SELECTIVE CHEMICAL WEED CONTROL STUDIES WITH CANNING PEAS

by

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INTRODUCTION

Many chemicals are currently in use as selective weedicides in several crops but relatively few are suitable for use in peas. The present recommendation for the control of broad-leaved annual weeds in peas grown in Manitoba is the application of Sinox at 3 quarts per acre in 80 gallons of water (34). The high volume of water required for effective application of this chemical presents a serious problem in some parts of this province where water is not readily available. Lesser disadvantages are the objectionable staining property of this chemical, the large, heavy equipment required for its application and the erratic results sometimes encountered. A study was initiated in 1951 to evaluate other weedicides in relation to Sinox and to determine possible advantages which they might possess when used in peas.

Successful weed control is essential for economical production of peas in this area. It has been estimated that wild mustard alone may increase the tonnage to be vined as much as 30 to 50% (11). Aside from the serious decrease in yields, weeds greatly increase the time, labor, and the expense of harvesting peas (30). With the expansion of the canning industry in Manitoba any improvement in the cultural management of this important canning crop would be of much value to the growers.

The four weedicides listed below were selected for this study due to the promising results reported with them in other areas:

MCP ------ 2-methyl-4-chlorophenoxy acetic acid, commercially known as Methoxone, Agroxone, or Chloroxone.

DNOC ----- Dinitro-ortho-cresylate, commercially known as Sinox.

KCNO ----- Potassium cyanate, commercially known as AERO cyanate.

$NaHCN_2$---- Monosodium cyanamide, commercially known as X-5.

This plot work was carried out during the two growing seasons of 1951 and 1952. In both years, the same two varieties of canning peas, Pacemaker and Early Perfection, and the same chemical formulations were used.

LITERATURE REVIEW

A number of investigators have reported on various chemicals for the control of weeds in peas. Out of a relatively large number of chemicals and compounds only a few have been reported to be satisfactory. Many weedicides produce undesirable effects either on the crop or the soil, or are difficult or dangerous to handle. Others require a rather specific set of conditions before desirable results can be obtained.

Westgate and Raynor (33) in 1940 reported on "... a non-corrosive, relatively non-hazardous selective herbicide used for controlling certain common broad-leaved annual weeds..." in peas. This weedicide, Sinox (sodium dinitro-o-cresylate), was demonstrated in France in 1933 to 1937, to have weed killing properties. It was first used in the United States in Oregon and in California in 1938. Barrons and Grigsby (2) and Robbins et al (25) advise caution in the use of dinitro compounds because they are toxic to humans. Persons using Sinox should avoid breathing the spray mist or having prolonged skin contact.

Harris and Hyslop (14) in 1942 found that Sinox was superior to other chemicals in current use for the control of weeds in field crops. They also studied the use of a fertilizer along with the herbicide and noted that the addition of ammonium sulphate increased the effectiveness of Sinox.

The effects of the addition of ammonium sulphate as an activator in Sinox were studied by Crafts (8) at Davis, California and by Barrons and Grigsby (2) in Michigan in 1944. Reductions in pea yields were reported by these workers when Sinox was used at the recommended rates with the addition of the activator. However, without the activator, yields from Sinox treated plots were not significantly reduced. They also noted that weather conditions at the time of spraying, and several hours afterwards, seriously altered the tolerance of the peas to this chemical. Best results were obtained when the temperature was about 70°F. and when the relative humidity was high. They recommended the use of nozzles giving a coarse fan-shaped spray at relatively low pressures to lessen the extent of wetting the foliage of the peas. In Wisconsin, Warren (31) also observed injury to peas when the above activator was used.

Litzenberger *et al* (22) at Bozeman, Montana recommend 1 gallon of Sinox and 2 pounds of ammonium sulphate in 100 gallons of water applied at the rate of 80 gallons per acre. These rates were also recommended for the control of weeds in peas grown in Manitoba (34). Warren and Buchholtz (32) in reporting injury to peas caused by Sinox with the activator summarize results to date as follows:

> "This is in agreement with the results reported by Barrons and Grigsby [2] and Warren [31]. On the other hand Harris and Hyslop [14] and Litzenberger *et al* [22] reported good results on peas using an activator with

> similar concentrations of Sinox. The greater success obtained by these latter workers may be due to the generally drier weather conditions under which they worked."

A similar compound which has shown promise for the control of weeds in peas is DNOSBP, dinitro-ortho-secondary-butyl phenol. Significant yield increases were reported by Dearborn (10) when he used DNOSBP (Dow Selective Weed Killer) to control weeds in peas. Barrons and Grigsby (2) reported on the use of DNOSBP (G506) and found that this chemical gave larger yield increases than Sinox. They recommended that this compound be used at 3 pints per acre per 100 gallons of water. Warren and Buchholtz (32) using similar rates of the ammonium salt of DNOSBP (Dow Selective Weed Killer) obtained significant yield increases over untreated plots and slightly greater yields than with Sinox. They concluded that greater injury resulted with Sinox causing slightly lower yields. Warren (31) working in Wisconsin reported that Sinox caused more injury to peas than G506. Roberts and Woodford (26) working in England found that this dinitro compound was more toxic to weeds than DNOC (Sinox). Furthermore, they claimed that toxicity of DNOSBP was affected more by weather conditions than DNOC. The effects of temperature on the efficiency of this herbicide had previously been noted by Barrons and Grigsby (2).

Leefe (21) working in Nova Scotia reported that the ammonium salt of DNOSBP at the rates of 1½ and 3 quarts per acre gave excellent control of weeds when hot, dry weather followed the treatment.

Dearborn (11) used two preparations of DNOSBP, Sinox W and Dow Selective Weed Killer, and recommends the use of the latter at 7 pints in 70 gallons of water applied with a power sprayer at 50 pounds pressure. He obtained excellent kill of common broad-leaved annual weeds with a significant increase in pea yields. Leefe (21) reported that the amine salt of DNOSBP (54%) resulted in a weed-free condition in treated plots right up to harvest time.

Crafts (8) studied six different dinitro compounds and noted that DNOSBP had the greatest toxicity to weeds. Robbins et al (25) explain how rates of dinitrophenolic compounds may be adjusted upward or downward according to the temperature.

Selective chemical weed control in crops made sudden and rapid advances with the introduction of hormone type weed killers early in 1940. Slade et al (27) tested, in November 1941, thirty-two substituted phenoxy acetic acids for the suppression of wild mustard in crops. They found that 4-chloro-2-methyl-phenoxy acetic acid (MCP) was one of the most active. They also found, in 1943 field trials, that MCP at 1 pound per acre gave excellent results. They noted that "the substance appears to persist in the soil for several weeks."

In 1944 USDA scientists (24) suggested the use of a growth regulating substance, 2,4-dichlorophenoxy acetic acid, as a selective herbicide in field crops. Marth and Mitchell (23) and Hammer and Tukey (13) successfully used 2,4-D in spraying field crops for the control of weeds.

MCP and 2,4-D have been applied to a great number of plants at different levels of concentration and their value as weedicides with certain crops is well established.

The effects of 2,4-D on peas was described by Spangelo (28) from an experiment carried out in 1946 at the University of Manitoba. When the peas were three to six inches tall they were sprayed with 2,4-D at 0.10, 0.23, 0.53, and 1.20 pounds per acre. Recovery was complete with no yield reductions at the three lower levels of concentrations. However, when 2,4-D was applied at a later stage reductions in yield were obtained with all rates.

Dearborn (11) obtained satisfactory results using 2,4-D amine at 0.25 pound per acre applied at emergence of the peas. Taylor (29) observed that pre-emergence application of 2,4-D at 1, 2, and 3 pounds per acre resulted in basal distortion of the pea vines.

Birt (3) reported on the use of MCP and 2,4-D both applied at 6 ounces per acre on field peas in 1950. MCP had no adverse effect on yield whereas 2,4-D caused thinning and stunting of the crop. Buchholtz in 1950 (5) and again in 1951 (6) reported that MCP was less toxic on peas than 2,4-D when sprayed post-emergently at the rates of 0.125, 0.25, and 0.50 pounds per acre. The amine preparation was used in both years. He observed that tenderometer readings remained unaffected only at the lowest rate. All other rates gave significantly lower readings indicating a delayed maturity. These two reports are contradictory to an earlier report by the same author (4) in which these two chemicals were applied post-emergently at the rate of 0.25 pounds per acre. In that report he states that "by grouping the sodium salt and amine preparations of 2,4-D and MCP it was shown that those [plots] treated with 2,4-D yielded significantly better than those treated with MCP." Ahlgren et al (1) in 'Principle of Weed Control' states that 2,4-D applied either as a pre- or post-emergence spray is too harmful to use on peas.

Some effects of 2,4-D in the soil and upon the roots of certain crops were reported by Carlyle and Thorpe (7) in 1947. They studied the Rhizobium bacteria on beans, peas, red clover and alfalfa as affected by 2,4-D and reported:

> "Hence it would appear that deleterious effects on the symbiotic relationship is apparent by a reduction or inhibition of nodulation caused largely by the action of the herbicide [2,4-D] through the medium of the plant.
> ....
> The results suggest that ordinary field application of the herbicide would probably be harmful to these legume crops.
> ....

> Results...reveal that 2,4-D salts present in the soil solution at the rate of 0.5 ppm (0.21 pound per acre) would seriously restrict germination, limit growth and practically inhibit nodulation of these four legumes."

Ling Lee (18) reports that 2,4-D tends to disappear from the soil more quickly than MCP.

The value of an herbicide having crop fertilizing effects has prompted many research workers to include calcium cyanamide in their tests. This compound ($CaCN_2$) contains about 21% nitrogen which becomes available to plants when sufficient moisture is present. The lime (CaO) which is also released may be beneficial for the improvement of acid soils. However, under limited moisture conditions, such as provided by heavy dews or light drizzle, toxic and herbicidal intermediate compounds such as calcium dicyandiamide and nitrites are produced (16).

Dearborn (11) used aero cyanamid ($CaCN_2$) at the rate of 100 pounds per acre in 1947 and 75 pounds per acre in 1948. Excellent control of weeds was obtained in 1947 but only partial control was obtained in 1948. Damage to peas was noticed in both years but yields were observed to be similar to those of untreated plots. Ferguson and Jasmin (12) used pulverized $CaCN_2$ at three stations, Smithfield, Ontario, L'Assomption, Quebec, and Kentville, Nova Scotia, with conflicting results during 1949, 1950, and 1951. Taylor (29) in British Columbia and Leefe (20) in Nova Scotia both noticed a reduction in weeds and an increase in pea yields when granular $CaCN_2$ was used pre-emergently and observed, in making weed counts one week after the emergence of the peas, that 100% control was obtained. However, these same plots were weedy at harvest time. Pea yields were significantly higher in the treated plots. Vittum and Paterson (30) at Geneva, New York in 1950 reported satisfactory weed control in peas with 250 to 300 pounds per acre of granular cyanamide.

Dearborn (11) used potassium cyanate in 1949 at 8, 10, 12 and 14 pounds per acre applied post-emergently for the control of weeds in peas. Excellent results were obtained at the 12-pound-per-acre rate whereas the 8 pound rate was considered too low for effective control. Leefe (21) reported using potassium cyanate (KCNO) at 21 pounds per acre applied post-emergently. Poor results were explained by the fact that hot dry weather which followed the application of the herbicide probably rendered this rate ineffective. Howat (17) used KCNO at the rates of 15, 20 and 30 pounds per acre. Although the highest rate injured the lower leaves of the peas good control of weeds was obtained at all levels of concentration.

Since calcium cyanamide is applied in a dry state and is dependent upon moisture for its activation its effective usage is related to moisture conditions. On the other hand, monosodium cyanamide (X-5), an analogous product, may be effectively applied in a spray form. Leefe (11) used this compound at 50 pounds per acre applied post-emergently and found that this material gave good control of weeds with a significant increase in yield.

Numerous other chemicals have been tested for use as herbicides in peas. Many have already been discarded as ineffective or impractical. Many are presently in the process of evaluation.

MATERIALS and METHODS

A double split-plot design as outlined by Cochran and Cox (9) was used to evaluate the effects of four chemicals, MCP, DNOC, KCNO, and $NaHCN_2$. The plots were split for the chemicals and doubly split for the rates of concentrations used on two varieties of peas, Pacemaker and Early Perfection.

The sodium salt of MCP was applied pre-emergently at the rates of 1, 2, and 3 pounds per acre in 50 gallons of water. DNOC was applied post-emergently at the rates of $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ quarts per acre in 80 gallons of water. Ammonium sulphate was used as an activator by mixing it with the stock solution at the rate of 2 pounds per acre. KCNO at 8, 16, and 24 pounds per acre and $NaHCN_2$ at 16, 32, and 48 pounds per acre were both applied post-emergently in 50 gallons of water. For each chemical two non-sprayed checks were maintained; one uncultivated and the other was hand weeded at weekly intervals.

The experiments were conducted on Riverdale silty clay soils at the University of Manitoba.

The regular practice of seeding canning peas with a grain drill was followed in these experiments. Thus the rows were spaced six inches apart and the seeds were spaced at about one to one and a half inches with Pacemaker and one and a half to two inches with Early Perfection. The seed had previously been treated with Ceresan. Just previous to sowing, Nod-o-gen, a pea nodule-forming inoculum, was mixed with the peas.

A knapsack sprayer with a small brass auxillary side tank was used to make all applications. A stopcock in the hose line connecting the two tanks made it possible to fill the side tank without losing pressure in the main tank. The pressure used was thirty pounds per square inch and the nozzle used was (Teejet) 8007.

Procedure in 1951.

On May 10, both varieties were sown at a depth of two inches. Soil conditions were considered excellent with ample moisture below one inch.

Individual plots consisted of eleven rows, fourteen feet long giving an area of seventy-seven square feet. Each treatment was replicated four times with each variety.

On May 19, one to two days before emergence of the peas, MCP was applied. The soil surface was dry and the highest temperature registered for that day was 78°F. At the time of application very few weeds were present. On June 6, weed counts in check plots revealed that the predominant weeds were: red root pigweed *Amaranthus retroflexus* L., wild buckwheat *Polygonum convolvulus* L., lamb's quarters *Chenopodium album* L., green foxtail *Setaria viridis* L., stinkweed *Thlaspi arvense* L., and wild mustard *Brassica arvensis* (L.) Rabenh.

On June 11, DNOC, KCNO, and $NaHCN_2$ were applied to the plots. The maximum temperature for the day was 73°F. and the lowest was 41°F. On June 12, the maximum registered was 78°F. At the time of spraying, Pacemaker was seven inches tall whereas Early Perfection was six inches tall. The predominant weeds in the plots were: red root pigweed, green foxtail, wild buckwheat, lamb's quarters, boxelder Acer Negundo L., and wild mustard.

The variety Pacemaker was harvested on July 13, and Early Perfection on July 18. The plots were harvested by pulling both weeds and pea plants. Weeds were then separated from the peas and the total green weight of weeds per plot recorded. Filled pods were then removed from the pea vines, shelled in a small mechanical pea sheller and the weights of peas recorded for each plot. To determine whether the treatments affected the maturity of the peas a hand refractometer was used to obtain sugar readings from five random samples for each plot.

Procedure in 1952.

The experiment was carried out in the same manner as in 1951 with the exception that plot size was reduced from seventy-seven to forty square feet.

Due to the abnormally dry spring conditions, seeding was delayed until rain improved moisture conditions. Both varieties of peas were sown on June 4.

Pre-emergence applications of MCP were made on June 11, one to two days before emergence of the peas. The temperature for that day registered a high of 75°F. Very few weeds were present in the plots. Precipitation data show that the month of May was unusually dry and June unusually wet (see Appendix). Because of the high precipitation during the latter part of June the post-emergent treatments were delayed a few days. The precipitation data (see Appendix, Table 2) show that in the interval between the pre-emergent and post-emergent treatments a total of 6.89 inches of rain was recorded at the University of Manitoba.

On July 3, DNOC, KCNO, and $NaHCN_2$ were applied. Plots were extremely muddy at that time, and in some, water was still standing. A maximum temperature of 78° F. and a minimum of 55° F. were registered on that day. On July 4, the maximum was 85° F. and on July 5, 90° F. At the time of application the peas were at varying heights; on drier grounds, Pacemaker plants ranged up to eight inches in height, whereas in flooded areas, Early Perfection plants were dwarfed to four inches. Few weeds were present at the time of application of the post-emergent chemicals. However, during the period immediately following the treatments weed growth became very active.

Hand cultivation of one of the two check plots was not attempted in 1952 partially due to the unusual weather conditions.

At harvest time the predominant weeds in the check plots were: red root pigweed, lamb's quarters, maple-leaved goosefoot <u>Chenopodium hybridum</u> L., stinkweed, and barnyard grass <u>Echinochloa crusgalli</u> (L.) Beauv.

Two replications of each of the varieties of Pacemaker and Early Perfection located on slightly higher ground were harvested on July 25 and on August 6 respectively. The other two replications which were located on slightly lower ground, were considered too severely damaged to warrant harvesting by the usual method. Only the weights of the weeds and of the entire pea plants from each plot were recorded.

RESULTS and DISCUSSION

Experiment in 1951.

The results from the 1951 trials indicated that each of the four chemicals used gave good control of weeds, particularly at the higher rates of application. Table I, the analysis of variance for pea yields, indicates that replications were not significantly different. This fact, coupled with a low coefficient of variability obtained, suggests that this experiment was relatively free from any apparent disturbing influences.

Table I

The Analysis of Variance for Pea Yields, 1951.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	3	20.23	2.19	9.01	28.24
Varieties	1	433.62	47.05**	10.13	34.12
Error (a)	3	9.22			
Chemicals	3	.79			
Chem. X Var.	3	.87			
Error (b)	18	2.48			
Rates	4	4.93	4.12**	2.46	3.51
Rates X Var.	4	.37			
Rates X Chem.	12	1.77	1.47	1.85	2.36
Rates X Var. X Chem	12	1.19			
Error (c)	96				
Total	159				

** Highly significant
Coefficient of variability ---- 12.7%

It may be observed from Table I that variation due to varieties was highly significant. This fact may be explained in that Early Perfection generally outyields the earlier variety, Pacemaker. The two main features to be noted from Table I are that differences due to chemicals were far from being significant and that variations due to rates exceeded the 1% probability level. The significant differences caused by rates of treatment may be explained by the fact that the highest rate of some of the chemicals substantially injured the peas.

The effects on yield of the chemicals at different rates of application may be studied in some detail in Table II.

Table II

The Combined Average Yields of Two Varieties of Peas in Pounds per Plot for Three Levels of Treatment with Four Chemicals, 1951.

Chemicals	Check weed-free	Check uncultivated	Levels of treatment 1	2	3
MCP	9.21	8.55	8.56	8.52	8.96
DNOC	9.05	7.90	9.20	8.96	7.82
KCNO	8.59	8.41	8.62	8.92	7.69
$NaHCN_2$	9.45	8.86	8.47	8.10	7.55

Necessary difference for rates within any one chemical
P.= 0.05 ----0.95
P.= 0.01 ----1.26

The necessary differences when applied to this table indicate that the reduction in yield between treatment with $NaHCN_2$ at 48 pounds per acre (level 3) and its two checks was highly significant. The slight reductions obtained with DNOC at 3½ quarts per acre (level 3) and KCNO at 24 pounds per acre (level 3) were not significant when compared to their uncultivated checks. However, DNOC at 3½ quarts per acre was significantly lower than that of its weed-free check. It may also be observed from Table II that the different levels of treatment with MCP and KCNO did not significantly affect yields.

Data for weed weights for 1951 were imcomplete due to a number of missing plots. These were calculated by a method devised by Yates (15) for estimating missing plots. The following analysis of variance was thus made possible.

Table III

The Analysis of Variance for Weed Weights, 1951.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	7	98.70	4.44**	2.49	3.65
Chemicals	3	92.42	4.15*	3.07	4.87
Error (a)	21	22.24			
Rates	3	244.80	18.60**	2.73	4.06
Rates X Chem.	9	13.16			
Error (b)	76				
Total	119				

* Significant
** Highly significant
Coefficient of variability ----- 82.5%

From Table III it may be seen that differences due to replications were highly significant. This is probably due to the fact that the weed population was extremely variable in type, density, and vigor in various parts of the field. The extremely high coefficient of variability obtained from Table III verifies the heterogeneity and inconsistency of the weed population apparent in the plots.

The principal features to be noted from Table III are that chemicals and rates were found to be significant at the 5% and 1% levels, respectively. In other words, the four chemicals were significantly different in their effectiveness, and that the differences due to rates used were highly significant.

The relative effectiveness of the different treatments may be seen in Table IV.

Table IV

The Average Weight of Weeds in Pounds per Plot Obtained with Four Chemicals, Each at Three Levels of Concentration, 1951.

Chemicals	Levels of treatment			
	0	1	2	3
MCP	7.31	1.76	.91	.96
DNOC	7.30	2.52	2.61	2.52
KCNO	7.29	5.01	3.45	3.11
$NaHCN_2$	12.14	6.95	3.82	3.97

Necessary difference for rates within any one chemical
P. = 0.05 ----- 3.68
P. = 0.01 ----- 4.90

Due to a local infestation of false ragweed _Iva xanthifolia_ Nutt., the weight of weeds recorded for one of the check plots for $NaHCN_2$ was unusually high which in turn affected the average for this treatment as seen in Table IV.

By applying the necessary differences to Table IV it is shown that all treatments, with the exception of KCNO at 8 pounds per acre (level 1), had a significant effect on the weights of weeds, causing a reduction when compared to their respective checks. Field observations during the season indicated that the lowest level of KCNO was inadequate for effective control of weeds. The excellent control obtained with the pre-emergent treatments of MCP, even at the 1-pound-per-acre rate (level 1), is of considerable interest. The 2-and 3-pound per-acre rates (levels 2 and 3) gave the best average control of weeds. The 3-pound-per-acre rate was no better than the 2-pound rate in providing effective control of weeds.

Observations made soon after the application of MCP revealed that the peas were unaffected by the treatment as they emerged. However, a few peas which were located in shallow furrows and which had visibly emerged at the time of application were affected by the chemical. Photographs taken on May 28, 1951 show the typical injury which was in the form of elongation, thickening and whitening of the stem. Normal leaves did not develop until the pea plants were about two inches tall. (See Plate I). This injury was of a temporary nature only since the affected plants appeared to have recovered at blooming time.

Plate I

Pea Plants Showing the effect of MCP at 3 pounds per Acre. In the first photograph the pea plants at the left and right show MCP injury. Note the thickened white stem and the vestigial leaves. The second photograph is a close up view of the affected pea plants.

The effects of MCP on weeds were not immediately discernible. A few days after the date of treatment, stinkweed, wild buckwheat, and lamb's quarters became twisted and deformed. Green foxtail was apparently unaffected. Two weeks after treatment, the degree of deformity and stunting of the weeds was observed to be in proportion to the level of concentration of the herbicide used. By the middle of June all plots treated with MCP were relatively weed-free.

The effects of the post-emergent chemicals, DNOC, KCNO, and $NaHCN_2$ applied on June 11, were noticeable on the weeds soon after application. The type of injury caused to peas by KCNO and $NaHCN_2$ treatments is shown in Plate II and in Plate III respectively.

Plate II

Pea Plants Showing the Effect of KCNO at 24 Pounds per Acre. Note the yellowish-brown areas of the lower leaves and stipules.

Plate III

Pea Plants Showing the Effect of $NaHCN_2$ at 48 Pounds per Acre. Note the yellowish-brown areas on the lower leaves and stipules.

With both chemicals the injury was in the form of marginal necrosis of the basal leaves which later affected pea yields.

DNOC at 3½ quarts per acre (level 3) caused light speckling on the older and basal leaves of the pea plants. Although this injury appeared light it nevertheless affected pea yields. Good control of stinkweed and pigweed with severe injury to wild buckwheat resulted with all DNOC treatments. Lamb's quarters appeared only slightly affected and green foxtail was unharmed.

Observation of the KCNO-treated plots two days after treatment revealed that the 8-pound-per-acre rate (level 1) caused only slight injury to the weeds. With the 16-pound-per-acre rate (level 2), injury was more evident and a complete kill of wild mustard, wild buckwheat and boxelder resulted. The highest rate, 24 pounds per acre (level 3), gave an excellent kill of all broad-leaved annual weeds.

Observation of the $NaHCN_2$ treated plots two days after treatment indicated that the 16-pound-per-acre rate (level 1) caused only speckling and spot burning of the leaves of stinkweed, wild mustard, and pigweed. The 32-pound-per-acre rate (level 2) destroyed wild buckwheat and stinkweed and the 48-pound-per-acre rate (level 3) effectively controlled most broad-leaved annual weeds.

A final field observation was made at the time that the peas started to bloom. The MCP-, DNOC-, and KCNO-treated plots appeared normal when compared to their checks. Plots treated with $NaHCN_2$ at 32 and 48 pounds per acre (levels 2 and 3, respectively) could be detected from a distance by the stunted plants and the light green color of the pea foliage. Furthermore, there was a lesser amount of bloom in the plots that received the highest rate of $NaHCN_2$.

The analysis of variance on sugar readings revealed that replications, varieties, chemicals, and rates of application were not significant. This may be seen in Table V.

Table V

The Analysis of Variance for Sugar Readings, 1951.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	1	5.05	24.04	161.0	4052.0
Varieties	1	18.72	89.14	161.0	4052.0
Error (a)	1	.21			
Chemicals	3	.12			
Chem. X Var.	3	.54			
Error (b)	6	.68			
Rates	4	.65	2.03	2.67	3.97
Rates X Var.	4	.15			
Rates X Chem.	12	.18			
Rates X Var. X Chem.	12	.32			
Error (c)	32				
Total	79				

Coefficient of variability ----- 3.9%

Because of a relatively large number of missing plots in one of the varieties only two replications of each variety were used in the analysis of variance as shown in Table V. The extremely low coefficient of variability obtained from Table V indicates a high degree of accuracy in sampling and suggests that none of the treatments used under the conditions of the experiment significantly affected the maturity of the peas.

Experiment in 1952.

Due to weather conditions which caused considerable damage to a portion of the experimental plots, two methods of harvesting were carried out in 1952. These are described on Page 16 under Materials and Methods. One analysis of variance was performed on weights of shelled peas and another was carried out on the data obtained for weights of whole pea plants. Two replications of each variety were used in each method of harvest as shown in Table VI and in Table VII.

Table VI

The Analysis of Variance for Shelled Peas, 1952.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	1	37.52	3.75	161.0	4052.0
Varieties	1	21.45	2.15	161.0	4052.0
Error (a)	1	9.99			
Chemicals	3	.47			
Chem. X. Var.	3	2.11	2.73	4.76	9.78
Error (b)	6	.77			
Rates	4	.88	7.13**	2.67	3.97
Rates X Var.	4	.04			
Rates X Chem.	12	.19	1.53	2.07	2.80
Rates X Var. X Chem.	12	.12			
Error (c)	32				
Total	79				

** Highly significant
Coefficient of variability ----- 16.5%

Table VI shows that differences in replications, varieties, and chemicals were not significant. However, rates exceeded the 1% probability level. This is similar to the results obtained in 1951 (See Table I, page 17).

Table VII

The Analysis of Variance for Whole Pea Plants, 1952.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	1	101.25	1.16	161.0	4052.0
Varieties	1	104.65	1.21	161.0	4052.0
Error (a)	1	87.15			
Chemicals	3	7.54			
Chem. X Var.	3	22.01			
Error (b)	6	52.35			
Rates	4	18.32	3.62*	2.67	3.97
Rates X Var.	4	1.90			
Rates X Chem.	12	5.37	1.06	2.07	2.80
Rates X Var. X Chem.	12	5.06			
Error (c)	32				
Total	79				

* Significant
Coefficient of variability ----- 33.0%

It may be seen that Table VII yielded similar information to that of Table VI with the exception that rates were significant at the 5% level instead of the 1% level. Since both tables yielded similar information it was thought that they should be combined for greater accuracy. Bartlett's Chi-square test for homogeneity, as described in Hayes and Immer (15), was applied to test the homogeneity of the calculated error variances of the two methods of harvest. The variances were found to be heterogeneous, which indicates that they can not be statistically combined into one analysis of variance. Since the coefficient of variability for shelled peas (Table VI) is less than that of whole pea plants (Table VII) the former may be expected to give the more reliable information. Therefore, discussion of the 1952 results will be based entirely on shelled pea weights.

The effects of the different treatments are summarized in Table VIII for further study.

Table VIII

The Combined Average Yields of Two Varieties in Pounds of Shelled Peas for Three Levels of Treatment with Four Chemicals, 1952.

Chemicals	Check uncultivated	Levels of treatment 1	2	3
MCP	2.47	2.15	1.69	1.38
DNOC	2.35	2.63	2.34	2.36
KCNO	2.40	2.29	2.16	2.09
$NaHCN_2$	2.43	2.25	2.09	1.97

Necessary difference for rates with checks within any one chemical P. = 0.05 ----- 0.46

This table shows that the higher rates of MCP and $NaHCN_2$ significantly reduced yields of peas when compared with their respective checks. It is interesting to note that progressive yield reductions occurred as the rate of MCP increased. The 1951 results showed no such relationship between yield and rates of application of MCP. The excessively high precipitation which occurred in 1952 soon after the application of MCP may possibly explain this difference. During the period of high rainfall it is presumed that some of the chemical leached down to the pea rhizosphere and there, interfered with the normal development of the pea plants by affecting ~~its~~ their roots and nodulation. This assumption is based upon the fact that MCP is similar to 2-4,D and possibly the effect is comparable to that described by Carlyle and Thorpe (7). This might explain why plots treated with the highest rate of MCP were delayed in blooming and were slightly stunted when compared to the checks.

The post-emergent weedicides, DNOC, KCNO, and $NaHCN_2$, which were applied on July 3, appeared more toxic to the peas in 1952 than in the previous year. This fact may also be attributed to the weather. The peas appeared succulent and weak due to flooding thus possibly rendering them more susceptible to chemical injury.

The weed infestation was lighter in 1952 than in 1951. This fact was possibly due to the spring drought and the effects of flooding at the end of June.

Weed weights obtained in 1952 were analyzed as shown in Table IX.

Table IX

The Analysis of Variance for Weed Weights, 1952.

Source of variance	D.F.	M.S.	F.	5%	1%
Replications	7	47.62	12.56★★	2.49	3.65
Chemicals	3	28.07	3.41★	3.07	4.87
Error (a)	21	3.79			
Rates	4	34.55	19.32★★	2.45	3.49
Rates X Chem.	12	1.79			
Error (b)	112				
Total	159				

★ Significant
★★ Highly significant
Coefficient of variability ----- 56.6%

The analysis of variance carried out for weed weights indicated that variations due to replications were highly significant. This may be attributed to similar factors as those which affected the 1951 weed results with possibly the added effects of flooding. Reductions in weed weights as affected by the various chemicals were found to be significant at the 5% level as seen in Table IX. This is similar to that of the previous year as shown in Table III. Similarly, in both years the 1% probability level for rates was exceeded.

The effectiveness of the treatments may be seen in Table X.

Table X

The Average Weight of Weeds in Pounds per Plot Obtained with Four Chemicals, each at Three Levels of Concentration, 1952.

Chemicals	Levels of treatment			
	0	1	2	3
MCP	6.00	1.30	.37	.35
DNOC	7.75	8.56	6.06	3.50
KCNO	5.96	4.12	2.94	1.65
$NaHCN_2$	6.90	6.50	3.25	2.81

Necessary difference from checks for levels within any one chemical P. = 0.05 ----- 0.55

Table X indicates that excellent control of weeds was obtained with MCP, even at the 1-pound-per-acre rate. The necessary difference reveals that DNOC at 1½ quarts per acre (level 1) and $NaHCN_2$ at 16 pounds per acre (level 1) did not significantly reduce the weed population when compared with their respective checks. All other levels of treatment significantly reduced weed weights.

At the time of application of the post-emergence treatments the weed population was considered insignificant. Therefore, the results obtained at harvest time may partly be due to the residual action of the weedicides. Table X shows that KCNO gave relatively good control of weeds possibly by having greater residual toxicity than DNOC and $NaHCN_2$.

Normally, results obtained in two consecutive years from similar experiments are combined into one analysis for greater sensitivity. Bartlett's Chi-square test (15) was used to test the error variance of pea yields obtained in 1951 and 1952. The Chi-square value was calculated to be 14.5 for 1 D.F. Since this is beyond the P.= 0.01 value from Fisher's table (15), we can assume that the error mean squares for the two years are heterogeneous and therefore we can not statistically combine the two analyses.

Similarly, Bartlett's Chi-square test was applied to weed weights obtained in the years 1951 and 1952. A value of 88.4 for 1 D.F. was calculated and therefore, since the error mean squares are heterogeneous, these results should not be combined into one analysis. These tests would seem to indicate that the two seasons were too different to permit a direct comparison of results.

SUMMARY and CONCLUSIONS

Experiments were conducted in 1951 and 1952 to evaluate four promising chemicals for the control of weeds in peas. These chemicals, MCP, DNOC, KCNO, and $NaHCN_2$, were applied at three levels of concentrations on two varieties of canning peas, Pacemaker and Early Perfection each replicated four times.

Results obtained indicated that the pre-emergence application of MCP effectively controlled the weeds even at the 1-pound-per-acre rate and, under normal conditions, increased the pea yields due to the elimination of weed competition. One application of this herbicide gave satisfactory control of most broad-leaved annual weeds right up to harvest time.

The use of DNOC at $2\frac{1}{2}$ to 3 quarts per acre has been recommended for the control of weeds in peas grown in Manitoba since early in 1944 (38). Results obtained indicated that this rate is effective for the control of seedling broad-leaved weeds in peas. The highest rate used in this experiment ($3\frac{1}{2}$ quarts per acre) caused reductions in pea yields. The 1952 results indicate that this herbicide has relatively little residual action.

The 8-pound-per-acre rate of KCNO was ineffective for the control of most weeds under the conditions of the study. However, at 16 pounds per acre, fair control of weeds was obtained with little injury to peas. The highest rate (24 pounds per acre) caused considerable damage to the pea plants. This chemical seems to possess some residual toxicity to germinating weed seedlings.

The 16-pounds-per-acre rate of $NaHCN_2$ also appeared ineffective for the control of weeds. Better weed control results were obtained at higher rates, but these rates injured the peas to a considerable extent and reduced pea yields.

None of these herbicides at the rates used controlled grassy weeds such as green foxtail and barnyard grass.

MCP, due to the low volume of spray required (as low as 5 gallons per acre) as well as the comparative ease and safety in handling, seems to offer real promise for the control of certain broad-leaved weeds in canning and field peas grown in Manitoba.

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APPENDIX

Table I

Temperature and Precipitation Data for the Month of May, 1951 and 1952.

	1951			1952		
	Temperature		Precipitation	Temperature		Precipitation
Date	Max.	Min.	in inches	Max.	Min.	in inches
1	78	54	.17	76	41	
2	76	56		84	47	
3	71	39		85	47	
4	59	35		88	60	
5	57	31		56	48	
6	65	32		64	30	
7	75	42		58	48	.05
8	76	47		67	35	
9	55	31		45	37	
10	66	26		54	34	
11	59	37		62	25	
12	66	33		68	34	.03
13	75	48	.04	72	38	
14	80	58		57	34	
15	60	30		54	41	
16	58	39		52	35	
17	78	40		59	40	
18	70	52	.10	66	44	
19	78	52		71	40	
20	61	47		70	39	
21	60	37		75	40	
22	81	39	.10	81	50	
23	92	56		83	52	
24	89	58		75	52	
25	70	49	.15	75	45	
26	70	43		68	45	
27	71	38		51	38	.14
28	74	42		56	34	.06
29	93	52		59	34	
30	61	37		61	33	
31	56	35		60	32	
Mean	69	43	Total .56	66	40	Total .28
Normal	64	40	2.16	64	40	2.14

APPENDIX

Table II

Temperature and Precipitation Data for the Month of June, 1951 and 1952.

	1951			1952		
	Temperature		Precipitation	Temperature		Precipitation
Date	Max.	Min.	in inches	Max.	Min.	in inches
1	59	32		72	36	.70
2	55	46		62	48	.06
3	61	42		74	44	
4	60	44	.15	81	49	
5	59	42		91	56	
6	64	43	.72	78	55	.05
7	70	52	.30	87	58	
8	68	51		68	51	
9	67	53		75	49	
10	67	44		71	40	
11	73	41		85	56	
12	78	46		77	51	
13	86	55		81	59	.08
14	81	59		75	50	
15	87	59	.31	80	59	.95
16	73	56		69	59	
17	72	47		76	56	.14
18	76	44		62	49	.07
19	78	45		70	44	
20	70	46		73	55	
21	71	47		78	55	
22	74	39		71	56	
23	72	47		76	57	2.80
24	75	44	1.07	79	57	
25	69	60	.60	62	51	
26	75	48		65	53	
27	64	54		73	50	
28	59	44		64	60	1.40
29	65	50		66	58	
30	68	41		79	60	.14
Mean	70	47	Total 3.15	74	53	Total 6.39
Normal	73	50	3.09	73	50	3.12

APPENDIX

Table III

Temperature and Precipitation Data for the Month of July, 1951 and 1952.

	1951			1952		
	Temperature		Precipitation	Temperature		Precipitation
Date	Max.	Min.	in inches	Max.	Min.	in inches
1	73	46		84	60	1.06
2	75	45		75	59	.15
3	76	51		78	55	
4	83	49		85	57	
5	80	51		90	68	
6	78	63		71	63	.07
7	79	62		70	56	.15
8	79	51	.20	79	51	.04
9	67	51		76	54	.06
10	71	43		76	60	
11	75	44		65	50	
12	80	46		72	49	.24
13	71	59		70	52	
14	64	51		75	47	
15	65	42		82	52	.27
16	77	43		80	60	
17	77	62		81	57	
18	70	47		78	58	.10
19	77	40		76	55	
20	83	58		75	62	
21	72	56	1.48	79	58	.30
22	77	47		68	57	.09
23	87	54		81	49	
24	95	61		85	56	
25	86	57		82	65	
26	81	60		88	62	
27	91	56		88	55	
28	97	59		69	44	
29	93	66		71	51	.10
30	79	68	.19	72	48	
31	77	53		90	52	
Mean	78	53	Total 2.19	78	55	Total 2.75
Normal	79	55	2.92	79	55	2.87