A STUDY OF SELECTIVE CHEMICAL WEED CONTROL POSSIBILITIES FOR ONION SET PRODUCTION

by

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INTRODUCTION

The production of onio n sets has long been of importance as a vegetable crop in the Winnipeg area. The total production in some years has exceeded four million pounds (IO), which is approximately 65 per cent of the total Canadian production. Control of weeds is a major item of expense (15, 19) in the production of this crop. Onions grown for sets are planted relatively close together, both with respect to distance between the rows and to distance between the plants in the rows, and for this reason mechanical and hand weeding is often difficult and costly. In view of these facts, the possibilities of chemical weed control have received much attention from research workers. The discovery or development of a suitable chemical which would cause no significant reduction in yield or storage capacity of onions, and yet control or aid in the control of weeds, would be a boon to the onion set grower.

This thesis presents a report of studies of several phases of weed control in onions. Potassium cyanate has been in fairly general use as a post-emergent weed control in the Eastern United States and Canada for several years. In order to establish rates of potassium cyanate which could be used safely under Winnipeg conditions, the chemical was applied at

several rates in experiments carried out in two consecutive years. The effect of the spray treatments upon both onions and weeds is reported in considerable detail.

A study was also made to determine what effects the factors of climate, such as temperature and relative humidity, might have upon the degree of injury caused by post-emergence spray treatments of potassium cyanate. This was an attempt to provide information as to the most desirable time for application from the standpoint of effect on weeds and possible injury to onions.

The effects of pre-emergence application of calcium cyanamid, monosodium cyanamide, potassium cyanate, and 2,4-D were also studied.

REVIEW OF LITERATURE

Considerable research work has been done on chemical weed control in onions during the last 10 years. This work has included studies of many chemicals. Those showing most promise and most widely studied are: dilute sulphuric acid (H_2SO_4), cyanamids and cyanates, 2,4-dichlorophenoxy acetic acid (2,4-D), and various dinitro compounds.

Dilute sulphuric acid, as a selective herbicide in growing crops, has been used for about 50 years. In the more recent years it has been used commercially on onion fields with a considerable amount of success. Lee and Ellis (20) state that of all the chemicals used on onions in their experiments in Indiana, dilute sulphuric acid was the only effective one which showed sufficient selectivity. They recommend that the onion plants should have two true leaves and that the foliage be dry at the time of spraying. They also found that temperatures ~~of~~ above 70 degrees F. and a high relative humidity are desirable in order to obtain maximum effectiveness from sulphuric acid, and that low spraying pressures (below 50 pounds) should be employed to avoid excessive wetting of the onion plants. Warren (29) also found that sulphuric acid in 3 per cent solution was one of the best chemicals tested on onions as a selective post-emergent spray. Chappell (6) used dilute sulphuric acid (2 per cent) and controlled weeds

effectively without significant reduction in the yield of onions. There was no significant difference in the number or weight of bulbs, nor any effect upon the amount of sprouting in storage. Lachman (17) obtained no control of purslane, lamb's quarters, or grass weeds with the use of sulphuric acid, and considered the use of the chemical to be of questionable value. He suggested that environmental conditions may play an important part in the success of this method. Most research workers agree, however, that because of its highly corrosive ~~chemical~~ nature there is little hope that it will be developed for extensive use as an herbicide.

Sinox and other dinitro compounds have been used with considerable success in the control of weeds in onions, especially in the western part of the United States. In California, Westgate and Raynor (33) reported that sinox at the rate of 1 gallon in 160 gallons of solution per acre proved satisfactory for weed control in transplanted onions, providing they were healthy, and not over 10 inches high. Good control of various species of mustard and pigweed was obtained with no control of purslane and many grasses. Crafts and Raynor (9) in 1944 found that sinox could be safely used on onions during the first to third true-leaf stage. Sinox has been used on a commercial scale in California onion fields. Warren (29) working in Wisconsin found that spray concentrations of sinox strong enough to

give good control of weeds resulted in considerable burning and a small amount of killing of the onion plants. Sinox was therefore not considered satisfactory under conditions existing in that state.

Considerable work has been done to discover the possibilities of using various forms of 2,4-D as a pre-emergence treatment on onions. Warren, et al., (30) concluded that to be effective, 2,4-D must be present in toxic concentrations at the time weed seeds are germinating. Several workers (2, 30, 16, 20, 19) reported that 2,4-D at rates high enough to effect practical weed control seriously injured the onion plants. This was found especially true when 2,4-D was applied before seeding, and even more evident if applied before seeding and mixed into the soil. Warren and Hernandez (32) found that in onions grown from sets, a pre-planting treatment of 2 to 4 pounds per acre delayed emergence from 10 days to 2 weeks. It was concluded that 2,4-D soil treatments offer little promise as a method of controlling weeds in Golden Globe onions grown from sets. Taylor (24) on the other hand, found that ½, 1, and 1½ pounds of sodium salt of 2,4-D on onions grown from sets gave significant weed control without reduction in yield or change in the average weight per bulb.

Warren and Hernandez (32) applied several formulations of 2,4-D to onions grown from seed and reported that the only ones which did not reduce yield were the sodium and amine salts. These formulations at 2, 3, and 4 pounds per acre were found to give generally good control of pigweed, lamb's quarters, purslane, shepherds purse, witch-grass, and foxtail for a period of from 4 to 6 weeks. They found that crop injury increased almost directly with the rate of application, and suggest that the lowest rate of 2,4-D which will give good weed control should be used. The amine salt of 2,4-D was also found to be effective for weed control by Denisen et al. (11), but significant reductions in yield were obtained at rates above $\frac{1}{2}$ pound per acre. Grigsby (13) found that of several chemicals, the amine salt of 2,4-D, potassium cyanate, and sodium 2,4-dichlorophenoxy-ethyl sulphate (EH-1) caused the least reduction in yield.

Taylor (28) made several treatments on onions in the greenhouse, using the sodium salt of 2,4-D. He reported that the stand was better and the seedling injury was less when applied just before emergence than when applied earlier. Percentage weed control was also higher at the later date. Rates as high as 2 pounds per acre seemed satisfactory on onions grown from seed. These results were generally verified in outdoor trials by Taylor (23).

Taylor (26) found that in pre-emergence treatment of onions grown from sets, there was no significant reduction in set yield from treatments of ½ to 1½ pounds of the sodium salt of 2,4-D per acre. The stand, however, was reduced which resulted in larger sets being produced. Pre-emergence applications of 2 pounds of amine and 2 pounds of the ester formulation of 2,4-D per acre were made by Bakke and Staniforth (4), and gave good control of weeds in onions for about three weeks after the onions emerged.

The alkyl ester of 2,4-D was applied to onions as a pre-emergence treatment by Alban (1). Excellent weed control was obtained for a period of several weeks. All other 2,4-D treatments caused severe damage to all onion varieties.

Hedlin (15) carried out work using calcium cyanamide as a pre-emergent dust treatment on onions. He found that 100 and 200 pounds per acre of this chemical delayed the emergence of the onions by 24 to 48 hours. Weeds were reduced about 50 per cent by pre-emergent treatment, but crop yields were not reduced. Plots which received an additional post-emergence treatment of calcium cyanamide at 50 and 100 pounds per acre, showed a reduction in yield of onions, and eliminated about 90 per cent of the hand weeding.

Potassium cyanate has proven to date to be one of the most promising of post-emergent selective chemicals which can be used safely on onions. Experimental workers in various

parts of the continent have obtained results which differ widely. In general, higher rates have been found necessary in the inland regions than in coastal regions. Work carried out at the University of Manitoba in 1949 (3) indicated that 72 pounds per acre, applied in two applications of 36 pounds, did not produce any apparent injury to onions grown for sets. Such rates are far in excess of those in use in Eastern United States at the present time.

Potassium cyanate was applied by Hedlin (15) as a post-emergent treatment in an effort to control late germinating purslane. When the spray was applied during hot and dry weather and the weeds were in very small stages, purslane and lamb's quarters were readily killed. He found that when the weeds were small, there was no need to go above a 2 per cent solution at 80 gallons per acre. Lachman (19) and Nylund (22) found that of several chemicals used, potassium cyanate was the most effective, but that it was not sufficiently selective to permit direct application to the onion plants without some reduction in yield. Cockrum and Warden (8) applied potassium cyanate to onions at 20 pounds per acre and produced a slight burning of the onion leaves.

Denisen, et al. (11) obtained significant yield reductions using potassium cyanate at 1 and 1½ per cent as a post-emergent treatment, and obtained also, a good measure of weed control. Grigsby (13) used several chemicals in pre-emergence

treatments of onions, and found that least reduction in yield was caused by potassium cyanate and 2,4-D. Nylund (21) found that potassium cyanate applied pre-emergently gave from 90 to 100 per cent weed control.

Several other chemicals have been used with varying amounts of success. Lachman (18) obtained good control of grass weeds with isopropyl n-phenyl carbamate (IPPC), and found that it possessed good selectivity for beans, beets, spinach, and onion sets. IPPC supplemented with 2,4-D was found to be valuable in the prevention of weed growth in fields of onion sets. Crafts and Raynor (9) indicate that good pre-emergent control of weeds, including grasses, can be obtained by the use of either diesel oil or stove oil at rates of 60 to 75 gallons per acre. Alban (1) found that 8 pounds of sodium pentachlorophenate (Na PCP) per acre applied when the onions were 2 inches high gave excellent weed control for three weeks. Sodium isopropyl xanthate used at 8 pounds per acre by Grigsby (12) caused a 16 per cent stand reduction, with no reduction in yield. Barnard and Warden (5) found that pre-emergence treatments of 15 pounds of sodium isopropyl xanthate per acre produced onion stands approximating those of check plots.

MATERIALS AND METHODS

Two main experiments were conducted. (1) Potassium cyanate was used post-emergently in experiments which were repeated for the two years, 1950 and 1951. Observations were made on the amount of weed control obtained and on the effect of this control on the yield of onion sets. (2) A study was made in 1951 to determine the effect of the stage of growth, temperature, and relative humidity upon the amount of injury caused to the onion plants with various rates of potassium cyanate. (3) A small pre-emergence study was carried out in 1950 and 1951 using 2,4-D, monosodium cyanamide, calcium cyanamid, and potassium cyanate.

The Red River flood in May of 1950 necessitated the moving of all plots to Headingly, Manitoba, for that year. In 1951, all trials were conducted at the University of Manitoba, Fort Garry.

In all tests, Yellow Ebenezer onions were used. A knapsack sprayer to which a brass auxiliary side tank had been attached was used for all applications. A measured amount of chemical and volume of solution were placed in the auxiliary tank sufficient to cover the plot area. The side tank was connected to the main knapsack sprayer tank by a hose line in which was located a stopcock. This made

it possible to fill the side tank without losing pressure in the main tank. The nozzle used was a "Teejet" 8007, at a pressure of 30 pounds per square inch.

1. Post-emergence experiments.

In 1950, the onions were sown on May 27 into fairly wet soil. Row spacing used in this experiment was 14 inches and plots consisted of 5 rows, 12 feet long. Planting depth was 1½ inches. A randomized block with four replicates was used.

On June 11, 1950, potassium cyanate was applied at rates of 8, 16, 24, and 32 pounds per acre, in 60 gallons of solution per acre. On this date the onions were in the crook stage and about ½ to 3/4 inches high. The soil was wet at the time of application. Applications were made both with the addition of a wetting agent (Nonic 218, Sharples Chemicals, Inc.) at 0.05 per cent and without a wetting agent. Weeds present at this time were wild mustard (Brassica arvensis), stinkweed (Thlaspi arvense), wild buckwheat (Polygonum convolvulus), red root pigweed (Amaranthus retroflexus), wild oats (Avena fatua), perennial sow thistle (Sonchus arvensis), and giant ragweed (Ambrosia trifida). Not until after planting was it discovered that the land was heavily infested with wild oats and perennial sow thistle. Because these two weeds are not normally a problem in onion fields and because no control of these weeds was obtained, they were removed manually on July 10 - 12. Weed counts were

made on 3 square feet out of each plot. The number of mustard, stinkweed, ragweed, spotted spurge, and wild buckwheat were counted separately and totalled. There was no other hand weeding or cultivation.

Since no observable differences could be detected between those plots which earlier had received a wetting agent and those which did not, it was decided to use these plots in a further experiment to obtain additional information. By the middle of July, a new crop of weeds was emerging and on July 21, 1950, a duplicate set of treatments was made to those plots which received the potassium cyanate and the wetting agent of June 11. A high temperature of 71° F. and a low relative humidity of 57 per cent was recorded on the day of the application.

The onions were pulled on September 5 and allowed to dry on the ground. They were then removed to the dryer, thoroughly dried, screened, and the plot weight recorded.

In 1951, wild mustard seed was mixed with the onion seed and sown on May 7. The plots consisted or 5 rows, 12 feet long, as in 1950, but with a row spacing of 12 inches. The same rates were used. Potassium cyanate was applied on May 26 when the onions were in the flag stage and from 1½ to 2 inches high. No wetting agent was used. The temperature at the time of spraying was 62° F. with a high of 71° for the day. The low during the following night was

43°. The relative humidity was 45 per cent at spraying time and dropped to 22 per cent in the afternoon. The high during the following night was 92 per cent.

Weeds present at the time of application were wild mustard, stinkweed, lamb's quarters (Chenopodium album), wild buckwheat, and red root pigweed. At this time, mustard, the predominant weed was in the 4 to 6 true leaf stage, while the other weeds were in various stages from seedling to the 8 to 10 leaf stages.

Shortly after spraying, it was observed that there was no control of lamb's quarters, and they were subsequently removed. Weed counts were made on June 6. The onion sets were harvested on September 10.

2. Experiment to determine the effect of environment on the amount of injury to onions caused by potassium cyanate.

This experiment was carried out only in 1951. Three dates of planting were used, May 7, May 14, and May 21. The purpose of the three dates was to provide three stages of growth at each spraying date.

Three spray applications dates were employed, and on each of these dates identical treatments were made, one in the forenoon at 10:00 a.m. and one in the evening at 8:00 p.m., in an attempt to obtain different humidity and temperature conditions. The morning application would be followed by a period of low humidity and high temperature, and the evening

application would be followed by the reverse conditions. At all dates the rates used were 20, 40, and 60 pounds of potassium cyanate in 60 gallons of solution per acre. These heavy rates were used to insure a measurable amount of injury.

The first application date was June 9. At the time of spraying the ground was in a fairly moist condition having received approximately 1 inch of precipitation during the three days previous to spraying. The onions were in a very active stage of growth. Those of the first planting were in the 2 leaf stage, about 4 inches high, and showed some injury received during a hot dry wind of May 29. The onions of the second planting date were also in the 2 leaf stage, and from 1½ to 2 inches high. The onions of the third planting date were about 2 inches high and in the advanced flag stage with the first true leaf just emerging. At the time of the morning application, the relative humidity was about 85 per cent. This was followed by a low of 50 per cent in the afternoon. The temperature was 53° F. at the time of the morning application with a high of 63° in the afternoon. The evening application was made when the relative humidity was 75 per cent. The relative humidity during the night was 100 per cent. The temperature at the time of the evening spraying was 62° F. with a low of 41° during the night. (See fig. 1.)

The second application date was June 18. The onions of the first planting were up to 8 inches in height with two true leaves on most plants. On some, the third true leaf was emerging. Those of the second planting date were about 6 inches high and had two true leaves. The onions of the third planting date were 5 to 6 inches high with 2 true leaves. At the time of the second date of spraying, many onion plants of the second and third planting dates were in the flag stage. This retarded emergence was caused by poor germination in these later plantings because of exceptionally dry soil conditions. At spraying time the soil was dry in the upper inch but quite moist below that depth. At the time of the forenoon spraying, the temperature was 66° F. with a high of 74° for the day, and the relative humidity was 33 per cent followed by a low of 25 per cent. The evening application was made when the temperature was 54° F. followed by a low of 44° for the night (see fig. 2). The relative humidity was 54 per cent followed by a high of 100 per cent during the night. There was a trace of rain in the mid-afternoon.

At the time of the third application, June 30, onions of the first planting date were about 12 inches high with four true leaves. Those of the second planting were 10 to 12 inches high with the fourth leaf emerging. The fourth leaf was also emerging on the last planting, and they were

8 to 10 inches high. The temperature at the time of the morning application was 55° F. with a high of 63° for the day. The relative humidity was 68 per cent followed by a low of 50 per cent. The evening application was made when the temperature was 62° F. with a low of 44° during the night, and a relative humidity of 66 per cent followed by a high of 100 per cent (see fig. 3). There was a trace of rain at noon.

3. Pre-emergence experiments.

Pre-emergence treatments were made to onions both in 1950 and 1951. In 1950, materials used in these treatments included: X10 (monosodium cyanamide dust) at 100, 200, and 400 pounds per acre; calcium cyanamid (special grade) at 60 and 90 pounds per acre; Aero cyanate dust at 40 and 60 pounds per acre; Aero cyanate spray at 10 and 20 pounds per acre; and a mixture of calcium cyanamid (special grade) and IPC in the proportions of 30:15, 40:10, and 60:5 (in pounds per acre). All treatments were made on plots containing five 12 foot rows spaced at 14 inches. The onions were sown on May 27.

The applications of Aero cyanate spray were made on June 5. At this time, the onions had just germinated. The weeds present were stinkweed, wild mustard, and ragweed in the 2 and 4 leaf stages, wild oats in the 2 leaf stage, and perennial sow thistle.

The other pre-emergence applications could not be made until the morning of June 10 because of adverse weather conditions. This treatment followed a light shower, which fell during the preceding evening, and left the surface of the soil moist. The onions at this time were just breaking through the surface of the ground.

In 1951, monosodium cyanamide spray (X5) at 25, 50, and 100 pounds per acre and the isopropyl ester of 2,4-D at 1, 1½, and 2 pounds acid equivalent per acre were applied pre-emergently to onions sown on May 7. The 2,4-D was applied on May 16, eleven days after seeding. X5 was applied on May 18 just as the onions were emerging from the ground.

RESULTS AND DISCUSSION

1. Post-emergent treatments with potassium cyanate.

Experimental results obtained with potassium cyanate in the two years of the trials carried out in 1950 and 1951 were similar with respect to weed control and onion set yield. In 1950, potassium cyanate at 8 pounds per acre burned only the outer leaves of stinkweed and mustard and gave no control. One day after treatment it was noted that with rates of 16 pounds per acre and higher that there was very severe burning of mustard, red root pigweed, and buckwheat. Three days after application, the above mentioned weeds were dead in the plots receiving 24 and 32 pounds per acre. There was a partial kill of ragweed and a very slight burning of the wild oats and sow thistle at these rates. There was no observed injury to the onion plants at any of the rates of application used. In all cases, the difference between the treatments with and without the wetting agent was negligible as determined by inspection of the original data.

The average number of weeds for each treatment, based on four replicates, is given in Table I. It should be pointed out that the figures given include many weed species upon which relatively poor control was obtained. These species included giant ragweed and spotted spurge. These, as well as wild oats and sow thistle, are normally not

Table I. The average number and per cent control of weeds obtained with four rates of potassium cyanate, 1950.

Treatment (pounds per acre)	Without wetting agent[1] Weeds per plot	Per cent control	With wetting agent[2] Weeds per plot	Per cent control
Check	23.75		22.25	
8	18.75	21.0	19.25	13.5
16	11.00*	53.7	15.75	29.2
24	7.50*	68.4	9.25*	58.4
32	10.50*	55.8	7.50*	66.3

*Significantly different from check.
[1]Necessary difference = 5.87 at the 5 per cent level.
[2]Necessary difference = 6.67 at 5 per cent level.

present in onion fields and their control, therefore, is not a problem with the onion grower. The inclusion in the weed counts of the two species, giant ragweed and spotted spurge, tends to make the figures larger than if only the more susceptible weeds had been counted. However, the relative control of weeds obtained with each treatment is apparent.

In 1951, a repetition of the experiment carried out in 1950 yielded very similar results.

It was observed two days after spraying that the 8 pound per acre rate of potassium cyanate caused only very slight burning around the margins of the leaves of stinkweed and mustard. Buckwheat was somewhat more severely injured, but very little killing was evident. Red root pigweed was not affected by the chemical at 8 pounds per acre, and lamb's quarters was not affected at any of the rates. Treatment

at 16 pounds per acre resulted in very severe burning of the larger stinkweed, buckwheat, and mustard. The smaller ones were killed. Red root pigweed appeared quite resistant in the larger stages but was readily killed in the small seedling stage at this rate. There was very slight burning of the onion plants, and this was evident only in the upper ½ to 1 inch of the leaves. At 24 and 32 pounds per acre there was a complete kill of the small mustard, stinkweed, buckwheat, and red root pigweed plants. There was slightly more damage to the onion plants at these rates that at 16 pounds per acre, and this was confined mainly to that part of the onion plant above the crook.

Warm dry winds reaching a velocity of 38 miles per hour seriously damaged the onions in one section of the field 3 days after spraying. It was noted that damage was greater in the treated plots than in the untreated plots.

Weed counts were made on June 6, 1951. The total number of mustard plants and the total number of all weeds remaining in the plots were counted. The averages, based on four replicates, are shown in Tables II and III.

Weed counts, as given in Tables I, II, and III, indicate that all applications of potassium cyanate at 16, 24, and 32 pounds per acre without the use of a wetting agent significantly reduced weed stand when compared with the unweeded checks. When the wetting agent was applied, as seen in Table I, a

Table II. The average number and per cent control of weeds obtained with four rates of potassium cyanate, 1951.

Treatment (pounds per acre)	Weeds per plot	Per cent control
Check	106.75	
8	125.50	-17.6
16	54.25 *	49.2
24	30.00 *	71.9
32	20.00 *	81.3

*Significantly different from check.
Necessary difference = 33.75 at the 5 per cent level.

Table III. The average number and per cent control of mustard plants obtained with four rates of potassium cyanate, 1951.

Treatment (pounds per acre)	Weeds per plot	Per cent control
Check	62.25	
8	54.50	12.5
16	18.50 *	70.3
24	15.50 *	75.1
32	6.25 *	90.0

*Significantly different from check.
Necessary difference = 12.16 at the 5 per cent level.

significant reduction was not obtained at the 16 pound per acre rate. The 8 pound per acre rate, on the other hand, showed no significant amount of weed control in any of the experiments. The amount of weed control increased directly with the amount of potassium cyanate applied. These data could have been analyzed to give more information on the weed killing effect per pound of treatment per plot. This would have involved a lengthy computation a nd the analysis used seems to have provided the desired information. The photographs (Plates 1 to 5 inclusive) very clearly indicate the amount of weed control that was obtained at each rate of the chemical. The plots shown in these photographs received no hand weeding or cultivation from the time of planting until harvest.

Plate 1

Unweeded check plot for comparison with potassium cyanate treatments. Photograph - August 29.

Plate 2

Potassium cyanate at 8 pounds per acre applied on June 11, 1950. Photograph - August 29.

Plate 3

Potassium cyanate at 16 pounds per acre applied on June 11, 1950. Photograph - August 29.

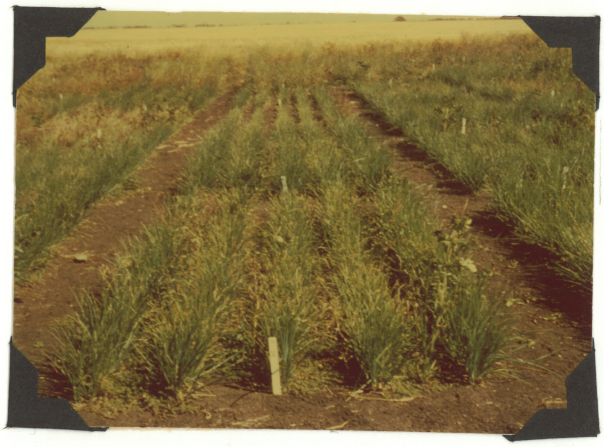

Plate 4

Potassium cyanate at
24 pounds per acre
applied on June 11, 1950.
Photograph - August 29.

Plate 5

Potassium cyanate at
32 pounds per acre
applied on June 11, 1950.
Photograph - August 29.

Several species of weeds which may create a problem in some areas or seasons were not included in this study because of their absence in the experimental plots. One of these is purslane (Portulaca oleracea) which often does not emerge until the latter part of June, about one to two months later than most broad-leaved weeds. For this reason, the use of potassium cyanate may not prove successful for the control of this weed. Likewise, many grasses may pose a serious and additional problem because they respond differently to herbicides than do broad-leaved weeds.

The yields of onion sets in 1950 as seen in Table IV and those in 1951 in Table V were similar and decreased with increasing weed counts. These results were quite consistent with field observations made throughout the year. It will be noted that all plots treated with potassium cyanate yielded less than the weeded check plots except in the 1950 experiment when the 32 pound rate was not significantly different. There was no appreciable weed control at 8 pounds per acre, nor was there any appreciable increase in yield above the unweeded check with the 8 pound treatment. As the main object of this study was to measure the amount of weed control rather than the effect of the chemical upon the onions, the plots were not handweeded at any time. Had hand weeding been combined with the chemical treatments, a more favorable yield picture would, no doubt, have resulted. The

Table IV. The average yield of onion sets in pounds obtained with four rates of potassium cyanate, 1950.

Treatment (pounds per acre)	Yield per plot	Per cent of weeded check
Unweeded check	2.17**	19.7
8	3.49**	31.8
16	6.08*	55.4
24	7.21*	65.7
32	8.25	75.1
Weeded check	10.98	

*Significantly different from weeded check.
Necessary difference = 3.34 at the 5 per cent level.

Table V. The average yield of onion sets in pounds obtained with four rates of potassium cyanate, 1951.

TReatment (pounds per acre)	Yield per plot	Per cent of weeded check
Unweeded check	0.00*	0.0
8	0.00*	0.0
16	7.34*	35.1
24	12.42*	59.4
32	13.39*	64.1
Weeded check	20.90	

*Significantly different from weeded check.
Necessary difference = 4.59 at the 5 per cent level.

yield, therefore, is indicative of the amount of weed control obtained rather than a measure of the injury to the onion plants.

The application of potassium cyanate with a wetting agent at the late date of July 21, 1950, produced some very striking and interesting results. The yield data obtained are presented in Table VI.

Table VI. Average yield of onion sets in pounds obtained from plots receiving a second treatment of potassium cyanate plus a wetting agent, 1950.

Treatment (pounds per acre)	Yield per plot	Per cent of weeded check
Unweeded check	2.18*	24.4
8	2.65*	23.0
16	3.60*	31.3
24	3.49*	30.3
32	5.73*	49.8
Weeded check	11.51	

*Significantly different from weeded check.
Necessary difference = 3.09 at the 5 per cent level.

The chemical in this case showed a high degree of toxicity to onions when compared to similar treatments earlier in the season. The amount of injury to the onions was severe at all rates with the amount of injury proportional to the rate. Burning occurred from the tips down, and 6 days after treatment the onions in plots receiving the 24 and 32 pound per acre rates were burned nearly to the ground. Despite this severe setback, no plants were completely killed. Mustard appeared to be the most susceptible weed. It was defoliated even at the 8 pound per acre rate. Wild buckwheat was somewhat more resistant requiring 16 to 24 pounds per acre to effect a kill. Most other weeds, including giant ragweed, were killed by the 24 and 32 pound per acre rates. The yields of onions harvested from these plots were considerably reduced compared to those from the plots receiving only a single treatment early in the season. The severe injury to

the onion plants from these treatments was reflected in the yield data, Table VI. These show that at all rates the yields were significantly lower than the weeded check. The unusually great toxicity observed in this case may have been due in part to the high temperature and the relatively humid conditions (near 60 per cent) which existed at the time of application.

2. The effect of environment on the amount of injury to onions caused by potassium cyanate.

It was observed in the field that there was a greater degree of injury to the onion plants at the higher rates used in this experiment than there was in the experiment outlined earlier in this report where the object of the experiment was weed control. The injury which appeared at most rates and dates of treatment was in the form of tip burning. Some of the more severe cases of injury resulted in the yellowing of the plants immediately above the ground level and was accompanied by a wilting of the whole plant. The amount of injury appeared relative to the rate of potassium cyanate applied with most injury occurring at the 60 pound per acre rate and the least at the 20 pound rate. The symptoms described were temporary in nature as the plants produced new leaves and continued normal growth in nearly all cases.

Onions treated at the first spraying date, June 9, showed considerable injury at the 60 pound per acre rate on plots of all three planting dates. The onions of the first planting date wilted and became slightly chlorotic; those of the second planting date showed only very slight wilting, but considerable tip burning; and those of the third planting date produced symptoms of tip burning only. There were no onions above 2 inches in height at this time.

Treatments on the second spraying date, June 18, generally showed less injury to the onion plants than did those of the earlier treatment. There was no evidence of injury at the 20 pound per acre rate. However, some injury was evident at both the 40 and 60 pound rates. The only types of injury observed was temporary wilting and slight burning of the tips of the plants.

Treatments at the third date of spraying, June 30, produced injury at all three rates. The 40 and 60 pound per acre rates showed a severe burning of the onion tips along with a wilting of the plants. (Plate 6). Severe chlorosis also developed which appeared several days after spraying. Similar but less severe symptoms were produced with the 20 pound per acre rate of treatment..

The aforegoing discussion is based entirely upon observation of growing plots in the field. Statistical analysis of the yield data is presented below and indicates

Plate 6.

Potassium cyanate applied at 60 pounds per acre on June 30, 1951. Note the burned onion tips and the weeds which were killed by the treatment. Photograph - July 5.

that no significant differences in the yields resulted from any rates of treatment. It must, therefore, be concluded that the observed effects were of a temporary nature.

The average plot yields and the average plot stands are presented in Tables VII and VIII respectively. The analyses of variance for yields and for stands were calculated according to methods outlined by Cochran and Cox (7) and are given in Tables IX and X respectively.

Table VII. Average plot yields of onion sets in pounds obtained with various rates of treatment, spraying dates, and planting dates, 1951.

Spraying date	Planting date	Rates of treatment (lbs. per acre) 20 a.m.	20 p.m.	40 a.m.	40 p.m.	60 a.m.	60 p.m.	Check a.m.	Check p.m.
	May 7	13.11	12.73	11.51	12.40	12.81	13.78	13.67	12.59
June 9	May 14	11.97	12.50	11.50	10.34	11.65	12.63	13.05	11.49
	May 21	10.91	11.20	10.23	10.98	10.77	11.76	9.45	8.56
	May 7	11.96	12.36	13.64	13.19	11.78	14.73	12.22	10.78
June 18	May 14	12.78	12.34	13.42	14.01	13.54	14.76	11.00	10.08
	May 21	11.35	11.33	11.68	13.48	13.83	15.39	11.44	10.84
	May 7	12.78	12.00	12.34	11.70	10.54	11.59	12.37	10.09
June 30	May 14	11.71	10.82	10.81	10.44	8.64	13.67	9.66	9.49
	May 21	12.39	11.01	10.36	9.40	10.64	10.56	10.18	7.11
Ave.		12.11	11.81	11.72	11.77	11.58	13.21	11.45	10.11

An experimental design with 4 replications of a 4 x 3 layout for rates and spraying dates, with the plots split three ways for planting dates and the subplots split two ways for time of day was used.

Table VIII. Average stand of onion plants obtained with various rates of treatment, spraying dates, and planting dates, 1951.

Spraying date	Planting date	Rates of treatment (lbs. per acre) 20 a.m.	20 p.m.	40 a.m.	40 p.m.	60 a.m.	60 p.m.	Check a.m.	Check p.m.
	May 7	625.7	571.3	466.5	503.6	517.5	576.7	719.0	693.0
June 9	May 14	581.4	550.7	610.3	474.6	426.1	540.0	534.7	518.7
	May 21	499.2	473.9	557.1	571.8	475.8	530.7	465.7	442.2
	May 7	592.5	603.3	768.9	699.8	574.1	655.5	671.7	623.5
June 18	May 14	557.2	545.7	582.2	610.1	543.2	531.2	635.5	598.0
	May 21	499.7	473.7	386.4	493.9	480.2	536.7	572.2	533.7
	May 7	652.0	690.1	709.0	716.7	537.5	603.0	616.7	631.5
June 30	May 14	533.9	441.1	598.4	493.7	498.0	606.5	485.0	427.7
	May 21	493.3	429.2	482.6	391.7	477.0	443.2	468.0	376.0
Ave.		559.4	531.0	573.5	550.7	503.3	558.2	574.3	538.3

Table IX. The analysis of variance for onion set yield data (averages of which are given in Table VII).

Source of variation	Sum of squares	D.F.	M.S.	F.
Replicates	327.34	3	109.11	7.03**
Rates (Ra.)	93.21	3	31.07	2.00
Spraying dates (Sp. D)	136.29	2	68.14	4.39*
Ra. x Sp. D	95.52	6	15.92	1.03
Error (a)	496.53	32	15.52	
Planting dates (Pl. D)	74.09	2	37.49	3.10*
Pl. D x Ra.	28.45	6	4.74	.39
Pl. D x Sp. D	43.98	4	10.99	.91
Error (b)	1002.89	83	12.08	
Hour of day (hour)	.33	1	.33	.08
Hour x Ra.	86.93	3	28.98	7.22**
Hour x Sp. D	8.41	2	4.20	1.05
Error (c)	168.38	42	4.01	
Hour x Pl. D	1.67	2	.83	1.12
error (d)	6.63	9	.74	
Residual	285.75	85	3.36	
Total	2875.30	285		

* Significant.
**Highly significant.

It is realized that more information might have been obtained with a factorial analysis both of this data and that for stands in Table X, but it appeared that the analysis of variance as used provided the desired information.

Table X. The analysis of variance for data on stands of onions (averages of which data are given in Table VIII).

Source of variation	Sum of Squares	D.F.	M. S.	F.
Replicates	957,091	3	319.030	10.97**
Rates (Ra.)	49,142	3	16,390	.56
Spraying dates (Sp. D)	120,397	2	60,198	2.07
Ra. x Sp. D	90,760	6	15,127	.52
Error (a)	930,218	32	29,069	
Planting Dates (Pl. D)	1,018,135	2	509,067	11.54**
Pl. D x Ra.	71,555	6	11,926	.34
Pl. D x Sp. D	161,410	4	40,352	1.15
Error (b)	2,904,897	83	34,999	
Hour of day (hour)	312	1	312	.03
Hour x Ra.	122,879	3	40,960	3.94*
Hour x Sp. D	2,170	2	1,085	.10
Error (c)	463,131	42	10,384	
Hour x Pl. D	7,866	2	3,933	2.24
Error (d)	15,739	9	1,749	
Residual	1,140,240	85		
Total	7,593,240	285		

* Significant.
**Highly significant.

The analysis of variance for stand and yield, Tables IX and X, indicate that planting dates produced significant differences in both cases. The yield and stand of onions at the three planting dates are presented in Table XI below.

Table XI. The yield of onion sets and the stand of onion plants obtained from plantings made at three dates.

Planting date	Yield		Stand	
	Total	Average[1]	Total	Average[2]
May 7	1178.96	12.28	59976	624.75
May 14	1129.36	11.76	50945	530.60
May 21	1059.54	11.04*	46217	481.43*

1 Necessary difference = 0.99 at the 5 per cent level.
2 Necessary difference = 53.70 at the 5 per cent level.

The last planting date, May 21, resulted in a yield which was significantly lower than that from the first planting date. The data on stand for the three planting dates shows a somewhat higher degree of significance. In the field it was observed that there was a slightly slower and poorer germination of the later planted onions due to adverse weather conditions. The slight difference in the yields and stands of onions from the three planting dates may be accounted for by this factor. This trend is also evident in the raw data for the untreated check plots. A comparison, therefore, cannot be made from these data of the relative injury by the chemicals for the three different stages of growth of the onions.

In nearly every case, observations made three to four days after treatment indicated that more injury occurred when the onions were treated at 10:00 a.m. than those treated at 8:00 p.m. The analysis of variance of both stand and yield data for these treatments, as shown in Tables IX and X , gave a very low F value, indicating no significance in the differences obtained from the morning and evening treatments. The differences noted, therefore, must have been temporary in nature.

The yields of sets from the third spraying date were significantly lower than the yields from the second spraying date, but not from the first spraying date, Table XII.

Table XII. The yield of onion sets and the stand of onion plants at three spraying dates.

Spraying date	Yield		Stand	
	Total	Average[1]	Total	Average[2]
June 9	1122.58	11.69	51625	537.75
June 18	1203.52	12.53	55070	584.06
June 30	1041.76	10.85	50443	525.44

1 Necessary difference = 1.16 at the 5 per cent level.
2 Necessary difference = 50.16 at the 5 per cent level.

There was a similar trend in the stand data. It can be seen from Fig. 3 that on the third spraying date when there was a maximum reduction in yield the relative humidity was high at the time of spraying. It did not go below 54 per cent on the day of spraying and not below 48 per cent on

the day following. On the other hand, the relative humidity at the time of the first and second spraying dates (Figs. 1 and 2) was relatively low and very similar. There were no significant differences between the yields or stands at these two dates of treatment. The prevalence of a high relative humidity during and following spray application is believed to be a major determining factor in the amount of injury to the onion plants. It should be kept in mind, however, that at the third spraying date the onion plants were considerably larger than they were at the other dates. The fact that there was no uniform trend established to correspond to the increasing size of the plants at each successive spraying date would indicate that the plant size did not appreciably affect the amount of injury.

As mentioned above, it appeared that there was considerably more injury to the onion plants at the higher rates of potassium cyanate. This was not borne out in the analysis of variance. The injury observed in the field may have been of such a temporary nature that all plants recovered so as to cause no reduction in the yield or stand.

3. Pre-emergence treatments.

In the pre-emergent treatments made in 1950, potassium cyanate gave the best control. At both 10 and 20 pounds per acre about 80 per cent control of both mustard and stinkweed

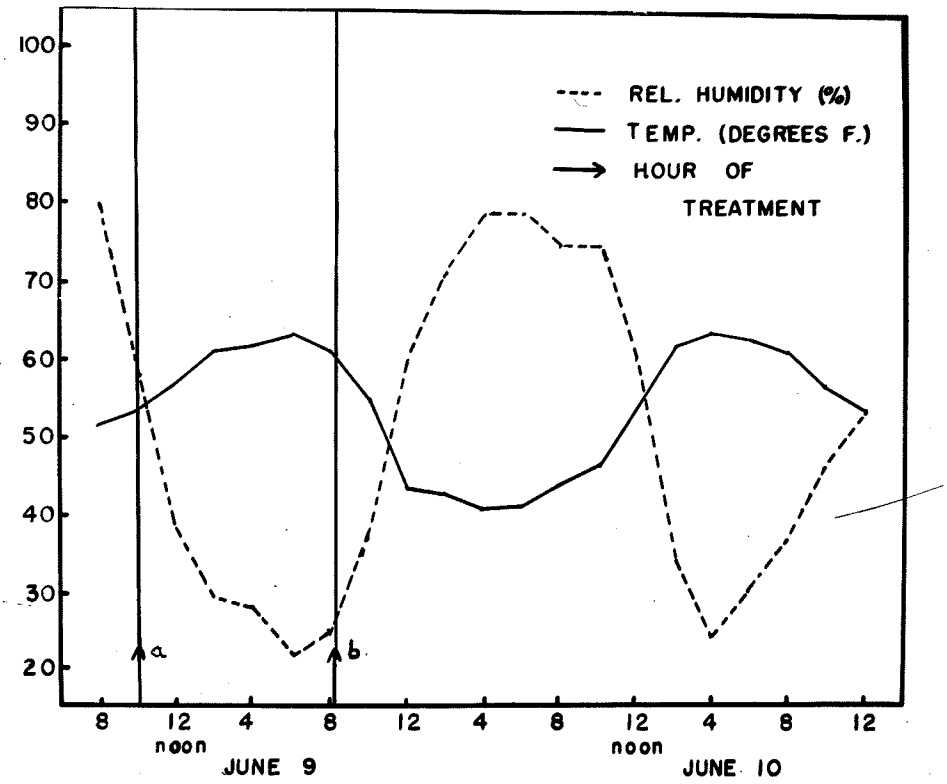

Fig. 1

Relative humidity and temperature for June 9 and 10 showing the hours (a and b) at which spraying was done (first spraying date).

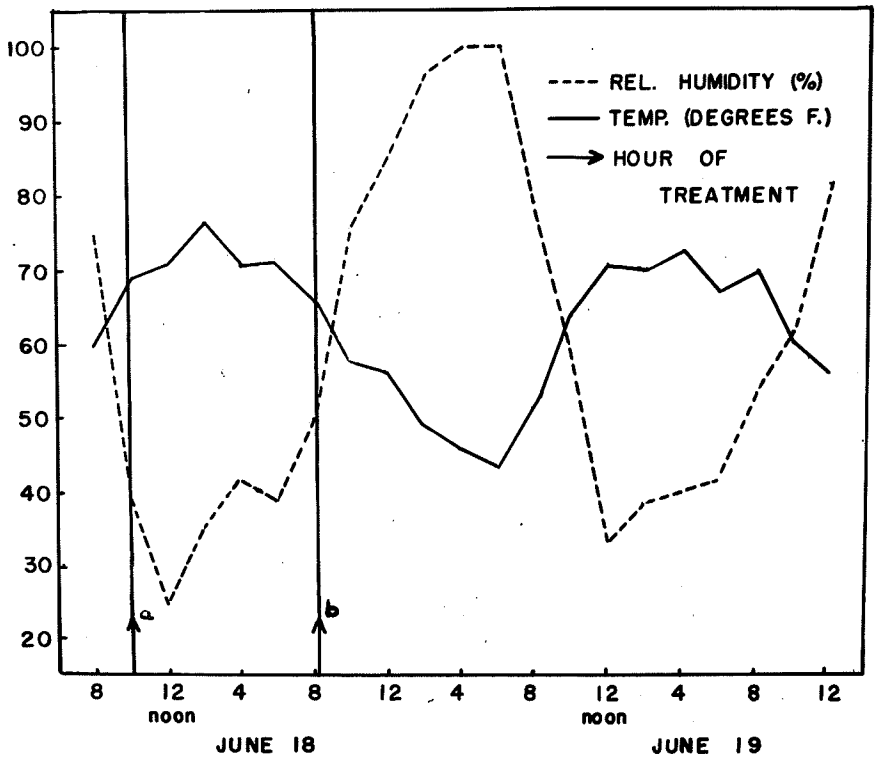

Fig. 2

Relative humidity and temperature for June 18 and 19 showing the hours (a and b) at which spraying was done (second spraying date).

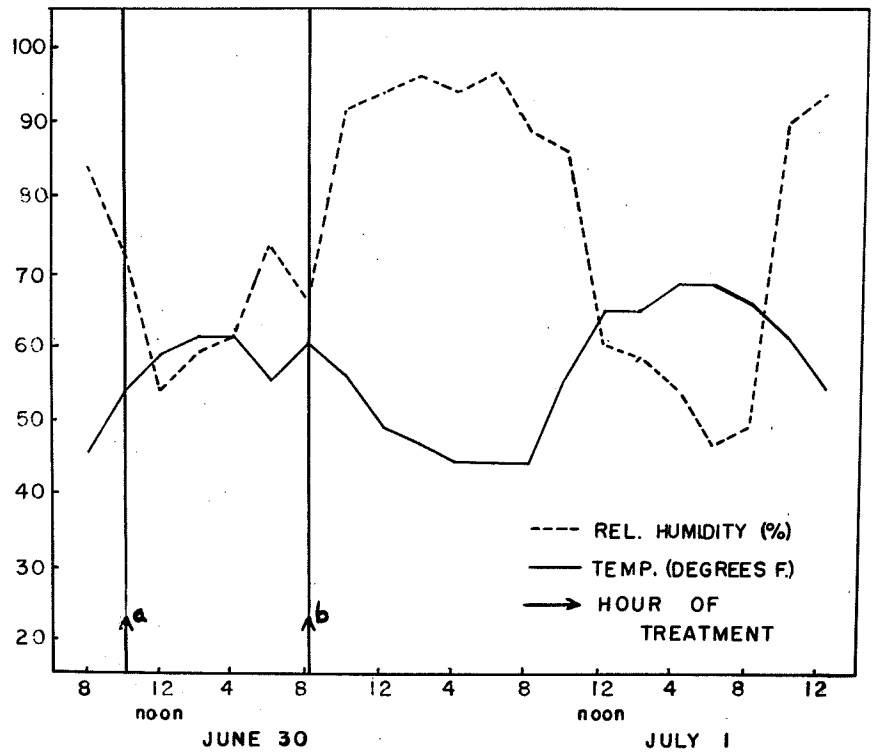

Fig. 3

Relative humidity and temperature for June 30 and July 1 showing the hours (a and b) at which spraying was done (third spraying date).

was obtained. There was no effect on wild oats or sow thistle and only slight burning of the ragweed. There was no apparent injury to the onions. T he 100 and 200 pound treatments of monosodium cyanamide (X10) showed considerable burning of all weeds including wild oats and sow thistle. At 400 pounds all the smaller broad-leaved weeds were killed. Wild oats were severely checked but not killed. Ragweed showed initial injury but later recovered and was quite normal. At this heavy rate there was a very slight burning of the onion tips in some parts of these plots. The calcium cyanamid (special grade), calcium cyanamid granular, potassium cyanate dust, and the mixture of cyanamid (special grade) and IPC showed no effect on either the weeds or the onions.

The onions in the pre-emergence treatments were not carried through to the end of the season because of the heavy infestation of wild oats.

In 1951, pre-emergence treatments both with 2,4-D and monosodium cyanamide spray (X5) showed considerable weed control. 2,4-D at all rates gave excellent control of all broad-leaved annuals for a period of three to four weeks after treatment. Four days after treatment, the onions showed slight foliar distortion and a yellowing of the cotyledon at the ground level. Onion injury was evident all through the growing season, mainly in the form of root retardation and a softening of the bulbs. Green foxtail (Setaria viridis),

which was very abundant throughout the plots, exhibited a very retarded root system and consequently a general reduction in vigor. Very few plants were killed, however, and none produced seed stalks.

Observations made 12 hours after application indicated that the 25 pound per acre rate of X5 produced a spotting and burning of the broad-leaved weeds but with very little kill resulting. Application of 50 pounds per acre gave nearly a complete kill of mustard, red root pigweed, and buckwheat. Treatment at 100 pounds per acre gave results similar to the 50 pound rate but produced slight wilting of the onions. Following the first rain after treatment a severe caking of the soil was observed at both of these rates. There was no apparent residual action from the application of X5. A new crop of weed seedlings emerged 1 to 2 weeks after treatment and quickly enveloped the crop.

SUMMARY AND CONCLUSIONS

In experiments using 8, 16, 24, and 32 pounds per acre of potassium cyanate, the three highest rates gave a significant reduction in the weed stands. The weeds controlled were stinkweed, wild mustard, wild buckwheat, and red root pigweed. From the experiment it would appear that 16 pounds per acre is the lowest rate which will give a significant and satisfactory measure of weed control, and as the cost of potassium cyanate is relatively high this rate would likely prove most economical under Manitoba conditions. Along with "between-the-row" cultivation this rate of treatment should give a satisfactory control of common broad-leaved weeds. Effectiveness of the chemical was greatest when applied to weeds in small seedling stages.

The application of potassium cyanate at rates up to 60 pounds per acre produced no injury to onions as measured by the stand and the yield of sets obtained,

Relative humidity affects the amount of injury to the onion plants. Serious injury to the plants occurred when potassium cyanate was applied during a period of high relative humidity. Although detailed studies were conducted only on onion plants, observations indicated that a high relative humidity also increased the injury and destruction of weed species.

Under the conditions of the experiment, the size of the onion plants at the time of spraying did not influence the degree of injury which resulted from treatment with potassium cyanate.

Applications of potassium cyanate made before 10:00 a.m. produced results which were not significantly different from treatments made at 8:00 p.m.

Pre-emergence treatments using dust materials requiring atmospheric moisture for activation were generally unsatisfactory for weed control. These dusts were difficult to apply because of the excessively dry conditions and the high winds which were encountered in the early spring. Pre-emergence spray treatments of potassium cyanate and monosodium cyanamide gave considerably better control but this was of a temporary nature. 2,4-D gave good control of all weeds but the injury to the onions was excessive at the rates used.

Experiments indicated that potassium cyanate should be applied when the greatest number of weeds are in the early seedling stages, regardless of the stage of growth of the onions.

LITERATURE CITED

1. Alban, E. K. Chemical weed control and vegetable crop production. Ohio Vegetable and Potato Growers Assn. Annual Proceedings.

2. _____ and Keirns, V. E. Pre-emergence and post-emergence weed control in vegetable crops with 2,4-D and oil. Proc. Amer. Soc. Hort. Sci. 51: 526-532. 1948.

3. Andersen, E. T. and Shadbolt, C. A. The use of aero cyanate (potassium cyanate) as a herbicide in onions. Research Report. North Central Weed Control Conference. 6: 128. Dec. 1949.

4. Bakke, A. L. and Staniforth, D. W. Pre-emergence treatments in the control of weeds in onions. Research Report. North Central Weed Control Conference. 6: 129. Dec. 1949.

5. Barnard, E. E., Jr., and Warden, R. L. The effects of sodium isopropyl xanthate on weeds and various vegetable crops. Research Report. North Central Weed Control Conference. 7: 144. 1950.

6. Chappell, W. E. The effect of some weed control practices on the yield and keeping quality of onions. Proc. Amer. Soc. Hort. Sci. 51: 497-500. 1948.

7. Cochran, W. G. and Cox, G. M. Experimental designs. John Wiley and Sons, Inc., New York. 1950.

8. Cockrum, E. E. and Warden, R. L. Post-emergence weed control in onions with Aero Cyanate, NIX, and Exp. Herb. # 1. Research Report. North Central Weed Control Conference. 6: 130. 1949.

9. Crafts, A. S. and Raynor, R. N. Weeding onions. Western grower and Shipper. Aug. 1944.

10. Davis, M. B. Fruits and vegetables. Agricultural Institute Review. 1. No. 5: 311-315. May 1946.

11. Denisen, E. L., Staniforth, D. W., and Bakke, A. L. Onion weed control with chemicals. Research Report. North Central Weed Control Conference. 7: 146. 1950.

12. Grigsby, B. H. Effects of pre-emergence treatments on onion stands and yields. Research Report. North Central Weed Control Conference. 6: 131. 1949.

13. _____. Pre-emergence use of herbicides on onions. Research Report. North Central Weed Control Conference. 7: 149. 1950.

14. Hayes, H. K. and Immer, F. R. Methods of plant breeding. McGraw-Hill Book Company, Inc., New York. 1942.

15. Hedlin, W. A. Chemical weed control in onions (preliminary paper). Proc. Amer. Soc. Hort. Sci. 51: 501-504. 1948.

16. Hernandez, T. T. and Warren, G. F. A comparison of 2,4-D pre-emergence treatments on onions on two soils. Proc. Amer. Soc. Hort. Sci. 56: 283-286. 1950.

17. Lachman, W. H. Weed control in vegetable crops. Mass. Agric. Exp. Sta. Bul. 451. 1948.

18. _____. Some studies using isopropyl n-phenyl carbamate as a selective herbicide. Proc. Amer. Soc. Hort. Sci. 51: 541-544. 1948.

19. _____. Weed control in onions grown from sets. Proc. Amer. Soc. Hort. Sci. 54: 429-434. 1949.

20. Lee, O. C. and Ellis, N. K. Weeding onions with dilute sulfuric acid and other chemical materials. Purdue Agric. Exp. Sta. Circ. 325. 1947.

21. Nylund, R. E. A study of the chemical control of weeds in onions by pre-emergence treatments. Research Report. North Central Weed Control Conference. 7: 155. 1950.

22. _____. A study on post-emergence application of herbicides to onions. Research Report. North Central Weed Control Conference. 7: 154. 1950.

23. Taylor, C. E. Pre-emergence chemical control of weeds in onions. Research Report. North Central Weed Control Conference. 7: 157. 1950.

24. _____. Pre-emergence chemical control of weeds in onions (sets to bulbs) at three rates of Na-2,4-D. Research Report. North Central Weed Control Conference. 7: 158. 1950.

25. Taylor, C. E. Pre-emergence chemical control of weeds in onions (seed to bulbs) at three rates of Na-2,4-D. Research Report. North Central Weed Control Conference. 7: 158. 1950.

26. _____. Pre-emergence chemical control of weeds in onions (seed to sets) at three rates of Na-2,4-D. Research Report. North Central Weed Control Conference. 7: 159. 1950.

27. _____. Time and rate of pre-emergence application of Na-2,4-D to seed onions for weed control. Research Report. North Central Weed Control Conference. 7: 157. 1950.

28. _____. Pre-emergence chemical control of weeds in onions (greenhouse preliminaries). Research Report. North Central Weed Control Conference. 7: 157. 1950.

29. Warren, G. F. The value of several chemicals as selective herbicides for vegetable crops. Proc. Amer. Soc. Hort. Sci. 47: 415-419. 1946.

30. _____, Buchholtz, K. P., and Hernandez, T. P. Preliminary studies on the effects of soil applications of 2,4-D on crop and weed growth. Proc. Amer. Soc. Hort. Sci. 50: 373-382. 1947.

31. _____ and Ellis, N. K. Post-emergence weed control in onions. Research Report. North Central Weed Control Conference. 7: 169. 1950.

32. _____ and Hernandez, T. P. Weed control in certain vegetable crops with soil applications of 2,4-D. Proc. Amer. Soc. Hort. Sci. 51: 515-525. 1948.

33. Westgate, W. A. and Raynor, R. N. A new selective spray for the control of certain weeds. Calif. Agric. Exp. Sta. Bul. 634. 1940.