CLIMATIC FACTORS AFFECTING HERBICIDAL ACTIVITY OF SODIUM TRICHLORACETATE IN DIFFERENT SOILS

- - - 0 - - -

A thesis submitted to The University of New Zealand in partial fulfillment of the requirements for the Degree of Master of Agricultural Science (Horticulture).

- - - - 0 - - - -

by

R. Pengelly

Massey Agricultural College

1956

TABLE OF CONTENTS

INTRODUCTION

Trichloracetic acid (T C A) has long been known as a protein precipitant, but it was not until 1947 that research workers in the U.S.A. found it to be an effecive grass killer. Immediately it was subjected to a considerable amount of experimentation, but it is only since 1950 that any trials have been conducted with this herbicide in New Zealand.

Most of this early research was of an observational or emperical nature, and the results obtained were often inconsistent. However, it was soon determined that there was little downward translocation of T C A when foliar applications were made, and that for maximum kill it was essential for the herbicide to come into contact with the grass roots. Best control of couch (Agropyron repens L.), for example, has been obtained when the T C A was sprayed on the upturned sod and light rain fell within a few days after application.

Before commerical usage of any newly developed herbicide is recommended on agricultural land it is desirable to know the fate of that herbicide when applied to the soil, whether it will persist and be cumulative so that subsequent crops will be effected, if a short period of residual activity can be expected, or if the compound is rapidly dissipated. To this writer's knowledge, no attempt had been made in New Zealand to undertake a quantitative study of the effects soil type, temperature and rainfall have on the rate of inactivation and distribution of T C A when applied to the soil. Such an investigation therefore seemed pertinent, and more especially because results of similar studies overseas were not in full agreement.

The published reports showed that both chemical and biological tests had been employed to determine the concentrations, or relative amounts of T C A in the soil, but in no instance had the two methods been employed for the one experiment. It was therefore considered that in a future investigation some useful purpose would be served by a comparison of results obtained by both tests.

REVIEW OF LITERATURE

The first published report of the herbicidal potential of T C A was by Ryker (43) in 1947 at the Fourth Annual North Central (U.S.A.) Weed Control Conference. He claimed that T C A had given encouraging results when applied as a pre-emergence treatment for the control of grass weeds in broadleaf crops.

According to McCall and Zahnley (22), the grass killing properties of T C A were first discovered by E.I. du Pont de Nemours and Company, Inc. Their tests had shown that ammonium trichloracetate was useless as a general contact herbicide for it produced only superficial damage to some of the broad-leaved weeds on which it was applied, but it completely killed all grass plants against which it was tested, including barley, wheat, corn, couch (Agropyron repens L.) and Bermuda grass (Cynodon dactylon (L.) Pers.).

Residual Activity

McCall and Zahnley (22) concluded from their experiments that the control of perennial and annual grasses could be obtained with acre rates of 80 to 150 lb. and 20 to 60 lb. T C A respectively. They found that soil sterility was severe but temporary, toxicity disappearing within 30 to 90 days depending upon the amount of rainfall. Similar figures were quoted by Lynch (21). The North Central (U.S.A.) Weed Control Conference Research Committee of 1948 (27) reported that the residual toxicity of T C A persists for 30 days or more, depending upon precipitation, while Barrons (2) suggests 60 to 90 days as the maximum period. Much longer residual action was reported by Arakeri and Dunham (1). Under the conditions of their experiments T C A persisted in lethal amounts to soybeans for about 120 days and it remained in smaller quantities for at least another 90 days. Normal growth of spring planted crops on land treated with T C A the previous autumn, to control perennial grasses, was demonstrated by the Dow Chemical Company (11) but Carder (8)

claims that in Western Canada the effects of 50 lb. or more of T C A per acre applied in the autumn may last well into the following spring.

As the result of some Australian work, Green (17) considers that T C A breaks down rapidly in the soil, but it is advisable to wait 60 to 90 days before replanting, and a full year's weathering may be necessary before extremely sensitive plants could be planted.

Turnquist (47) observed no differences in growth and yields of spring sown sweet corn, onions, beans, peas, cabbage, cauliflower and tomatoes, on land that had received 38 to 114 lb. T C A per acre the previous autumn. Summer applications of up to 200 lb. T C A were found by Pavlychenko (33) not to impair the germination and normal development of spring sown cereals.

Extreme residual effect has been reported by Robinson and Dunham (42). T C A applications ranging from 11 to 176 lb. per acre were made by them to an old sod of Agropyron repens in September, 1948. Soybeans planted in February, 1949 were killed or severely injured by all rates of application. A second planting in 1950 was materially reduced in yields on the 48 to 176 lb. plots. It was not until the following year that the latter plots produced symptomless crops.

Temperature Effects

The shortest period of residual activity of T C A has been reported by Loustalot and Ferrer (20). They found that soil treated at the rate of 30 lb. per acre and subsequently stored at 45°C was devoid of toxicity at the end of 2 weeks, whereas toxicity persisted for at least 2 months when the soil was similarly treated and stored at 10°C. Ogle and Warren (29) also demonstrated that breakdown of T C A was proportional to the temperature and concluded that long residual control could not be expected in humid regions.

Ebell (14) has found TCA most effective under West Canadian conditions when applied in the late autumn. Cold weather and frozen soil does not appear to permit appreciable decomposition or leaching of TCA during the winter months yet the chemical penetrates to seedling root depth where it is most effective against early spring weed growth. Because of the slow rate of breakdown under those conditions, Ebell states that TCA must be used in the summerfallow year to allow ample time for residual effect to disappear before a crop is planted.

For similar reasons the North Central (U.S.A.) Weed Control Conference Research Committee of 1953 (28) consider that in sub-humid regions the residual effect of the late summer or autumn applications of TCA can be expected to extend into the growing season following treatment.

Soil Type Effects

Loustalot and Ferrer (20) observed that TCA persisted longer in clay soil than in sandy soil or a sandy-clay mixture. Jary (18) reported that there was a tendency for the control of Agropyron repens from any particular dosage to be better on heavy soils than on light ones, while McCall and Zahnley (22), and research workers of the Dow Chemical Company (11) found the reverse to be so. Matthews (24) considers that the efficiency of TCA is impaired on heavy soils. Lynch (21) emphasises the importance of soil type on the action of TCA and states that heavy soils require heavier rates of this herbicide to give a similar result to lighter rates in sandy soils.

Ogle and Warren (29) demonstrated that the rate of breakdown of TCA increased progressively from sandy soil to silt loam to muck soil.* Because of this slow breakdown in mineral soils they contended that a long residual effect might be expected in arid and semi-arid regions. Barrons and Hummer (3) likewise demonstrated that the inactivation

*- Muck soil is American equivalent for peat.

of TCA was greater in a soil high in organic matter than one of low organic content, but Rai and Hamner (38) found the reverse to obtain. The latter observed that in sandy and clay loams dissipation of TCA, as shown by wheat yields, was complete after 64 days whereas injury occurred even after 108 days in muck soil.

Parker (31) in his review of chemical weed control in sugar beet states that the activity of salts of TCA is greatest in the least organic soils. Blough and Fults (6) experienced some damage to sugar beets grown in sandy soil treated with TCA at rates as low as 5 lb. per acre but detected no injury to this crop grown in a loam treated at 15 lb. per acre. More recently Blough and Fults (7) have reported that in the same geographical and climatic areas the selective action of TCA is variable between soil types. In support of these field observations they have demonstrated in the glasshouse that on a medium textured loam relatively high in organic matter, selective control of annual grasses without crop injury was obtained with TCA at 15 lb. per acre, whereas non-selective phytotoxicity resulted at this and lesser rates when applied to a loamy fine sand and a silty clay loam, both of which were deficient in organic nitrogen. They suggest as one possible explanation that a substantial portion of the herbicide may be adsorbed by the organic colloids in the case of the loam. Rai and Hamner (38) support this theory, but Peters (37) reports that there is no evidence of TCA fixation by soil colloids.

Moisture Effects

Loustalot and Ferrer (20) found that TCA persisted for 2 months in soil with moderate moisture, a greater period than that in saturated soil, and that toxicity did not decrease with time as long as the soil remained air dry. Lynch (21) observed that TCA did not give satisfactory control of grasses on land subject to frequent flooding.

It is generally agreed that the moisture content of the soil has an important influence upon the effectiveness of soil applications of TCA, best control of grass weeds having been obtained when the soil is moderately moist. (2, 4, 5, 12, 16, 17, 22, 24, 50). Ten to twenty pounds of TCA per acre is usually sufficient to control seedling grasses, but Barrons and others (4) stress the importance of adequate soil moisture for control at these rates. They point out that if TCA is applied to soil so dry that the surface does not become moist at night through capillary movement, much of the herbicide will remain ineffective on the surface and though subsequent rains may dissolve it, the grass weeds may meanwhile have reached appreciable size and require much greater rates for control.

Moore and Myers (25) considered that the moisture condition of the soil prior to treatment with TCA did not influence the control of deep rooted Johnson grass (Sorghum halepense (L.) Pers.)

Rainfall Effects

Arakeri and Dunham (1) concluded that of the factors they studied, rain had the most important influence over results with TCA. Soybeans they sowed in plots given a pre-emergence spray of TCA, germinated and grew normally when protected from rain, but immediately they were exposed to rain plant injury occurred and increased in intensity as the season progressed and more rain fell. Where water was added after TCA application the crop was a complete failure.

Moore and Myers (25) also demonstrated conclusively the importance of adequate rain shortly after TCA applications for effective control of Sorghum halepense. They obtained excellent control with 200 lb. per acre when rain in excess of one inch fell within 14 days after treatment, whereas three times this dosage was ineffective when no rain exceeding 0.10 inches fell until 55 days after treatment.

Many other workers (2, 4, 11, 12, 16, 17, 30, 37) have reported superior control of grass weeds when rain fell within a few days of TCA application, but that excessive rains following treatment has resulted in inferior control, especially of shallow rooted species such as Agropyron repens, for much of the herbicide is leached below the zone of root growth, particularly on porous soils. One report (11) states that in light sandy soil a prolonged heavy rain can almost completely leach TCA from the soil. Barrons et al (4) and other (21, 22) consider that the adverse effects of soil moisture extremes are less likely on heavy to medium textured soils than they are on light sandy soils.

It is the opinion of Lynch (21) that a considerable fall of rain is essential subsequent to TCA applications for effective herbicidal activity. Peters (37) studied rainfall data in connection with his experimental control of Agropyron repens with TCA and concluded that 1.5 to 3 inches of rain followed by several days of little or no rainfall resulted in good control. Matthews (24) considers that on heavy soils up to 1 inch of rain is required for activation of TCA.

Arakeri and Dunham (1) found that small quantities of TCA did not disappear more rapidly in 2 inches of soil leached with 4 inches of water than in unleached soil. Loustalot and Ferrer (20) determined that with no rain TCA remained in the upper 2 inches of soil, $\frac{1}{4}$ inch rain moved it down into the fourth inch of soil and $\frac{1}{2}$ inch or 1 inch caused it to move to at least the eight inch depth.

Ogle and Warren (29) applied a small amount of TCA to the surface of different soils and determined at which depth the greatest concentration of the herbicide occurred after leaching with 2 inches of rain. These were found to be 2, 4 and 6 inches for silt loam, muck soil and sandy soils respectively. Their leaching studies showed

that in sandy soils most of the TCA moved out with 2 inches and all with 4 inches of water. Likewise in the muck soil all the toxicity disappeared with 4 surface inches of water, but slightly more was required for complete leaching of the TCA from the silt loam. They concluded that soil type had little effect on the movement of TCA, but the writer considers their results show a definite soil type effect.

Action of TCA

Barrons (2) observed that more TCA was required for a given result on very fertile soil, and with the knowledge that TCA is utilized as a protein precipitant, postulated that its action may be related to nitrogen absorption and metabolism. However, as pointed out by Woodford (51), the concentration at which trichloracetic acid affects plant tissue growth is well below the concentration required for the precipitation of plant proteins. Woodford suggested that TCA had a much more subtle effect on plant metabolism, and was probably associated with auxin controlled growth processes.

Tibbits and Holm (46) were unable to determine whether the tolerance of many dicotyledons to TCA is associated with an ability of those plants to prevent absorption and translocation of the chemical to meristematic tissues, or whether the lack of injury may be due to an early metabolism of the compound.

The exact nature of the action of TCA is still unknown.

Effect of TCA on Soil Micro-organisms

Kratochvil (19) treated small samples of silt loam with eight herbicides and determined the effect on soil micro-organisms by measuring the reduction in evolved gas. TCA caused the greatest depression in microbial activity. Data is not given in respect of the toxicity period.

Use of TCA

The differences in susceptibility to TCA between

certain crop plants and grass weeds has enabled the weeding of several crops with this herbicide (4). Agropyron repens has been controlled in areas planted with asparagus, cabbage and cauliflower; annual grasses have been controlled in linen flax and established lucerne. Pre-emergence applications of TCA have been used to control annual grasses in sugar and red beets, gladiolus, asparagus, potatoes and cruciferous crops, (4, 21, 36).