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CHEMICAL WEED CONTROL IN FINLAND IN 1887—1965

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INTRODUCTION

The first published reference to chemical weed control in Finland appeared in a textbook written by J. E. SUNILA (1899) and entitled *Finnish Weeds and their Control* (p. 29). The author referred to studies made by M. VON ESSEN to control coltsfoot (*Tussilago farfara*) by »strewing large amounts of salt [=sodium chloride] on the ground, which in this case cannot be used for growing crops until the following summer». This method is described in greater detail in the book *Studies on the Cultivation of Fodder Crops* which was written by von ESSEN (1912, 1913) and edited after his death by G. GROTFELT. In this book are collected many of the lectures given by von ESSEN, one of which, entitled *Fodder Crop Production on Peat Soil at Herniäinen* and presented at the autumn



Fig. 1. Mikael von Essen (1845—1905), pioneer of chemical weed control in Finland.

meeting of the Uusimaa and Häme Provincial Agricultural Societies in 1897, included the following statements (von ESSEN 1912, p. 275; 1913, p. 278):

»The victory of which I am most proud, and whose ten-year anniversary I can celebrate at this time, is that which I achieved over the notorious weed coltsfoot. One spring, after having remained scarcely unnoticed for many years, this weed suddenly appeared in large numbers in a newly sown field of foxtail [*Alopecurus pratensis*], and later in the summer its large leaves had covered areas of 30 to 40 square metres, smothering completely the growth of the grass. My method of combatting this enemy was to scatter sufficiently large amounts of common salt over the field twice at an interval of a couple of weeks. The effect was quite devastating: within a year or two not the least sign of this weed remained on the treated field».

From this report it is clear that a) von ESSEN used common salt or crystalline sodium chloride as a soil herbicide, not as a foliar herbicide and b) the chemical killed coltsfoot but not foxtail. In other words, this was a case of selective weed control in a foxtail ley. The statement by SUNILA (1899) that salt-treated ground should not be cultivated until following summer apparently referred to the growing of crops other than foxtail.

In another lecture given by von ESSEN (1912, p. 258, 261; 1913, p. 261, 263—264) at the 1904 spring meeting of the Uusimaa and Häme Provincial Agricultural Societies and entitled *The Most Noxious Grassland Weeds*, von ESSEN described his experiences during a 10-year period in the use of common salt to control mugwort (*Artemisia vulgaris*), cow parsley (*Anthriscus silvestris*) and dandelion (*Taraxacum*

officinale). His method was to cut the weeds at the stem base and to apply to the cut surface of the root »a handful of this plant poison which is readily obtainable everywhere and easy to carry». Von ESSEN recommended this method particularly for the controlling of dandelions and considered that »it had many advantages over the weed-killing chemicals which were commonly recommended at that time, such as sulphuric acid, arsenic compounds, etc., not to mention solutions of common salt or 'salt water' whose effect is of very short duration».

Again von ESSEN had made noteworthy observations: when used as foliar sprays, i.e. in the form of solutions, the above compounds had no lasting effect on perennial weeds because they were not translocated. Secondly, he had devised spot treatment of perennial weeds, for which the chemical did not necessarily have to be selective in its action.

»In my weed-exterminating team», continues von ESSEN (1912, p. 264; 1913, p. 266), »there are both women and children, of which the former resort to steel and the latter to poison». Apparently von ESSEN realized one of the most important advantages of chemical control. Namely that it is easier and quicker than mechanical methods.

Where did von ESSEN get the idea of using these chemicals for weed control?

The selective chemical control of weeds has usually been claimed to have been discovered almost simultaneously and quite independently by BONNET in France, SCHULTZ in Germany and BOLLEY in the USA (e. g. KLINGMAN 1961, CRAFTS and ROBBINS 1962, BRIAN 1963). Actually BONNET was the first one of these three workers. He had observed the phytocidal effects of »copper salts», apparently before 1896. In that year he sprayed his 1-hectare oat field with »copper solution» in order to kill wild radish (*Raphanus raphanistrum*) and charlock (*Sinapis arvensis*). The concentration was 6% »acid solution». Apparently this refers to copper sulphate, which is a component of Bordeaux mixture. The treatment killed the weeds, but did not injure the oats. On December 12, 1896, BONNET reported his findings to the Société Nationale d'Agriculture de France, Comice de Reims (HITIER 1897 a).

In the beginning of May 1897, the results obtained by BONNET were verified by the French workers BENARD and BRANDIN (HITIER 1897 a). Furthermore, MARTIN

(1897) discovered the phytocidal effects of ferrous sulphate, and DUCLOS successfully experimented both with copper and ferrous sulphate as well as with sulphuric and nitric acid (HITIER 1897 b). In 1898 several French workers, e.g. WAGNER, began with similar experiments.

German weed workers were informed of these studies by an article published in the *Deutsche Landwirtschaftliche Presse* on June 30, 1897. As a result, comprehensive research on chemical weed control was started in Germany. At the end of October SCHULTZ (1897) gave the first report on the German trials. Two years later SCHULTZ (1899 c) made the following statement on his studies:

»The discovery that charlock and wild radish can be destroyed through metal salt compounds originated in the Frenchman BONNET and was mentioned for the first time in Germany in an article in the *Deutsche Landwirtschaftliche Presse* (No. 51, 1897). On the basis of this statement I have been the first one to put the French discovery to a test in Germany, and already on October 1, 1897 (*Landw. Ztg. Westfalen u. Lippe*, No. 39) I published the results of my experiments which had led to the conclusion that the 15% ferrous sulphate proved the most suitable compound for the purpose. My work was published in almost all agricultural publications and was the cause of subsequent trials.»

On the basis of this account it is clear that SCHULTZ started his trials with ferrous sulphate in 1897, but probably not before getting acquainted with MARTIN's and DUCLOS experiments with the same compound. In any case this was a year after BONNET's experiments with copper sulphate.

Progress in Germany was rapid in the following years (SCHULTZ 1898, 1899 a—c, 1909). By 1900 it was discovered that many commercial fertilizers, e.g. sodium nitrate, ammonium sulphate and certain potassium salts also had herbicidal properties (cf. RADEMACHER 1940, TIMMONS 1963). According to the bibliography published by HORTON in 1906, the use of copper and ferrous sulphate as herbicides became known also in Austria, Australia, Belgium, Canada, England and Ireland during the years 1898—1900, and, according to SjöSTRÖM, also in Sweden in 1899.

The first trials in chemical weed control in the USA were made by BOLLEY in 1896, using corrosive sublimate, i.e. mercuric chloride. The results, however, proved unsatisfactory. Having heard of WAGNER's (1898) investigations in France, dealing with copper and ferrous sulphate, BOLLEY again took up the work. This time he included several other compounds in his trials and succeeded in obtaining encouraging results. BOLLEY's first unpublished report of Aug. 10, 1899 reads as follows:

»During the spring of 1896 I made some attempts at this station to destroy English Charlock, *Brassica sinapistrum*, in an oat field by means of a solution of corrosive sublimate sprayed evenly over all the plants.

The strength of solution selected and the weather conditions were such that the results obtained discouraged further attempts during that season, and I did not take up the work again until the past spring [1899], when the appeals from the farmers of the state for some extensive method of weed destruction again induced a further consideration of the idea. About this time, Professor L. H. Dewey — of the Department of Agriculture at Washington, D. C. called my attention to a paper by Mr. Wagner in the *Journal D'Agriculture Pratique*, in which the author claims to have found some success in destroying thistles and mustard in grain fields by means of iron sulphate and copper sulphate solutions sprayed upon grain fields. This was encouraging and the work has been prosecuted quite continuously since that date with most encouraging results.»

The other compounds which BOLLEY included in his trials were copper sulphate (BOLLEY 1899), sodium arsenite, sodium arsenate, »salt» or sodium chloride (BOLLEY 1901) and ferrous sulphate (BOLLEY 1908).

In his final bulletin of 1908 (p. 541) BOLLEY claims that

... »the preliminary results conducted at North Dakota Experiment Station in 1896, were, perhaps, the first experiments of the kind conducted in any country» . . .

This statement seems to prove that BOLLEY was not aware of BONNET's work of 1896, but only of WAGNER's work of 1898.

The story of chemical weed control is not complete unless we mention the preliminary attempts made in Germany in the early 1800's. For example BECKER (1840) recommended lime against horsetail (*Equisetum*), MEYN (1854) recommended common salt and BROCKMAYER (ref. LÖBE 1874, p. 53) chlorcalcium for the same purpose. KIRCHHOF (1855) recommended sulphuric acid and iron sulphate against weeds on open fields, and THORSYTH (ref. LÖBE 1874, p. 90—91) sulphuric acid and common salt against couch grass (*Agropyron repens*). The idea of selective control had been discussed in Germany by e.g. KIRCHHOF (1855, p. 36, 47—48, 103), BROCKMAYER (ref. LÖBE 1874, p. 53) and HOFFMANN (1871). Furthermore, MARGUERITE-DELARCHARLONNY (1887, 1888) in France, and RHODIN (1891) in Sweden had obtained selective control of moss in grassland.

Although von ESSEN in his lectures in 1897 and 1904 mentioned his experiences over ten years, it is clear that information on chemical weed control had already been available when he started his trials. At the time of his second lecture in 1904, von ESSEN was apparently familiar with HITIER's (1897 b) and BOLLEY's (1901) reports, since he mentioned that sulphuric acid and arsenic compounds were »commonly recommended plant poisons». On the other hand, it is questionable whether the results which von ESSEN obtained with sodium chloride against coltsfoot were as good as he claimed. Trials carried out

by the Department of Plant Husbandry in the 1950's and 1960's showed that coltsfoot is rather resistant to sodium chloride, and high rates are needed to kill this weed.

The trials of von ESSEN evidently did not arouse any great interest in chemical weed control in this country. It is true that in the years 1905—1915 »herring brine», i.e. sodium chloride solution, was used in the coastal towns of southern Finland to keep sidewalks (cobble footpaths) clear of weeds. However, von ESSEN's recommendation of the use of dry sodium chloride was not adopted.

BRENNER (1918) was probably the first Finnish worker to make a close study on the toxicity of mineral acids to leaf tissue. He observed that the acids readily penetrated the tissue, instantly destroying the protoplasm. GROTENFELT (1914 a—b), GROTENFELT and AALTO-SETÄLÄ (1924) and RELANDER (1923) recommended some chemicals against weeds on the basis of foreign experiments. KITUNEN (1929, 1930), however, stated that although some farmers may have used chemicals on their own fields, actual field experiments were not carried out until 1926—29, when he began to conduct studies on four farms near Helsinki and on one farm at Rantasalmi.

The Department of Plant Husbandry of the Agricultural Research Centre carried out its first herbicide trials on uncultivated land in 1926 and on cultivated fields in 1927. The Department of Pest Investigation initiated similar trials in the late 1920's, the Department of Horticulture and the Satakunta Agricultural Experiment Station in 1931. The agricultural experiment stations in South and North Ostrobothnia, Häme and Karelia began their herbicide trials in 1936, the Department of Plant Husbandry of the University of Helsinki in 1945, and the Forest Research Institute in 1950. Finland's Swedish-language agricultural advisory organization initiated similar research in 1947 and the Finnish organizations in 1948.

The first commercial weedkillers were put on the market in Finland at the end of the 1920's, but not until the 1950's did the sales and use of herbicides attain economically substantial

proportions. In accordance with the Finnish Pesticide Law of 1951, the Office for Plant Protectants was given the authority to supervise the regulations concerning the sales of herbi-

cides, while the Department of Plant Husbandry of the Agricultural Research Centre was responsible for carrying out the necessary biological tests (Dec. Min. Agric. 1952).

CHRONOLOGICAL REVIEW OF HERBICIDES USED IN FINLAND IN 1887—1965

In this chapter the herbicides used in Finland during the period 1887—1965 are discussed in chronological sequence. Most of the compounds were not discovered in Finland. The year given after each title denotes the time when herbicidal experiments with the compound were begun in this country. References to the literature are also made in the text whenever published data exist.

1. Chlorides

Sodium chloride, 1887

Common salt or sodium chloride, NaCl, was the first chemical tested as a herbicide in Finland. As mentioned above, von ESSEN (1912, 1913) tried it in 1887. He used sodium chloride in crystalline form against *Tussilago farfara* and both in crystalline form and water solution for spot treatment of *Taraxacum officinale* and *Anthriscus silvestris*. Prior to the first world war, water solutions of common salt were used to destroy weeds on sidewalks in southern coastal towns. In the 1940's and 1950's crystalline sodium chloride was commonly employed to keep yards and pathways free of weeds. JAMALAINEN and KANERVO (1953) also recommended sodium chloride for the control of barberry (*Berberis vulgaris*) bushes. In 1945 a Finnish product called *Rikkaruohontuho* consisting of a

mixture of sodium chloride and sodium chlorate in the proportion 55:45 (p. 9), was put on the market. A similar Norwegian preparation, *Kap-rex*, was introduced in 1964. Both of these were in powder form and intended for use either dry or as water solutions. They were approved by the Office for Plant Protectants for weed control on non-agricultural sites. Trials showed that the herbicidal activity of the chloride-chlorate mixture was slightly weaker than that of pure chlorate (SÄKÖ 1956) and much weaker than that of the modern non-selective organic herbicides (MUKULA 1959 a, 1960 c, LALLUKKA and BORG 1965). Nevertheless, the sales of both these sodium chloride-chlorate products increased yearly. In 1964—65 their annual sales amounted to about 50 tons, of which sodium chloride made up about one-half. This quantity represented a treated area of just over 100 hectares.

Magnesium chloride, 1960

In the years 1960—62 magnesium chloride, MgCl₂, was tested at the Department of Plant Husbandry of the Agricultural Research Centre mixed with sodium chlorate (p. 9), 2,4-D (p. 15) and monuron (p. 19). The Office for Plant Protectants approved the mixture in 1962 for weed control on non-agricultural sites. It was, however, not marketed in Finland.

2. Inorganic acids

Sulphuric acid, 1903

Sulphuric acid, H₂SO₄, was another herbicide tried by von ESSEN (1912, 1913). He probably began his trials with this chemical before

the 1904 spring meeting of the Uusimaa and Häme Provincial Agricultural Societies, i.e. during the summer of 1903. RELANDER (1923), on the basis of foreign reports, recommended sulphuric acid for selective weed control in

cereals. More extensive field trials with this compound were carried out by KITUNEN (1930) in 1926—29. The effect was poor against *Chenopodium album* but good against other broad-leaved annuals. The treatment did not injure the cereals, and resulted in yield increase.

At the Department of Plant Husbandry, additional trials with sulphuric acid on spring cereals were done as late as in 1944 and 1947 and on bulb onions in 1951—53 and 1959. Similarly, the State Department of Forestry organized trials with sulphuric acid in a re-forestation area at the Nikkarila School of Forestry in 1950 (PAAVOLA 1953). Sulphuric acid was also recommended in several advisory papers for weed control in spring cereals, bulb onions and peas (LÄHDE 1948, 1954, LÄHDE and BREITENSTEIN 1952, LÄHDE et al. 1955). The use of this unpleasant chemical, however, was never accepted by farmers.

Nitric acid, 1929

Nitric acid, HNO_3 , was tested by KITUNEN (1930) on oats in the year 1929. Its effect in controlling weeds was as good as that of sulphuric acid, and it gave greater yield increases.

Hydrochloric acid, 1947

Hydrochloric acid, HCl , was tested against annual weeds in spring cereals in 1947—48 at the Anttila Experimental Farm of the Co-operative Hankkija. Its contact effect proved similar to that of sulphuric acid. In the 1940's and 1950's hydrochloric acid, under the name of *AIV Solution*, was quite commonly used in Finland for killing weeds in yards and pathways. No statistical data, however, are available on its use for this purpose.

3. Arsenicals, 1903

Von ESSEN (1912, 1913) was also the first to experiment with arsenicals as herbicides in Finland. As early as 1903 he used unspecified arsenic compounds as foliar sprays for spot treatments against perennial weeds.

In 1954, experiments were begun at the Department of Plant Husbandry using sodium

arsenite, Na_3AsO_3 , as a foliar herbicide on non-agricultural sites. Its contact effect was rapid but the residual effect in the soil was short. Owing to the toxicity of the compound, the product was not granted a sales permit. The trials were terminated in 1956.

4. Sulphates

Ferrous sulphate, 1926

Ferrous sulphate, FeSO_4 , was recommended by GROTENFELT (1914 a, b) and RELANDER (1923) for selective weed control in cereals. KITUNEN (1930) carried out extensive trials with this compound in the years 1926—29, using it both in solution and as a dust powder mixed with gypsum. He had acquired the latter formulation from Germany as a commercial herbicide called *Hederichpulver*. The contact effect of the solution of ferrous sulphate was almost as good in KITUNEN's trials as that of sulphuric

acid. The powder formulation, however, gave poor results. At the end of the 1920's and in the 1930's, the Department of Pest Investigation of the Agricultural Research Centre conducted trials using another German ferrous sulphate powder, *Raphanit*. Trials with *Raphanit* were also carried out at the Karelia Agricultural Experiment Station in 1936.

Hederichpulver and *Raphanit* were apparently the first commercial herbicides to be tested in Finland. As far as is known they were never sold in this country.

Copper sulphate, 1959

The use of copper sulphate, CuSO_4 , in Finland as a herbicide for cereals was first mentioned by KITUNEN (1930). LÄHDE (1954) also reported on this chemical in a paper. These workers did not themselves carry out trials with copper sulphate. It was apparently not until 1959 that copper sulphate was tried against an alga, *Anabena circinans*, in the Vantaa River and

Tuusula Lake (KANGAS 1963). This chemical was never approved by the Office for Plant Protectants. However, it was sold as a technical product and, in accordance with a Decree on Water Rights (1962), it was used every year since 1962 on the waterways of the Vantaa River. The area treated ranged from a few score to 100—200 hectares annually. Application was carried out partly from the air.

5. Calcium cyanamide, 1926

R e s e a r c h. The first studies with calcium cyanamide, CaCN_2 , as a herbicide were carried out in Finland by KITUNEN (1930). In 1926—28 he organized field trials at three farms near Helsinki and in 1928 at a farm in Rantasalmi. In addition, at the end of the 1920's and during the 1930's, VIRRI (1937, 1944, 1946) studied the use of calcium cyanamide at the Satakunta Agricultural Experiment Station. In the years 1936—41 this compound was also tested at the agricultural experiment stations of South and North Ostrobothnia, Häme and Karelia. Nevertheless, there was little active interest in calcium cyanamide as a herbicide until 1944, when the Production Division of the Ministry of Agriculture published bulletins on the use of calcium cyanamide and other means of weed control (ANON. 1944 a-c).

Calcium cyanamide was employed in powder form either as a pre-sowing or a post-emergence

treatment against annual weeds in cereals, peas and onions, and as a pre-emergence treatment in potatoes. Under moist conditions it provided good control of germinating weed seeds and weed seedlings, but under dry conditions its herbicidal effect was poor, especially against *Chenopodium album* (HILLI 1948 b, 1950, LÄHDE 1948, 1954, MARJANEN 1958, SIMOJOKI 1961).

A p p r o v a l s. Soon after the Pesticide Law had come into force, 1953, calcium cyanamide was approved for pre-sowing and post-emergence use against annual weeds in cereals, peas and onions, and for pre-emergence treatment in potatoes.

S a l e s. Calcium cyanamide was already imported to Finland as a fertilizer in the 1920's. In the early 1950's manufacture of the compound was started in this country. However, it never became popular, and from time to time production and sales stopped.

6. Chlorates

Sodium chlorate, 1926

R e s e a r c h. In 1926, the Department of Plant Husbandry acquired powdered sodium chlorate, NaClO_3 , from Germany. The product was tested in water solution for destroying herbaceous weeds along roadways, banks of ditches, yards, on hard tennis courts, etc. In 1927, successful trials were also carried out in

controlling *Tussilago farfara* on fallow fields. The work begun by von FEILITZEN (1925) in Sweden provided the stimulus for these trials. Sodium chlorate acted rapidly on weeds both through their leaves and through the soil. Its herbicidal effect persisted for about a year.

In 1945, experiments were started in Finland with a mixture of powdered sodium chlorate and sodium chloride. This mixture was used

either dry or in water solutions. In 1957—62, similar trials were also made with mixtures containing sodium metaborate, sodium tetraborate, sodium pentaborate (p. 26), magnesium chloride (p. 6), monuron (p. 19), 2,4-D (p. 15) and other chemicals (HILLI 1946, LÄHDE 1947, 1949, 1954, SÄKÖ 1956, MUKULA and SÄKÖ 1961). Chlorides decreased the effectiveness of sodium chlorate, while the other chemicals either enhanced the herbicidal action or prolonged it (MUKULA 1960 c). Compared with the best non-selective organic herbicides, however, mixtures of sodium chlorate — especially those with sodium chloride — gave only a moderate or weak control, even though the dosage was raised as high as 600 kg/ha (MUKULA 1960 c, LALLUKKA and BORG 1965).

Approvals. After the Pesticide Law had come into effect in 1952, the sodium chlorate-chloride mixture was approved against herbaceous weeds on uncropped land. During the years 1958—61 the other mixtures were approved for the same purpose.

Sales. Sodium chlorate was the first commercial herbicide sold in Finland. In 1927, the German product *Wegebellum* was put on the Finnish market, and in the early 1930's the domestic *Kitko* and the Swedish *Klorex* became commercially available. Sales, however, were small and gradually ceased toward the end of the 1930's. In 1945 the Finnish product, *Rikka-ruohontubo*, appeared on the market. It contained 45 % sodium chlorate and 55 % sodium chloride. At the end of the 1950's, the proportions of these ingredients were reversed (55:45). The following imported sodium chlorate mixtures were also available on the Finnish market: *Klorea*, both in granular and powder form, since 1958, manufactured in England (*Chlorex*), containing sodium chlorate, sodium metaborate and monuron; *Kaprex*, in powder form, since 1964, manufactured in Norway, containing sodium chlorate and sodium chloride.

The annual sales of sodium chlorate mixtures rose gradually since 1945 to about 60 tons, of which sodium chlorate made up about one-half.

This represents a treated area of 150 hectares annually. The mixtures were used chiefly against herbaceous weeds in yards, on pathways, sports fields and industrial sites. In the early 1960's the sodium chlorate-chloride mixture was also employed on railways.

Potassium chlorate, 1931

Research. Experiments with potassium chlorate, $KClO_3$, were begun at the Department of Horticulture in 1931 and in various other institutes in 1944—60. The chemical was used dry as a coarse crystalline formulation.

When potassium chlorate is chemically reduced, it becomes potassium chloride, which acts as a plant nutrient. This fact stimulated an interest in experimenting with this compound not only on uncropped areas but also on cultivated land (VIRNES 1946, HILLI 1946, 1948 c, d, LÄHDE 1948, 1949, 1954, LÄHDE and BREITENSTEIN 1952). In practice, however, it proved too persistent and caused injury to the following field crops (VALLE 1946) as well as to the tree plants in reforestation (PAAVOLA 1953). Only in apple orchards the use of potassium chlorate proved safe and resulted in substantial yield increase (MEURMAN 1944, 1946, 1948, 1950, SÄKÖ 1956).

Approvals. When the Pesticide Law came into effect in 1952, potassium chlorate was officially approved against herbaceous weeds on non-agricultural sites and under full-grown apple trees. Its post-harvest use on open fields as well as on fallow land was also approved. In 1958 the Office for Plant Protectants, however, withdrew the permits concerning the use of potassium chlorate on cultivated land.

Sales. Potassium chlorate was sold in Finland in the years 1935—63 as a coarse crystalline preparation manufactured under the trade name *Fekabit*. Because of its low price and easy application, *Fekabit* soon displaced the early sodium chlorate powders. Mixtures of sodium chlorate with other chemicals were likewise unable to compete with *Fekabit* because

of their weaker effect or higher price. The sales of *Fekabit* rose rapidly, exceeding 100 tons annually in the 1950's. This amount corresponds

to nearly 400 hectares of treated land. The main use of *Fekabit* was on uncropped sites, such as yards and pathways.

7. Nitrates

Calcium nitrate, 1936

The herbicidal properties of calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, were first studied at the South Ostrobothnia Agricultural Experiment Station in 1936. The compound showed some contact effect on the foliage of broad-leaved weeds.

Sodium nitrate, 1958

In the years 1958—62 sodium nitrate, NaNO_3 , was tested as a post-emergence spray on sugar beet, both alone and in 1962 together with pyrazon (p. 19). The chemical gave satisfactory contact effect on many annual weeds and caused no appreciable damage to the beet. *Chenopodium album* resisted the treatment.

8. Halogenated aliphatic acids

TCA, 1940

R e s e a r c h. The herbicidal properties of trichloroacetic acid or TCA were discovered by VIRTANEN in 1940. He began with pot trials and continued with field trials in 1941—45. On August 27, 1945, VIRTANEN presented a patent application in Finland »for the use of those organic compounds in which the carbon atom adjacent to CO group was completely chlorinated, such as trichloroacetic acid and chloral, against perennial weeds, especially couch grass» (VIRTANEN 1948). The next year he presented a similar application in Sweden. The Finnish patent (No. 22 562) was granted on December 10, 1947, and the Swedish patent (No. 122 159) on May 5, 1948. Both remained in effect until 1961, when they expired.

On November 28, 1944 in the USA, BOUSQUET (1946), assignor to the firm E. I. du Pont de Nemours & Co., applied for a patent for the ammonium salt of TCA. This was about nine months earlier than VIRTANEN's application in Finland. The American patent was granted on January 15, 1946 (U.S. Pat. No. 2 393 086), or only a few months after the date of VIRTANEN's applications. As is well known, the American TCA patent was weak, because it covered only the ammonium salt of this compound. On the other hand, the Finnish and Swedish patents were not sufficiently comprehensive to include

2,2-dichloropropionic acid or dalapon (cf. BARRONS 1953) which was patented a few years later in the USA (U.S. Pat. No. 2 642 353). In dalapon the carbon adjacent to the CO group has only two chlorine substitutions, its third valence being occupied by a methyl radical (CH_3).

Further trials dealing with the use of TCA against *Agropyron repens* in Finland were begun in 1951 by the Department of Plant Husbandry and the Bureau for Local Experiments of the Agricultural Research Centre. A number of publications appeared on the results obtained with the sodium salt of TCA (MARJANEN 1954, LÄHDE 1955 a, 1956, MUKULA 1958 b, 1961 b, MUKULA and SÄKÖ 1961, RUUTTUNEN 1960, 1962, 1964). Finland also participated in the inter-Scandinavian research programme on the use of TCA against *Agropyron repens* (GRANSTRÖM et al. 1960).

Owing to the peculiarities of the Finnish springtime, with its rapid onset and its frequent lack of rainfall, the acceptability of a soil-acting, relatively nonselective herbicide like TCA was questionable. Treatments made late in the autumn gave more reliable results.

In the years 1959—60, TCA was also tested in mixtures with other herbicides, such as chloral chloroacetamide (p. 27) and MCPA (p. 13).

Approvals. When the Pesticide Law came into effect in 1952, the sodium salt of TCA was approved for pre-sowing or pre-planting and post-harvest use against *Agropyron repens* on crop land and on non-cultivated sites such as ditches.

In addition to TCA, trials against *Agropyron repens* were carried out with dichloroacetic acid (LÄHDE 1954, 1955 a). On the basis of official tests a commercial «dichloroderivative», *WA-60*, was approved by the Office for Plant Protectants in 1953. Chemical analyses conducted in 1955 revealed that the product was a mixture of dichloro- and trichloroacetic acids. Trials with pure dichloroderivative showed no herbicidal effects.

Sales. The first commercial TCA preparation to be marketed in Finland was a soluble sodium salt powder, *Juolavehnäntubo*, imported from West Germany. After the expiration of the Finnish TCA patent in 1961, several new products containing sodium salt of TCA appeared on the market. In the years 1953—58 there was also a Finnish liquid preparation available under the trade name *WA-60*. At first the sales of TCA rose rapidly, from 6 tons in 1952 to 27 tons in 1954, and to 50 tons a year later. In the following two years 1956—57, the consumption dropped to 48—30 tons, thereafter it gradually increased to a level of about 100 tons, where it remained with minor fluctuations since 1962. This quantity of TCA was sufficient for treating an area of about 3 000 hectares annually.

Dalapon, 1955

Research. The sodium salt of 2,2-dichloropropionic acid, or sodium dalapon, was acquired by the Department of Plant Husbandry from the USA in 1955 and was included in field trials for control of *Agropyron repens* in the following year. The compound acts strongly through the leaves and, to some degree, also through the soil. Because of the short growing season in Finland, the pre-planting foliar use of dalapon against *Agropyron repens* is difficult. On the other hand, post-harvest treatments gave unsatisfactory control (RUUTUNEN 1962). Like TCA, dalapon showed a low selectivity and

persisted in the soil about three months (RUMMUKAINEN 1961 a, MUKULA and SÄKÖ 1961).

Against *Phragmites communis* (SILVO 1960, 1962—63) and *Deschampsia caespitosa* (RUUTUNEN 1964) dalapon gave satisfactory control.

During the years 1960—65 dalapon was also tested in mixtures with MCPA (p. 13), 2,4-D (p. 15) and 2,4,5-T (p. 16). The latter compounds were effective against several broad-leaved weeds. They also enhanced the foliar effect of dalapon on grasses.

Approvals. In 1958 dalapon was approved against *Agropyron repens* and other grass weeds on non-agricultural sites without limitations and on crop land for post-harvest use. In 1961, the compound was further approved for control of *Phragmites communis* in waters.

Sales. In 1960, three dalapon products were put on the market in Finland. These were *Dalaami* and *Fragulan* from Sweden and *Dowpon* from the USA. Besides dalapon *Fragulan* contains also phenoxycarboxylates. Calculated as dalapon acid, the annual sales of these products in the years 1960—65 were a few hundred kilograms, an amount sufficient to treat an area of 100—150 hectares annually.

Erbon, 1956

A derivative of dalapon, 2,4,5-trichlorophenyl-ethoxy ester, or erbon, was tested at the Department of Plant Husbandry in 1956—58. This compound had a stronger and more rapid effect than sodium dalapon, killing not only grassy weeds but some broad-leaved weeds as well. Erbon was also more toxic to crop plants than dalapon (MUKULA and SÄKÖ 1961).

In 1957, erbon was approved for weed control on uncropped land. A few tons of the commercial product *Baron* were imported from the USA at the end of the 1950's.

SMA, 1958

The sodium salt of monochloroacetic acid, or SMA, was tested against annual weeds in cereals in 1958—60 and 1963—64. Satisfactory contact

effect was achieved. In comparison with DNOC this compound gave poorer control of *Chenopodium album* and *Tripleurospermum inodorum* but better control of *Polygonum* spp. (MUKULA and PIRTILÄ 1959).

SMA was approved in 1959 for post-emergence use in spring cereals. The permission was withdrawn in 1961, mainly because of the poor control of *Chenopodium*.

A few hundred kilograms of SMA was manufactured and sold in Finland under the

trade name *Äänekosken Tehostusmyrkkö* in 1959—61.

2,2-dichlorobutyric acid, 1961

The sodium salt of 2,2-dichlorobutyric acid, whose mode of action resembles that of dalapon, was tested on uncropped land in 1961—62. It gave slightly better control of some grassy species than dalapon.

9. Phenols

DNOC, 1944

Research. 2-methyl-4,6-dinitrophenol, or DNOC, was included in trials at the Department of Plant Husbandry in 1944. The first preparations were *Hedolit Paste* and *W 6239 Powder*, probably of Dutch origin. Trials were continued in 1948 with a product containing the ammonium salt of DNOC and in 1955 with the sodium and amine salts as well as with a mixture of DNOC acid and ammonium sulphate. When used in cereals DNOC provided excellent contact effect against broad-leaved weeds. The best effect and the highest yield increases were obtained with a mixture of DNOC and MCPA (MUKULA 1958 a, MUKULA and PIRTILÄ 1959).

Approvals. In 1957 several DNOC products were approved for post-emergence treatment against broad-leaved weeds in cereals. In 1960, these permits were suspended for the purpose of carrying out further investigations. In 1965, a new sales clearance was granted for a liquid product of DNOC ammonium salt. The decision was preceded by a declaration that the product is »highly toxic», i.e. it may be purchased only with permission from the police authorities.

Sales. About 50 kg of DNOC was sold in Finland in 1958. Two commercial products were then available, an English liquid preparation, *Denocate* (an acid), and a Danish wettable powder,

Herbanit-25 (an amine derivative). Both products were used on winter wheat in southern Finland.

Dinoseb, 1951

Research. The first preparation containing 2-(1-methylpropyl)-4,6-dinitrophenol, or dinoseb, was acquired from England and included in trials at the Department of Plant Husbandry in 1951. The product consisted of ammonium salt and had the trade name *Sevtox*. It showed good contact properties. Peas resisted foliar treatment with this product (LÄHDE 1954, 1955 b).

The amine and acetate derivatives of dinoseb were tested at the Department of Plant Husbandry in 1960—65 and at agricultural experiment stations in 1962—65. These derivatives were more selective than the ammonium salt. As post-emergence sprays they were satisfactory not only on peas but also on clover and cereals (KÖYLJÄRVI 1964). Moreover, they were successfully used on beans at the emergence stage (LÖNNBERG and SALOKANGAS 1965). A further derivative of dinitrophenol, 2,4-dinitrophenyl-2-(1-methylpropyl)-4,6-dinitrophenyl carbonate, with the trade name *Tribonate*, was tested by the Department of Plant Husbandry in 1964—65. It gave promising results when applied pre-emergence to peas and beans.

Approvals. In 1952, the ammonium salt of dinoseb was approved for post-emergence treatment on peas, and in 1961—62 the amine and acetate products were cleared for similar uses, both on peas and on cereals, including cereals undersown with clover. In 1963 the amine salt was approved for spring treatment of second-year clover for seed. In 1964 all these products were approved for treatment of beans at the time of emergence.

Sales. The liquid product *Sevtox*, consisting of the ammonium salt of dinoseb, was sold in Finland since 1954 for use on peas. Its annual sales rose gradually to a level of 2000 litres, corresponding to a treated area of 600—800 hectares. Sales of the amine and acetate products began in 1961—62. The amine was available in the form of several liquid products and the acetate as a soluble powder *Aretit*. All of these

were imported. The annual consumption of the amine products rose to over 8 000 litres in 1965 and that of the acetate product to 12 tons. This combined amount was sufficient to treat an area of about 8 000 hectares, in contrast to only 3 000 hectares in the previous year.

PCP, 1957

Pentachlorophenol, or PCP, was tested at the Department of Plant Husbandry in 1957—59 on sugar beet and vegetables as pre-crop-emergence sprays (MUKULA 1958 d). Preparations were obtained both from Finnish manufacturers and from abroad. PCP proved to be a highly active but relatively non-selective foliar herbicide. It also had some effect through the soil which caused injury to the crops.

10. Phenoxyacetic acids

MCPA, 1946

Research. The first products containing 4-chloro-2-methylphenoxyacetic acid or MCPA were acquired from England in 1946. Tests were initially carried out by the Departments of Plant Husbandry of the University of Helsinki and the Agricultural Research Centre and since 1947 in various other institutes.

In the first trials MCPA was used as dust and as spray. The dusting method proved poor in its effect and was abandoned in 1949.

MCPA gave better control of *Galeopsis* spp. than 2,4-D or other phenoxyacetic compounds (p. 15). Furthermore, MCPA was less toxic to spring cereals, particularly oats, than 2,4-D (HILLI 1947 a, b, 1948 b, d, LÄHDE 1948, 1949, PAAATELA 1950). Extensive field trials in oil flax showed that this crop was likewise injured less by MCPA than by 2,4-D (PAAATELA 1949, VALLE et al. 1949). The average increases in grain yield in spring cereals provided by MCPA were 15 % for oats, 10 % for barley and 12 % for spring wheat. The best results with oats were achieved when treatment was made at a rather

late stage of growth while for barley earlier application was better. As for spring wheat, the time of treatment had no influence on the yield (MARJANEN 1962, 1963). The greatest yield increases were obtained from low-yielding crops and the smallest increases from high-yield crops (MUKULA and KÖYLIJÄRVI 1965). This was due to the fact that the competitive effect of weeds is most pronounced in a poor stand of crop. A close positive correlation was found between the abundance of weeds and the magnitude of yield increase afforded by MCPA (MUKULA and KÖYLIJÄRVI 1965). On the other hand, yield increases were sometimes obtained even in weed-free environments. In dry and poorly fertilized soil MCPA injured spring cereals (SUOMELA and PAAATELA 1962, SUOMELA 1963).

In winter cereals and grasses for seed, MCPA, when used alone in the spring, had a poor effect against *Tripleurospermum inodorum* (MUKULA 1961 a, PIRTILÄ 1961, KÖYLIJÄRVI 1962, 1963 a, b).

When applied to cereals undersown with clover, MCPA gave satisfactory results in rainy

summers. In dry years it injured the clover, an effect due to the uneven emergence of the clover seedlings (KÖYLJÄRVI 1963 b, 1964).

Post-emergence application of MCPA on potatoes gave good weed control (LÄHDE and BREITENSTEIN 1952, LÄHDE et al. 1955), but sometimes resulted in an adverse effect on the taste of the tubers.

MCPA was also successfully tried for control of woody plants both as foliar sprays and applied on the stumps (HILLI 1948 a, 1949 b, MUKULA 1950). Against *Salix* spp. it was more effective than 2,4-D or 2,4,5-T (p. 15). In contrast, it gave poorer control of other deciduous woody species than the latter two chemicals (MUKULA 1962 b, 1963 c).

Further studies were carried out with MCPA to control *Equisetum palustre* and *Taraxacum officinale*. *Equisetum* was best controlled by using unusually high doses (MUKULA 1963 b). As for *Taraxacum*, MCPA gave the best results when treatment was made at the bud stage (HILLI 1948 b), but even then it was less effective than 2,4-D (LÖNNBERG 1964).

During the years 1957—65, particularly great interest was taken in testing MCPA mixed with other herbicides such as TCA, dalapon (p. 10), DNOC, dinoseb (p. 12), 2,4-D, 2,4,5-T (p. 15), fenoprop (p. 23), 2,3,6-TBA, dicamba (p. 24), ioxynil (p. 27), bromoxynil (p. 27) and flurenol (p. 29). Finland participated in the inter-Scandinavian research programme on the use of MCPA in mixtures with DNOC and dinoseb (PETERSEN et al. 1960).

Approvals. When the Pesticide Law came into force in 1952, MCPA sprays were approved for post-emergence control of broad-leaved weeds in cereals, cereals undersown with clover, potatoes, grasses and on uncropped land. In addition, MCPA was approved for the control of woody plants. In 1956, potatoes were withdrawn from the list of crops which could be treated. At the end of 1965, MCPA was no longer allowed for cereals undersown with clover, nor for pastures or leys. Spring application of MCPA on winter cereals was also discontinued and superseded by autumn application.

Sales of MCPA began in Finland in 1947. The first products were 1—2 % dusts named *Agroxone* and *Arotex*, and a 10 % liquid, *Acodrin*. In the following year, a second 10 % liquid preparation, *Agroxone*, appeared on the market. These early products were imported from England. In 1951 they were replaced by 25 % liquid formulations imported from various countries. The first water soluble MCPA powder was obtained from Germany in 1956 and put on the market in 1967. Domestic production of MCPA liquid began in 1953 and that of soluble powder in 1958.

Most of the MCPA products sold in Finland were sodium salts. Some potassium salts, mixtures of sodium, potassium and amine salts, and a butyl ester formulation were available since 1955. In addition, a mixture of MCPA and 2,3,6-TBA (*Pesco 18—15*) was imported to this country since 1959. An agreement was made between the manufacturers and importers of MCPA and the Office for Plant Protectants to standardize the contents of MCPA products to 250, 500 and 750 g/kg or g/l. This arrangement was in effect until the autumn of 1965 when it was cancelled at the request of one of the import firms.

The use of MCPA in cereals obtained a noteworthy foothold in Finland in 1950, when 20 tractor sprayers were imported. The sprayers were distributed in the region of the Uusimaa Swedish Agricultural Society along the southern coast. During the following year, sprayers were acquired to other areas in South and southwestern Finland as well as to the province of South Ostrobothnia on the western coast. In addition to cereal crops, the butyl ester of MCPA was also used on coniferous reforestation areas to control *Betula* spp.

In the beginning of the 1960's, the use of MCPA in cereals began to spread over the whole country. An outstanding stimulus to this development was provided by the National Weed Campaign, which was sponsored jointly by advisory organizations, research institutions and commercial firms (MUKULA 1963 a). By the year 1964, the proportion of spring cereal area

treated by MCPA averaged 31 % for the whole country, being 6 % in remote areas in the north and as much as 55—56 % in southern and southwestern Finland (Fig. 2, p. 30; MUKULA 1965). In 1965, the total sales of MCPA rose to 538 tons (Table 2, p. 31), corresponding to a treated area of 430 000 hectares, or 44 % of the area devoted to spring cereals in the country.

2,4-D, 1946

R e s e a r c h. Trials with 2,4-dichlorophenoxyacetic acid or 2,4-D were begun in Finland in 1946. At this time both Finnish and American preparations of the sodium salt of 2,4-D were acquired in the form of 1 % dusts as well as soluble powder concentrates. In addition, samples of the ethyl ester of 2,4-D were obtained from the USA in 1946 as well as the morpholin and triethanolamine salts and the butyl and butoxyethylesters in 1948. Later in the 1950's, more ester derivatives were tested.

It became evident from the very beginning that the 2,4-D dusts, similar to those of MCPA, were too weak in their herbicidal activity, and consequently they were superseded by sprays in 1949.

2,4-D gave considerably poorer control of broad-leaved annuals, particularly *Galeopsis* spp. than MCPA. In addition, 2,4-D caused more injury to spring cereals, especially oats (HILLI 1947 a, b, LÄHDE 1948, 1949, 1954, PAAATELA 1950). Likewise, oil flax was badly damaged by 2,4-D (PAAATELA 1949, VALLE et al. 1949).

Preliminary trials with 2,4-D on potatoes gave promising results (HILLI 1948 d). Late applications of 2,4-D, however, had an adverse effect on the flavour of the tubers. In winter cereals (MUKULA 1958 a, PIRTTILÄ 1961, KÖYLJÄRVI 1962, 1963 a, b) and grasses for seed (HEIKINHEIMO 1950, MUKULA 1961 a, KÖYLJÄRVI 1963 b) 2,4-D proved more suitable than MCPA, owing to its better control of *Tripleurospermum inodorum*. Moreover, *Taraxacum officinale* (HILLI 1948 b, LÖNNBERG 1964) and certain woody species (HILLI 1948 a, 1949 b,

MUKULA 1950, 1952, 1956) were more readily killed by 2,4-D than by MCPA, especially by the ester derivatives and mixtures with 2,4,5-T.

2,4-D was also tested in mixtures with the following herbicides: magnesium chloride (p. 6), sodium chlorate (p. 8), dalapon (p. 11), MCPA (p. 13), monuron (p. 19), 2,3,6-TBA, dicamba (p. 24) and sodium carbonate (p. 28).

A p p r o v a l s. When the Pesticide Law came into effect in 1952, the morpholin salt of 2,4-D was approved for post-emergence control of broad-leaved weeds in wheat and grasses and on uncropped land. It was also approved for woody plant control. In 1964 an aerosol formulation of the morpholin salt of 2,4-D mixed with 2,4,5-T was approved for spot treatment of *Taraxacum officinale* and other broad-leaved weeds on lawns and uncropped sites.

The sodium salt of 2,4-D was approved in 1958 for control of broad-leaved weeds in winter cereals, grasses for seed, and along roadways and ditches. The amine salts of 2,4-D were approved in 1961 for controlling broad-leaved weeds in lawns, along roadways and ditches, and for woody plant control.

Certain esters of 2,4-D, both alone and mixed with 2,4,5-T, were approved in 1952 for woody plant control and against broad-leaved weeds in lawns, along roadways and ditches etc. In 1963 a paraffin wax bar impregnated with the butyl ester of 2,4-D (*Wonder Weeder Bar*) was granted approval for control of *Taraxacum officinale* and other broad-leaved weeds in lawns.

S a l e s of the sodium salt of 2,4-D began in Finland in 1948. The first products were a dust and a water soluble powder, both of them *Hormotox*-named domestic products, and a liquid formulation *Hormoxol* from the USA. The sales of the sodium salt were small and ceased at the beginning of the 1950's.

In 1959 the sales of soluble powder formulations of the sodium salt began again. This time the products were imported from Germany and Denmark. In the years 1959—61, they were also manufactured in Finland.

The first morpholin salt product, named *Hormoxol*, was imported from the USA and put

on the market in 1949. Its sales ceased in 1956. An aerosol formulation containing the morpholin salt of 2,4-D mixed with 2,4,5-T was introduced to the market in 1964.

The amine salts of 2,4-D were first put on the market in 1956. They were imported from England, Germany and Sweden.

After the year 1959, the total annual sales of 2,4-D salts steadily increased, and in 1965 they exceeded 20 tons, calculated as acid equivalent, an amount which corresponds to a treated area of about 12 000 hectares.

Esters of 2,4-D were first sold in Finland in 1950—53. They were mostly mixtures with 2,4,5-T, imported from England, Denmark, Germany, Sweden and the USA. Domestic production of the butyl ester took place in 1955—60. The annual sales of 2,4-D esters rose continually and in 1965 exceeded 25 tons, calculated as 2,4-D acid. This figure also includes the 2,4-D used in mixtures with 2,4,5-T.

2,4,5-T, 1948

Trials with 2,4,5-trichlorophenoxyacetic acid or 2,4,5-T were begun in Finland in 1948. The first preparation tested was a mixture of the butoxyethyl esters of 2,4,5-T and 2,4-D. In the 1950's, trials were also carried out with the methyl, propyl, butyl, amyl, isooctyl and polypropyleneglycolbutylether (PPGB) esters, most of these in mixtures with 2,4-D esters. Applied to plant foliage as aqueous sprays, 2,4,5-T and the mixtures gave good control of several broad-leaved herbaceous weeds and woody plants such as *Alnus incana*, *Salix* spp. and *Betula* spp. The control of some other deciduous trees was weaker (HILLI 1949 b, MUKULA 1950). Applied to stumps of woody plants the aqueous sprays gave poor results (MUKULA 1952, 1956). Satisfactory control was achieved with oil solutions by sub-park treatment applied in drilled trunks. However, the amount of the chemical required was greater than with aqueous foliar sprays (MUKULA 1962 b).

A mixture of the morpholin salts of 2,4,5-T and 2,4-D was tested in 1963 as an aerosol. Satisfactory control was achieved in spot treatments of *Taraxacum officinale* on lawns.

Mixtures of 2,4,5-T with MCPA and mecoprop were tested with promising results in cereals at the end of the 1950's and in the 1960's. In addition, 2,4,5-T was tried as a mixture with 2,4-D and dalapon (p.11) on uncultivated sites.

Experiments with 2,3,6-trichlorophenoxyacetic acid were also conducted in 1946, when a Finnish sodium salt product under the name *Rikkaruobomyrkkö N:o 3/1945* was obtained for trial use. Slight phytocidal effects on broad-leaved weeds were observed.¹⁾

Approvals. The mixtures of 2,4,5-T and 2,4-D esters were approved in 1952 as aqueous foliar sprays for control of woody weeds and against broad-leaved herbaceous weeds on lawns and uncultivated land. Similar approvals were granted for 2,4,5-T esters alone in 1958—63. Mixtures of 2,4,5-T with MCPA esters were approved in 1958 for use in cereals. In 1964 approval was also given to the aerosol containing 2,4,5-T and 2,4-D morpholin salts for spot treatment of broad-leaved weeds on lawns and uncropped land.

Sales of 2,4,5-T began in Finland in 1950, when a mixture of the butyl esters of 2,4,5-T and 2,4-D named *Bernerin Lepikkomyrkkö* was obtained from England and a similar butoxyethyl ester mixture *Weedone Brushkiller 32* from the USA. In the early 1950's, several butyl ester mixtures from various countries were imported and marketed in Finland. Domestic production of this mixture took place from 1955 to 1960.

Toward the end of the 1950's, the butyl ester mixtures were replaced by butoxyethyl and isooctyl esters, which are less volatile. In addition, amyl, hexyl and PPGB esters and an aerosol with the morpholin salts of 2,4,5-T and 2,4-D were marketed. The countries supplying these 2,4,5-T herbicides were England, USA, Denmark, Germany and Sweden.

The annual sales of 2,4,5-T and its mixtures rose steadily and reached 40 tons, calculated as

¹⁾ In 1966 the same compound was introduced by Heyden Division of Tennaco Chemicals Inc., New York, as a herbicide for sugar cane. (Chem. Week. 99, 21: 138.)

2,4,5-T acid, in 1965. This amount corresponds to a treated area of about 25 000 hectares. The main use of these herbicides was for woody plant control along roads and railways, in reforestation areas and along power lines. Aerial application of 2,4,5-T and the mixtures was adopted in 1961.

2,4-DES, 1954

Sodium 2-(2,4-dichlorophenoxy)ethyl sulphate or 2,4-DES (sesone) was tested by the Depart-

ment of Plant Husbandry in 1954—59 on strawberries and other garden crops, using both pre-emergence and post-emergence applications. Slight herbicidal effects were observed.

4-CPA, 1961

4-chlorophenoxyacetic acid, or 4-CPA, was tested as a butoxyethyl ester formulation in 1961—62 for control of *Pteridium aquilinum*. Foliar sprays killed the leaves of *Pteridium* but not the rhizomes.

11. Aromatic oils, 1947

Research. Trials with mineral oils were begun by the Department of Plant Husbandry in 1947 and by the Department of Plant Pathology and the Forest Research Institute in 1955. Umbelliferous crops tolerated these highly active contact herbicides (LÄHDE and BREITENSTEIN 1952, LÄHDE et al. 1955, LEVONEN and MUKULA 1956). Satisfactory results were also obtained in coniferous nurseries (RUMMUKAINEN 1957, 1963 a).

Approvals. An American petroleum product with the name *Porkkanan Rikkaruohoöljy* (*Shell Weedkiller W*) was approved in 1956

for post-emergence use on carrots and other umbelliferous crops. This product contained 25 % aromatics.

Sales. The only approved product, *Porkkanan Rikkaruohoöljy*, was on the market during the years 1956—62. Its annual sales were 5 000—10 000 litres, or enough to treat an area of 8—12 hectares. Motor petroleum, kerosene and several unspecified aromatic oil mixtures were also used on umbelliferous crops and in coniferous nurseries since 1952. Statistics on the sales of such oils for these specific purposes are not available.

12. Carbamates and thiocarbamates

Propham, 1948

Isopropyl *N*-phenylcarbamate, or propham (IPC) was tested against *Agropyron repens* in 1948—51. The trials at the Department of Plant Husbandry of the Agricultural Research Centre gave poor results (LÄHDE 1954), whereas at the University of Helsinki propham was more promising (HILLI 1949 a). In 1961—63, propham was used together with endothal (p. 28) in pre-emergence trials against annual weeds on sugar beet. The results were not satisfactory.

A few hundred kilograms of a propham product obtained from England were sold in Finland

in 1951 for control of *Agropyron repens*. When the Pesticide Law came into effect in 1952, sales of this product were discontinued.

Chlorpropham, 1956

Isopropyl *N*-(3-chlorophenyl)carbamate, or chlorpropham (CIPC) was tested against *Agropyron repens* with promising results in 1956. The chemical was incorporated into the soil. The rate required for good control was so high that the residue in the soil constituted a serious problem (MUKULA 1958 c). Pre-emergence trials

with smaller doses gave good control of annual weeds. Young coniferous plants (RUMMUKAINEN 1963 a), set onions (LALLUKKA and SALOKANGAS 1964), beans (LÖNNBERG and SALOKANGAS 1965) and carrots tolerated the treatment.

In 1958, the Office for Plant Protectants approved chlorpropham for control of *Agropyron repens*. This permit was withdrawn four years later. In 1964 chlorpropham was approved as a pre-emergence treatment against annual weeds in bulb onions, beans and carrots.

A few hundred kilograms of the chlorpropham product *Sipulan* were imported from England and sold in 1964—65. The area treated was 150—200 hectares.

Metham-Na, 1958

Sodium *N*-methylthiocarbamate, or metham-Na, was tested for soil fumigation in 1958—60 and approved in 1959. A few hundred litres were imported from England in 1961—65 and sold under the trade name *Vapam*.

Barban, 1960

4-chlorobut-2-ynyl *N*-(3-chlorophenyl) carbamate, or barban, was tested against *Avena fatua* as a post-emergence treatment. The herbicidal effects were not satisfactory.

13. Cyanates and thiocyanates

Potassium cyanate, 1950

Potassium cyanate, KCNO, was tested in 1950—56 against annual weeds in bulb onions and cereals. Post-emergence treatments gave moderate control (LÄHDE and BREITENSTEIN 1952, LÄHDE 1954, LÄHDE et al. 1955). *Chenopodium album* and *Polygonum* spp. resisted the treatment.

After the Pesticide Law came into effect in 1952, potassium cyanate was approved for post-emergence use in bulb onions.

BiPC, 1960

1-methylprop-2-ynyl-*N*-(3-chlorophenyl)carbamate, or BiPC, was tried against annual weeds in mixtures with cycluron (p. 20), dimexan (p. 29) and paraquat (p. 27). Pre-emergence treatments with these mixtures gave promising results on sugar beet (BRUMMER 1963), bulb onions (LALLUKKA and SALOKANGAS 1964), beans (LÖNNBERG and SALOKANGAS 1965), carrots, spinach and coniferous nurseries (RUMMUKAINEN 1963 a).

EPTC, 1960

S-ethyl *NN*-dipropylthiolcarbamate, or EPTC, was tested in 1960 both as a pre-sowing soil-incorporated treatment and as a pre- and post-emergence surface treatment. The herbicidal effects were not satisfactory.

Di-allate, 1963

S-2,3-dichloroallyl *NN*-diisopropylthiolcarbamate, or di-allate, was tried for the same purpose as barban, both pre-sowing and pre-emergence. The herbicidal effects were not satisfactory.

Tri-allate, 1965

S-2,3,3-trichloroallyl *NN*-diisopropylthiolcarbamate, or tri-allate, was tested in the same manner and for the same purpose as di-allate. Slight herbicidal effects were observed.

Ammonium thiocyanate, 1960

Ammonium thiocyanate, NH₄SCN, was tested in a mixture with amitrole (p. 21). The compound enhanced the effect of amitrole against grasses but not against broad-leaved weeds or horse-tails (MUKULA 1963 b). A mixture of ammonium thiocyanate and amitrole was approved in 1964 for weed control on uncultivated sites and under fruit trees.

14. Diazines

MH, 1953

1,2,3,6-tetrahydro-3,6-dioxypyridazine, or maleic hydrazide (MH), was first tried by the Departments of Plant Husbandry and Plant Pathology in 1954 against *Agropyron repens* (MUKULA 1953). The formulations used were the sodium and amine salts. In 1957, the trials were suspended but were reinitiated in 1962. Foliar application in August and September gave promising results.

Dazomet, 1962

3,4,5,6-tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione, or dazomet (DMTT), was tested for soil fumigation. Incorporated into the soil the compound killed weed seeds and was approved in 1964. A few hundred kilograms were imported in 1964—65 from the USA and sold under the trade name *Mylone*.

Isocil, 1962

5-bromo-3-isopropyl-6-methyluracil, or isocil, was tested against herbaceous weeds on uncultivated land both alone and in mixtures with amitrole (p. 21). Excellent control of most herbaceous weeds was achieved. Only a few species of the family *Compositae* resisted the

treatment. The Office for Plant Protectants approved isocil (*Hyvar*) for weed control on uncultivated land in 1964.

Pyrazon, 1962

5-amino-4-chloro-2-phenyl-3-pyridazone, or pyrazon, was tested against annual weeds on sugar beet. Pre-emergence treatments gave moderate control on sandy soils. Post-emergence treatments with a wetting agent (*Citowett*) showed slight herbicidal effects.

Bromacil, 1963

5-bromo-6-methyl-3-(1-methylpropyl)uracil, or bromacil, was also tested against herbaceous weeds on uncropped land. It produced even better control than isocil (LALLUKKA and BORG 1965). The Office for Plant Protectants approved bromacil for the same purpose as isocil in 1965. A small quantity of bromacil was imported in 1965 from the USA and sold under the name *Hyvar X*.

Lenacil, 1964

3-cyclohexyl-5,6-trimethyleneuracil, or lenacil, was tested against annual weeds as pre-emergence treatment in sugar beet. The effect was weak and slow.

15. Ureas

Monuron, 1954

Trials with *N*⁷-(4-chlorophenyl)-*NN*-dimethylurea, or monuron, were initiated by the Department of Plant Husbandry in 1954. Excellent control of most herbaceous weeds was obtained on uncultivated land. *Plantago* and *Equisetum* spp., however, resisted the treatments. The mixture of amitrole (p. 21) and monuron proved especially effective against established

perennial weeds. Likewise, good results were obtained when monuron was used in combination with borates (p. 26), sodium chlorate (p. 8), magnesium chloride (p. 6), sodium carbonate (p. 28) and 2,4-D (p. 15) (LÄHDE 1954, MUKULA 1960 c, LALLUKKA and BORG 1965). Fruit trees and bushes did not tolerate monuron adequately (MUKULA and SÄKÖ 1961).

In 1955, the Office for Plant Protectants approved monuron for weed control on non-

cultivated areas. Mixtures of monuron with certain other herbicides were likewise approved in 1958—62. A few tons of an English product *Klorex* (*Chlorea*), containing monuron in combination with sodium metaborate and sodium chlorate, were imported and sold during the years 1958—64. Small amounts of mixtures with amitrole were also imported from Sweden in 1962—65.

DCU, 1957

Dichloral urea, or DCU, was tested in 1957—58 against annual and perennial weeds. The herbicidal effects were not satisfactory.

Neburon, 1958

N-butyl-*N'*-(3,4-dichlorophenyl)-*N*-methylurea, or neburon, was included in trials at the Department of Plant Husbandry in 1958—59. No satisfactory effects were achieved (MUKULA and SÄKÖ 1961).

Cycluron, 1960

N'-cyclo-octyl-*NN*-dimethylurea, or cycluron, was successfully tested in combination with BiPC (p. 18) as a pre-emergence treatment on sugar beet (BRUMMER 1963), bulb onions (LÄLLUKKA and SALOKANGAS 1964), beans (LÖNNBERG and SALOKANGAS 1965), carrots, spinach and in coniferous nurseries (RUMMUKAINEN 1963 a). The effects on annual weeds were satisfactory. Promising results were also obtained with cycluron in mixtures with dimexan (p. 29) and paraquat (p. 27) on sugar beet.

Diuron, 1960

N'-(3,4-dichlorophenyl)-*NN*-dimethylurea, or diuron, was tested with good results against annual weeds in nurseries (MUKULA 1962 a). Cultivated trees and bushes tolerated the treatment. Mixtures with amitrole (p. 21) resulted

in an excellent control of established perennial weeds on uncropped land (MUKULA 1963 c, LÄLLUKKA and BORG 1965).

In 1963 the Office for Plant Protectants approved mixtures of diuron and amitrole for weed control on uncultivated land. A few hundred kilograms of these mixtures were imported from Sweden in 1963—65.

Fenuron, 1960

NN-dimethyl-*N'*-phenylurea, or fenuron, was tested as a granular formulation against woody weeds. Some promising results were obtained at the Forest Research Institute (RUMMUKAINEN 1962 c).

Fenuron-TCA, 1960

A granular formulation comprising a complex compound of fenuron and TCA, known as fenuron-TCA, was tested against woody weeds. The control was not satisfactory.

Chloroxuron, 1961

N'-4-(4-chlorophenoxy) phenyl-*NN*-dimethylurea, or chloroxuron, was successfully tested against broad-leaved annuals in strawberries. The compound gave satisfactory control of several species at the early seedling stage. *Galium spurium*, *Polygonum* spp., *Viola arvensis*, *Lamium purpureum*, *Matricaria* spp. and *Tripleurospermum inodorum* resisted the treatment. Strawberries were only slightly injured. Umbelliferous crops tolerated chloroxuron both at pre- and post-emergence stages. Dormant woody plants showed some resistance to chloroxuron (RUMMUKAINEN 1963 b).

Chloroxuron was approved in 1962 for post-emergence use against broad-leaved annuals in strawberries. In 1963 the approval was extended to include post-emergence use in carrots and in 1965 in other umbelliferous crops. A few tons of chloroxuron were imported from France in 1962—65 and sold under the name *Teneran* (*Tenoran*).

The first methoxy derivative of substituted phenyl ureas to be tested in Finland was *N'*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea, or linuron. It gave excellent control of most broad-leaved annuals, both pre-emergence and more particularly post-emergence. Only *Galium spurium*, *Lamium purpureum*, *Matricaria* spp. and *Tripleurospermum inodorum* resisted the treatments. The highest herbicidal activity was obtained when linuron was used in combination with monolinuron. Carrots, celery and parsnip were not injured. Dill, parsley, bulb onions (LALLUKKA and SALOKANGAS 1964), beans (LÖNNBERG and SALOKANGAS 1965) and peas resisted the pre-emergence treatment. Dormant woody plants also showed some resistance to linuron (RUMMUKAINEN 1963 b).

In 1962 linuron was approved as a pre- and post-emergence treatment against broad-leaved annuals in main crop carrots. In 1963 both treatments were approved also in parsnip and celery and pre-emergence treatment in early carrots, dill, parsley, bulb onions, peas and beans. Furthermore, in 1963 the use of linuron was permitted in deciduous nurseries during the dormant period.

Linuron products were imported from the USA and Sweden in 1963—65. Their annual sales were about 0.4 tons a.i., corresponding to a treated area of about 250 hectares.

16. Amitrole, 1954

Research. Experiments with 3-amino-1,2,4-triazole, or amitrole, were started in 1954 at the Department of Plant Husbandry. Outstanding control of most herbaceous weeds was achieved with foliar sprays (MUKULA 1960 a, RUMMUKAINEN 1962 a, b). Rhizomes of *Agropyron repens* (MUKULA and SÄKÖ 1961, RUUTTUNEN 1962) and *Equisetum* spp. usually resisted the treatment (MUKULA 1963 b).

The best results with amitrole were achieved when it was combined with soil acting herbicides,

N'-(4-chlorophenyl)-*N*-methoxy-*N*-methylurea, or monolinuron, was tested against annual weeds in vegetables. The herbicidal properties of this derivative resembled those of linuron. It was, however, more active through the soil than through the leaves and also showed some effects on annual grasses. The best results were achieved in combination with linuron. Monolinuron was more toxic to crops than linuron; beans, however, were an exception (LÖNNBERG and SALOKANGAS 1965). Dormant woody plants were rather resistant to monolinuron (RUMMUKAINEN 1963 b).

Buturon, 1963

N'-(4-chlorophenyl)-*N*-methyl-*N*-(1-methyl-prop-2-ynyl)urea, or buturon, was tried against broad-leaved weeds in cereals at the Department of Plant Husbandry and the North Ostrobothnia Agricultural Experiment Station. An excellent control of *Polygonum* spp. was obtained.

Trimeturon, 1965

N'-(4-chlorophenyl)-*O**NN*-trimethylisourea, or trimeturon, was given a preliminary screening test against annual weeds. In pre-emergence it provided moderate control, while post-emergence treatments were ineffective.

such as triazines (p. 24) and urea derivatives (p. 19) (MUKULA and SÄKÖ 1961, RUMMUKAINEN 1962 a, b, LALLUKKA and BORG 1965). Mixtures of amitrole and ammonium thiocyanate (p. 18) gave slightly better control of grasses than amitrole alone.

In waterways amitrole gave moderate or good control of *Phragmites communis*, *Typha latifolia* and *Equisetum fluviatile* (SILVO 1960, 1962—63).

Approvals. Amitrole was approved in 1959 for control of *Agropyron repens* and other perennial weeds as post-harvest treatment on open fields, on fallow land, under fruit trees, and on non-cultivated areas. The first mixtures of amitrole and triazine were cleared in 1961, those containing urea in 1962, and those with ammonium thiocyanate in 1964.

Sales of amitrole in Finland began in 1959, when the product *Weedazol* from the USA was

put on the market. In the years 1962—65, amitrole was imported chiefly from Germany and Sweden. As early as 1959, several hundred kilograms were sold and the amounts used rose annually. In 1965 the total sales amounted to 7.55 tons a.i. Of this quantity, 1.7 tons were in the mixtures with triazines and 0.15 tons in the mixtures with ureas. The area treated in 1965 with amitrole and its mixtures was about 1 500 hectares.

17. Phenoxybutyric acids

MCPB, 1955

Research. Trials with 4-(4-chloro-2-methylphenoxy)butyric acid, or MCPB, were started in 1955 at the University of Helsinki. Good control of annual broad-leaved weeds, especially *Chenopodium album*, was achieved in clover (SUOMELA and PAAATELA 1958). Trials with MCPB were begun at the Agricultural Research Centre in 1956, at the Southwest Finland Agricultural Experiment Station in 1959 and the Häme Agricultural Experiment Station in 1964. Most of the experiments were made with the sodium salt of MCPB. This derivative was safe for use in red clover (KÖYLIJÄRVI 1963 a, 1964), but caused slight injuries to alsike and white clover. Likewise, peas were slightly injured and beans were killed. *Taraxacum officinale*, *Tripleurospermum inodorum* and *Stellaria media* resisted the treatment. The amine salt and ester derivatives

of MCPB were slightly more effective than the sodium salt.

Approvals. The sodium salt of MCPB was approved in 1957 for post-emergence use in cereal crops undersown with red clover and in peas. The latter crop, however, was withdrawn from the approval list owing to injuries which occurred in 1958.

Sales of MCPB started in 1957 with the English product *Tropotox* and in 1958 with *Bexome*. Consumption of both products was small and ceased in 1961—64.

2,4-DB, 1957

4-(2,4-dichlorophenoxy)butyric acid, or 2,4-DB, was tested as the amine salt and ester derivatives against broad-leaved weeds in red clover. The compound was more toxic to clover than MCPB.

18. Phenoxypropionic acids

Mecoprop, 1958

Research. Trials with 2-(4-chloro-2-methylphenoxy)propionic acid, or mecoprop, were begun at the Department of Plant Husbandry in 1956, at the Southwest Finland Agricultural Experiment Station in 1959, at other stations and in local experiments in 1961. The low dosage used in the first trials, 1 kg/ha, did not control

weeds (MUKULA and PIRTILÄ 1959). In later trials with rates of 2—3 kg/ha, better results were obtained. Mecoprop was more effective than MCPA against *Tripleurospermum inodorum*, *Lapsana communis*, *Galium spurium* and *Stellaria media* but weaker against *Galeopsis spp.* In winter and spring wheat, mecoprop brought about larger yield increases than MCPA (KÖYLIJÄRVI 1962, 1963 a, b, MUKULA and KÖYLIJÄRVI 1965).

On the other hand; it had a tendency to weaken the straw of wheat. Trials on barley, oats, rye, and cultivated grasses gave satisfactory results, although timothy was slightly injured.

Mecoprop was also tested in combination with MCPA (p. 13), 2,4,5-T (p. 16), fenoprop, amitrole (p. 21) and simazine (p. 24). The mixture containing 2,4,5-T was particularly good against *Lamium purpureum*.

Approvals. Potassium and amine salts of mecoprop were approved in 1961 for post-emergence application against broad-leaved weeds in cereals. The approval was extended in 1962 to grasses for seed. A mixture of mecoprop with amitrole and simazine was cleared in 1964 for use on non-cultivated land and a mixture containing 2,4,5-T for use in cereals.

Sales of mecoprop began in Finland in 1961. The potassium salt was imported from England, Germany, Denmark and Sweden. Consumption rose steadily and in 1965 it totalled 29 tons, calculated as the *dl*-acid, an amount sufficient to treat an area of nearly 12 000 hectares.

Fenoprop, 1961

2-(2,4,5-trichlorophenoxy)propionic acid, or fenoprop, was tried against woody plants and

Taraxacum officinale in grassland, against broad-leaved weeds in winter cereals, and against *Potamogeton natans* in waterways. Most of the trials were made with the PPGB ester. In cereals also the potassium and amine salts as well as the mixtures with MCPA (p. 13) and 2,4-D (p. 15) were tested.

Fenoprop gave better control of *Populus tremula* and *Sorbus aucuparia* than phenoxyacetic acids. It was also more effective against broad-leaved annuals, especially *Viola arvensis* and *Lamium purpureum*. On the other hand, cereals were more injured by fenoprop. *Taraxacum officinale* (LÖNNBERG 1964) and *Potamogeton natans* (SILVO 1962—63) showed moderate resistance to fenoprop.

Dichlorprop, 1962

The sodium salt of 2-(2,4-dichlorophenoxy)propionic acid, or dichlorprop, was tested against broad-leaved weeds in cereal crops, both alone and in combination with 2,4-D. The compound suppressed *Polygonum spp.* better than other phenoxy-carboxylates. Its effect on other broad-leaved annuals, particularly *Galeopsis spp.*, was poorer than that of MCPA and mecoprop.

19. Benzoic and phenylacetic acids

2,3,6-TBA, 1957

Research. 2,3,6-trichlorobenzoic acid or 2,3,6-TBA was tested as sodium salt in a mixture with MCPA (p. 13). The original ratio of the compounds was 1:3, later it was changed to 1:4. The mixture was more effective than MCPA alone against broad-leaved weeds, especially *Tripleurospermum inodorum*. The superiority of the mixture was most evident at low temperatures. Winter cereals, grasses and oats tolerated the treatments adequately, while spring wheat and barley were injured (MUKULA and PIRTILÄ 1959, MUKULA 1961 a, KÖYLIJÄRVI 1962,

1963 a, b, MUKULA and KÖYLIJÄRVI 1965). The amine salt of 2,3,6-TBA, applied alone or in mixtures with MCPA and 2,4-D, brought about the same herbicidal effects as the sodium salt.

Approvals. The mixture of 2,3,6-TBA and MCPA was approved in 1958 for post-emergence treatment against broad-leaved weeds in cereals and grasses for seed. In 1964, the permit for use in spring wheat was withdrawn and at the end of 1965 also that for other spring cereals.

Sales. Since 1958 the product *Pesco 18—15*, consisting of 2,3,6-TBA in combination with

MCPA, was imported from England. Sales rose constantly, amounting to a quantity equivalent to 0.4 tons of 2,3,6-TBA acid in 1965. The area treated with this quantity was about 1 500 hectares.

Fenac, 1958

2,3,6-trichlorophenylacetic acid, or fenac, was tested in 1958—59 against *Agropyron repens*. The results were not satisfactory.

Amiben, 1961

3-amino-2,5-dichlorobenzoic acid, or amiben, was tried in vegetables against annual weeds as

a pre-emergence treatment. The herbicidal effects were satisfactory. Carrots tolerated the treatment with minor injuries.

Dicamba, 1963

3,6-dichloro-2-methoxybenzoic acid, or dicamba, was tested in cereals against broad-leaved weeds in mixtures with MCPA and with MCPA plus 2,3,6-TBA. The compound enhanced the effects of MCPA on weeds, especially on *Polygonum* spp., *Spergula arvensis* and *Stellaria media*. Oats and winter wheat tolerated the treatment, while barley and spring wheat were slightly injured.

20. Triazines

Simazine, 1957

Research. Trials with 2-chloro-4,6-bisethylamino-1,3,5-triazine, or simazine, were begun in 1957 at the Department of Plant Husbandry, in 1958 at the Forest Research Institute, and in 1959 at the Department of Horticulture. The compound showed strong and persistent action through the soil (MUKULA 1960 b, c, LALLUKKA and BORG 1965). When applied pre-emergence, even small doses controlled annual weeds. With larger doses, satisfactory control of shallow-rooted perennials was also achieved. *Equisetum* spp. and *Taraxacum officinale* resisted the treatments.

Cultivated woody plants tolerated considerably high rates of simazine. Accordingly, good results were achieved with simazine under fruit trees and bushes (MUKULA 1959 a, 1960 b, MUKULA and SÄKÖ 1961), in fruit tree nurseries (MUKULA 1962 a) and in coniferous nurseries (RUMMUKAINEN 1958, 1959, 1961 a, b, 1962 b, d, 1963 b). Likewise, strawberries tolerated small amounts of simazine (SÄKÖ 1965).

Under dry conditions and on soils rich in clay or organic matter, the herbicidal effects of simazine were unsatisfactory, especially when used in granular form. The best results were

obtained with mixtures of simazine with amitrole (p. 21) or with amitrole and mecoprop (p. 22).

In this connection the works of VIRTANEN and HIETALA (1959) as well as WAHLROOS and VIRTANEN (1959) should be mentioned. Studying antibiotic compounds in cereal plants they isolated 2,4-dihydroxy-1,4-benzoxazin-3-one, and described its molecular structure. Later investigations in Switzerland (ROTH and KNÜSLI 1961) and in the USA (HAMILTON and MORELAND 1962) revealed that this compound has the capacity of hydrolyzing simazine derivatives thus increasing the resistance of plants to simazine.

Approvals. In 1959 simazine was approved for weed control under fruit trees and bushes, in raspberries and on non-cultivated sites. In 1961 the approval was extended to include strawberries and nurseries of cultivated woody plants.

Sales. Simazine was first imported from Switzerland in 1959, and its sales increased to the amount of 4.6 tons a.i. in 1965. Of this amount, preparations containing simazine alone (*Primatol Simatsin* and *Primatol S 8*) made up 3.5 tons and mixtures with amitrole (*Primatol-233*) 1.1 tons. The area treated with simazine in 1965 totalled nearly 1 000 hectares.

Atrazine, 1959

2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine, or atrazine, was first tested in 1959. It had a stronger and more rapid effect than simazine (LALLUKKA and BORG 1965). Woody crops were nearly as tolerant to atrazine as to simazine (MUKULA and SÄKÖ 1961, MUKULA 1962 a, RUMMUKAINEN 1963 b). The best results were achieved with mixtures of atrazine and amitrole (p. 21).

Atrazine and mixtures with amitrole were approved in 1962 for weed control on uncropped land, coniferous nurseries and reforestation sites.

Atrazine was imported from Switzerland since 1963. Sales in 1965, calculated as the active ingredient, amounted to 3.7 tons. Of this amount, 3.6 tons was made up of preparations containing atrazine alone (*Gesaprim 50* and *Primatol A*), while 0.1 tons was in a mixture with amitrole (*Campaprim—231*). The area treated with atrazine in 1965 was almost 1 000 hectares.

Propazine, 1960

2-chloro-4,6-bisopropylamino-1,3,5-triazine, or propazine, was tested with satisfactory results as a pre-emergence treatment against annual weeds in vegetables. Carrots and other umbelliferous crops resisted the treatment. The compound was approved in 1962 for pre-emergence use against broad-leaved annuals in carrots.

2-chloro-4-allylamino-6-isopropylamino-1,3,5-triazine, 1961

This compound was tested as a pre-emergence herbicide. Its selective activity resembled that of propazine, but was somewhat weaker.

Prometryne, 1961

4,6-bisopropylamino-2-methylthio-1,3,5-triazine, or prometryne, was tried for several

horticultural uses. In pre- and post-emergence treatments the compound controlled most broad-leaved annuals about as well as linuron (p. 21). Both treatments were non-toxic to umbelliferous crops (MUKULA 1963 c). In addition, bulb onions (LALLUKKA and SALOKANGAS 1964), beans (LÖNNBERG and SALOKANGAS 1965) and peas tolerated pre-emergence application. Dormant woody plants also showed some resistance to prometryne (RUMMUKAINEN 1963 b).

Approval was granted to prometryne in 1962 for pre- and post-emergence control of broad-leaved annuals in umbelliferous crops. In 1964, the approval for early carrots, parsley and dill was restricted to pre-emergence application only. At the same time, prometryne was approved for pre-emergence use in bulb onions, beans and peas.

Prometryne was imported from Switzerland since 1963 and sold under the name *Gesagard 50*. Annual sales were about 0.5 tons a.i., which was sufficient to treat an area of about 300 hectares.

Prometone, 1962

4,6-bisopropylamino-2-methoxy-1,3,5-triazine, or prometone, was tested against grassy and woody weeds. It had a weak herbicidal effect.

Desmetryne, 1964

4-isopropylamino-6-methylamino-2-methylthio-1,3,5-triazine, or desmetryne, was tried against annual weeds in cruciferous crops. Post-emergence treatments provided satisfactory control of several broad-leaved weeds, especially *Chenopodium album*. Cruciferous crops were slightly injured.

1-phenyl-3-methyl-5-allyl-hexahydrotriazinon-2, 1965

This compound gave excellent control of annual weeds in preliminary trials when applied post-emergence.

21. Borates

Sodium metaborate, 1957

Sodium metaborate, NaBO_2 , was tested in 1957—62 in combination with sodium chlorate (p. 8) and monuron (p. 19) against herbaceous weeds on uncultivated land. Herbicidal effects both through the foliage and the soil were observed. When comparisons were made between dosages of equal activity, the mixtures had a slower but more persistent effect than sodium chlorate alone though not as lasting as monuron alone.

The mixture of sodium metaborate, sodium chlorate and monuron was approved in 1958 against herbaceous weeds on uncultivated land. Similar approval was given to the mixture of sodium metaborate and monuron in 1962. The former product (*Chlorea*) was imported from

England and sold under the Finnish trade name *Klorea* in 1958—64.

Sodium pentaborate, 1958

Sodium pentaborate, $\text{Na}_2\text{B}_{10}\text{O}_{16}$, was tried in a mixture with sodium chlorate on uncropped sites. This mixture acted fairly rapidly through both the foliage and the soil. The duration of the control was longer than that of sodium chlorate alone.

Sodium tetraborate, 1958

Sodium tetraborate, or borax ($\text{Na}_2\text{B}_4\text{O}_7$), was tried in combination with monuron against herbaceous weeds on non-cultivated areas. Strong but slow action through the soil was observed.

22. Allyl alcohol, 1958

R e s e a r c h. Allyl alcohol, $\text{CH}_2 : \text{CH} \cdot \text{CH}_2 \cdot \text{OH}$, was tried by the Department of Plant Husbandry in 1958—60 for eradicating weed seeds in the soil. The surface treatment killed seeds to a depth of 4—5 cm. This was sufficient if the soil was not tilled after the treatment (MUKULA 1959 b; PIIRTILÄ 1960). Allyl alcohol disappeared from the soil within 1—3 days. Large volumes of water, 5 litres per square metre, (= 50 000 l/ha) were needed for good control.

A p p r o v a l s. Allyl alcohol was approved in 1959 for control of weed seeds in arable land. In 1960 the compound was declared a highly toxic pesticide, which could be purchased only with a special licence issued by the police authorities.

S a l e s of allyl alcohol began in 1959. One Finnish and one Danish product were put on the market. Their annual sales were initially 1 000—2 000 litres, but decreased in the following years to about 250 litres in 1965, an amount sufficient to treat an area of only 3 hectares.

23. Quaternary ammonium compounds

Diquat-dibromide, 1960

9,10-dihydro-8 a, 10 a-diazoniaphenanthrene dibromide, or diquat-dibromide was tested in 1960—62 for desiccation of clover and potatoes. Herbicidal trials with this chemical were begun in 1963. The compound had an outstanding contact effect. Almost all broad-leaved annuals

were killed in one or two days. No effect through the soil was observed. Good results were achieved in root crops when sowing was delayed several days after seed bed preparation. In this manner, weed seeds germinated before the crop. The weed seedlings were then destroyed by spraying just before the crop emergence (TAKALA 1964). In 1965 experiments with diquat against

submerged and emerged aquatic weeds were initiated.

By the end of 1965 diquat was not yet approved as a herbicide in Finland. The English product *Reglone* was available since 1961 for desiccation of clover and potatoes.

Paraquat-dichloride, 1963

1,1'-dimethyl-4,4'-bipyridylium dichloride, or paraquat-dichloride, was tried in a similar way as diquat in root crops. Both broad-leaved and grassy weeds were killed in 1—3 days. Paraquat was also slightly translocated (TAKALA 1964). The mixtures with BiPC (p. 18) and cycluron (p. 20) gave promising results in sugar beet. No residual effect was observed in nursery seed beds (RUMMUKAINEN 1964). Trials against aquatic weeds were begun in 1965.

Paraquat was approved in 1964 for pre-crop-emergence weed control. In 1965 the permit

was extended to cover use against established weeds under fruit trees and as directed sprays between strawberry rows.

Paraquat (*Gramoxone*) was imported from England in 1964—65. The sales amounted to about 0.5 tons and the area treated was slightly under 200 hectares.

Morfamquat, 1965

1, 1' - bis (3, 5 - dimethylmorpholinocarbonylmethyl)-4,4'-bipyridylium-2A, or morfamquat, was tried for post-emergence weed control in cereals. The compound gave excellent control of broad-leaved annuals, especially *Tripleurospermum inodorum* and *Polygonum* spp. High rates (1.5 kg/ha) also killed shallow-rooted perennials such as *Sonchus arvensis*. *Stellaria media* and *Galium spurium* showed some resistance to morfamquat. Cereals were not significantly injured.

24. Benzonitriles

Dichlobenil, 1961

2,6-dichlorobenzonitrile, or dichlobenil, was tried with varying success in a wide range of field and horticultural crops. Moderate activity through the soil was observed. The best results were obtained in controlling *Pteridium aquilinum* in forest renewal areas.

Dichlobenil (*Casoron*) was approved for control of *Pteridium aquilinum* in 1964.

Ioxynil, 1964

4-hydroxy-3,5-diiodobenzonitrile, or ioxynil,

was tried for post-emergence weed control in cereals. The compound was used as the lithium and potassium salts, mainly in mixtures with MCPA and mecoprop. Satisfactory contact effect on broad-leaved weeds was obtained. Cereals were not significantly injured.

Bromoxynil, 1965

3,5-dibromo-4-hydroxybenzonitrile, or bromoxynil, was used in a mixture with mecoprop for the same purpose as ioxynil. Its effect was similar to that of ioxynil.

25. Amides

Chloralchloroacetamide, 1960

The compound was tested in a mixture with TCA (p. 10) against grasses and gave satisfactory control. Cruciferous crops tolerated the mixture better than TCA alone.

»Dicryl», 1961

N-(3,4-dichlorophenyl)methacrylamide, or »dicryl», gave similar contact effect as »karsil» (p. 28), but did not control *Stellaria media*.

»Karsil», 1961

N-(3,4-dimethylphenyl)-2-methylpentanamide, or »karsil», was tried against annual weeds in vegetables. Good contact effect was achieved against several broad-leaved species. *Galium spurium*, *Lamium purpureum* and *Tripleurospermum inodorum* resisted the treatment. Umbelliferous crops were not appreciably injured. A high yield increase was obtained in carrots.

»Solan», 1961

N-(3-chloro-4-methylphenyl)-2-methylpentanamide, or »solan», also gave similar post-emergence effect as »karsil». *Galeopsis* spp. resisted the treatment.

»Monalide», 1964

N-(4-chlorophenyl)-2,2-dimethylpentanamide, or »monalide», was tried against annual weeds

in vegetables. Good effects on several broad-leaved species were obtained both through the leaves and the soil. Bulb onions and umbelliferous crops tolerated the treatment.

2-bromo-6'-t-butyl-N-(methoxymethyl)-O-acetotoluide, 1965

This compound showed some herbicidal activity through the soil. Sugar beet and red beet tolerated the treatment.

Propanil, 1965

N-(3,4-dichlorophenyl)propionamide, or propanil, gave a good contact effect on broad-leaved weeds. Cruciferous weeds resisted the treatment. No visual injury occurred in potatoes.

26. Miscellaneous

NAA, 1954

Naphthylacetic acid, or NAA, was tried for control of broad-leaved annual weeds in various horticultural crops. The effects were unsatisfactory both in pre- and post-emergence treatments.

Naptalam, 1955

N-1-naphthylphthalamic acid, or naptalam (NPA), was tried in the same manner as NAA. No satisfactory control was obtained.

OCH, 1958

Octachlorocyclohexane, or OCH, was tried in mixtures with petroleum, diesel oil and heating oil. The compound enhanced the contact activity of the oils. The product tested (*Good Rite Octone Weed Killer*) was not well formulated, and some difficulties occurred when mixing it with oils.

Sodium carbonate, 1960

Sodium carbonate, Na₂CO₃, was tried in combination with monuron (p. 19) and 2,4-D (p. 15) on uncultivated sites. Some phytocidal effects were observed both through the foliage and the soil.

AMS, 1961

Ammonium sulphamate, or AMS (NH₄SO₃-NH₂), was tried against *Equisetum palustre*. High rates, 250—750 kg/ha, killed both the shoots and the rhizomes (MUKULA 1963 b).

Endothal, 1961

Disodium 7-oxabicyclo-(2,2,1)heptane-2,3-dicarboxylate, or sodium endothal, was tried in a mixture with propham (p. 17) against annual weeds in sugar beets. Pre-emergence treatment gave poor control. Better effect was obtained

with endothal alone against *Tripleurospermum inodorum* in established red clover during the dormant period. The treatment, however, injured the clover. Some promising results were obtained with endothal against *Potamogeton natans* in waterways (SILVO 1962—63).

Methyl bromide, 1962

Methyl bromide, CH_3Br , was tried for destroying weed seeds in nursery seed beds before sowing. Volatilization of the chemical was prevented by covering the soil with plastic. The effects were satisfactory.

Dichlone, 1963

2,3-dichloro-1,4-naphthaquinone, or dichlone, was successfully tried by the Department of Plant Husbandry for killing *Ceratophyllum* in waterways (SILVO 1962—63).

Dimexan, 1963

Di(methoxythiocarbonyl)disulphide, or dimexan, was tried both alone and in mixtures with BiPC (p. 18), cycluron (p. 20), and chlorpropham (p. 17) as a pre-emergence treatment in root crops. Satisfactory control of weed seedlings was obtained. Dimexan disappeared from the soil in 1—3 days.

Flurenol, 1964

n-butyl-9-hydroxyfluorene-9-carboxylate, or flurenol, was tested in combination with MCPA (p. 13) in cereals. The mixture controlled certain broad-leaved annuals, particularly *Polygonum* spp., better than MCPA alone. Cereals tolerated the treatment sufficiently.

Picloram, 1964

4-amino-3,5,6-trichloropicolinic acid, or picloram, showed high and persistent herbicidal activity through the soil and also some systemic effects through the leaves. Most broad-leaved herbaceous weeds and woody species proved susceptible to picloram.

4-chloro-2-oxobenzothiazolin-3-ylacetic acid, 1965

This chemical was tested in a mixture with MCPA in spring cereals and red clover. A slight contact effect was observed on broad-leaved annuals. Cereals and clovers were not damaged.

Nitrofen, 1965

2,4-dichlorophenyl 4-nitrophenyl ether, or nitrofen, was used post-emergence in cruciferous crops. A good contact effect on several broad-leaved annuals was obtained. Cruciferous plants resisted the treatment.

PROGRESS IN CHEMICAL WEED CONTROL IN FINLAND

1. Trade in herbicides

Domestic manufacture of herbicides was relatively small in Finland during the period under examination. In 1935—63 potassium chlorate was manufactured by *Elektrokemiallinen Oy*, since 1944 calcium cyanamide by *Kymin Oy* and a mixture of sodium chlorate and sodium

chloride by *Rikkihappo Oy*, while *Äänekoski Oy* made TCA and phenoxyacetic acids during the period 1952—60. Allyl alcohol was manufactured by *Rikkihappo Oy* since 1959. From intermediate products the latter company also made phenoxyacetic acids since 1955 and mecoprop since 1961.

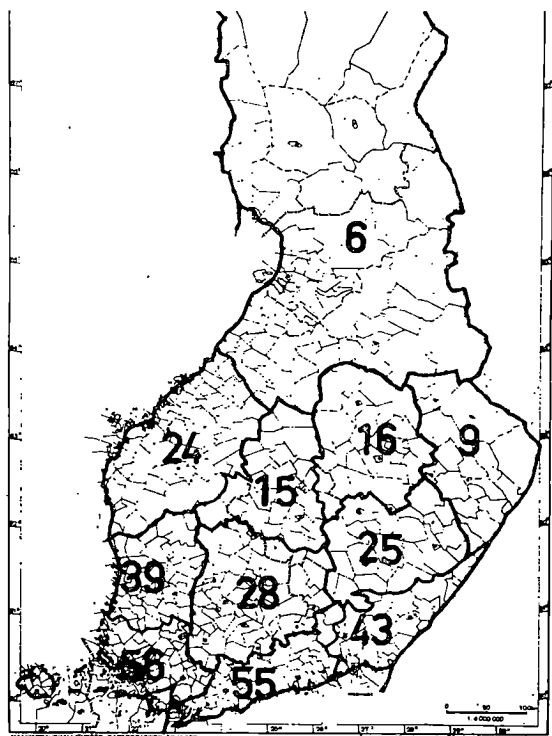


Fig. 2. Percentage of spring cereals sprayed with MCPA in different parts of Finland in 1964. According to J. MUKULA, 1965.

Most foreign products were imported from Western Germany (BRD), Denmark, England, Switzerland and Sweden. Smaller amounts were imported from the USA, the Netherlands, Austria, Eastern Germany (DDR) and Norway.

The first commercial herbicide (*Wegebellum*, p. 9) was put on the Finnish market in 1927. Owing to the lack of application equipment and of selective compounds there was little progress in the sales of herbicides during the 1930's and 1940's. Minor quantities of chlorates and calcium cyanamide were sold. In the 1940's the discovery of the herbicidal properties of phenoxy-carboxylates in England and the USA aroused the interest of commercial dealers even in Finland. Considerable sales of these chemicals commenced already in 1950, when 20 tractor sprayers were imported to the country (cf. p. 33).

The monetary value of the total herbicide sales in Finland during the years 1952—65 is

Table 1. Sales of herbicides in Finland, 1952—65

| Year | Mill. Fmk ¹⁾ | Year | Mill. Fmk ¹⁾ |
|------------|-------------------------|------------|-------------------------|
| 1952 | 0.50 | 1959 | 2.28 |
| —53 | 0.64 | —60 | 2.58 |
| —54 | 0.71 | —61 | 4.59 |
| —55 | 1.19 | —62 | 7.22 |
| —56 | 1.50 | —63 | 7.29 |
| —57 | 1.54 | —64 | 7.59 |
| —58 | 1.98 | —65 | 9.22 |

¹⁾ Fmk (Finnmark) = £ —,2 or \$ —,30.

shown in Table 1, based principally on the studies of TALVITIE (1953), MARKKULA (1954—57), MARKKULA and ROIVAINEN (1959), MARKKULA and RUUTTUNEN (1961), ROIVAINEN (1958) ROIVAINEN and TINNILÄ (1959), TINNILÄ (1960) and KÖPPÄ (1962—65). The figures show that there was a steady rise in the sales of herbicides. The progress, however, was considerably slower than in Scandinavia, Central Europe (WOODFORD 1964, HANF 1966) and North America (SHAW 1964). A significant turning point in herbicide trade in Finland occurred in the early 1960's, when the National Weed Campaign caused a sharp increase in sales (MUKULA 1963 a, 1965). In 1965, the total retail sales of herbicides amounted to 9.22 million Finnish marks (=£ 1.15 million or \$ 2.88 million), corresponding to a treated area of nearly 500 000 hectares. The greatest proportion of this amount consisted of MCPA products (Table 2). The 1965 sales of the most important herbicides are seen in Table 3 and the treated areas in Table 4. Table 5 (p. 32) gives the year when sales of each herbicide began.

As early as in the middle of the 1940's, there were three chemical companies in Finland specializing in imports, and partly also manufacture, of pesticides: *Berner Oy*, *Kasvinsuojelu Oy* and *S. G. Nieminen Oy* (later *J. H. Nieminen Oy*); in 1947 all three included herbicides in their trade activity. Similarly, *Rikkihappo Oy*, which had produced a mixture of sodium chlorate and sodium chloride since 1944—45, began selling a complete range of herbicides in 1950. Other companies later engaged in the herbicide trade were *Helkavaara-Halme Oy* in 1958—63, *Trans-*

Table 2. Sales and estimated use of MCPA in Finland, 1948—65

| Year | Sales of MCPA acid, tons | Treated area | |
|------|--------------------------|--------------|---------------------|
| | | 1 000 ha | % of spring cereals |
| 1948 | <1 | <1 | <1 |
| —49 | <1 | <1 | <1 |
| —50 | 1 | 1 | <1 |
| —51 | 3 | 3 | <1 |
| —52 | 10 | 10 | 1 |
| —53 | 44 | 45 | 6 |
| —54 | 44 | 45 | 6 |
| —55 | 72 | 65 | 8 |
| —56 | 91 | 84 | 11 |
| —57 | 99 | 90 | 12 |
| —58 | 109 | 99 | 12 |
| —59 | 121 | 97 | 12 |
| —60 | 148 | 119 | 14 |
| —61 | 198 | 159 | 17 |
| —62 | 386 | 290 | 30 |
| —63 | 400 | 296 | 31 |
| —64 | 402 | 321 | 32 |
| —65 | 538 | 430 | 44 |

Table 3. Sales of herbicides in Finland, 1965

| Compound | Commercial products, tons |
|---|---------------------------|
| MCPA salts, powder formulations | 763.7 |
| —»— liquid formulations | 43.4 |
| MCPA/2,3,6-TBA, mecoprop and MCPB | 55.0 |
| 2,4-D salts | 29.9 |
| 2,4,5-T and 2,4-D esters | 106.3 |
| dinoseb, diquat, paraquat and SMA | 24.7 |
| amitrole, dalapon and TCA | 123.3 |
| allyl alcohol and aromatic oils | 0.2 |
| prometryne, chloroxuron, linuron and chlorpropham | 3.3 |
| sodium chlorate, simazine and atrazine | 98.2 |

Meri Oy 1951—59, *Äänekoski Oy* 1953—59, *Fincos Oy* since 1960, *Farmos Oy* 1961 and *Suomen Gullviks Oy* 1963.

The chemical companies acquired their imported herbicides either directly from the foreign manufacturer or through an intermediate agency and sold the products to wholesale distributors. The latter supplied the products to retail dealers, who, in turn, sold the products to the consumer. In 1954, the biggest chemical companies founded a registered union called the *Pesticide Commission (Kasvinsuojelualan Valtuuskunta)*.

Table 4. Estimated areas treated with herbicides in Finland, 1965

| Crops, weeds and sites of application | Herbicide | Treated area 1 000 ha | |
|--|-----------------|-----------------------|------|
| Spring cereals | MCPA | 430.3 | |
| | MCPA/dinoseb | 2.0 | |
| | dinoseb | 2.3 | |
| | mecoprop | 4.8 | |
| Winter cereals | mecoprop | 9.0 | |
| | MCPA/2,3,6-TBA | | 10.5 |
| | 2,4-D | | |
| Grasses for seed | MCPA | 0.5 | |
| | MCPA/2,3,6-TBA | | |
| Field pea | dinoseb | 0.7 | |
| Carrot and set onion | linuron | 0.7 | |
| | prometryne | | |
| | chlorpropham | | |
| Other root crops, vegetables and potatoes | paraquat | 0.8 | |
| | diquat | | |
| <i>Agropyron</i> control: open fields | TCA | 3.6 | |
| | amitrole | | |
| Orchards, nurseries and forest plantations | simazine | 1.8 | |
| | atrazine | | |
| | amitrole | | |
| Brush control: right-of-ways, power lines, forest renewals | 2,4-D/2,4,5-T | 24.0 | |
| | 2,4-D | | |
| Railway tracks and -yards, lumber yards, sports fields | chlorates | 0.6 | |
| | simazine | | |
| | atrazine | | |
| | amitrole | | |
| Lakes and waterways | dalapon | 0.1 | |
| | copper sulphate | | |
| Total | | 491.7 | |

Companies which sold herbicides and acted at the same time as contractors were *Kiinteistön-omistajien Desinfektiokeskus Oy* since 1952, *Desinfektio Oy* 1958, *Metsälento Oy* 1963, and *Maa-talouspalvelu Oy* 1965. Such contracting firms used the chemicals which they imported for their own weed control operations or sold the products directly to the consumer.

After the Pesticide Law had come into effect in 1952, all dealers were obliged to submit their products for official testing and approval before sales were permitted (cf. p. 36).

Table 5. List of herbicides tested, approved or sold in Finland, 1887—1965

| Common or abbreviated name ¹⁾ | Starting year for | | | Common or abbreviated name ¹⁾ | Starting year for | | |
|--|-----------------------|------------------------|---------------------|--|-----------------------|------------------------|---------------------|
| | testing ²⁾ | approval ²⁾ | sales ²⁾ | | testing ²⁾ | approval ²⁾ | sales ²⁾ |
| Inorganic compounds | | | | | | | |
| AMS | 1961 | — | — | 'dicryl' | (1961) | — | — |
| CaCN ₂ | (1926) | 1953 | 1944 | dimexan | 1963 | — | — |
| Ca(NO ₃) ₂ | (1936) | — | — | dinoseb | 1951 | 1952 | 1954 |
| CuSO ₄ | 1959 | — | — | diquat-dibromide | 1960 | — | — |
| FeSO ₄ | (1926) | — | — | diuron | 1960 | 1963 | 1963 |
| HCl | (1947) | — | — | DNOC | 1944 | 1957 | (1958) |
| HNO ₃ | (1929) | — | — | endothal-Na | 1961 | — | — |
| H ₂ SO ₄ | (1903) | — | — | EPTC | (1960) | — | — |
| KClO ₃ | (1931) | 1952 | (1935) | erbon | 1956 | 1957 | (1958) |
| KCNO | (1950) | (1952) | — | fenac | (1958) | — | — |
| MgCl ₂ | (1960)* | (1962)* | — | fenoprop | 1961 | — | — |
| Na ₃ AsO ₃ | (1903) | — | — | fenuron | 1960 | — | — |
| NaBO ₂ | (1957)* | 1958 * | (1958)* | fenuron-TCA | (1960) | — | — |
| Na ₂ B ₄ O ₇ | (1958)* | — | — | flurenol | 1964 * | — | — |
| Na ₂ B ₁₀ O ₁₆ | (1958)* | — | — | ioxynil | 1964 | — | — |
| NaCl | (1887) | 1952 * | 1945 * | isocil | 1962 | 1964 | — |
| NaClO ₃ | (1926) | 1952 * | 1927 | 'karsil' | (1961) | — | — |
| NaCO ₃ | (1960)* | — | — | lenacil | 1964 | — | — |
| NaNO ₃ | (1958) | — | — | linuron | 1962 | 1962 | 1963 |
| NH ₄ SCN | 1960 * | 1964 * | — | MCPA | 1946 | 1952 | 1947 |
| | | | | MCPB | (1955) | 1957 | (1957) |
| | | | | mecoprop | 1958 | 1961 | 1961 |
| | | | | metham-Na | (1958) | 1959 | 1961 |
| | | | | methyl bromide | (1962) | — | — |
| | | | | MH | 1953 | — | — |
| | | | | monalide | 1964 | — | — |
| | | | | monolinuron | 1962 | — | — |
| | | | | monuron | 1954 | 1955 | 1958 |
| | | | | morfamquat | 1965 | — | — |
| | | | | NAA | (1954) | — | — |
| | | | | naptalam | (1955) | — | — |
| | | | | neburon | (1958) | — | — |
| | | | | nitrofen | 1965 | — | — |
| | | | | OCH | (1958)* | — | — |
| | | | | paraquat-dichloride | 1963 | 1964 | 1964 |
| | | | | PCP | (1957) | — | — |
| | | | | picloram | 1964 | — | — |
| | | | | prometone | (1962) | — | — |
| | | | | prometryne | 1961 | 1962 | 1963 |
| | | | | propanil | 1965 | — | — |
| | | | | propazine | (1960) | 1962 | — |
| | | | | propham | (1948) | — | (1951) |
| | | | | pyrazon | 1962 | — | — |
| | | | | simazine | 1957 | 1959 | 1959 |
| | | | | SMA | (1958) | (1959) | (1959) |
| | | | | 'solan' | (1961) | — | — |
| | | | | 2,4,5-T | 1948 | 1952 | 1950 |
| | | | | 2,3,6-TBA | 1957 | 1958 | 1958 |
| | | | | TCA | 1940 | 1952 | 1952 |
| | | | | tri-allate | 1965 | — | — |
| | | | | trimeturon | 1965 | — | — |
| | | | | | | | |
| Organic compounds | | | | | | | |
| allyl alcohol | (1958) | 1959 | 1959 | | | | |
| amiben | (1961) | — | — | | | | |
| amitrole | 1954 | 1959 | 1959 | | | | |
| aromatic oils | 1947 | 1956 | 1956 | | | | |
| atrazine | 1959 | 1962 | 1963 | | | | |
| barban | (1960) | — | — | | | | |
| BiPC | 1960 * | — | — | | | | |
| bromacil | 1963 | 1965 | 1965 | | | | |
| bromoxynil | 1965 * | — | — | | | | |
| buturon | 1963 | — | — | | | | |
| chloral | (1940) | — | — | | | | |
| chloroxuron | 1961 | 1962 | 1962 | | | | |
| chlorpropham | 1956 | 1958 | 1964 | | | | |
| 4-CPA | (1961) | — | — | | | | |
| cycluron | 1960 * | — | — | | | | |
| 2,4-D | 1946 | 1952 | 1948 | | | | |
| dalapon-Na | 1955 | 1958 | 1960 | | | | |
| dazomet | (1962) | 1964 | 1964 | | | | |
| 2,4-DB | (1957) | — | — | | | | |
| DCU | (1957) | — | — | | | | |
| 2,4-DES | (1954) | — | — | | | | |
| desmetryne | 1964 | — | — | | | | |
| di-allate | (1963) | — | — | | | | |
| dicamba | 1963 | — | — | | | | |
| dichlobenil | 1961 | 1964 | — | | | | |
| dichlone | 1963 | — | — | | | | |
| dichlorprop | 1962 | — | — | | | | |
| | | | | | | | |
| Organic compounds without established common name | | | | | | | |
| 2-bromo-6'- <i>t</i> -butyl- <i>N</i> -(methoxymethyl)- <i>O</i> -acetoluide | 1965 | — | — | | | | |
| chloralchloroacetamide | (1960) | — | — | | | | |
| 2-chloro-4-allylamino-6-isopropylamino-1,3,5-triazine | (1961) | — | — | | | | |
| 4-chloro-2-oxobenzothiazolin-3-ylacetic acid | 1965 * | — | — | | | | |
| 2,2-dichlorobutyric acid | (1961) | — | — | | | | |
| 1-phenyl-3-methyl-5-allyl-hexahydrotriazinon-2 | 1965 | — | — | | | | |

¹⁾ Names recommended by British Standards Institution and/or Weed Society of America.²⁾ () = discontinued; * = in mixtures only.

2. Application equipment

Until the end of the 1940's, the equipment used for applying herbicides was modest. Liquids were applied by hand-operated knapsack sprayers. Granular products were applied by hand, either alone or mixed with chemical fertilizers. Application of dusts was sometimes carried out with hand-operated dusters. Little horse-drawn application equipment (Figs. 3 below, and Fig. 4 p. 34) was in use. Once the sprayable formulations of phenoxyacetic acids began to appear on the market at the end of the 1940's, the first tractor-powered sprayers were imported. These were operated directly through the transmission shaft of the tractor. At first, only a few larger farms purchased tractor sprayers. As the use of herbicides began to spread, agricultural societies and farmers' co-operatives decided to acquire sprayers to be shared jointly by the farmers. The number of tractor sprayers increased steadily and was about 8 000 in 1965 (Table 6).

Initially all tractor-powered sprayers were imported from abroad, but in the mid-1950's domestic production made a good start. Because of the low price and the practical construction of Finnish sprayers they dominated the sprayer

Table 6. Approximate number of tractor sprayers in Finland, 1949—65

| Year | Sprayers | Year | Sprayers |
|------------|----------|------------|----------|
| 1948 | 1 | 1957 | 1 400 |
| —49 | 2 | —58 | 1 700 |
| —50 | 20 | —59 | 2 000 |
| —51 | 50 | —60 | 2 500 |
| —52 | 200 | —61 | 3 000 |
| —53 | 400 | —62 | 4 700 |
| —54 | 600 | —63 | 6 000 |
| —55 | 800 | —64 | 7 000 |
| —56 | 1 100 | —65 | 8 000 |

market until the year 1962, when foreign competition again became more intense.

During the years 1949—65 great progress was made in the construction of tractor sprayers. In the first models, piston pumps were mostly used. These were gradually replaced by the more reliable nylon roller-vane pumps and, after 1962, by diaphragm pumps. Some domestic models made use of cheap centrifugal pumps, which, however, had a shorter useful life.

The first models of nozzles had small openings and gave a fan type spray. They readily became clogged and were soon replaced by the large-opening nozzle type (*Hâte*) giving an umbrella

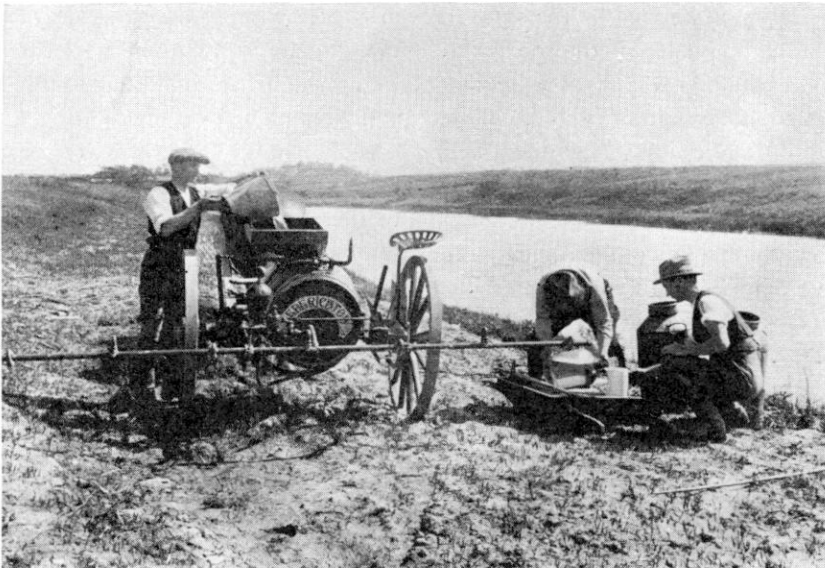


Fig. 3. Preparing for cereal spraying with sulphuric acid at Tammisto Farm near Helsinki. Sprayer, a German horse-drawn type, *Hederichod*. Photo O. Valle, June 1927.



Fig. 4. Spraying oil flax with MCPA on the Farm of the Agricultural Research Centre, Tikkurila. Sprayer, a Swedish-made type, *Favorite*. Photo O. Valle, June 21, 1947.

broadcast spray pattern. This type of spray, however, was more likely to drift. In 1962—63 the umbrella nozzles began to be superseded by hollow cone nozzles. The spray pattern given by this type was less subject to wind drift and penetrated better into densely growing foliage.

The volumes of liquid applied by the sprayers at normal operating speed (6—7 km/hour) were initially small. As progress was made in sprayer construction, it soon became possible to apply larger volumes of liquid (600—800 litres/hectare). Since 1962, all the models of tractor sprayers on the market were able to apply at least 150—200 l/ha at normal operating speed.

The effective spray width of the smaller tractor sprayers was 6—7 metres and that of larger equipment 9—11 metres. The tank capacity originally was about 200 litres. This size persisted for a long time, since the manufacturers used cheap petrol and oil containers to serve as tanks. In later years, higher-capacity, 300—500 litre, tanks were made for the larger models of sprayers. Only in exceptional cases were motor-driven knapsack sprayers (*Solo*) used for applying herbicides (LÄHDE and BREITEN-

STEIN 1952, BREITENSTEIN 1954, 1963, PIRTTILÄ 1962, NIEMINEN 1960, 1963).

Aerial application of herbicides on fields in Finland was tried in 1952, by using a *Piper Cub* aeroplane. The application, however, was not performed with sufficient precision. Moreover, drift of the spray due to wind caused considerable damage to surrounding areas. In 1960, trials were made to apply herbicides for brush control in forest plantation areas using a *Piper PA-18 Cub*. Not until 1962, however, was aerial treatment of brush undertaken on extensive areas. In these operations a Polish aeroplane *PZL-101 »Gawron»* was used. By the end of 1965, the number of aeroplanes used for spraying had increased to four. In addition to brush control, aeroplanes were also employed for the spraying of lakes to control algae.

In aerial applications, dilution of the herbicide was initially made with water, later with a mixture of water and diesel oil, and after 1964 with diesel oil alone. At first the volume was 25—80 l/ha. When diesel oil alone was used for dilution, the volume was reduced to as little as 6 l/ha.



Fig. 5. Spraying spring wheat with MCPA at Kujala, Lahti. Sprayer, a Finnish-made type *Agra*. Photo T. Kanerva, June 1965.

3. Research and enforcement of the Pesticide Law

Research dealing with herbicides in Finland was unorganized until the late 1940's. Occasional studies were conducted on a small scale, mostly as a »side-line», in various institutions. A Committee on Plant Protection, appointed by the Ministry of Agriculture in 1944, called attention to this unsatisfactory situation and recommended that a weed research institute should be founded in Finland. As a preliminary solution a full-time weed researcher post was created at the Department of Plant Husbandry of the Agricultural Research Centre in 1947. Mr. VIHTORI LÄHDE was appointed the first weed researcher.

He was succeeded in 1956 by the senior author of this paper, Dr. JAAKKO MUKULA.

The need of more research on weed control was further discussed by the Parliament in 1957 and 1959 (Preventing Losses 1958, Statement of the Parliament 1959). Also the establishment of a weed research institute was discussed by the Weed Section of the Plant Protection Society in 1961 and 1965. In the latter year, a proposal was drawn up with the intention of presenting it to the authorities for consideration. It proposed the establishment of a Department of Weed Investigation in the Agricultural Research

Centre. In addition, posts should be created for weed research at various experimental stations of the Agricultural Research Centre as well as at the Department of Horticulture and Forest Research Institute.

In the meantime, in 1951, the law calling for official testing of pesticides had been passed and had come into effect in 1952. This law stipulated that all chemicals used for plant protection, including herbicides, had to be officially tested and approved before being put on the market. The testing, which involved a fee paid by the companies, was performed by the »Office for Plant Protectants», which was established by the Departments of Plant Pathology and Pest Investigations of the Agricultural Research Centre. The Department of Plant Husbandry was designated to »assist» the Office for Plant Protectants in carrying out the biological testing of herbicides (Dec. Min. Agric. 1952). In 1960, a full-time post was created at the Department of Plant Husbandry for the biological testing and evaluation of herbicides. This post was held by Mr. HANNU PIRTILÄ in 1960, by Mr. ESKO RUUTTUNEN in 1960—61, and by Mr. RISTO LALLUKKA in 1961—65. At the end of 1965, it was decided to establish a permanent full-time »herbicide inspector» at the Office for Plant Protectants to supervise the marketing of commercial herbicides and to handle their official approvals.

The Pesticide Law was applied as follows: The Office for Plant Protectants submitted the herbicide samples and the applications for testing to the Department of Plant Husbandry, which performed field trials for one or more years and, on the basis of the results obtained in the trials, made a report to the Office for Plant Protectants, which subsequently made the final decision regarding approval. In its report, the Department of Plant Husbandry listed the weeds controlled, the crops which should be treated, the times of treatment and the recommended doses of the herbicides. There were two classes of approval, the lower one being »sales permission» and the higher one »official approval». Officially approved products had a triangular

mark on the label. Having reached its decision the Office for Plant Protectants, among other things, defined the precautions to be printed on the label of the herbicides and made sure that the label and other forms of publicity were in accordance with the official decision. The toxicity of herbicides was classified on the Decree on Pesticides (1951, 1956, 1960). Highly toxic liquid formulations could be bought only with a special licence issued by the police authorities (Dec. Min. Agric. 1960). Such products carried marks prescribed by the decree, such as »Dangerous if taken internally» as well as a picture of skull and cross bones (Dec. Poisons 1946). Other less strict precautionary markings were used on other herbicides, depending on their degree of toxicity.

In the years 1952—65, a total of 356 applications for approval of commercial herbicidal products were submitted (Table 7, below). These applications represented 72 different chemical compounds. A total of 139 decisions of approval were made, pertaining to 36 different compounds (List Pestic. 1953, 1955, 1958, 1960, 1963, Suppl. List Pestic. 1955, 1958). In the same period 1952—65, 30 approvals were withdrawn pertaining to 6 different compounds. There were two reasons for such withdrawals: (1) during the course of several years, certain shortcomings in the compound had become evident which were not originally known or

Table 7. Official testing of commercial herbicides in Finland, 1951—65

| Year | Number of applications | Number of approvals | |
|---------------|------------------------|---------------------|---------------|
| | | total | valid in 1965 |
| 1951/52 | 30 | 10 | 9 |
| 1953 | 7 | 4 | 3 |
| —54 | 16 | 3 | 1 |
| —55 | 19 | 3 | 1 |
| —56 | 22 | 11 | 5 |
| —57 | 23 | 8 | 7 |
| —58 | 16 | 14 | 10 |
| —59 | 15 | 18 | 14 |
| —60 | 28 | 4 | 2 |
| —61 | 25 | 16 | 13 |
| —62 | 36 | 24 | 21 |
| —63 | 40 | 19 | 19 |
| —64 | 43 | 15 | 15 |
| —65 | 36 | 20 | 19 |
| Total | 356 | 169 | 139 |

anticipated; (2) new and more effective herbicides were being introduced, and the continued use of the older, less effective or otherwise inadequate products was not considered desirable.

During the early years after the Pesticide Law had come into effect, sales permissions and official approvals were given on the basis of one year's tests, providing that the herbicide gave satisfactory control of weeds and did not injure the crops. Later the requirements were made more stringent. Consequently approvals regarding new compounds or new uses and methods were granted only after several experiments had been conducted in various ecological conditions during 2—3 or even 4—5 years. Products containing previously approved compounds were, however, still granted sales permits or official approval on the basis of a single field test or a chemical analysis. As from 1961 the State Institute of Agricultural Chemistry was designated to assist the Office for Plant Protectants by performing chemical analyses to check the quality of the products on the market. Random samples were taken from retail shops and analyzed chemically. The frequency of these checkings increased from year to year.

In 1964, studies on herbicide residues in crops were included in the inspection programme without any special law or decree stipulating it. On the basis of these »unofficial» residue ana-

lyses, certain approvals were reconsidered. Since the year 1964, approvals of new herbicides for use on cultivated land were not granted until residue studies had shown that their use was safe.

The primary purpose of the Pesticide Law was to ensure the supervision of sales and advertising of herbicides as well as other pesticides, and not specifically the use of these chemicals (cf. MARKKULA 1962). Consequently, certain compounds were occasionally used as herbicides even after 1952, although they did not have the approval of the Office for Plant Protectants.

After 1962, the use of herbicides in waterways was not allowed until the Court of Water Rights had taken a decision, specifically in cases where the herbicidal treatment was considered as possibly causing pollution of the water (Law on Water Rights 1961, Dec. on Water Rights 1962). In such instances the Water Protection Office of the Board of Agriculture first made a report on the matter. Only in the treatment of small water areas with dalapon, did the Water Protection Office consider such a report unnecessary.

A second restriction concerning the use of herbicides was imposed in 1962, when dinoseb, DNOC and 2,4-D esters were declared poisonous to bumble and honeybees and their use on flowering vegetation was prohibited (Dec. Min. Agric. 1962).

4. Teaching, extension and advisory service

Before the second world war, only limited instruction in chemical weed control was given in conjunction with the regular lectures in crop husbandry at the University of Helsinki. During the 1950's, instruction dealing with herbicides was gradually increased and the subject was taught both by the regular professor of plant husbandry and by some special lecturers.

An extension service pertaining to chemical weed control and based on domestic research was organized by the Finnish Plant Protection Society as from the beginning of the 1950's. For this purpose, the society published also three

bulletins (ANON. 1952, LÄHDE et al. 1955, MUKULA 1962 b). Furthermore, in 1960 was founded the Weed Section of the Plant Protection Society, whose function was to furnish the advisory service with the results of research. The chairman of this committee was the senior author of this paper, while the secretary was the junior author. In collaboration with the Agricultural Research Centre the section organized 2-day extension courses in 1961, 1963 and 1965.

Chemical weed control was also included in the programme of the agricultural advisory service in the early 1950's. The first step in this

direction was taken by the Uusimaa Swedish-speaking Agricultural Society, which in 1950 published a bulletin on chemical weed control (ANON. 1950). Similarly, at the initiative of the Finnish advisory organization, many articles on this subject were written in agricultural newspapers and magazines (e.g. JYSKE 1949, 1959). Advisory booklets on chemical weed control were also published in the 1960's (BREITENSTEIN 1963, LALLUKKA 1963, MUKULA 1963 c) and courses for farmers were organized. The chemical companies effectively contributed to this service (ANON. 1958, 1960, 1962, VARKKOLA et al. 1952, 1955, 1959, 1962).

An outstanding achievement in the field of agricultural advisory service was the National Weed Campaign in 1962, initiated by Mr. YRJÖ K. K. TALVITIE and carried out as a co-operative project by advisory organizations, chemical companies, central agricultural firms and their retail dealers, as well as research and

educational institutions. The chairman of the committee supervising this campaign was Mr. NIILLO KORPELA, and the secretary Mr. HANNU PIIRTILÄ. The members were Mr. WALTER BREITENSTEIN, Mr. JAAKKO JYSKE, Mr. ERKKI SARVIALA and the senior author of this paper. Thanks to the intensively organized advisory service of the committee, the use of herbicides in Finland increased 2 ½-fold within a year.

In this connection the large-scale surveys of weeds in leys (1950—51) and spring cereals (1961—64) should be mentioned (PAAATELA 1953, MUKULA et al. 1962). On the basis of these surveys, information was obtained on the weed species which occur on the fields in Finland, as well as on the frequency and abundance of each species in different parts of the country. Acting on this information, the agricultural advisory service was subsequently able to draw up plans for effective weed control.

5. Side effects of chemical weed control

Owing to the rapid development of chemical weed control, damage and accidents sometimes occurred. Initially sufficient experimental data were not available for ensuring the safe use of herbicides. Some actual mistakes were also made either by the manufacturer or dealer, or by the farmer himself. If the responsibility lay with the firm, it usually reimbursed the farmer voluntarily. In very few cases was it necessary to take the matter into court. Economically the biggest damage occurred in 1954, when a 5-hectare apple orchard in southwest Finland was badly injured by the misuse of MCPA. The error had been made by the dealer, who paid a total of 4 million old Finnmarks (=£ 3 200 or \$ 12 800) to the grower in compensation. Up to the year 1958, the Finnish State Railways spent nearly 30 000 Finnmarks (=£ 2 400 or \$ 9 600) in compensation for damage to crops and deciduous trees caused by the use of high-volatile butyl esters of 2,4-D and 2,4,5-T (Auditors' Report 1958). This led to criticism on the part of the

state auditors, and subsequently the railways began to use low-volatile butoxyethyl and isooctyl esters of 2,4-D and 2,4,5-T instead.

In the 1950's, large-scale killing of fish resulted from the *Äänekoski Factory* releasing waste products of phenoxycarboxylates into the adjacent waterways. Within a radius of about 50 km from the factory, large numbers of fish were killed in the lakes by MCPA, and even three years after the cessation of its manufacture, a strong and unpleasant flavour of this chemical or related products was observed in the fish. At the end of the 1950's, the factory made an effort to improve the situation by burying the waste products in a bog between two gravel ridges. Nevertheless the waste, carried by the ground water, ultimately found its way to the lakes. No active-charcoal purifying of waste products was attempted. Finally, the local health authorities forbade the production of phenoxycarboxylates at *Äänekoski* (Water Pollution 1964).

Copper sulphate caused extermination of fish in the lakes of Tuusula and Kyröjärvi in 1959, and the matter was taken into court. The demands of the prosecutor for compensation were rejected on the grounds that the immediate cause of death was not the direct toxicity of copper sulphate to the fish, but the fact that the copper sulphate killed off the water plants. The dead plants later decayed, exhausting the supply of oxygen in the water, which in turn was responsible for the death of the fish (Death of Fish, May 10 and 28, 1962).

The most notable case of injuries caused by herbicides to domestic animals concerned the large-scale killing of honeybees by phenoxy-carboxylates. A few cases occurred around the beginning of the 1950's, when flowering dandelions were sprayed with 2,4-D esters. In 1964 there were also some instances of death to honeybees after herbicidal treatment with salts of MCPA and mecoprop.

The misuse of certain herbicides also caused injuries and even death to humans. Such accidents occurred when the potassium chlorate herbicide named *Fekabit* was used for rock blasting. Likewise, toy rockets for children made with *Fekabit* occasionally led to fatal accidents. The sales and use of *Fekabit* ceased in 1963 (cf. p. 9).

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¹⁾ The abbreviations in brackets are those used by the journals of the Commonwealth Agricultural Bureaux and refer to the languages as follows: Dan = Danish, E = English, Fin = Finnish, G = German, Nor = Norwegian, Sw = Swedish. An initial capital denotes the language of the paper, unless English, German or French. A small letter denotes the language of the summary.

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Rikkakasvien kemiallinen torjunta Suomessa 1887—1965

J. MUKULA ja E. RUUTTUNEN

Maatalouden tutkimuskeskus, Kasvinviljelylaitos, Tikkurila

Ensimmäiset kokeet rikkakasvien hävittämiseksi kemiallisin menetelmin lienee Suomessa suorittanut Mikael von Essen Herniäisten kartanossa Hauholla 1887—1905. Sirottelemalla kasvustoon ruokasuolaa von Essenin onnistui hävittää leskenlehdet puntarpäänurmesta. Voikukkia ja koiranputkia hän tappoi katkaisemalla ne juuren niskasta ja ripottelemalla suolaa juurten katkaisupintaan. Liuoksena ruokasuolan teho osoittautui von Essenin kokeissa lyhytaikaiseksi, samoin rikkihapon ja »arsenikin».

Ruokasuolalla saavuttamiensa myönteisten kokemusten nojalla von ESSEN (1912, 1913) ryhtyi suosittelemaan sen käyttöä rikkakasvien torjuntaan. Menetelmä ei kuitenkaan yleistynyt. Sen sijaan »suolavettä», siis ruokasuolaliuosta, ruvettiin Suomessa käyttämään rikkakasvien hävittämiseen katukäytäviltä jo ainakin vuosina 1905—1915. Lisäksi GROTFELT (1914 a, b), GROTFELT ja AALTO-SETÄLÄ (1924) sekä RELANDER (1923) suosittelivat ulkomaisen kirjallisuuden nojalla mm. ferrosulfaattia rikkakasvien torjuntaan viljelysmailla. BRENNER (1917) kokeili epäorgaanisten happojen ja emästen myrkkövaikutusta kasvien lehtisolukkoon, mutta hänen tutkimuksensa jäivät teoreettiselle asteelle. KITUSEN (1929—1930) mukaan vuoteen 1926 mennessä »jotkut viljelijät olivat mahdollisesti saattaneet käyttää kemikaaleja rikkakasvien torjuntaan omilla viljelyksillään». Mainittuna vuonna Kitunen aloitti laajamittaiset kenttäkokeet neljällä maatilalla lähellä Helsingiä ja yhdellä maatilalla Rantasalmella. Ulkomaisten esimerkkien mukaisesti hän käytti rikki- ja typpihappoa sekä ferrosulfaattia ja kalkkityyppä rikkakasvien hävittämiseen korsiviljoista. Samantapaiset tutkimukset aloitettiin Maatalouskoelaitoksen Tuhoeläinosastolla 1920-luvun lopulla, Satakunnan koeasemalla 1931 sekä Etelä-Pohjanmaan, Pohjois-Pohjanmaan ja Karjalan koeasemilla 1936. Maatalouskoelaitoksen Kasvinviljelyosasto puolestaan ryhtyi Ruotsista saadun esimerkin (FEILITZEN 1925) mukaisesti kokeilemaan natriumkloraaattia, vuonna 1926 viljelemättömällä maalla ja 1927 myös viljelysmaalla sekä Puutarhaosasto kaliumkloraaattia omenatarhassa 1931. Viimeksi mainitut, Meurmanin alulle panemat tutkimukset olivat alallaan uraa uurtavia (MEURMAN 1944, 1946, 1948, 1950).

1940-luvulla ruvettiin Suomessa kokeilemaan rikkakasvien torjuntaan myös orgaanisia kemikaaleja. Ensimmäinen orgaaninen rikkakasvihävitte, DNOC, oli keksitty Ranskassa muutamaa vuotta aikaisemmin (TRUFFAUT ja PASTAC 1935). Suomessa Virtanen huomasi Joensuun kartanossa Sipoossa 1940 aloittamisissaan astia-

kokeissa ja 1941—44 jatkamisissaan kenttäkokeissa sellaisen orgaanisten yhdisteiden, joiden molekyylissa karboksyyliyhdyntien viereinen hiiliatomi on täysin kloorattu, kuten TCA:n ja klooraatin, vaikuttavan tappavasti juolavehnan juurakoihin. Elokuulla 1945 hän anoi tällaisille yhdisteille käyttöpatenttia Suomessa ja vuotta myöhemmin Ruotsissa. Molemmat anomukset hyväksyttiin (VIRTANEN 1948). Tosin E.I. du Pont de Nemours & Co:n edustaja (BOUSQUET 1946) oli USA:ssa tehnyt vastaavanlaisen, TCA:n ammoniumsualetta koskevan patenttihakemuksen yhdeksän kuukautta aikaisemmin, mutta tämä patentti myönnettiin vasta tammikuussa 1946. Rajoituksaan TCA:n ammoniumsualetta koskevaksi se jäi Virtasen patentin rinnalla merkityksettömäksi. Viimeksi mainittu puolestaan tuli voimaan vain Suomessa ja Ruotsissa eikä pystynyt peittämään sellaisia karboksyylihappoja kuin esim. dalaponi ja 2,2-diklorvoihappo, joiden molekyylissa yksi karboksyyliyhdyntien viereisen hiiliatomin valensseista on kloorin asemesta korvattu alkyylillä.

Ulkomaisten esimerkkien mukaisesti ryhdyttiin Suomessa 1940-luvun jälkipuoliskolla kokeilemaan rikkakasvien torjuntaan muitakin orgaanisia yhdisteitä, MCPA:ta, 2,4-D:tä, 2,4,5-T:tä, petrolia ja dalaponia. Kehitys jatkui 1950- ja 1960-luvuilla. Kokeiltujen kemikaalien lukumäärä kohosi vuoden 1965 loppuun mennessä yhteensä noin sataan. Tietelle uutena saavutuksena on 1950-luvulta mainittava Virtasen johdolla tehdyt, kasveissa esiintyviä antibioottisia aineita koskevat tutkimukset, jotka johtivat 2,4-dihydroksi-1,4-bentsoksatsin-3-ketonin löytymiseen (VIRTANEN ja HIETALA 1959, WAHLROOS ja VIRTANEN 1959). Myöhemmät ulkomaiset tutkimukset ovat osoittaneet tämän aineen pystyvän hajottamaan simatsiinia ja siten parantavan kasvien simatsiinin kestävyyttä (ROTH ja KNÜSLI 1961, HAMILTON ja MORELAND 1962).

Rinnan tutkimustyön edistymisen kanssa alkoi rikkakasvien kemiallinen torjunta Suomessa vähitellen levitä myös käytäntöön. Ensimmäiset kaupalliset rikkakasvihävitteet, saksalainen *Wegebellum* ja kotimainen *Kitko* saatiin markkinoille 1927—30. Ne sisälsivät natriumkloraaattia ja olivat tarkoitettuja levitettäväksi vesiliuoksena lähinnä viljelemättömiin paikkoihin. Ruiskukaluston puuttumisen vuoksi niiden käyttö jäi vähäiseksi. Kotimainen kaliumkloraaattivalmiste *Fekabit* (1935), joka oli tarkoitettu levitettäväksi sirotteena, syrjäytti ne vähitellen. Samoin sirotteena levitettävä natriumklooraatin ja natriumkloridin seos, *Rikkaruohontubo* (1944) jäi markkinoille

pysyvästi. Lisäksi jauheena levitettävää kalkkityyppä ruvettiin käyttämään paitsi lannoitteena myös rikkakasvihävitteenä.

MCPA:ta ja 2,4-D:tä alettiin Suomessa markkinoida 1947 sekä 2,4-D:n ja 2,4,5-T:n seoksia 1949. Merkittävän laajuuden niiden käyttö saavutti 1950, jolloin maahan hankittiin 20 traktoriruiskua. Kehitys jatkui myöhemmin 1950-luvulla, tosin hitaampana kuin Skandinaviassa, Länsi-Euroopassa ja Pohjois-Amerikassa. Torjunta-aineiden myyntiluvut lisääntyivät vähitellen, samoin ainevalikoima, ruiskukalusto ja rikkakasvihävitteillä vuosittain käsitelty pinta-ala. Vuonna 1955 ruiskutettu peltoala kohosi 50 000 ha:iin ja kolme vuotta myöhemmin 100 000 ha:iin. Voimakkaan sysäyksen rikkakasvien kemiallisen torjunnan yleistymiselle antoi 1962 järjestetty ns. valtakunnallinen rikkaruohosota, jonka aikana peltoviljelyksiä ruiskutettiin yli 300 000 ha. Seuraavina vuosina kehitys jatkui edelleen nopeana. Vuonna 1965 kohosi maassa myytyjen rikkakasvihävitteiden raha-arvo yli 9 milj. mk:n ja ruiskutettu pinta-ala lähes 500 000 ha:iin. Eniten käytettyjä hävitteitä olivat MCPA-valmisteet (807 tn), TCA (110 tn), 2,4-D:n ja 2,4,5-T:n esteereiden seokset (106 tn), kloraatit (80 tn) sekä mekopropi (50 tn). Laajimman käyttöalueen muodostivat kevätiljat (439 000 ha), toisella sijalla olivat tienvarret, voimalinjat ja metsänuudistusalueet (24 000 ha) sekä kolmannella syysviljat (20 000 ha).

Suurin osa Suomessa rikkakasvien torjuntaan käytetyistä kemikaaleista hankittiin ulkomailta. Tärkeimpinä tuontimaina olivat Länsi-Saksa (BRD), Englanti, Sveitsi ja Ruotsi. Kotimaassa valmisti *Elektrokemiallinen Tehdas Savo Oy* kaliumkloraattia vuosina 1935—63, *Kymn Oy* kalkkityyppä vuodesta 1944, *Äänekoski Oy* TCA:ta ja fenoksietikkahappojohdannaisia 1952—60 sekä monoklorietikkahappoa 1959—60. *Rikkihappo Oy* valmisti kotimaassa natriumkloraaatin ja ruokasuolan seosta vuodesta 1944 sekä fenoksietikkahappojohdannaisia 1955, allyylialkoholia 1959 ja mekopropia 1961 lähtien, pääasiassa syntetisoimalla ne ulkomailta hankituista puolivalmisteista.

Rikkakasvihävitteiden levittämiseen käytetyt traktoriruiskut tuotettiin aluksi ulkomailta, mutta 1950-luvun puolivälistä lähtien niitä valmistettiin merkittävässä määrin myös kotimaassa. Vuonna 1965 kohosi käyttökuntoisten traktoriruiskujen lukumäärä 8 000:een. Viljelijät suorittivat torjunta-ainekäsittelyt yleensä itse. Vain metsänuudistusalojen lentoruiskutuksissa saavutti ns. urakoitsijajärjestelmä merkittävän jalansijan. Torjuntaan käytettyjen lentokoneita oli vuonna 1965 neljä.

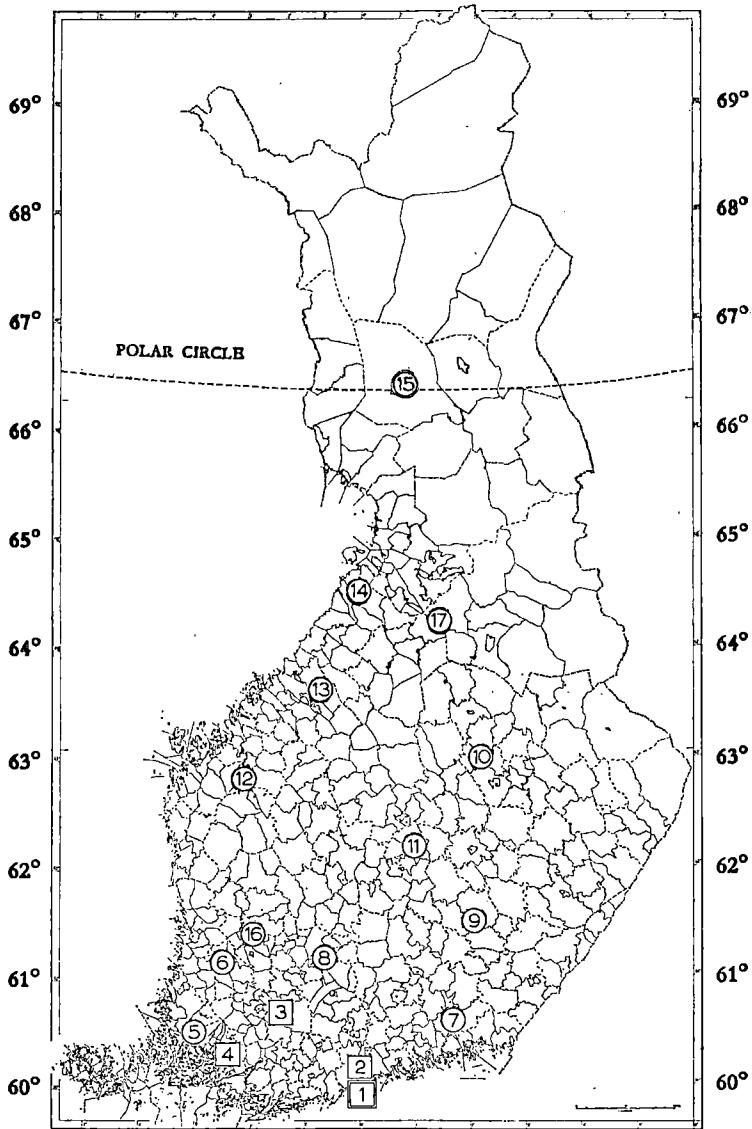
Vuonna 1952 Suomessa voimaan tulleen kasvinsuojeluainelain nojalla määrättiin Maatalouskoelaitoksen Kasvin-

viljelyosasto, sittemmin Maatalouden tutkimuskeskuksen Kasvinviljelylaitos avustamaan Kasvinsuojelulaitosta suorittamalla rikkaruohontorjunta-aineiden »biologisen» tarkastuksen. Mainitusta vuodesta lähtien saatiin maassa myydä vain Kasvinsuojelulaitoksen hyväksymiä kasvinsuojeluaineita. Rikkakasvihävitteitä koskevia tarkastushakemuksia jätettiin Kasvinsuojelulaitokselle vuoden 1965 loppuun mennessä yhteensä 356, joista 169 tuli hyväksytyiksi. Nämä edustivat 72 erilaista kemiallista yhdistettä. Myöhemmin peruutettiin eri syistä 30 hyväksymispäätöstä, jotka koskivat 6 yhdistettä.

Vuonna 1961 määrättiin myös Valtion maatalouskemiallinen laboratorio (nykyisin Valtion maatalouskemian laitos) avustamaan Kasvinsuojelulaitosta suorittamalla kemiallisia analyyseja kasvinsuojeluaineista. Kolme vuotta myöhemmin maatalouskemiallinen laboratorio otti lisäksi ohjelmaansa kasvinsuojeluaineiden käyttöön liittyvät kemialliset jäämätutkimukset.

Kemiallisen torjunnan laajenemisen ja monipuolistumisen vuoksi jouduttiin myös rikkakasvialan tutkimustoimintaa kehittämään. Maatalouskoelaitoksen Kasvinviljelyosastoon, sittemmin Maatalouden tutkimuskeskuksen Kasvinviljelylaitokseen perustettiin ensimmäinen ympärivuotinen rikkakasvitutkijan toimi 1947 ja toinen 1960. Verrattuna useissa muissa maissa tapahtuneeseen kehitykseen on näitä toimenpiteitä pidettävä riittämättöminä. Edellytykset erillisen rikkakasviosaston tai laitoksen perustamiselle Maatalouden tutkimuskeskukseen eivät kuitenkaan, mm. koulutetun henkilökunnan puuttumisen vuoksi, vielä olleet riittäviä.

Rikkakasvien kemiallisen torjunnan laajenemisella ja monipuolistumisella oli epäilemättä Suomessa kuten muissakin maissa voimakas myönteinen vaikutus kasvin tuotannon kehitykseen erityisesti 1950- ja 1960-luvulla. Vaikutus ilmeni paitsi satojen määrän ja laadun kohoamisena myös koneistamisen edellytysten paranemisena ja työkuormituksen alenemisena. Nopea kehitys ei kuitenkaan tapahtunut ilman haitallisia sivuvaikutuksia. Rikkakasvihävitteiden käyttö aiheutti toisinaan viljelykasvien vioittumista, josta oli seurauksena merkittäviä taloudellisia vahinkoja. Esim. Valtionrautatiet sekä Tie- ja vesirakennushallitus joutuivat 1950-luvulla maksamaan viljelijöille korvauksia vesakkoruiskutusten viljelykasveille aiheuttamista vahingoista. Äänekoski Oy puolestaan joutui vastaamaan fenoksietikkahappojohdannaisien valmistuksessa syntyneiden sivutuotteiden aiheuttamasta vesistön pilaantumisesta. Myös joitakin mehiläisten kuolemaan johtaneita tapauksia todettiin. Lisäksi rikkakasvihävitteenä myydyin kaliumkloraaattivalmisteen (*Fekabit*) joutuminen lasten käsiin ja käyttö räjähdysainekokeiluihin aiheutti eräitä henkilövahinkoja.



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