CHEMICAL CONTROL OF WOODY PLANTS IN CALIFORNIA

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SUMMARY

THERE are about 900 native species of woody plants in California. Many of these sprout after being cut or burnt. Present chemicals applied as broadcast treatments are ineffective against many species; however, sprays are finding an important place in control programmes, generally as supplements to fire and mechanical methods. Many species must be controlled, individual plant applications being used. Fenuron pellets appear to have some promise for controlling certain types of scrub. Radioactive tracers have been used in experimental studies in an effort to help understand why certain results were obtained. The tracers have proven their value in such cases.

Californians are interested in the control of woody plants for a number of reasons, including (a) range improvement, (b) forestry improvement, (c) watershed management, (d) rights-of-way maintenance, (e) poison oak control, etc. Because of these interests the Botany Department on the Davis Campus included scrub as a part of its over-all programme on the chemical control of weeds. The objectives have been not only to seek practical answers but to understand the physiological aspects behind control. I shall talk mainly about the use of chemicals on scrub and how radioactive isotopes have aided us in interpreting some of the results. Before going into this discussion, I should like to develop a brief background on the native vegetation of California.

NATIVE VEGETATION OF CALIFORNIA

It is of interest to make certain comparisons between New Zealand and California floras. Due to geographical isolation about 75 per cent. or 1,400 species of the New Zealand flora are endemic. It is surprising to note that the California flora also has 1,400 or 40 per cent. of its species endemic. This very high percentage of endemic species in a political area on a large land mass can only be explained as being due to there being numerous isolated climatic areas within the state. That this is true is well known to California botanists and to other people who know that state. It is clear at the same time that numerous climatic areas, also, make for a wide array of problems.

There are about 900 species of native trees and shrubs in California. Most species have evergreen leaves. They are adapted to survive under conditions of periodic fire. Many species sprout immediately after being burnt and seedlings develop in profusion. Shrub and tree growth is normally so dense that grass is sparse and the areas must often be seeded to convert them into grasslands. Chemicals aid in such a conversion by killing woody plant sprouts and seedlings.

USE OF FIRE

Fire is used extensively as a tool for range improvement. It is now possible for a rancher to conduct control burns, but he must follow certain safety regulations that have been laid down by the legislature. The California Division of Forestry issue the permits after they are satisfied that adequate precautions have been met. They furnish stand-by crews

which are available in case the fire escapes. Neighbours help each other in conducting these burns.

Considerable research has gone into the development of better methods for conducting burns. It is now considered that the trees and scrub should be crushed wherever possible before burning. This makes possible better burns under safer conditions. Research has gone into simultaneous ignition techniques, which was demonstrated as being quite effective on the Hopland Experimental Range.

Reburns are made 2 or 3 years after the initial burn. This kills the brush sprouts back to the ground and kills brush seedlings. Chemicals are being used more and more to make the control more complete.

MECHANICAL CONTROL

Large areas have been cleared by the use of the bulldozer. The brush piles are burnt and the sprouts are now frequently controlled by the use of chemicals.

CHEMICAL CONTROL

Airplane Applications

Some types of scrub in California can be controlled by aircraft application of herbicides, without other types of treatment, such as fire, being involved. Big sagebrush (*Artemisia tridentata*) grows on about 5 million acres in California and is one of the types that can be controlled. Mixtures of coastal sagebrush (*Artemisia californica*), sages (*Salvia* spp.) and coyote brush (*Baccharis pilularis*) may be satisfactorily controlled by this method of application. An ester of 2,4-D may be used at 2 lb. acid equivalent per acre applied in $\frac{1}{2}$ gallon of diesel oil and enough water to make either 5 or 10 gallons of spray per acre. Good kills are obtained if sufficient care is given to proper timing of application. Under some conditions, the amine of 2,4-D is used at 3 lb. acid equivalent per acre and gives better kills than is obtained with the esters.

Mixed stands of dense coastal brush cannot be killed by aircraft application of sprays without involving in addition other methods of control. Ester forms of a mixture of 2,4-D and 2,4,5-T are applied at 3 lb. acid equivalent per acre in the late spring. The site is burnt in the fall and seeded. The regrowth is sprayed the following summer, using ground spray equipment. This series of procedures has resulted in satisfactory conversion of such areas into grasslands.

Many types of scrub cannot be satisfactorily killed by spraying, without first being burnt or mechanically controlled. Chamise (*Adenostoma fasciculatum*) is a dominant constituent of some 5 million acres of California chaparral. It is best to burn the chamise-covered slopes in the fall and to seed the area immediately. These plants immediately begin to sprout and brush seedlings develop in profusion during winter and spring. Ester forms of a mixture of 2,4-D and 2,4,5-T are applied at 3 lb. acid equivalent per acre about mid spring. The 2,4-D used alone will often do just as well as the mixture; however, results appear to be more consistent when some 2,4,5-T is used. It is essential that the sprays be applied during the first year after a burn, if a satisfactory kill is to be obtained by aircraft application. Follow-up spraying with ground equipment is necessary to kill those sprouting brush species that are not killed by aircraft spraying.

Individual Plant Treatment by Foliage Sprays

Individual plant treatments are quite popular and commonly used because many scrub species are not controllable by broadcast spray applications. All woody plants are susceptible to either 2,4-D or 2,4,5-T

after the leaves have fully expanded in spring until they have stopped growing, generally due to an exhaustion of the soil moisture. The evergreen woody plants have other periods of susceptibility during the late fall and winter.

Amitrol is proving to be a valuable chemical for us primarily because it will kill certain types of woody plants growing in areas where it may be hazardous to use 2,4-D or 2,4,5-T. By adjustment of the dosage this chemical will kill poison oak (*Rhus diversiloba*), blackberries (*Rubus* spp.) and most species of oak (*Quercus* spp.). There are a great number of species of woody plants that amitrol will not kill, but fortunately the species mentioned above are common problems in hazardous areas. Woody plants are probably most sensitive to amitrol after shoot growth has slowed considerably, the optimum period being somewhat later than with 2,4-D and 2,4,5-T.

Tree and Stump Treatments

Both trees and stumps are readily killed using esters of 2,4-D and 2,4,5-T in diesel oil. The chemicals are fairly costly and large volumes of chemicals may have to be hauled to isolated localities in the hills. The undiluted amine formulations of 2,4-D are more popular with California ranchers because the chemical cost is considerably less and only small quantities of chemical need to be carried around; also, the amine treatments are relatively effective.

The amine salts of 2,4-D are applied with a pump-type oil-can to cuts made in the tree trunks. The cuts are placed within 1 ft. of the ground and sufficiently close so as to overlap; however, the cuts are either above or below the other cuts, so that each cut forms a V-shaped cup for holding the liquid. The cuts must penetrate the wood, since this is the tissue in which the chemical moves most freely. Best kills are obtained by treatments made in autumn through mid spring. Sprouts that develop 2 or 3 years after treatment generally die, due to drawing 2,4-D into themselves by transpiration pull from the wood.

The stumps are treated by applying liberal quantities of the amine salt of 2,4-D to the sapwood immediately after cutting the tree. The stumps should be cut flat and close to the ground for the best results.

Soil Applications

Only a few results with soil applications will be mentioned. Fenuron pellets are effective against blackjack and post oaks (*Quercus marilandica* and *Q. stellata*) when applied by aircraft. The dosage necessary to achieve satisfactory control is 16 lb. of pellets containing 4 lb. of actual fenuron per acre. Application is made between mid winter and mid spring. Best control occurs on the more open-type soils. Grass seems to be injured but little by such treatments. The same treatment appears satisfactory against 6-year-old chamise sprouts and brush seedlings growing upon soil derived from granite. The scope of use may broaden with further testing. Late autumn and winter are the best seasons for application, because this is when most of our rainfall occurs.

There appears to be a difference in the effectiveness of the powder form of a herbicide and the pelleted form. The surprisingly low dosages necessary to obtain control when used in the pelleted form opens up new avenues of research. We should look at the older herbicides with a view to testing their effectiveness when pelleted. Again, the optimum pellet size has not been determined. If by chance I should return to your New Zealand Weed Conference 7 years from now, I might see pelleted herbicides in common use.

Studies with Radioactive Herbicides

Studies with radioactive tracers have helped us understand some reactions of scrub to herbicides. Such studies are valuable aids in that they give confidence in making recommendations. Considerable research with radioactive herbicides has been conducted by members of the staff and graduate students. I will draw on the results of this research in the following discussion.

It was mentioned earlier that deciduous woody plants were most sensitive to 2,4-D or 2,4,5-T after the leaves had fully expanded in the spring while growth was still active. Amitrol was most effective at a later period after the rate of growth had become considerably reduced. The tests to be considered were on poison oak, a deciduous and poisonous shrub. About 50 per cent. of the plants can be killed with one application of either 2,4-D, 2,4,5-T, or amitrol after the leaves have fully expanded. The data in Table 1 indicate generally the movement of the radioactive chemicals when applied at this time.

TABLE 1—THE RELATIVE TRANSLOCATION OF RADIOACTIVE 2,4-D, 2,4,5-T, AND AMITROL IN THE BARK OF POISON OAK WHEN SHOOT GROWTH WAS ACTIVE AND AFTER IT HAD NEARLY CEASED.

Movement	2,4-D	Relative translocation 2,4,5-T Shoot growth rapid	amitrol
Apex (up 6 in.)	1.5	1.2	2.0
Point of leaf attachment of treated leaf	2.5	2.0	2.2
Down 6 in.	1.5	0.5	1.5
Down 24 in.	0.5	0.2	1.2
Shoot growth nearly ceased			
Apex (up 6 in.)	0	0	0
Point of leaf attachment of treated leaf	2.5	2.0	2.2
Down 6 in.	0.5	0.2	2.2
Down 24 in.	0	0	1.8

Relative translocation was calculated and represents averages:

- 0—No translocation (no image on x-ray film).
- 1—Slight translocation (faint image on x-ray film).
- 2—Moderate translocation (image of moderate density on x-ray film).
- 3—Intense translocation (image dark on x-ray film).

These chemicals moved both up and down, and there was no outstanding difference between them; however, amitrol appeared to move slightly more freely than the phenoxy compounds. After growth had essentially ceased, outstanding differences in the movement of these chemicals occurred. Neither 2,4-D nor 2,4,5-T appeared to move appreciably, whereas amitrol moved fully as freely as it did when growth was rapid, except the movement was entirely downward. These results correlate with the observations that good kills of poison oak can be obtained with amitrol after shoot growth has nearly ceased.

Tests with radioactive tracers have aided in understanding why certain results have been obtained when 2,4-D has been applied to blue oak

(*Quercus douglasii*). This species is easily killed when 2,4-D is applied to cuts made in the wood, but the tree appears to be immune to aerial applications of the same chemical. Radioactive 2,4-D applied to the leaves remained, for the most part, in the leaves. When radioactive urea was mixed with non-radioactive 2,4-D the urea moved freely throughout the plant. Evidently translocation was active, but there was something about the leaf that prevented the movement of 2,4-D. One might question whether it is possible to modify the 2,4-D molecule in such a way as to facilitate its translocation; also, would such a modification result in a loss of toxicity?

Nutritional conditions are often considered as being of importance in determining the sensitivity of plants to 2,4-D and 2,4,5-T. It seems that legumes, as a family, are one of the more sensitive groups of plants to these chemicals; likewise the genus *Ceanothus* belonging to the *Rhamnaceae* is generally sensitive. These plants are well off with respect to nitrogen nutrition, due to the presence of nodules on the roots. Another factor of nutritional interest is that plants are most sensitive generally when shoot growth is occurring in spring, or when new sprouts have formed after a fire (such as with chamise). Young seedlings are easier to kill than older brush seedlings. All of the above statements suggest that nutrition plays an important part in the sensitivity of plants to 2,4-D. A. S. Crafts and S. Yamaguchi of our Department conducted some tests which had a further bearing on the problem. Zebrina was grown in tap water and in $\frac{1}{2}$ Hoagland nutrient solution. Both groups of plants were treated with radioactive 2,4-D, amitrol, and maleic hydrazide. 2,4-D essentially failed to move in Zebrina plants growing in the tap water, but movement was extensive in the plants growing in the nutrient solution. Amitrol and maleic hydrazide moved freely under both conditions of nutrition. This test verified the marked effect of nutrition on the movement of 2,4-D. It supports the hypothesis that actual translocation of 2,4-D is apt to be quite limited under conditions of poor nutrition; this could be a major factor affecting control.

Radioactive 2,4-D was useful in some other tests. Very little was known as to how the 2,4-D actually moved within stumps and the factors that affected movement. Radioactive 2,4-D was mixed with the amine salt of non-radioactive 2,4-D and sufficient chemical was applied to stumps to kill them. Rain was found to be essential to move the 2,4-D through the stumps. Treatments applied during summer were less effective than treatments applied in autumn, winter, or spring because the 2,4-D largely remained near the point of application until after rainfall had occurred (no summer rainfall). When the stumps were burnt before such rainfall had occurred, the kills were poor. The 2,4-D was found still to be present in very large quantities on top of the burnt stumps; burning seemed to interfere with the downward movement of the 2,4-D in the wood.

The above results give some insight into the use of chemicals for woody plant control in California, and some further insight into research which is being conducted on the problem. We have come quite a way during the past 8½ years. I hope that the next 8½ years will show similar progress.

DISCUSSION

Q.—Would the speaker give more details on the use of radioactive tracers as in the study of herbicides?

A.—A wide number of tracers have been used, but in the main those used are labelled with C¹⁴. For general survey work these materials are very helpful. These materials composed and dissolved in solution of 50 per cent alcohol + water and wetting agent. The tracers are applied to the leaf and left for a determined period; then the plant section is pressed

flat, dried, and mounted on stiff paper, freeze dried, and humidified to induce a dampness; then it is exposed to X-ray film.

With woody plants sections of the bark are dried and the under surface of the bark exposed to X-ray film. It is often possible to pick up radioactivity on the bark with a geiger counter, but usually not sufficiently strong to be of benefit.

Q.—Would radioactive tracers be useful for screening new materials so that those which are likely to be of benefit could be selected for further work and others discarded? Also in what way is gibberellic acid effective, if at all?

A.—If radioactive materials are available at reasonable cost, they could be very helpful in aiding the sorting out of new materials. Gibberellic acid has been found to favour the movement of 2,4-D within the plant.

Q.—Have you done any work on willows and if so with what results?

A.—From leaf application of radioactive material it has been found 2,4-D moves freely within the willow tested. Willows have extensive root systems and usually require more than one application for a kill. Some species are very tough to kill.

Q.—To what degree is amitrol translocated when compared with 2,4-D and 2,4,5-T in gorse.

A.—Amitrol is translocated much better than 2,4-D and 2,4,5-T, but it is not a herbicide on gorse.

Q.—As amitrol is translocated so well, has any work been done using amitrol as a carrier for other herbicides?

Comment: It is not easy to get amitrol and 2,4,5-T in solution together, but when this has been achieved there has been no benefit when applied to gorse. To date for gorse control there is nothing better than 2,4,5-T.

Some slight improvement in kill may be obtained from a 2,4,5-TP plus amitrol mixture when applied to sweet briar, but even in this there has been much recovery.