ADJUVANTS AS AN AID TO INCREASING THE EFFICIENCY OF WEEDKILLERS

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SUMMARY

A BRIEF review of literature allied to the subject of spray coverage, retention, and penetration is given.

Laboratory experiments designed to discover the effects of a particular spreader and spreader-sticker on a herbicide formulation are described.

Results of field trials involving the use of a spreader-sticker with 2,4,5-T on gorse (*Ulex europaeus*) are presented.

The experimental results are discussed, together with the use of spreaders and spreader-stickers with herbicides in general.

Extensive trials and field usage of herbicides have established recommendations for the control of many problems associated with weed infestation.

Some variability of results must be expected in general, however, for we are dealing with complex situations in which growth regulating materials are applied to living plants growing in a variable environment.

Besides the occurrence of inconsistent results, there are some applications of herbicides where the products at present available fail to give a degree of control of a particular weed which is generally considered satisfactory.

We cannot expect new products to meet the type of situation described above with any degree of certainty, and often this is not warranted because the material in question may be highly effective in the control of many weeds for which it is intended and prove to be deficient in only a limited number of cases.

It is obviously in our interests to consider the possible use of adjuvants in an endeavour to increase the efficiency of spray materials either by eliminating factors which may cause variable results or by actually improving the general potency of a weedkiller.

It is generally recognised that an improvement is desirable in the control of certain weeds occurring in New Zealand which are known to be susceptible to a particular hormone weedkiller, but which display variations in susceptibility for reasons which are not completely clear. Weeds of this type include gorse (*Ulex europaeus*), rushes (*Juncus* spp.), and manuka (*Leptospermum scoparium*).

There is evidence that the spray coverage achieved and the wettability of these species are allied to the control obtained.

For this reason we have carried out investigations concerning the use of spreaders and spreader-stickers to increase the efficiency of weedkillers in certain applications.

This paper is necessarily of a preliminary nature and describes laboratory experiments designed to discover how particular adjuvants may exert their effects and the extent to which the effects observed in the laboratory also operate in the field.

GENERAL DISCUSSION

The physical effect of a spreader or spreader-sticker is to lower the surface tension or inter-facial tension of the spray material in contact with plant material. Further effects may involve physico-chemical influences on plant tissue.

The large number of spreaders and spreader-stickers available exert these influences to different degrees, some for instance reduce surface tension without affecting the inter-facial tension, and some do and some do not have any effect on plant tissue directly. Because of the current uses of

adjuvants of the type mentioned and the properties which they are known to impart to spray materials, it is logical to presume that they could be of considerable benefit to users of herbicidal sprays in certain situations.

Owing to the important consideration of the relative selectivity of many herbicides to weed and crop plants which is known to involve differential wetting in many cases, the use of adjuvants with herbicides would require further extensive trial work before using such mixtures on a field scale. The most obvious application where adjuvants warrant trial at present would appear to be those where selectivity is not an important consideration, that is, the control of gorse and certain other woody weeds, or where a principle of selectivity other than differential wetting of weed and crop plants operates, that is, the use of the phenoxybutyrics.

THEORETICAL CONSIDERATIONS

Ennis (1) has suggested that the varying effectiveness of herbicides in different carriers might be partly due to different retention of the sprays by the foliage. Later, Ennis et al showed that spray retention differences attributable to leaf type, carrier, and leaf angle were highly significant. Fogg (2) showed that distinct variations in the degree of wetting of leaves by water may occur not only between species or varieties, but also from place to place on the same plant and within a short period of time on the same leaf.

Fajans and Martin (3) have found that the initial retention of emulsions of sufficient stability for practical use is determined by the properties of the aqueous phase and is intermediate between that of the emulsifier solution alone and that of water.

Taylor (4) quotes work carried out with colloidal acids and states that resistance to rain is improved by the addition of white oil to the spray mixture. This was observed to assist in killing some weeds even in the absence of rain.

Currier and Dybing (5) consider that the ideal formulation is one that will penetrate stomata immediately, but one that will also provide a relatively large external reservoir, the thick deposit remaining liquid or at least plastic, not interfering greatly with gaseous exchange, and containing substances that improve stomatal and cuticular penetration; surfactants, penetrants, and possibly stimulants.

The penetration of plant growth regulators through the cuticle and into leaf cells is reviewed by van Overbeek (6).

Penetration through the unbroken waxy cuticle of a mature leaf would be difficult due to its structure and van Overbeek lists the following alternative routes:

- (a) Penetration through the modified epidermal cells which overlie the veins.
- (b) Stomatal penetration.
- (c) Penetration of the cuticle stretched by expansion of the underlying tissue.
- (d) Penetration through faults in the cuticle.

The work and opinion of others quoted above strongly suggest the following reasons for possible increased efficiency of herbicidal sprays resulting from the use of spreaders and spreader-stickers:

1. Increasing spreading of spray droplets, which creates a greater area of absorption of spray material by the leaf, and a greater number of routes by which absorption may take place.
2. Increasing the degree of adhesion of spray material to plant surface, which should assist penetration, spray retention, and resistance to weathering.
3. Reduced evaporation of spray material, which should lead to a longer period of contact between plant surface and active spray ingredient and to reduced loss of spray material by evaporation or volatilisation.

Laboratory experiments as described below were carried out in an endeavour to discover which of these factors may operate, using an example of a spreader and a spreader-sticker.

The spreader used was the sodium salt of a secondary alkyl sulphate, the

spreader-sticker an emulsifiable oil of a type especially selected to give a high degree of tackiness.

Initially work of an exploratory nature was necessary to determine the type of experiment which would give consistent results.

The following were finally selected due to their practicability and bearing on the subject:

EXPERIMENTAL

1. *Effect of Adjuvant on Coverage*

Freshly collected gorse stems in the early flower bud stage were cut into apical sections approximately 4 in. long. Spray mixtures were prepared as follows, to which was added sodium fluorescein, 3.1 milligrams per 100 c.c.

1. Water
2. Ester 2,4,5-T plus spreader
3. Ester 2,4,5-T
4. Ester 2,4,5-T plus spreader-sticker.

Each gorse segment was then immersed completely for three seconds, carefully withdrawn, and suspended to dry. After 30 minutes no surface moisture was visible and each treatment was subjected to ultra-violet light. There were five replications of each treatment. A clear estimation of spray coverage was made possible, and by use of a system of count grading 0-10, the extent of the coverage was recorded. Rush stems 8 in. in length were treated similarly.

Results are shown in Table 1.

TABLE 1—EXTENT OF COVERAGE OF GORSE AND RUSH SEGMENTS DIPPED FOR THREE SECONDS IN VARIOUS SOLUTIONS

Plant material	Water	Ester 2,4,5-T + S. (1:300) (0.05%)	Ester 2,4,5-T (1:300)	Ester 2,4,5-T + S.S. (1:300) (0.125%)
Gorse	5	7	6	8
Rush	1	2	2	6

S. = Spreader. S.S. = Spreader-sticker.

Count grading 0-10 in order of increasing coverage.

2. *Effect on Rate of Evaporation of Water Droplets*

Segments of gorse approximately 4 in. long were prepared and weighed. The solutions used were water alone and water plus spreader-sticker. Each treatment was carried out by immersing the gorse segment for 3 seconds, withdrawing it carefully, and allowing to drip dry. Each treatment was then weighed immediately and reweighed at intervals of 10 minutes, 20 minutes, and 30 minutes. Prior to and between weighings the treated gorse was held at controlled room temperature in still air.

The loss of weight of each gorse segment represented the loss of applied solution due to evaporation, after being corrected for loss of weight as occurred in an untreated gorse segment.

Results are shown in Table 2.

TABLE 2—RATE OF EVAPORATION OF WATER AND WATER PLUS SPREADER-STICKER FROM THE SURFACE OF GORSE SEGMENTS

Time interval	Water. % water lost by evaporation	Water + S.S. (0.125%). % solution lost by evaporation
After drip dry	0	0
After 10 minutes	12.6	11.2
After 20 minutes	29.8	29.9
After 30 minutes	51	51.2
	Average of 5 determinations	Average of 5 determinations

3. *Microscopic Examination of Spray Droplets*

Droplets 1/25th in. in diameter were inspected under a microscope and behaviour noted.

The droplets were derived from a mixture of ester 2,4,5-T 1:300 plus spreader-sticker 0.125 per cent in water. The sequence of changes was as follows:

1. Viewed from above, the globules of suspended ester/solvent (average diameter 3 to 5 microns) and spreader-sticker globules (average diameter 30 microns) were evenly dispersed throughout the droplet when first formed.
2. The spreader-sticker globules commenced to break from the emulsion first and concentrated at the upper surface of the droplet, while the ester/solvent globules remained evenly dispersed.
3. As water evaporated aggregates of spreader-sticker globules gathered at the top of the droplet and at the sides, while ester/solvent globules remained dispersed in general but tending to concentrate at the outer margins of the droplet at solid/solution interface.
4. Finally when all water had evaporated away, the spreader-sticker globules and ester/solvent globules maintained their individual shape for a short while and then suddenly merged together. The possible significance of these changes is discussed later.

FIELD TRIALS

The literature concerning the use of spreaders and spreader-stickers with herbicides suggests that improved efficiency results with certain combinations of these, and the laboratory experiments described have shown sufficient evidence of desirable effects produced to warrant extensive field trials.

As the spreader and spreader-sticker used have shown approximately equal ability to improve the covering power of a spray material, field trials were carried out with the spreader-sticker only, due to the additional properties which this adjuvant is shown to possess.

Trials concerning gorse, rush, and manuka control have been carried out, the most extensive having been applied to gorse. These particular trials have been carried out throughout New Zealand and results are considered sufficiently conclusive to report at this stage.

The nature and results of these trials are as follows: Control of gorse (*Ulex* sp.) with octyl ester 2,4,5-T, with and without spreader-sticker. The results of eight field trials are summarised as follows:

Treatments:

1. Octyl ester 2,4,5-T (3.6 lb acid equivalent per acre).
2. Octyl ester 2,4,5-T (3.6 lb acid equivalent per acre) plus spreader-sticker 0.125 per cent of spray mixture, and 0.25 per cent of spray mixture when applied at low volume.
3. Control.

Application was made with high pressure ground equipment to the point of run-off in six trials and by aircraft in two trials. These trials have indicated:

1. In five trials the use of spreader-sticker with ester 2,4,5-T has improved the initial gorse control obtained in terms of death to stems by 20 to 50 per cent.
2. Where this improvement in initial control has occurred there has been less regrowth from sprayed stems, the regrowth occurring mainly from the crown or below ground and in less amount.
3. None of the trials has shown ester 2,4,5-T to give better control than ester 2,4,5-T plus spreader-sticker.
4. In trials where excellent control of stem growth has been obtained with ester 2,4,5-T alone, the addition of spreader-sticker has not given further improvement in terms of speed of control or amount of regrowth.
5. The general benefit of using spreader-sticker in conjunction with ester 2,4,5-T spray mixtures on gorse has been to increase the chances of obtaining good control of gorse stem growth.

DISCUSSION

Because plants vary with respect to wettability even within the same species it is obvious that variable results with herbicides could be partly attributed to this factor. Spreaders and spreader-stickers of the type mentioned are capable of improving this property of a herbicide formulation, and their use would appear to be warranted for this reason.

Leonard and Yeates (7) have shown that 2,4,5-T is poorly absorbed by gorse and it is evident that maximum spray coverage is desirable to obtain as high a degree of absorption of the active ingredient as the plant is capable of achieving. Incomplete coverage must aggravate the situation of poor 2,4,5-T absorption by gorse. It is impossible to assess the importance of utilising the various routes of absorption outlined by van Overbeek, but improved coverage must also give the active ingredient opportunity to utilise any points of more ready absorption which may exist in gorse as in other species.

The merging of the ester/solvent and spreader-sticker following evaporation of the water phase of spray droplets is considered to have significance which requires detailed study. This effect could account for a resistance to removal by washing of the combination observed in the laboratory, and as the spreader-sticker is a petroleum fraction it could be expected to act as a co-solvent of plant cuticle.

In line with the opinion of Currier and Dybing concerning the properties of an ideal formulation the spreader-sticker/ester/solvent deposit would provide an external reservoir of a thick nature which would remain semi-liquid or plastic, and may provide an added reason for the field results recorded.

The spreader-sticker has shown no effect on the rate of evaporation of water from the surface of gorse. This result was not expected as the increased surface area exposed by the spray mixture incorporating a spreader-sticker could be expected to increase evaporation.

It is postulated that this effect was counteracted by the accumulation of non-volatile spreader-sticker globules at the surface of the spray mixture, thereby reducing the surface area free to evaporate.

In conclusion it could be said that the immediate need in assessing the usefulness of spreaders and spreader-stickers with herbicides in general is an accurate knowledge of the wettability of various weed species and whether or not this is closely allied to variations in susceptibility.

The use of the phenoxybutyrics and their mode of action indicates the possibility of using adjuvants with these materials in herbicide applications even where selectivity is required. We therefore now have the opportunity to consider the use of spreaders and spreader-stickers both in selective and non-selective applications.

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DISCUSSION

Q.—Could you give your impressions on the use of different pressures and their effects on droplet sizes?

A.—Pressures of 150 lb break up particles sufficiently to give good cover. The formation of droplets depends on normal properties of water and spreader sticker should not alter this.

Q.—Did you determine the surface tension of mixtures?

A.—No, did not determine surface tension, as many materials that lower surface tension do not give better cover.

Q.—Did you compare additions of adjuvants to various formulations of 2,4,5-T? With one formulation we get poorer results by using adjuvants.

A.—No, did not try adjuvants on number of formulations.

Q.—I am surprised that there is little field evidence of benefit from adjuvants in view of laboratory evidence of better coverage, etc.

A.—Paper by Freed at California Weed Conference shows that if conditions of humidity are ideal, no advantage from adjuvants will be obtained, but under adverse conditions; for example, dry weather or plants with thicker cuticle, the adjuvants may give considerably better results.

Q.—If a spreader sticker can be shown to be useful, can it not be included in the original formulation of a weedkiller?

A.—Formulations are used at different concentrations for different weeds. Might add sticker spreader at right concentration for a particular weed, but with different dilution for another weed, the concentration of spreader sticker would be wrong.

Q.—Would one obtain the similar results in the case of broom that have been obtained by the use of a spreader sticker on gorse?

A.—I expect that similar results would be obtained, but have no experimental evidence to confirm this contention.

Comment: Incongruous that any material could at the same time act as sticker and a spreader. The penetration of water soluble salts would be improved by the use of a spreader sticker, particularly if application was followed by period of high humidity. Doubt if the use of spreader sticker aids the penetration of uptake of emulsifiable concentrates.

A.—Some advantage may be derived from the use of spreader sticker with emulsifiable concentrate, and solvents soften the plant cuticle.

Comment: Most emulsifiable formulations contain solvent materials.

Q.—Has any field work been done with sticker spreaders on rushes?

A.—Some trials have been done, but I am cautious about publishing results, because I feel that proper identification of rushes is required.