefer a solid brass boom for carrying the spray nozzles notwithstanding the fact that such a long, rigid boom presents many difficulties in driving about. The spray nozzles should all be of the self-cleaning type; and they should be set to cast a fine misty spray, the whole system of sixteen or eighteen nozzles throwabout one barrel of liquid to the acre. It is highly important, finally, that the machine should be well rinsed out after using and water should be forced through the nozzles. Otherwise the iron sulphate remaining in the machine may corrode the brass parts with which it is in contact or may deposit as small flakes of iron rust.

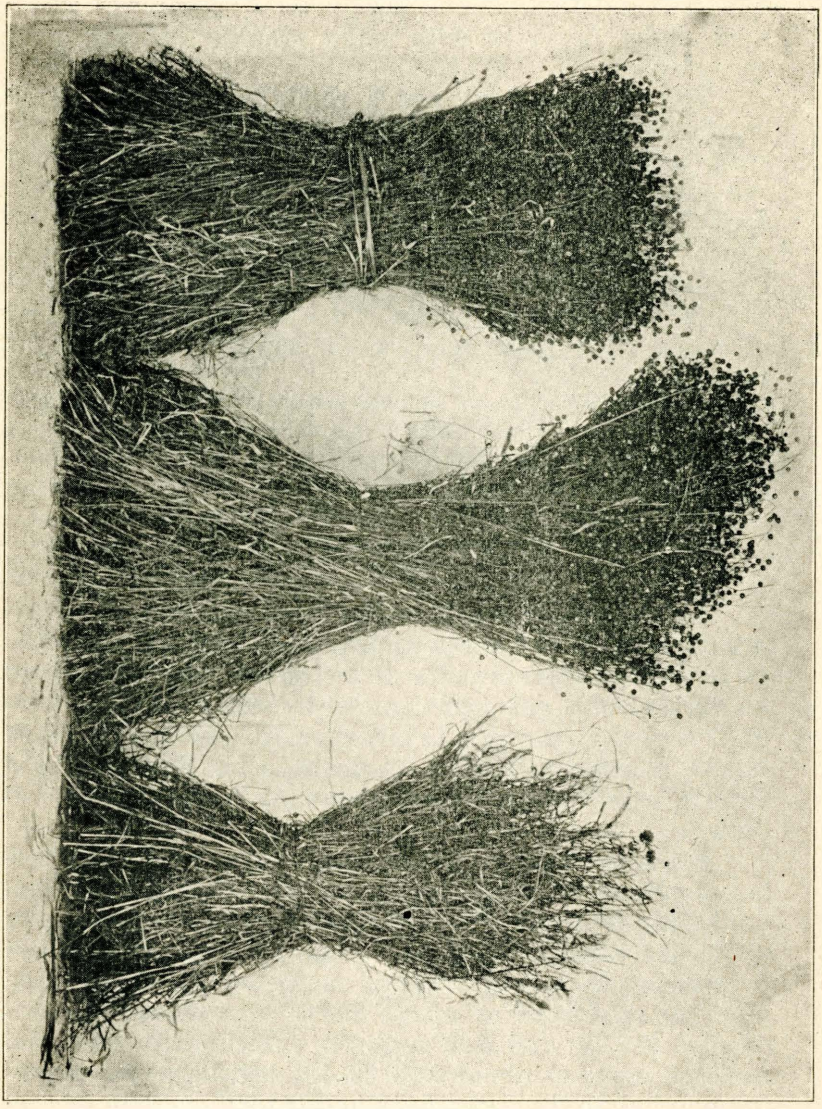

FIG. IV.—At the left, a bundle of flax from the Arlington field, sprayed with iron sulphate, showing the uniform length of the straw and heavy yield of seed pods. There are practically no weeds in this bundle. The middle bundle of flax came from a measured space of exactly equal area, from the unsprayed part of the same field. Note that the straw in the latter case lacks uniformity, due apparently to uneven ripening and development. At the right is a bundle of weeds, principally mustard, separated from the flax in the middle bundle.

Such flaky deposits will make trouble for the next spraying.

The last question which remains to be answered is whether spraying will pay or not. It certainly would seem to entail considerable expense in the first cost of the spraying machine—about two hundred to two hundred and fifty dollars—not to mention labor and sulphate. A number of people have made estimates as to cost per acre, and one low estimate places the cost at a $1.08 per acre simply for the chemical and the cost of labor. We may make a conservative estimate as follows:

Cost of machine one season (sprayer should last ten years)	$ 20.00
Labor for six days (three men at one dollar a day)	18.00
Two teams at $3.00 per day for six days	36.00
Iron sulphate for 300 acres, about	300.00
(Iron sulphate in carload lots, delivered at Brookings costs 93 cents per hundred pounds).	
Total	$374.00

This estimate would make the total cost of spraying three hundred acres approximately $1.25 per acre. If we accept the estimate of one-third gain on sprayed fields, the total net profit gained by spraying three hundred acres, counting the average income per acre at $10.00, (certainly too low an average for South Dakota farms), would approximate about six to seven hundred dollars.

Even on smaller areas than three hundred acres, (on one hundred acres, for example) spraying would undoubtedly be profitable. Estimating the first year cost of the machine at $20.00 (even this cost may be reduced by sharing in a neighborhood machine); labor of three men for two days at about $9.00; two teams for two days at $12.00; and iron sulphate sufficient to cover one hundred acres at about $100.00, the total cost for spraying one hundred acres would be $141.00. A gain of two or three bushels of grain (of wheat, for example) to every sprayed acre in this case would bring an extra $200.00 to $300.00, thus giving a net profit on one hundred acres of about $50.00 to $150.00.