WEED CONTROL OVERSEAS

Chairman: Prof. G. E. Blackman

WEED CONTROL RESEARCH AND DEVELOPMENT IN SWEDEN

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Weed control research in Sweden must be seen against the background of the Swedish crop production and recent changes in that production. The main part of the agricultural land in Sweden is used for cereals and grass-clover leys. Thus, of the total acreage of 3,700,000 hectares, approximately 42% is used for cereals, 41% for grass-clover leys, 12% for oil crops, roots, potatoes, legumes etc., and 5% for fallow. There have been slight changes in these figures during the last 30 years indicating more specialized crop production today than during earlier periods. For the discussion on weed control it is of particular interest to note that fallow occupied 8.5% of the land in 1924 as against 5% in 1954, however, in 1955 there was a tendency towards an increasing acreage of fallow, which was reported as occupying 6% of the agricultural land during that year. This is interesting because mechanical treatment on a fallow or in row-seeded crops in combination with chemical treatments in cereals, linseed, flax etc. is needed for an effective weed control in a country with as short a growing season as Sweden. This is undoubtedly more necessary now than during any earlier period as so much of the cereal acreage is used for wheat and barley. These two cereals are grown as cash crops from which the farmers want to obtain high yields of a high quality product. However, such yields cannot be obtained over a long period of time unless:

(1) cereals are grown in alternation with grass-clover leys and legumes (with a good stand), as well as in alternation with oil crops, roots and potatoes in which cultivation is possible during the vegetative period.

(2) cereals are grown in rotations which include fallows and

(3) regular plans for spraying the cereals with chemical weed killers exist.

The attention that must be given to the production of good crops of wheat and barley can easily be understood if it is remembered that on the average 39% of the cereals grown in 1954 and 1955 were wheat and barley while the percentage of wheat and barley in 1937 was 26 and in 1924 only 19. Cereals are now very often harvested with combines. This is especially the case for wheat and barley. Should weeds be common in the cereal fields their seeds can be easily and evenly distributed through the combines. It has been shown by Carlström* in a preliminary study in oats during the summer of 1955 that the number of weed seeds left on the ground is higher when the field is combined than it is when the field is harvested with binder, dried in shocks and then threshed. When Carlström studied the weed seeds falling on the ground after binder harvest, he determined the number of weed seeds spread when the field was cut with the binder and when the oats were put up in shocks and later loaded on wagons for transport to the thresher. He estimated the weed seeds after combine harvesting by determining the number of weed seeds that had fallen to the ground between

* Unpublished data. Institute of Plant Husbandry, Royal Agricultural College of Sweden, Uppsala.

the time for cutting with a binder and the time for cutting with a combine harvester, as well as the number of seeds that was spread through the combine harvester. The results from Carlström's studies are found in table 1.

Table 1. Number of weed seeds spread after cutting a field of oats with a binder and with a combine harvester. Uppsala 1955.

1	2	3	4	5
Weed species	No. of plants per 1700 m^2	Total number of seeds on the ground, 1700 m^2		Relation between col. 3 and 4
		After combine harvest	After binder harvest	
Chenopodium album L.	3584	35280	2057	17.2
Thlaspi arvense L.	112	4168	628	6.6
Galium aparine L.	168	784	50	15.7
Matricaria inodora L.	56	1600	922	1.7
Cirsium arvense Scop.	600	7360	42	175.2
Centaurea cyanus L.	1232	4648	395	11.8

The figures in the table show clearly how effectively the weed seeds are spread through the combine harvester and tell us that in modern mechanized farming cereal fields with no or few weeds are highly desirable. To achieve this in Sweden great efforts must be made.

A study by Granström and Almgård (1955) has shown that the most frequent weeds in winter cereals in Sweden are scentless mayweed (Matricaria inodora), cornflower (Centaurea cyanus), chickweed (Stellaria media cyr.) and nettle (Lamium sp.) while the most frequent weeds in spring sown cereals are fat hen (Chenopodium album), hempnettle (Galeopsis sp.), corn spurrey (Spergula arvensis L.), chickweed, pale persicaria (Polygonum lapathifolium Ait.), and field pennycress (Thlaspi arvense). Other frequent weeds are charlock (Sinapis arvensis L.), and field cabbage (Brassica campestris L.). Granström and Almgård have also found that the weed flora in the main farming areas in Central and Southern Sweden shows a larger number of species than the weed flora in other parts of the country. In northern Sweden fat hen, hempnettle, chickweed and corn spurrey are most common while cruciferous weeds are not very common.

This discussion on the general background to weed control research in Sweden makes it clear that both for good crop husbandry and for good weed control we should aim at crop rotations in which mechanical treatments are possible in row-seeded crops or on a fallow. Such mechanical treatments in combination with chemical treatments, first of all in cereal crops, should make it possible to reduce the weeds to such an extent that we can reckon with clover-grass leys of such good stands that the weeds cannot compete. On the whole good rotations in connection with effective crop production plans considering clean seeds, fertilizers, disease control etc. should permit effective weed control.

With this in mind we may ask what has been achieved so far and to what extent research work has been able to give an impulse to continued development along the desired lines? The answer to this question can perhaps best be found in a discussion of the development after the second World War. In 1946 MCPA and 2,4-D were introduced into Sweden. Their effectiveness on weeds soon made them well known and quite widely used. At present MCPA is the most commonly used weed killer in Sweden and about three quarters of the money spent on chemical weed killers in the country is for this compound. This indicates that most of the spraying is carried out in cereals. But even so not more than one fourth of the cereal acreage is sprayed. This development, caused mainly by the use of phenoxyacetic acids, has had favourable and unfavourable results. It has been favourable because it has given us methods whereby some of our common weeds can be controlled in cereals, linseed, flax and potatoes and on grasslands; it has been unfavourable because the interest in other means of control, such as cultivation and good crop rotations, has decreased. It has been unfavourable also because those weeds, which are resistant or slightly susceptible to chlorinated phenoxyacetic acids have thus been able to increase in number as susceptible weeds have been killed. The want of attention to weed killers other than chlorinated phenoxyacetic acids has also favoured development of weeds that cannot be controlled with phenoxyacetic acids.

In this situation rotations of chemical weed killers can be considered. Besides MCPA and 2,4-D, dinoseb and DNC, alone or mixed with MCPA, are also used under Swedish conditions. Maybe MCPA can, in the future, also be used in this rotation of selective weed killers. But even if a rotation of chemicals for selective weed control is established, there appears to be a definite need also for an alternation between chemical weed killers and mechanical means of weed control on all farms where good crop husbandry is expected. Otherwise certain weeds will soon increase in number.

Among weeds that seem to increase in Sweden in areas with regular use of phenoxyacetic acids for weed control could be mentioned: couch grass (Agropyron repens PB), loose silky bent (Apera spica i-venti PB), wild oat (Avena fatua L.), scentless mayweed, cleavers (Galium aparine L.) Fig. 1, annual meadowgrass (Poa annua L.), sowthistle (Sonchus sp.), nipplewort (Lapsana communis L.), and hairy vetch (Vicia hirsuta S.F. Gray). Other weeds that are causing problems are wild onions (Allium sp.) and buttercups (Ranunculus sp.). We need to know more about the competition of these weeds with other weeds and with cultivated plants. Some of these species need to be studied in regard to their biology, ecology and resistance or susceptibility to chemicals. Such studies have been commenced and a few examples will be given.

Results from an experiment on the effect of mechanical methods alone and in combination with propham on wild oat in peas (Åberg, Knutsson and Roland 1952) show clearly the competitive ability of wild oat against peas and weeds other than wild oat.

Table 2. Effect on wild oat and peas of harrowing alone and in combination with propham.

Treatment	Green weight: Peas kg/ha	Peas rel.no.	Wild oat kg/ha	Wild oat rel.no.	Other weeds kg/ha	Other weeds rel.no.	Number of wild oat per m^2
Harrowed	5399	100	14458	100	593	100	1010
Harrowed + propham, 7.5 kg/ha	17647	327	91	0.6	5062	854	17
Harrowed + propham, 10 kg/ha	16409	304	85	0.6	4706	794	5

Fig. 1. Cleavers can mix seriously with winter cereal and are difficult to separate from it.

In 1956 Granström gave a short report on his rather detailed study of the competition between weeds and cultivated plants, which study is expected to be published in full during next year. Granström has given special attention to the effect of density of stand in cultivated plants on the competition between such plants and weeds. For this reason he studied barley, flax, timothy, red clover and lucerne. He also followed the influence of the fertility of the soil on the development of cultivated plants and weeds respectively, and for this purpose compared barley on soils where no nitrogen had been added with barley on soils where 300 kg/hectare of calcium nitrate (15.5%) had been applied. On these soils he had a normal stand of barley, corresponding to 400 plants per m^2, and also stands of 200 and 600 plants per m^2. In his experiment there were 15-25 plants of fat hen per m^2. The results Granström obtained in his experiment are shown in table 3.

Table 3. Effect of nitrate on stand of barley and fat hen.

	Total weight per plant, g		No. of leaves per plant	
	No nitrate	Nitrate 1)	No nitrate	Nitrate 1)
Barley, 200 kg/hectare	6.8	8.3	9.2	9.6
Fat hen	2.2	2.4	11.1	9.3
Barley, 400 kg/hectare	3.4	4.9	3.2	6.7
Fat hen	1.8	0.9	7.8	6.6
Barley, 600 kg/hectare	2.2	4.1	4.6	6.4
Fat hen	0.8	1.1	6.9	6.0

1) Nitrate = 300 kg/hectare calcium nitrate (15.5 per cent)

From the figures it is clear that barley can use the added nitrate better than fat hen. More studies of this type are needed so that the value of a good stand of cultivated plants for successful weed control can be clearly demonstrated. Also the growth habit of the plant is important. The competition between scentless mayweed and cultivated plants such as timothy, red clover and lucerne can lead to a completely different development of plants of the same weed species (Fig.2). Timothy has difficulty in competing with scentless mayweed, lucerne has a better competitive ability and red clover is unquestionably the best fitted for competition with this weed in a first year ley.

In older leys the competitive ability of timothy, lucerne and red clover may, however, be different. Lucerne is able to compete better than the others due to the denser stand of lucerne than of red clover in these leys. This can be illustrated with a few figures (Fig. 3-6) from a crop rotation experiment at the Institute of Plant Husbandry during the period 1947-1955 (Åberg 1956 a). Table 4.

Table 4. Number and weight of dandelions and legume plants in the leys October 24, 1955.

Leys	No. of plants per m^2 dandelions	No. of plants per m^2 legumes	Weight per plant, g dandelions	Weight per plant, g legumes
First year red clover	72	404	2.7	5.6
Second " " "	84	24	14.2	14.2
First year lucerne	344	176	2.3	2.4
Second " "	220	132	3.3	7.2
Third " "	320	148	2.0	14.3
Fourth " "	500	100	1.3	16.6

Fig. 2. Development of scentless mayweed when growing in competition with timothy (a) lucerne (b) and red clover (c). (After Granström, 1956).

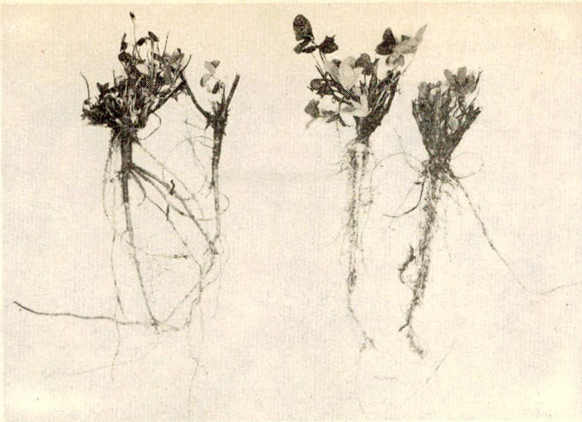

Fig. 3. Red clover plants on October 24, 1955. From first year ley (left), from second ley (right).

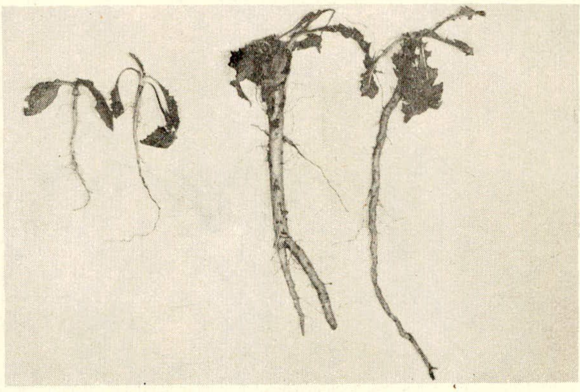

Fig. 4. Dandelions on October 24, 1955. From the first year red clover ley (left), from the second year red clover ley (right).

Fig. 5. Lucerne plants on October 24, 1955. From first to fourth year leys (left to right).

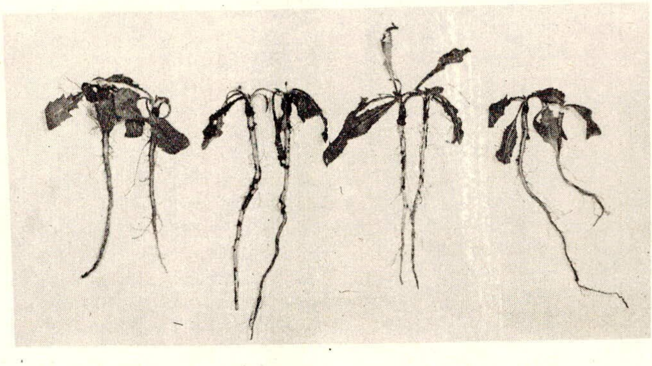

Fig. 6. Dandelions on October 24, 1955. From first to fourth year leys (left to right).

The figures in the table show that dandelion cannot compete well with red clover in the first year ley but very well in the second year ley. In a ley with lucerne as the main crop plant there are as many or more dandelions in the second, third and fourth year leys as in the first year ley. They cannot, however, develop well enough to compete with the lucerne. This is also very clearly demonstrated in the figures. The red clover from the first and second year leys are of about the same size while the dandelion plants from the two red clover leys are very different in size. (Fig. 3 and 4). In the lucerne leys the lucerne plants increase very markedly in size as the leys become older, while the dandelion plants are almost the same in all four leys. (Fig. 5 and 6). In practice this means that the dandelions will show up in the lucerne leys during the first year and the early part of the second. After that time they are no longer competitors to the lucerne.

Observations like those mentioned give us special reasons to study biology, ecology and resistance of certain weeds to different chemical weed killers. Such studies should also include biology of seed germination which is important to understand how to use the chemicals effectively. Some studies of this type are under way. Kolk (1947) carried out such studies at the Institute of Plant Husbandry and used some common weeds in his studies. He is continuing his studies at the Government Seed Testing Station in Stockholm with the special aim of finding out the particulars of the weed seeds appearing in seeds of grasses and clovers. Sjöstedt* studied the germination biology of cleavers (Galium aparine). He found that newly harvested seeds of cleavers germinate better in darkness than in light. One year old seeds germinate just as well in light as in darkness, provided the light intensity is not more than 15-25% of full day light. Optimum temperature for the germination of newly harvested seeds is 12-15°C. A water content corresponding to 40-50% of the maximum water uptake in the soil is sufficient to ensure germination. The seeds germinate poorly on filter paper. The germination can, however, be greatly increased if the filter paper is moistened with a soil extract. This indicates the presence in the soil substrate of some substance able to stimulate the germination of the seeds.

In this connection some data from a study by Aamisepp* should be mentioned. It had been noticed in 1947 (Åberg, Hagsand, Väärtnõu 1948) that the germination ability of seeds of cleavers was higher if these seeds had been harvested on plots which were sprayed with MCPA or 2,4-D (sodium) than if they came from untreated plots. Not until the summer of 1955 could this observation be used in new studies involving a number of weeds, beside cleavers. It was then found that seeds of weed species with dormancy could be stimulated to an increased germination through spraying the weeds with chlorinated phenoxyacetic acid. The studies were continued in 1956, but results from these studies are not yet available. Therefore no comparison between the results from 1955 and those from 1956 can now be made. It was, however, found in the experimental field in 1956 that of seeds of cleavers, corn spurrey and pale persicaria that had fallen on the ground before harvest, those that came from plots treated with 2,4-D or 2,4,5-T germinated immediately while those that came from untreated plots had not germinated before the ploughing of the field on October 19th (fig. 7). If the spraying was carried out just before the flowering time, it hastened the ripening of the seeds. Aamisepp has also included red clover and lucerne in his experiments in order to study the effect of spraying with chlorinated phenoxyacetic acids on hard seeds in these legumes.

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* See footnote on p. 141.

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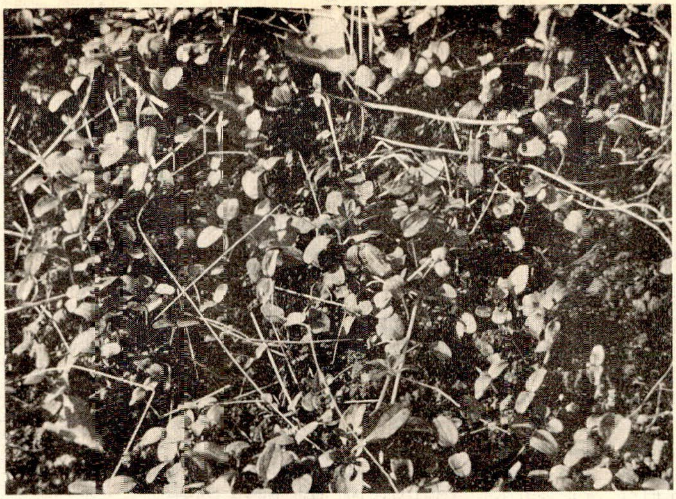

b

Fig. 7. Seedlings on the ground of a plot of cleavers sprayed with 2,4-D on June 15, 1956. The seedlings originated from seed that fell on the ground before the plot was harvested (a). On the unsprayed plot no seedlings appeared in spite of the fact that seed had fallen on the ground also on this plot (b). Photo October 5, 1956.

Aamisepp's studies seem to be of interest also for wild oat which has been included in his experiments. There is a real need for solving the question of dormancy and germination ability of wild oat. Both for chemical weed control and for control with mechanical means a better knowledge of the germination biology of this weed species is necessary.

The main investigations on wild oat are, however, concerned with ways of chemical control and methods for mechanical control in good crop rotations. For a number of years propham has been tried against wild oat. Recommendations can still be based on the results reported on in 1952 (Åberg, Knutsson and Roland). Consequently use of propham is justified as a part of intensive control measures against wild oat but should be employed together with other control methods, i.e. mechanical treatment. During the years 1953-1956 Wiberg* studied the effect of propham, CIPC and TCA on wild oat. Monuron was tried during the last two years. He used amounts varying between 2.5 and 10 kg/hectare of propham, 2.5 and 40 kg/hectare of CIPC and 5 and 120 kg/hectare of TCA. Monuron was applied at 20 to 120 kg/hectare. The chemicals were applied at seeding time in the spring. Peas were seeded on the plots. From the experiments it can be concluded that propham has an effect as stated above, CIPC is slightly better, while TCA has not given satisfactory results. The experiments with monuron have given promising results as far as the effect on wild oat is concerned but its long residual effect may make it impossible to use it in a regular crop rotation system.

The possibilities of controlling wild oat by mechanical methods in good crop rotations are being studied in an experiment at the Institute of Plant Husbandry. In this experiment mechanical treatments alone or in combination with chemical means are investigated. The experiment was started in 1952 on a field of 3000 m^2 where the 15 cm top layer of the soil contained 5000 wild oat kernels per m^2. The field was divided into 15 plots. Of these plots five are used for mechanical treatments alone, five for mechanical and chemical treatments in combination and five for chemical treatments. On the latter plots no more mechanical treatments are used than is absolutely necessary for seeding the crops.

Time does not allow me to go into details of the results from the period 1952-1956, which I hope will be published in Växtodling (Plant Husbandry) in 1957. Instead I should like to show the trend in regard to the effect of mechanical treatment in different crops as mechanical treatment has so far given good results. This can be shown in three diagrams (fig. 8-10). In 1952 the field was seeded with peas, in the fall of 1952 with oil rape, which was, unfortunately, killed during the winter 1952-53. Therefore, the field had to be used for green fodder peas in 1953. It carried winter rye and winter wheat in 1954, roots and potatoes in 1955 and an early ripening barley in 1956. This barley crop was undersown with a mixture of lucerne, red clover and timothy and, therefore, the field will now carry ley for a period of time, presumably two, three or four years. No wild oat kernels have been allowed to fall on the ground since the fall of 1954 and the experiment is planned to continue until the soil is free from wild oat kernels. It has been interesting to follow the number of wild oat plants in different crops. There were, for example, 384 plants per m^2 in the winter rye plots in 1954, while there were 1048 plants in the winter wheat plots. Presumably the stand of rye has a better competitive ability than the stand of wheat. The number of wild oat plants per m^2 has been higher after cultivation in spring and early summer than

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* Data for publication in Växtodling (Plant Husbandry) 1957

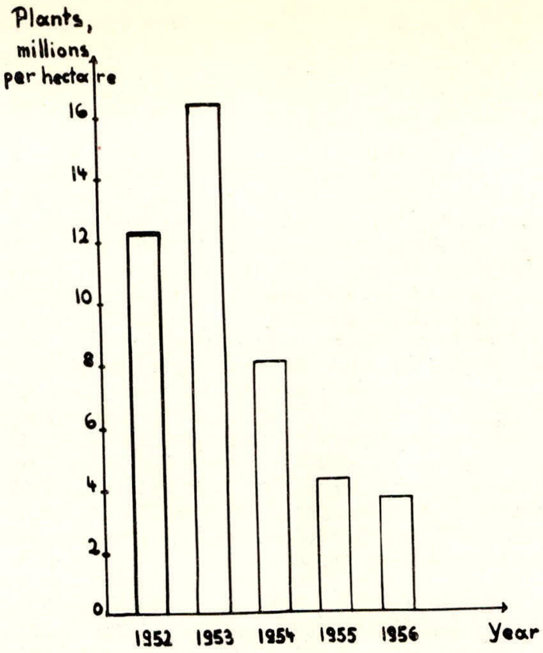

Fig. 8. Plants of wild oat (millions per hectare) removed by cultivation in the various crops 1952-1956.

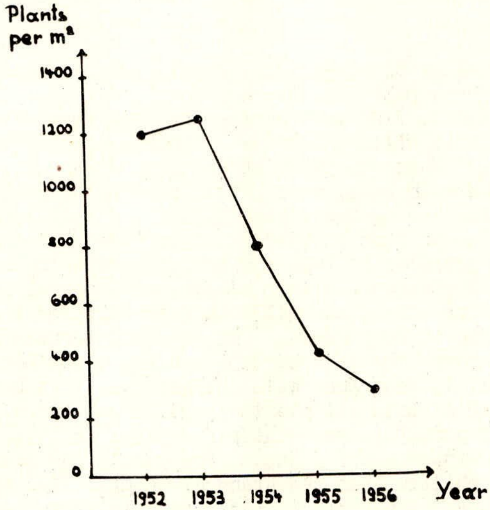

Fig. 9. Plants per square meter during the years 1952-1956.

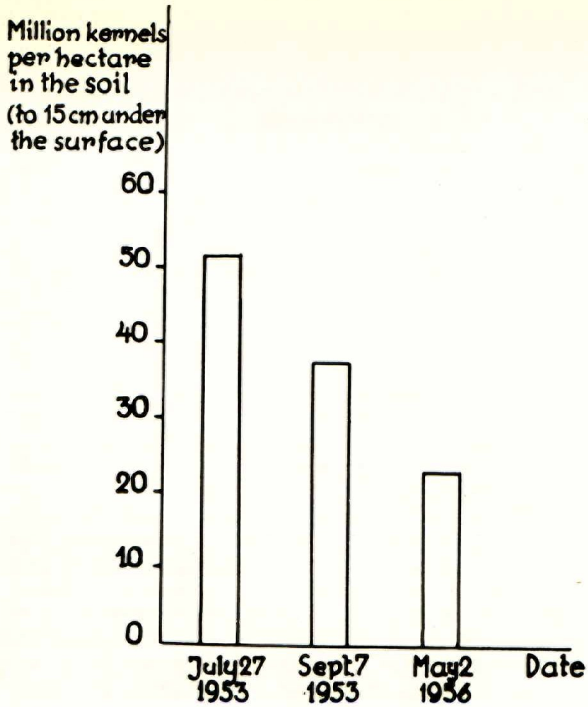

Fig. 10. Million kernels per hectare in the upper 15 cm of the soil at two occasions in 1953 and in the spring of 1956.

after cultivation in late summer or fall which was to be expected as the wild oat species in this case is Avena fatua.

The conclusion from the experiments on wild oat in Sweden, so far carried out, would be that the chemicals we have tried have not been as effective against wild oat as the mechanical treatments in a good crop rotation. In such a rotation on lands infested with wild oat we aim at using fall sown crops, roots, potatoes and leys. The latter should last for three to four years.

Granström* has studied the competition between wild oat and cereals and found that wild oat in thin stands of cereals and peas can lower the yield considerably. In these experiments he had around 40 wild oat plants per m^2. Thus both yield and quality of the crop are suffering from the appearance of wild oats in the field.

Hedge bedstraw (Galium mollugo L.) is not a serious weed in your country. In northern Sweden and parts of central Sweden it can, however, be serious in leys, especially in the older ones. It is spreading into the fields from

* Data for publication in the Annals of the Royal Agricultural College of Sweden in 1957

roadsides and ditchbanks where the vegetation is not always cut or sprayed. In the fields hedge bedstraw is difficult to control if the crop rotation does not permit adequate mechanical weed control. It cannot be effectively controlled with MCPA and 2,4-D and even if it could, these chemicals cannot be used against it because they damage the clover in the leys. Methods of controlling the weed in grass seed production fields and on road sides etc. with chemicals have therefore been tried during the years 1951-1955 (Åberg, unpublished data*). It has been found that with 2,4,5-T hedge bedstraw can be controlled in places like the ones just mentioned. To reach these results spraying with 2.5 - 5 l/hectare of 2,4,5-T is necessary. These results are interesting also because they show that there is a need for a development in regard to chemical weed killers which calls for chemicals with still more specialized effect than the present ones have. This, it could be said, is the result of the last ten years' achievements in weed control research.

In a special research report to be discussed at this conference Håkansson gives some data on his studies of wild onions. Five species of Allium are appearing in fields and on natural pastures along the coast in south Sweden and parts of central Sweden and on the islands of Öland and Gotland. Håkansson has proved that it is necessary to carry out, first of all, a detailed study of the biology and ecology of the wild onions. Not until such a study has been completed can definite recommendations as to the use of chemicals or mechanical methods against wild onions be made. In Håkansson's investigation we have another example on how necessary studies of this type are, and it is clear that a number of weeds which we do not know enough about today must be studied in the same way. Weed biology and weed ecology need more attention than they have had during recent years. Information that can be obtained is as valuable for those who want to control the weeds by chemicals as for those who want to control them by other means.

Above I have attempted to illustrate work in Sweden with regard to weeds of special interest. But there remains the question of the chemicals applied and developments in that particular field. Earlier this year (Åberg 1956 b) the comparison between MCPA and 2,4-D was discussed with special emphasis on the effect of these two chemicals on weeds and cultivated plants, which were sprayed in different stages of development. Sir John Russell mentioned yesterday that malformations are found in cultivated plants after spraying with weed killers of the phenoxyacetic type and pointed out that this might influence the production of seeds by cereals. To avoid this, Sir John stated, it is necessary to spray at a late stage of development. This is true also under Swedish conditions if 2,4-D esters are used. However, malformations do not appear if MCPA is used. As MCPA is the most commonly used herbicide in Sweden we risk advising farmers to spray at an early stage of development and it is expected that this will cause no seed malformities. It is, under all conditions, safe to tell the farmers to spray when the cereal plants are 3-4 inches high.

If we consider these experiences from England and Sweden we have reason to observe also another side of this problem of deformity. There is need for more knowledge on the influence of climatic conditions on the effect of herbicides of the phenoxyacetic acid type on weeds and crops. Is this not a field that we should now explore more in order that we can clarify, amongst other things, the reaction of cereals in England and in Sweden with regard to malformations? Certainly it must be the result of a combined effect of environment and of constitution of the plants in different stages of development.

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* See footnote on p. 151.

There are differences in reaction between varieties, Sir John pointed out. Under Swedish conditions such differences have been studied in a few cases (Hagsand 1954). In his experiments Hagsand found that varietal resistance is dependent on both the tillering capacity of the varieties and the speed of tillering during the spring. A slowly tillering variety is likely to get more abnormal ears than a rapidly tillering variety because late tillers of any variety are apt to be caught in a sensitive stage unless the spraying is carried out very late. On a number of plants of different varieties Hagsand marked the shoots as they appeared and then followed up by spraying at different stages of development.

On the basis of studies of MCPA preparations with a high content of the pure 2-methyl-4-chlorophenoxyacetic acid and on the effect of different isomers of phenoxyacetic acids (Åberg 1954) it has been agreed in Sweden to use 250 g/l technical product of MCPA with a high isomer content, i.e. it should contain around 95% of the 4-isomer. Thus the further development that is now of special interest is how the already existing beneficial effect of the 4-isomer can be further increased. At present Bengtsson at the Institute of Plant Husbandry is working on this problem and it is hoped that he can continue these studies. What we would like to have are MCPA- preparations with specialized effects so that they can be recommended for special crops as for example cereal, linseed, flax or potatoes or for certain weeds as field pennycress, cornflower or buttercups. Can this be achieved to meet a desire for an even more specialized weed control than we have now? Or should we aim at completely new chemicals instead? Perhaps the best solution at present is a combination of Phenoxyacetic acids and dinitro compounds as is now often used when weeds with varying susceptibility towards present day herbicides appear. Or should substances like these be combined into some new chemical for general use?

Among new herbicides we have tried MCPB during the last two years. It has been stated before (Åberg 1955) that the results from the experiments with MCPB in 1955 were markedly influenced by the drought during the summer of 1955. Therefore I would like to base my statements on MCPB in Sweden on results from 1956. As there will be a discussion on MCPB later during this conference I will be brief. Experiments in 1955 had shown that the possible value of MCPB would be for weed control in clovers and peas. The experiments in 1956, carried out by Walther*, were also planned with this in mind and laid out in peas, red clover and barley. Barley was chosen to make it also possible to follow the effect of MCPB in the cereal. Some of the experiments were sprayed with MCPB every third day from the one- or two-leaf stage up to the flowering stage. This gave 10-12 sprayings in peas, 16 sprayings in red clover and 18 sprayings in barley. Of peas two varieties, namely the medium early type, Torsdags III, and the very early type, Nola II, were used. They reacted in the same way. In other experiments in Sweden in 1956 it was, however, found that other varieties, such as Kloster and Stråal, were more susceptible to spraying with MCPB than Torsdags III and Nola II. Variety differences must therefore be further studied. In Walther's experiments the spraying caused small deformities, which were especially noticeable after spraying in the four- or five- leaf stage. These deformities brought with them shorter plants. In red clover a medium early type, Ultuna, and an early type, Essi, were sprayed. Leaf deformities were found after all sprayings. The edges of the leaves were

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* See footnote on p. 141.

rolled backwards. It was found that those deformities were of no importance or did not even occur if the spraying was carried out in very early stages of development. They became more serious after spraying in later stages of development so that up to 30% of the leaves were abnormal after spraying when the plants were 20-25 cm high. Spraying after this stage again gave less abnormality. In barley no ear- or straw-abnormalities were found that could be attributed to spraying with MCPB.

The effect of MCPB on the weeds can best be illustrated by grouping the weeds in the experiments as a result of their reaction to spraying as follows:

Table 5. Effect on weeds after spraying with MCPB. Uppsala 1956.

Very good effect:	Chenopodium album
Good effect:	Polygonum amphibium
	" aviculare (young stage)
	" convolvulus (young stage)
	Stachys palustris
	Sinapis arvensis
	Sonchus oleraceus
Some effect:	Polygonum persicaria
	Lamium purpureum
	Galeopsis speciosa
No effect:	Stellaria media

If the reaction of both clover and weeds is considered it appears that the best time of spraying should be when the clover plants have three or four leaves (i.e. a height of 10 cm). The best results in red clover have been obtained with 6.3 l/hectare of Tropotox which is one and a half times the amount normally recommended. The results in peas indicate that also in peas early spraying is desirable.

Observations by Granström have indicated that MCPB may be useful for the control of Sonchus sp. and especially for the control of Ranunculus sp. in pastures. In the latter case 2 kg/hectare (active substance) is required. If this promise is fulfilled it would be a very great help as Ranunculus sp. are the worst weeds in our natural pastures.

In a recent paper (Burström, Sjöberg and Hansen 1956) the plant growth activity of phenoxy-thioacetic acids was discussed. Judging from this paper the thio acids are on the cell level generally more active than the acetic acids. But the 2-methyl-4-chlorothiophenoxy-acetic acid shows a weaker response than 2-methyl-4-chlorophenoxyacetic acid in flax and in peas with higher concentrations and in old seedlings. This is attributed to a slower transport or an increased destruction of the thio-compound. In the trichloro compounds the thioacetic acid is more growth-inhibiting and also possesses a specific direct killing effect on roots of wheat and peas. Thio-2,4-D has a similar effect on peas but for the rest the irregular differences between this acid and 2,4-D cannot be explained without further studies on the modes of action and the metabolism of the coupounds. In field experiments the phenoxy-thioacetic acids have been studied by Wiberg* during the years 1954-1956.

* See footnote on p. 141.

Their effect against weeds in barley, wheat, oats, peas and flax has been studied. The cultivated plants mentioned react in about the same way for spraying with phenoxy-thioacetic acids as for spraying with the phenoxyacetic acids. The effect of the phenoxy-thioacetic acids on the weeds such as charlock and fat hen appears to be slightly less than the effect of phenoxyacetic acids. The possibilities of using phenoxy-thioacetic acids as weed killers therefore seems to depend on their effects on special weeds. This has not been investigated so far.

At the second British Weed Control Conference the use of TCA and dalapon was briefly discussed (Osvald and Åberg 1954). These studies were later on continued by Beinhauer who is now busy analysing results from the years 1954-1956 when he studied the effect of these two substances on couch grass and common reed (Phragmites communis Trin.). Most of his experiments have dealt with applications of these chemicals on a fallow where winter rape and winter cereals were later seeded. Some, however, have dealt with treatments on ploughed stubble in the fall followed by seeding of cereals or other crops next spring. Beinhauer* has used rather high rates of the herbicides, i.e. between 25 and 100 kg/hectare of TCA and 25-50 kg/hectare of dalapon. Since the results from Bylterud's investigations in Norway were published (1956) the studies are being enlarged so that lower rates (12.5 and 25 kg/hectare) are applied. This is mainly done with the aim of studying the possibilities of applying the chemicals early in the spring, as Bylterud has done, and then using the fields for potatoes during the same year. Beinhauer's investigations have, however, mainly observed the breakdown of the herbicides in the soil under varying conditions. The chemicals seem to break down more easily in sandy soils than in other soils. There is, of course, a variation depending on the precipitation. It is interesting that Beinhauer has been able to connect the breakdown of TCA with microbial activity in the soil just as is the case for the breakdown of dalapon. It is evident from Beinhauer's studies that at present the best way of using TCA and dalapon in Sweden is to apply them on a fallow where couch grass is abundant or common reed appears. Either would help to increase the effect of mechanical methods against these weeds. Further use for them may be disclosed by continued investigations. The observation of Beinhauer that dalapon is effective on field horsetail (Equisetum arvense L.) is worth mentioning in this connection. Such investigations are also of interest because they may lead to the discovery of new chemicals. It is not likely that both TCA and dalapon are only intermediates in the search for a good herbicide against couch grass, common reed and others?

The general reaction of cultivated plants to different weed killers has been discussed above. The reaction of special properties in the cultivated plants to spraying with weed killers is also of interest. Thus the effect of MCPA, 2,4-D and 2,4,5-T on baking quality of wheat, malting quality of barley and on oil content of linseed has been studied in experiments where these cultivated plants were sprayed in three different stages of development and with three different dosages of the herbicides. The experiments were carried out during the years 1952-1955. As far as can be judged from the data available before all final analyses have been made there is little effect, if any, on the quality of the products as long as normal dosages are applied at the right stage of development of the plant. The material is being prepared for publication in Växtodling (Plant Husbandry) in 1957.

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* See footnote on p. 141.

Last summer it was stated (Åberg 1956 b) that Bengtsson studied the effect of droplet size during his work on design of sprayers and found that it has a very great influence on the effect of the weed killers irrespective of the volume rates used. Thus it is very important to follow the effect of different droplet sizes in the same amount of liquid. In his investigations Bengtsson has arrived at the following results. If MCPA (sodium) in a certain amount of liquid is sprayed on such cultivated plants as peas, flax, linseed and barley a greater effect is obtained if the liquid is applied in small droplets than if it is applied in large droplets. The same happens when weeds like fat hen and cornflower are sprayed (fig. 11). But if MCPA (sodium) is used in the same way for spraying charlock or hemp nettle the effect on these weeds is influenced little or not at all by the droplet size used (fig. 12). This must be seen against the background that in plants with poor wettability the droplet size has a definite influence on the effect of the chemical. Smaller droplet sizes bring with them greater retention and vice versa. The varying droplet size, therefore, appears to be mainly due to retention. When contact herbicides are used a better effect is obtained from small droplets than from large ones (fig. 11 and 12). Bengtsson's results will be published in detail in the Annals of the Royal Agricultural College of Sweden in 1957.

Most of the research work on weed control in agriculture, reported on above, has been carried out at the Institute of Plant Husbandry, Royal Agricultural College, Uppsala. Local trials in regard to weed control are organized by the National Agronomy Experiment Station at Uppsala and supervised by Granström. Some of these trials are, however, interscandinavian as a coöperative interscandinavian committee organizes and supervises some such local trials, the results of which, are judged as being of interest for the whole of Scandinavia. Herbicides for non-agricultural lands, such as road sides and railroad banks, and methods for using such herbicides are studied at the National Agronomy Experiment Station by Beinhauer.

Weed control research within horticulture is carried out by Åvall at the Government Horticultural Research Station at Åkarp in south Sweden. The studies at this station have mainly dealt with the use of dinitro compounds in canning peas, with potassium cyanate in onions and with mineral oils in carrots. Weed control research in the forested areas is taken care of by Bärring at the Forest Research Station of Sweden in Stockholm and by Häggström of the Swedish Forest Service, Stockholm, and is mainly concerned with methods for the control of birch and aspen in the coniferous woods in northern Sweden and the control of hazel (Corylus avellana L.) and bracken (Pteridium aquilinum) in central and southern Sweden. Also weed control methods that can be used in forest nurseries are studied. The most common way of controlling undesirable forest vegetation is spraying with ground sprayers. Spraying from airplanes is used to some extent but has its limitations because the time for spraying in northern Sweden is rather short. It cannot be carried out until after the new shoots on the coniferous trees have developed, which means that it cannot start until the end of July. But by early August the leaves on the trees that are to be controlled have begun to turn yellowish and then it is too late for a good effect. Treatment of the stumps is used quite extensively with good results. 2,4,5-T or mixtures of 2,4-D and 2,4,5-T are most commonly used. Esters with low volatility are preferred. For pocketing of the trees, a method that is also used, 2,4-D amines are preferred as they are readily taken up by the tree. It should be noted that the use of chemicals against undesirable vegetation in the forests is almost as widespread as their use in agriculture.

Fig. 11. Effect on fat hen by spraying with 1.5 l/ha Agroxone in 200 litres liquid (jars 171, 174, 179) and by spraying with 1.5 l/ha Sevtox in 200 l (jars 183, 186, 189).
Untreated plants in not unnumbered jar.
Small droplets, 80μ, in jars 171, 183
Medium sized droplets, 150μ, in jars 174, 186
Large droplets, 380μ, 179, 189
(After Anders Bengtsson, Master's thesis in Plant Husbandry, Royal Agric. College, Uppsala, 1956).

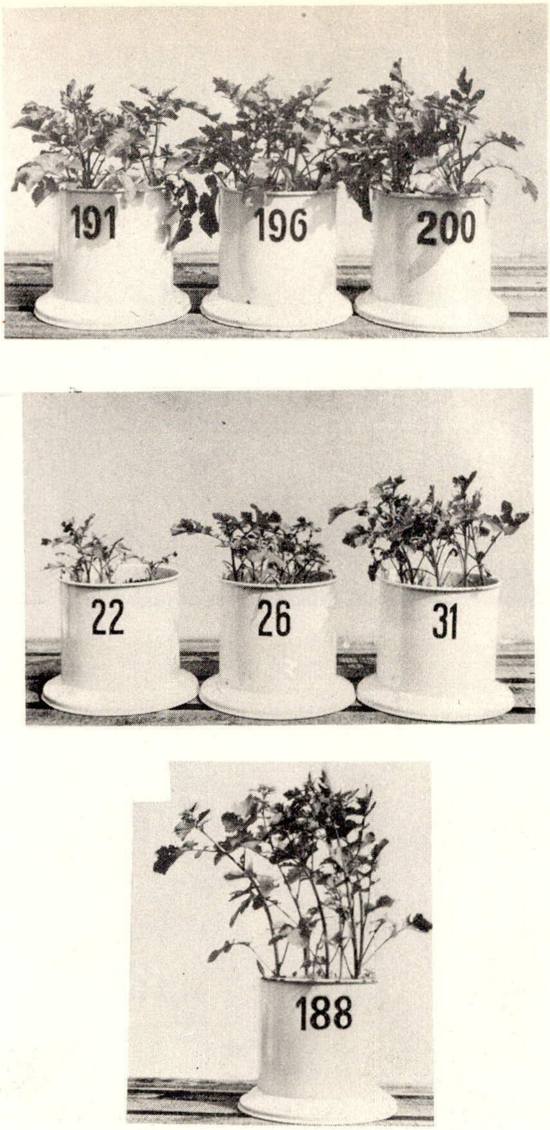

Fig. 12. Effect on white mustard by spraying with 0.75 l/ha Agroxone in 200 litres liquid (jars 191, 196, 200) and by spraying with 2 l/ha Sevtox in 200 l liquid (jars 22, 26, 31).
Untreated plants in jar 188.
Small droplets, 80μ, in jars 191, 22
Medium sized droplets, 150μ, in jars 196, 26
Large droplets, 380μ, in jars 200, 31
(After Anders Bengtsson, Master's thesis in Plant Husbandry, Royal Agric. College, Uppsala 1956).

To sum up:

Farming today is more intensive than during any earlier period. Farmers are looking for cash crops giving good yields. This often results in specialized farming and such farming brings with it an increased need for a weed control using all means available. It must be remembered that one of the very best means of controlling weeds is to use good crops able to compete with the weeds. To know the competitive ability of cultivated plants and weeds under various conditions we need more research on their biology and ecology. Developments during recent years have shown that we are running short of time for such studies, because we are very occupied within other fields of weed control. This needs to be corrected, especially as certain weed species are becoming more serious when other weed species are controlled by chemicals. To be able to control those weeds, which are gaining ground, we need first to know the details of their biology and ecology.

This is, however, not enough. Of course we can control the weeds by mechanical means in good crop rotations when we have in our hands data on their biology and ecology. But for still better results we need to develop our chemical weed killers so that they have a more specialized effect, can be readily sprayed, and can be effectively used in rotation with other weed killers. We should need to learn more about their use under various environmental conditions as well as about the combined effect of environment and constitution of plants in different stages of development. Also we cannot consider some of our weed killers today as anything but intermediates in a continuous development toward better products. Consequently, we look for further progress in regard to

(1) Biology and ecology of cultivated plants and weeds.

(2) Mechanical methods in good crop rotations.

(3) Readily sprayed herbicides with specialized effects.

(4) Importance of environmental factors for the effect of chemical weed killers.

May I end with expressing my gratitude to you for inviting me to give a paper on our research work in weed control in Sweden. Already after the first day at this conference I am very much aware of the value for me to be able to take part in your meetings. I thank you most sincerely for asking me to come.

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DISCUSSION ON THE PREVIOUS PAPER

Dr. W. Linke (Introduction to discussion)

There are a number of problems which are of acute interest not only in Sweden, but also in other continental countries as well as in England.

It is, for instance, a generally accepted fact that at least as far as the average farm is concerned, the cultivation and mechanical methods for weed control have been somewhat neglected since the hormone weed killers came into use. It is also common knowledge that the increased use of selective weed killers was followed by a remarkable increase in certain types of weeds. In addition to those given by Dr. Åberg, there is one species I would like to mention in this connection, at least as far as Western Germany is concerned. I refer to Tussilago, which is becoming more and more serious, especially as we still have not found any really satisfactory means of control.

As is the case in Sweden, there is also an increase in Apera spica-venti, and in some areas of Allium, in pastures. Perhaps I might mention as a matter of interest, that a good control of A. spica-venti is achieved by applying calcium cyanamide in autumn, combining the fertilising effect of that product with the herbicide properties of the cyanamide which develop in the soil.

As far as Allium in pastures is concerned a certain degree of control can be achieved by applying 2,4-D and 2,4,5-T ester formulations in early April. One treatment will, however, never give 100% results, because those plants which germinated in autumn, have developed bulbils in the meantime which survive treatment, as the esters do not seem to be translocated to them.

In view of the increase in the use of combines, Dr. Åberg's reference to studies on the influence of various methods of harvesting on the quantity of weed seeds falling to the ground, deserves special attention. Perhaps I may be permitted to refer to similar experiments carried out by Petzold in 1952/5 at the Institute of Professor Rademacher in Stuttgart-Hohenheim. Surprisingly enough, these experiments reveal that by using the ordinary binder, more weed seeds fall to the ground than when the combine is used. According to these investigations, the quantity of weed seeds dropping to the ground when combine harvesting is used, depends upon three factors:

1. The system of combine harvester used.

2. Whether the chaff is blown on to the field or collected.

3. The type of weeds.

These three factors taken together, may be the explanation for the discrepancy in the results in Sweden and Hohenheim.

Under Hohenheim conditions and using a combine of the Class system, 85% of the total weed seeds were collected together with the grain, 5% in the straw and 10% in the chaff. In the chaff were found weed seeds with a similar specific weight to that of the chaff i.e. Rumex, A. spica-venti and Avena fatua. If these weeds are predominant, it is strongly recommended not to leave the chaff in the field.

Another interesting fact arising from Dr. Åberg's paper, is that continental countries are now showing an increasing interest in the use of MCPB, although none of them seem to have reached the stage when a firm recommendation can be made.

As in Sweden, West German research workers are faced with the problem of ascertaining the susceptibility of a great number of pea varieties to MCPB.

Finally, everybody will strongly support Dr. Åberg's request for more basic biological and ecological research work on weeds and the development of a system of rotation in weed control, making use of all cultivation methods in conjunction with a suitable crop rotation as part of good husbandry and the sensible application of the various chemical weed killers.

Mr. R. F. Norman

What were the exact droplet sizes? Were they uniform and how were they produced?

Dr. E. Åberg

The droplets were 80μ (20-200), 150μ (50-400) and 380μ (100-800). They were produced by nozzles specially made for the investigation.

An increase in weed seed germination as a result of treatment with phenoxyacetic acid was first shown by Aamisepp in laboratory tests where material from field experiments in 1955 was used. The material from the experiments in 1956 has still to be tested in the laboratory. It was harvested only a few weeks ago.

WEED CONTROL AND WEED BIOLOGY IN CANADA

C. Frankton

(Senior Botanist, Weed Investigations Section, Botany and Plant Pathology Division, Science Service, Canada Department of Agriculture, Ottawa, Canada.)

I shall first mention the functions of the various agencies concerned with weeds in Canada. Several services within the Canada Department of Agriculture are among the agencies involved. The Experimental Farms Service at many of its 32 branch farms and 232 illustration stations conducts research on herbicides, tillage and cropping methods and so on. Production Service is responsible for the administration of several Acts that have a bearing on weeds: the Seeds Act, the Feeding Stuffs Act, and the Pest Control Products Act. Weed survey and weed biology are taken care of by a small group in Science Service. This group, of which I am part, is also called on for advice on registration of herbicides. Provincial Departments of Agriculture have jurisdiction in weed control through Provincial Weed Control Acts. Both Provincial Departments and agricultural colleges serve as extension agencies and the agricultural colleges in addition usually have a program of weed control experiments. It should be made clear that, in general, herbicide chemicals are synthesized by companies which have their development organization outside Canada and the preliminary screening has already been performed before we receive new herbicides. In Canada the task of the various agencies concerned is to find out how these chemicals act under our conditions and to fit them into control recommendations. Coördination of research on herbicides and the preparation of recommendations are achieved through the medium of the National Weed Committee.

Organization of weed committees in Canada began in 1924 with the establishment by the National Research Council of an "Associate Committee on Weed Control". This Committee was responsible for co-operation by Federal and Provincial agencies on weed control problems in the Prairie Provinces. In 1933 the Federal Department of Agriculture and the National Research Council jointly sponsored a continuing committee with the title "Associate Committee on Weeds". Eastern and Western sections of this group met in alternate years and the proceedings of five meetings were mimeographed and copies distributed to members and to agriculturel libraries. Recommendations for control were not formulated at these earlier meetings.

During the winter of 1939-40 the National Advisory Committee on Agricultural Services reconstituted the "Associate Committee on Weeds" as the "National Weed Committee" but meetings were not held regularly until after the war years. In 1947 eastern and western sections were organized and a permanent secretary appointed. From that year, progress in organization and, above all, in the development of recommendations has been rapid, a turn of events coincident with the appearance of the synthetic plant growth regulatorss.

All 10 Provinces are represented on the National Weed Committee. There are 63 members with voting rights and 68 regular members without voting rights. Most of the membership is drawn from Federal and Provincial Departments of Agriculture and from Universities. Representatives of commercial companies attend meetings by invitation. Meetings are held annually in Eastern and Western Canada in the autumn and the 10th meeting of each section will be held in 1956. A provincial representative discusses weed control activities in his

Province, progress reports are given on special problems, the status of new chemicals and of all investigations is reviewed, and there is usually some panel discussion.

Before the meetings control workers send abstracts of experimental results to project summarizers, each of whom is responsible for one particular subject. Recommendations based on the abstracts submitted and on the standing recommendations are then prepared by the summarizer for submission to the members of the National Weed Committee. Registration and labelling considerations are not lost sight of in that minor or unnecessary changes in the recommendations are avoided. The final recommendations for weed control, in effect equivalent to your "Weed Control Handbook", are not distributed to the public but are used after supplementation and modification as a basis for provincial recommendations.

I shall now deal with our system of registration of herbicides. Registration of all pesticide products in Canada is compulsory under Federal law. No brand of pesticide can be manufactured, imported or offered for sale without registration. The legislation governing registration is contained in the Pest Control Products Act, administered by the Plant Products Division, Canada Department of Agriculture. This Act, passed in 1927, was revised to its present form in 1939. Regulations implementing the Act are published from time to time, the latest in 1954.

Applications for herbicide registration are reviewed by an officer in the Botany and Plant Pathology Division, Science Service, Department of Agriculture. Label texts are examined in detail to see if the claims and directions for use are in accord with information available and are sufficiently complete. Recommendations from the National Weed Committee meetings, both eastern and western sections, are followed closely and are the major basis for review. When a herbicide has been in use for some years and has entered into recommendations, the amount of information available is usually adequate for review, but with those herbicides entering the field for the first time in Canada supporting evidence is required in the form of abundant documentation, experimental results, and so forth. Registration may be refused if the brand name is misleading, another brand of pest control product registered by the same manufacturer is essentially similar, the product is unsuited for the purpose for which it is represented, or is injurious to vegetation other than weeds, to domestic animals or public health when used according to directions.

The registration number assigned to an approved product by the Plant Products Division must be shown on the label. Also required are the brand name, name and address of applicant, guarantee, and in the case of poisonous material, poison markings and antidote. The guarantee must be stated as the number of ounces of active principle in a gallon of product or as the percentage, if a dry material. Improperly labelled herbicides offered for sale in Canada may be placed under detention until the legal requirements are met. Chemical analyses are not made at the time of application but one of the duties of the Inspection Service of the Plant Products Division is to collect samples from time to time from retailers' shelves for analysis and verification of the guarantee. The margin of discrepancy permitted is a narrow one.

Registrations are renewed annually so it is possible to prepare a list of herbicidal products for the current year in May. This list is circulated widely and quite a number of copies are directed to addresses in the British Isles.

There has been a constant annual increase in the number of registrations since the first year of the scheme, 1928, when only 11 products were registered. By 1947 the number was 91 and from that year the advent of the synthetic growth regulators has led to remarkable increases as evidenced by a total of 361 herbicidal products in 1956. In the last 6 years, 532 products have been registered, so there is apparently a considerable mortality.

You will be particularly interested in the status of MCPA products in Canada. A product containing this herbicide was registered for the first time in 1951 but little MCPA was used until 1953. Each year since 1951 there has been an increase in the number of products until in 1956 registration for 28 products was granted to 16 registrants. Amine salt sprays number 16 while 7 registrations are for ester sprays or dusts.

The advantages to be derived from the use of MCPA have been tardily recognized in North America but I think that 1956 will be noteworthy as the year when this chemical achieved prominence. In 1955 MCPA was used on 283,000 acres in Canada (about 2% of the treated acreage) and in 1956 on 1,737,000 acres. MCPA is now finding a place in control of weeds in small grains at earlier stages of growth when 2,4-D is dangerous to employ. Hemp nettle is a serious pest in the northern prairies and MCPA will be used wherever this weed occurs. Because of wheat surpluses, the flax acreage has increased and this larger acreage will undoubtedly be treated with MCPA. Part of our small acreage of peas is treated with MCPA; 2,4-D is more injurious to this crop particularly in low volumes of water. One special use of MCPA is for the control of black bindweed, Polygonum convolvulus in small grains. For successful control this weed must be treated early and it has been found that split applications of synthetic growth hormones are more effective than a single application. The first treatment is usually given at a stage of crop growth when MCPA is safer than 2,4-D. Application of 5 oz MCPA followed by 5 oz of 2,4-D ester not more than one week later has given good control.

Products containing 2,4-D were first registered in the autumn of 1945 after extensive trials during the summer of that year. The very prompt appreciation by the Western farmer of this new weapon in weed control is shown by the fact that in 1947 500,000 acres were treated and by 1950 the total had reached over 13 million acres. The percentage of total crop treated in that year in the three Prairie Provinces ranged from 20% to 38%, far above the percentage treated even in adjoining States. No other innovation in Canadian agriculture has had such ready and rapid acceptance as the use of the synthetic plant growth regulators. 161 products containing 2,4-D alone are on the Canadian market this year, about the same number as for the previous two years. Amine salt spray formulations total 56 and ester sprays 79, but this proportion is not an indication of relative use. The amines are used largely for control of lawn weeds while the esters in recent years have been applied to more than 90% of the treated crop acreage in the Western Provinces.

Products with 2,4,5-T as the active agent were registered for the first time in the autumn of 1948 and we now have 17 trade names. Mixtures of 2,4-D and 2,4,5-T have become increasingly popular and the number of such products attained a total of 41 this year. Approximately 50,000 acres of brush on roadsides, power lines and so on are treated with 2,4,5-T or mixtures of 2,4-D and 2,4,5-T.

Before mentioning briefly some of the other herbicides used in Canadian agriculture I shall draw your attention to the pre-eminent place held by the synthetic growth regulators. In 1954 some 11,500,000 acres were treated with herbicides yet herbicides other than the synthetic growth regulators contributed very little to this staggering total, probably not much more than 50,000 acres. This situation may in part be ascribed to the predominance of the small grains in our agriculture, 45 million acres out of a total field crop acreage of 58 million acres. The more than a million acres of flax are also largely dependent on the growth regulators for weed control. Hay and fodder crops totalling 11 million acres receive little herbicide treatment of any kind. other crops amount to less than a million acres.

Dinoseb is used on perhaps 1,000 acres of the 300,000 acres of potatoes and is recommended for treatment of small grains and flax seeded down to legumes. Nearly all of the pea crop in British Columbia is treated with dinoseb. There is no widespread use of chemicals on our small acreage of horticultural crops except for carrots where some 50% of the crop is treated with herbicidal oils.

Inorganic chemicals have found application as soil sterilants and for control of persistent perennial weeds. No herbicide in present use seems to be entirely satisfactory as a soil sterilant and a ready market would be found for a really effective sterilant. The use of sodium chlorate for spot application to persistent perennials is losing place to substituted ureas, monuron, boron compounds and various mixtures.

Dalapon and TCA are finding use for treatment of patches of couch grass but cultivation is still depended on for control of field infestations. TCA is also effectively employed for the control of annual grasses other than wild oats in sugar beets and flax.

At this point I shall refer to some of our serious weed problems that are still far from solved. The most important agricultural pest in Canada is wild oats. This weed is found across the country but only in the Prairies under extensive mechanized grain growing does it interfere in a major way with crop production. More than half of the agricultural acreage in the Prairies is infested with this weed and in the recent cycle of wet years it has extended into areas where it was previously unknown. No chemical is yet recommended for control of this weed in small grains although pre-planting treatments of CIPC are giving fair control in resistant crops such as sugar beets and peas. Intensive research is now under way by companies, Experimental Farms, and Western universities, to find if any of the present herbicides applied before seeding will kill germinating seeds of wild oats in the soil without injuring the crop. Cultural practices such as delayed seeding, use of quick maturing barley, and growing of fall-sown crops where feasible, are now employed with a measure of success.

Persistent perennials such as toadflax, leafy spurge, hoary cresses, Russian knapweed, field bindweed and others, are spreading rapidly in Western Canada. These weeds can be controlled by thorough and long-continued cultivation coupled with use of herbicides but a more effective herbicide is needed for economic control.

The general problem of weed control on pastures and rangelands, undeniably important crops, has barely been tackled. Many of our Eastern pastures present little to the grazing animal beyond hardhack, Spiraea spp., buttercups, ox-eye daisy, hawkweeds and so on. Chemical control has not found acceptance except by a minority of farmers, and either more effective chemicals or more extensive publicity are needed.

The rest of this paper will be devoted to survey and other biological aspects. Weed survey began in 1922 when a now retired botanist of the Canada Department of Agriculture, Mr. Herbert Groh, decided to undertake reconnaissance surveys throughout Canada as a first approach to the understanding of our weeds. In its simplest terms Groh's survey consisted of a listing of all weedy species at any given survey site. These sites were selected as occasion offered during travels across the country and might be at railway stations, on road-sides or in agricultural fields. In the 25 years, 1922-47, devoted to this work by Mr. Groh all settled areas were covered and a well-distributed sampling resulted.

As a first step in assembling the data, field notes were mapped on squared paper numbered to indicate meridians of longitude and parallels of latitude. Each of these maps represented 7 degrees of longitude and sufficient degrees of latitude to cover our comparatively narrow north-south agricultural lands. For a widely distributed species eight such maps were needed to cover Canada from east to west. The percentage frequency of a weed in any 7 degree longitude belt could be readily ascertained by comparison of the total number of surveys as shown on master sheets with the number of occurrences of the weed in that belt. For instance milkweed was found at 570 survey sites in the 76°-83° longitude belt (Central Ontario and Northern Quebec) out of a total of 947 surveys, a percentage frequency of 60.2. These frequencies were recorded in tabular form in the 7 Reports of the Canadian Weed Survey. This simple method produced a remarkable amount of data on weed incidence and distribution across Canada that is serving as a basis for studies on distribution. I imagine that your 5 years' Distribution Maps Scheme will serve much the same purpose.

More intensive surveys have been carried out to establish the abundance and distribution of certain weeds and groups of weeds. I can only mention a few of these surveys here and shall refrain from saying very much about methods. The ragweeds, Ambrosia spp., are not only serious agricultural weeds but also during their flowering season cause a remarkable amount of suffering to those susceptible to their pollens. The ragweeds are most abundant in the areas of largest populations in northeastern North America where some 3 million people are susceptible. Many of these individuals spend their vacations where ragweed pollens are not a problem and some even move to centres outside the ragweed belt. Up to a few years ago the Canadian Weed Survey was the only source of information on areas where ragweed sufferers could expect relief. In recent years we have coupled field surveys of ragweed with pollen surveys and now can give very exact data that is used in answering enquiries by allergists, travel bureaus, departments of health and our own department. Our pollen survey studies are also serving to measure the efficacy of control campaigns. Bulletins based on survey for barberry and buckthorn, alternate hosts for cereal rusts, in Eastern Canada, are assisting those engaged in control of these shrubs to carry out intelligent control campaigns. We are now trying out a new type of survey in Eastern Canada with promising results. Complete farms are selected at 20-mile intervals: all weeds are recorded together with notes on abundance, information on soil type, crops harbouring the weeds and so on.

Survey has probably reached its highest development with us in the surveys for persistent perennial weeds in Western Canada. Staff limitation made it impossible for the Federal Government to carry out the intensive surveys required, so funds were supplied to the four Provincial Departments of Agriculture in Western Canada. I shall only refer to the results of the work in Saskatchewan under the leadership of Dr. R. T. Coupland of the University of Saskatchewan. When the survey was started in 1949 little was known about the abundance of toadflax, leafy spurge, hoary cresses, Russian knapweed, and field bindweed, although estimates based on questionnaires and general impressions had been made. Survey was preceded in the rural municipalities by press releases, field days and demonstration of the species concerned, correspondence with municipal officers and discussion with agricultural representatives, and weed inspectors. By these methods many infestations became known and the surveyor then visited each reported infestation, circumscribed its limits by farm to farm search, and estimated the acreage infested. Random checks were then made in parts of the municipalities where the weeds had not been found.

By the end of the first year, with little more than 5% of the agricultural lands of the Province surveyed, it became clear that the earlier estimates for the whole Province had been exceeded. By 1955, 114 municipalities, about a third of the settled area, had undergone survey and the following alarming situation is now known to exist:

Species	Number of infested		
	Municipalities	Quarter Sections	Acres
Leafy spurge	87	933	9,634
Toadflax	84	4,993	142,700
Hoary cresses	38	133	1,764
Russian knapweed	41	120	1,960
Field bindweed	54	570	11,096

As each municipality, usually 324 square miles, was finished, a list of locations for these weeds together with maps showing the situation on each section was supplied to municipal officers. The Province and municipalities have made concerted attacks on these weeds since the survey information became available, but resurvey of selected municipalities has shown that the methods of control at present being applied are not adequate to check the spread of the weeds. In one rural municipality the number of acres infested with toadflax increased from 4,411 to 10,395 in 5 years despite considerable application of soil sterilants. Undoubtedly the persistent perennials pose a serious threat to Prairie lands.

Apart from their primary function the various surveys are also basic to other types of investigation particularly the ecological. Coupland has made strides in studies of the ecology of the persistent perennials and a project to be shared by the Federal Government and the University of British Columbia will be incepted in 1957 to tackle the ecology of tansy ragwort, Senecio jacobaea, and knapweeds, Centaurea spp. One of the most interesting tasks for an ecologist would be to explain the major patterns of distribution shown by our weeds. When the sight records of survey and plant collections are entered on outline maps of Canada, as has been done for many hundred species, several distinct patterns emerge. One of these patterns exemplified by quite a few species is that of abundance in Eastern Canada and British Columbia and absence or near absence from the Prairies. Yellow bristlegrass or foxtail, Setaria glauca, belongs to this group although green bristlegrass, S. viridis, a very similar species, is found across Canada and in recent years has become one of the most troublesome annual grasses of Prairie grainfields. Yellow bristlegrass does not reach as far north in Europe as does it companion species and this may be part of the explanation. Other annuals of far more southerly range in their homelands do however reach the Prairies, so some other factors may be involved. Experimental ecology should furnish answers to this and many other similar problems.

The various surveys have served to uncover new introductions. As a result the inventory of our weed flora containing something over a thousand species out of a total flora not much exceeding 5,000 is constantly receiving additions. How successful survey is in finding new introductions may be gauged by the fact that we have collections of more than 10 species in the mustard family not recorded in North American floras.

Our large weed flora of so many diverse origins has presented many problems in identification. I can only refer here to a very few of those on which we have made progress. We now know that hoary cress in Canada really consists of three distinct taxa differing in field performance to such an extent that each will probably require different control methods. Curiously enough your rapidly spreading Cardaria draba, the only hoary cress listed in "Flora of the British Isles" is quite rare with us. As a further example a study of wormseed mustards has recently revealed that material collected in 1946 and mistakenly considered to be a native western species invading the East was actually a plant not mentioned in any North American flora: Erysimum hieraciifolium. This particular mustard has since been investigated in the field and found to have a very extensive distribution in southeastern Ontario. It is a perennial from Eurasia and will require a type of attack very different from the one given our common annual or winter annual plant. We are attempting to unravel the complex of species that has passed for lamb's quarters, Chenopodium album. Certain native species appear to be more aggressive weeds than C. album at least in the Prairie Provinces and there is some evidence that they are less easily controlled with herbicides.

Our interests in correct identification have carried us beyond studies limited to gross morphology and we have entered the field of cytotaxonomy. One of our staff, G. A. Mulligan, is now involved in a cytotaxonomic study of Canadian weeds and his findings have not only helped in solving some long-standing problems but also pose serious new problems. I mentioned earlier that we recognize three morphologically distinct hoary cresses. It may not be this simple as Mulligan has found more than 3 chromosome counts in this group including a higher count than any yet reported for the mustard family. Yarrow, the Achillea millefolium complex, is one of our commonest plants. Botanists using a traditional approach have held that a large part of the yarrow in Eastern Canada is an introduction from the Old World. Mulligan finds that our native species in the East has a different chromosome number to the European. Pollen size fortunately varies directly with chromosome number in this complex so that herbarium sheets may also be utilized. From these studies we now find that the European plant is confined to a very few locales on the extreme eastern seaboard. Again our native rosebay willow herb, Chamaenerion angustifolium has a somatic chromosome number of 72 while your native species has 36. It would be of considerable interest to know if the rapid spread of this species in the British Isles is due to the introduction of the North American species, as suspected by some of your botanists. The difference in chromosome number would be a useful key in this study.

In concentrating our efforts on survey and taxonomy we have not neglected other facets of weed investigation. We early realized that much of the information on life history available in the literature is limited and frequently erroneous. Restricted staff numbers necessitated a simple approach that would give useful data without being too laborious. In our nursery we plant seeds immediately after collection and if there is germination in the first year remove all plants in half of the row in the following spring. Fresh germination takes place in the denuded half and these seedlings are permitted to grow on. By this method we have plants that have been exposed to our rather severe winter and plants of the year. Several hundred species have been dealt with in this way and notes have been recorded on winter hardiness, germination, flowering and seed maturity. Wild carrot is classified as a biennial in most floras and weed manuals. Nursery tests at Ottawa show that this plant is also an annual and that in most samples of seed the annuals predominate. Failures in controlling wild carrot may in part be ascribed to its being dealt with as a biennial without thought of its capacity for rapid multiplication. Until recent years yellow rocket, Barbarea vulgaris, in Canada was looked upon as an annual. Closer examination of field infestations and of plants in nursery plots at Ottawa has established that yellow rocket behaves as a perennial. It was also found that new shoots developed on all flowering plants in September. This fact coupled with abundant fall germination suggests that yellow rocket can be attacked at the end of the growing season as well as in the spring and a Canadian weed control specialist is now following this lead. We also discovered that yellow rocket has a remarkable capacity for maturing seed after being cut so that unless removed for silage the cut plants may be a source of further contamination.

Explanations for field behaviour and distribution can at least partly be derived from nursery studies. Two years ago I started a study of the docks, Rumex spp., and discovered several previously unrecognized species in Western Canada. These species were being confused with curled dock, R. crispus, a species that field and herbarium study showed to be very rare in the Prairies. Two Asiatic species are far commoner and one of these, R. fennicus is very abundant at least in Manitoba and Saskatchewan where south of Saskatoon it forms huge stands and is rapidly invading agricultural fields. We planted several samples of seed of R. fennicus and R. crispus soon after maturity and by the fall of the following year had information that may well explain why R. fennicus is the more aggressive weed under Prairie conditions. Although a perennial it can flower and produce seed in the year of germination while R. crispus has to pass a winter as a rosette before maturing seed. Spring plowing would eliminate rosettes of both species but R. fennicus would be favoured as it could still produce seed following new germination and would essentially behave as an annual.

I have confined my remarks on life history to work at Ottawa but I should mention the studies started at the University of Saskatchewan in 1949 with the assistance of the Saskatchewan Agricultural Research Foundation and continued in 1951 with funds from the Canada Department of Agriculture. Professor Coupland and his colleagues at the University working in close collaboration with Ottawa weed botanists have produced interesting life history data on leafy spurge and toadflax. Discontinuance of survey studies in 1956 will permit the Saskatchewan group to devote much greater effort towards life history studies.

These attempts to gain an understanding of our weeds are not altogether motivated by the needs of the control worker. In part we are studying weeds for their own intrinsic interest. Edgar Anderson in "Plants, Man and Life", draws attention to the fact that by a strange paradox weeds are comparatively unknown and that by an even greater paradox this perilous situation is very generally unsuspected. By "perilous" Anderson is not thinking of the intrusion of weeds into crops and the necessity for their control. Rather he has in mind the serious gaps in our knowledge of the history and evolution of weeds especially as related to the origin of cultivated plants and the development of human cultures.

Very little interest has been taken in the biology of weeds but I think there is a trend in this direction as exemplified by a number of papers that have appeared in your own Proceedings and by the session on ecology in the present meeting. It is encouraging to think that a philosophy is now developing that successful control of weeds must ultimately depend on a basic understanding of the plants that we are attempting to destroy. Until this understanding is gained weed control will remain in a curiously anomalous position when compared with entomology and plant pathology where control depends on a fund of basic knowledge.

THE APPLICATION OF HERBICIDES IN THE U.S.S.R.

(A BRIEF REVIEW)

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As is known, the Soviet Union includes a number of very different soil and climatic zones, beginning with the Arctic tundra and ending with the subtropics. Soviet agriculture is noted for a great variety of crops. As a result the weed flora of the country comprises a large number of species many of which are of great potential danger to farming and may cause huge losses if measures to suppress them are inadequate.

In view of this the agrotechnical measures worked out for different agricultural regions of the country (methods of soil cultivation, crop rotations, methods of tending plants, etc.) include weed control as one of the main tasks. Agrotechnical methods together with measures to prevent field infestation are the chief means of weed control. The application of herbicides is considered mainly as an important auxiliary measure which simplifies the elimination of weeds in the fields.

The study of the problems of chemical weed control began in the U.S.S.R. quite a long time ago. However, herbicides, tested in the different experiments failed to find practical application, with the exception of chlorates and sodium arsenite which were employed on a small scale to control certain pernicious perennial weeds and unwanted trees and shrubs.

After World War II the study and utilization of modern organic herbicides, especially substances of the hormone type proceeded to grow along with the restoration of industry, agriculture and the network of agricultural research institutions.

Within a comparatively short time research organizations managed to give a multilateral analysis of the herbicidal action of 2,4-D and MCPA preparations, at first in the form of sodium salts and then as ester and amine salts. Data were obtained in different zones of the country on the comparative sensitivity of individual weeds and cultivated plants to these herbicides at different phases of development, on the optimal doses and time of application, and on the technique of ground and aerial spraying and, finally, extensive tests were made under various conditions of farming.

As a result of this work sodium salts and butyl ester 2,4-D (to a lesser extent MCPA) are now successfully applied to cereals, especially spring crops and give an increase in yields of about 2-3 centners/hectare and even more, if the infestation be high. The demand for herbicides made by the farms is very great, thus it is planned to expand the output considerably.

Among the problems connected with the application of 2,4-D and MCPA to cereals research institutions paid special attention to the eradication of root-sprouting weeds, especially thistles (Sonchus arvensis and Cirsium arvense) bindweed (Convolvulus arvenis) and Russian knapweed (Acroptilon picris). Several schemes of combining cultivations (late fall ploughing and fallow tillage) with chemical methods to destroy these weeds have been worked out.

The elaboration of chemical means of combating aggressive annual weeds such as Ambrosia artemisiifolia also required considerable effort since the sensitivity of this weed to herbicides varies markedly depending upon age and conditions of growth.

Considerable work has been accomplished to study the conditions and technique of applying derivatives of 2,4-D to grain crops under conditions of artificial irrigation. The effectiveness of the treatment is particularly great here and the increase in spring wheat yields reaches 8 centners/hectare while that of millet and rice -- 12 centners/hectare.

In order to combat weeds in millet crops which grow slowly in the initial stages, two sprayings with at first a small and then a normal dose has proved to be most effective.

Good results are obtained by applying 2,4-D and MCPA to grass fields, in particular to seed grasses where the economic effect of chemical treatment is particularly great. Methods of combining applications of 2,4-D with fertilizers in particular with foliar fertilization and in certain cases also with insecticides are being worked out and tested on a wide scale.

The experience accumulated by research organizations on pre- and post-emergence treatment with herbicides in combination with interrow hoeing of maize shows that chemical methods are highly effective in this crop. Further work is necessary to determine the rate and technique of application in connection with soil and weather conditions and also in relation to particular varieties, especially hybrids.

Comprehensive experimental work has been conducted to study conditions of applying salts and esters of 2,4-D and 2,4,5-T for the destruction of trees and shrubs on farmlands. These herbicides are being applied to considerable areas to destroy alder, birch, and aspen thickets. In connection with the task of developing virgin lands in the central and northern regions the scope of this treatment will be considerably extended. Similar methods of applying 2,4-D and 2,4,5-T have been worked out for forestry. Considerable experience has been accumulated in applying 2,4-D for weed control on meadows and pastures.

Pre- and post-emergence treatments with herbicides have been widely tested in vegetable crops and potatoes. Pre-emergence treatment with 2,4-D and contact herbicides (ammonium dinitroorthocresylate and sodium pentachlorphenate) gave good results on potatoes, and on onions good results were obtained from pre- and post-emergence applications of DNC.

Petroleum fractions have been chosen for selective weed control in carrots and other umbelliferous crops while for emergence treatment shale resins have been applied.

The above-mentioned mineral oils are highly valued on the farms, as compared with hand weeding they save labour to the amount of 60 man days and more per hectare.

In combating Stellaria media, a pernicious weed in vegetable crops propham and CIPC were tested. Their effect depends upon soil conditions and is quite satisfactory on peaty and floodland soils. These and other preparations active against grasses (dichloral-urea, sodium trichloracetate,) are being widely tested under conditions of production on various dicotyledonous crops.

In some regions of the country much significance is attached to chemical control of weeds belonging to the genus Cuscuta in clover crops and especially alfalfa. For this purpose stubble is sprayed with herbicides of the DNC type immediately after mowing and hay making. At first sodium arsenite was applied, but recently it has been replaced by herbicides of the DNC and sodium pentachlorphenate type. At present emulsions of highly aromatic mineral oils are being tested for this purpose.

The application of herbicides on large areas is performed by aircraft and in rugged countries of the central and northern belt. Helicopters are being tested for this purpose.

Work has begun in research institutes on the search for new herbicidal compounds and on the study of the nature of the action of herbicides.