Remote Sensing for Optimum Herbicide Application Date for Rabbitbrush

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Highlight: *Color infrared photography was used to predict the occurrence and duration of the optimum period for applying herbicides for control of green rabbitbrush (*Chrysothamnus viscidiflorus*). Color infrared reflectiveness increases as shoot elongation approaches the optimum length for herbicide application provided the plants are not in moisture stress.*

By virtue of area occupied, aggressive competitiveness after disturbance, and lack of preference by grazing or browsing animals, green rabbitbrush (*Chrysothamnus viscidiflorus*) ranks as one of the most important weedy shrubs on Intermountain rangelands (Tueller and Evans, 1969; Evans et al., 1973). Green rabbitbrush is relatively resistant to applications of phenoxy herbicides; and careful timing in relation to stage of growth, temperature, and soil moisture is needed, to obtain control with applications of 2,4-D [(2,4-dichlorophenoxy) acetic acid] (Hyder et al., 1962).

The growth pattern of this deciduous shrub makes it difficult to predict the optimum date to spray (Young and Evans, 1974). Leaf buds burst in late winter, and optimum spray date follows roughly 2 months later. About 60% of the annual growth needed for optimum susceptibility to 2,4-D occurs in the last 2 weeks before the herbicide should be applied. The land manager is faced with a difficult timing problem, and must obtain his estimates of phenology from vast and often remote areas of variable elevation, topography, and soils. The collection of large sequential samples from inaccessible areas for technical interpretation is a natural application of remote sensing.

Our purpose was to evaluate the use of color infrared aerial photography to predict optimum date for application of herbicides to control green rabbitbrush.

Methods

At about 2-week intervals during May and June 1970, 1971, and 1972, we obtained sequential color infrared aerial photographs of green rabbitbrush-dominated plant communities. The communities were located in the Medell Flat area 35 km north of Reno, Nev., at 1,520 m elevation in a 20- to 25-cm precipitation zone. The plant communities have the potential for big sagebrush (*Artemisia tridentata*)/Thurber needlegrass (*Stipa thurberiana*) dominance. Currently the communities are dominated by rabbitbrush and downy brome (*Bromus tectorum*). Species composition, soils, physiography, and land-use history of the study area are detailed by Young and Evans (1974).

We used color infrared photography to obtain transparencies for interpretation. A 70 mm Hulcher 103 rapid-sequence camera and Kodak 2443 film[1] were used to obtain imagery at an approximate scale of 1:600. Approximately 70% overlap between frames permitted stereo comparisons. A variety of material was used to provide checks on scale and to mark flight paths. White butcher paper about 1 m wide and cut to the length desired proved most satisfactory.

We integrated this study with one of the phenology of green rabbitbrush (Young and Evans, 1974) and studies of the internal moisture stress, soil moisture availability, and temperature in relation to the optimum timing for applying 2,4-D to control green rabbitbrush (manuscript in preparation).

To obtain comparisons of the level of color infrared reflectance, we interpreted the color infrared transparencies by viewing them on light tables. Tone changes indicate current annual growth of rabbitbrush on sequential dates in relation to the optimum date of herbicide application for brush control. These tone changes result from infrared light scattered or reflected from leaves, mainly by the refractive index discontinuity at the cell wall/air space interface within the leaves (Gausman, 1974).

In addition to relative reflectiveness, the growth of green rabbitbrush can be estimated when the bright-red current annual growth on color infrared film is compared to the nonreflective inflorescences from the previous season. This is the principal feature we used to estimate growth.

To establish the identity on color infrared transparencies of all major woody and herbaceous species in the communities, we marked individual plants and studied their relative tone, texture, shape, and pattern characteristics.

Results and Discussion

Interpretation of color infrared transparencies of green rabbitbrush communities is an integrating measure of phenology and moisture relations of most species in the community. A large amount and a high intensity of red color on the images depends on (a) enough new growth of plants so they are

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[1] Mention of trade names does not constitute endorsement.

within the scale and resolution of the camera and film-filter system, and (b) freedom of the plants from moisture stress.

The latter is the bonus of color infrared over true color or black and white imagery. Plants stressed by moisture or injured by herbicide applications have radically reduced infrared reflectiveness. Quantitative measurements of moisture relations with color infrared film require corrections for exposure difference of sequential flights and microdensitometer measurements of resulting transparencies. However, the magnitude of differences in infrared reflectiveness through the growing season for green rabbitbrush is so great that they are easily recognized.

Interpretation of Transparencies

Green rabbitbrush flowers in early autumn (Young and Evans, 1974). The dense cymose clusters of inflorescences remain in place until the following summer. Vegetative buds burst in late winter, but there is a long period of limited shoot elongation during the extended cold of the typical spring in the Intermountain West. The inflorescences do not produce color infrared reflectiveness and appear dark gray on transparencies. This nonreflective canopy masks the elongation of current year's shoots in early spring. Green rabbitbrush does not elongate vertically from a terminal bud, but the current year's shoots elongate obliquely from lateral buds below the previous year's cymose inflorescences.

This fortuitous growth habit provides a simplistic method for measuring the current annual growth of green rabbitbrush by color infrared remote sensing. Transparencies exposed in late April show virtually no color infrared reflectance. At the optimum date for application of herbicides, the current annual shoot growth has elongated beyond the old inflorescences, outlining each shrub in bright pink halos (Table 1). This stage can be recognized even on black-and-white photographs by the white inflorescences surrounded by gray current annual growth. One color infrared print is more useful than thousands of words of explanation in showing these differences. For this purpose, we refer the reader to the cover picture on *Down to Earth* (Evans et al., 1973) for a color infrared photograph of rabbitbrush.

We know that the optimum date for herbicide application on green rabbitbrush can be determined by remote sensing because in a companion investigation we applied herbicides using standard experimental techniques for this species (Tueller and Evans, 1969) and at each date we took photographs. This companion study and the numerous published investigations (Hyder et al., 1962; Cook et al., 1965; Tueller and Evans, 1969) show that spraying too early or too late either fails to obtain adequate control or requires higher application rates of expensive herbicides. What we are illustrating in this current study is that the optimum date for herbicide application can be identified by remote sensing and, more importantly, we can use this technique to predict the optimum timing of herbicide application.

Predicting Optimum Date for Herbicide Application

Land managers must be able to predict the optimum date for application of herbicides for control of green rabbitbrush, so they can make arrangements with applicators. Color infrared remote sensing can be used to recognize the beginning of the optimum spray period, but these same methods can be used to predict in advance the optimum date.

When the first tinge of pink reflectiveness is visible around the margins of green rabbitbrush shrubs on the color infrared transparencies, the shrubs are within 2 weeks of the start of the optimum period for herbicide application (Table 1).

Table 1. Color infrared reflectiveness of a green rabbitbrush community in relation to optimum date for application of herbicides.

Stages of growth in relation to herbicide application	Color infrared reflectiveness: Green rabbitbrush	Color infrared reflectiveness: Other vegetation
Too early for herbicide application	No color infrared reflectivity	Downy brome bright red
Two weeks before optimum spray date	Slight fringe of infrared color on margins of canopy	Sandberg bluegrass and squirreltail bright red
Optimum spray-application period	Bright halos of infrared color surrounding old inflorescences	Downy brome color beginning to fade, Thurber needlegrasses bright red
Past optimum spray-application period	Color fading to dull pink to neutral gray	Downy brome and Sandberg bluegrass neutral gray; Thurber needlegrasses beginning to fade

Time Not to Spray

As important to the land manager as predicting when to spray is knowing when not to spray. If no color infrared reflectiveness is visible in the spring, there is not enough growth for application of the herbicide. With onset of moisture stress in late spring and early summer, the intensity of near-infrared color on the images of green rabbitbrush for determining when to stop spraying, for color infrared transparencies capture all species in the communities that reflect. Ephemeral annuals such as six-weeks fescue (*Vulpia octoflora*) or downy brome (*Bromus tectorum*) have relatively shallow root systems, exhaust the moisture from their rooting zone early in the growing season, and then lose reflectiveness. The short-lived perennial grasses Sandberg bluegrass (*Poa sandbergii*) and squirreltail (*Sitanion hystrix*) flower at about the optimum spray date for green rabbitbrush (Hyder et al., 1962). By the time color infrared reflectiveness drops for these species, the optimum herbicide application period is past. The deep-rooted perennial grasses are relatively later in phenology, and their peak reflectiveness corresponds to the end of the spraying period for green rabbitbrush. By interpreting these phenological events on color infrared film with those of green rabbitbrush itself, land managers can predict the occurrence and duration of the optimum period for applying herbicides (Table 1). This period may be 1 month to 6 weeks long in good years or as short as 1 week, or even nonexistent, in dry years.

Unfavorable Seasons

There are years when 2,4-D should not be applied for control of green rabbitbrush, because of lack of moisture. Failure to recognize these years has resulted in the killing of the relatively susceptible big sagebrush and the releasing of rabbitbrush (Evans et al., 1973). Shoot elongation on dry years does not extend beyond the canopy of the previous season's nonreflecting inflorescences. Therefore, color infrared imagery is interpreted as too early to spray throughout the season, until all reflectivity in the community fades.

Sample Size

Statistical analysis of shoot elongation of green rabbitbrush populations has shown that large numbers are required to obtain valid samples (Young and Evans, 1974). A single frame of 70 mm film at a scale of 1:600 captures more than 250 green rabbitbrush plants and permits easy interpretation.

Practical Application of the Method

A cooperative venture could be started among private ranchers, public land management agencies, extension services, and a remote sensing laboratory, in which all proposed herbicide application for green rabbitbrush control in the Intermountain area could be photographed and interpreted sequentially and optimum dates for herbicide application could be predicted for a nominal fee.

The advantages of this cooperative effort would include improved scheduling of application equipment, possible reduced cost through proper timing and lower rates of herbicide, and better control by not spraying at the wrong time.

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