Using Color Aerial Photography to Detect Camphorweed Infestations on South Texas Rangelands

J. H. Everitt
P. R. Nixon
Remote Sensing Research, USDA, Agricultural Research Service,
Weslaco, TX 78596

ABSTRACT: Camphorweed (*Heterotheca subaxillaris*) is a troublesome weed that is increasing in abundance in sandy soils on south Texas rangelands. During late September to late October, it produces a profusion of bright yellow flowers and becomes very conspicuous. Field spectroradiometric plant canopy measurements showed that camphorweed had significantly higher ($p \leq 0.05$) visible (0.45- to 0.75-μm waveband) reflectance than did five other associated species and mixtures of species. Its visible reflectance did not differ from that of broom groundsel (*Senecio spartioides*), a weed species toxic to livestock that also produces bright yellow flowers at the same time as camphorweed and occasionally occurs with camphorweed on rangelands. However, broom groundsel usually occurs in small stands and is not considered a major problem on south Texas rangelands. The conspicuous yellow flowers of both species made them distinguishable from other plant species on conventional color (0.40- to 0.70-μm waveband) aerial photos of rangeland areas. Microdensitometric film measurements showed that camphorweed could be distinguished quantitatively from other rangeland vegetation. Thus, conventional color aerial photography may be useful to distinguish camphorweed infestations and monitor its spread on south Texas rangelands.

INTRODUCTION

CAMPHORWEED (*Heterotheca subaxillaris*) is an annual, aromatic, herbaceous member of the Compositae family that reaches a maximum height of about 1 m. It occurs in coastal areas from New Jersey to Tamaulipas, Mexico (Correll and Johnston, 1970). In Texas, camphorweed occurs primarily on sandy soils and is most abundant within 50 km of the coast. However, camphorweed has increased its range westward in south Texas during the past 10 to 15 years, and well-developed stands now occur on sandy range sites 175 km inland (Mutz *et al.*, 1981). Camphorweed is not palatable to livestock or wildlife, and has become a dominant invader of many sandy range sites in south Texas. Once dense stands of camphorweed are established on a range site, production of desirable vegetation decreases. Approximately 700,000 ha of rangeland in south Texas are comprised of sandy range sites (Figure 1); thus, camphorweed has the potential of decreasing the desirable forage production over an extensive area. The recent spread of camphorweed and its persistence on rangeland are presently of concern to south Texas livestock producers and rangeland resource managers.

Camphorweed can be controlled by rangeland burning or by sprays of herbicides and/or broadcast pelleted herbicides (Mutz, 1980; Mutz *et al.*, 1981), but infestations over large and inaccessible rangeland areas often cannot be detected by ground observations. During late summer or early fall, camphorweed produces a profusion of bright yellow flowers and is very conspicuous in contrast to other rangeland vegetation. It was hypothesized that, during its flowering phenological stage, infestations of camphorweed might be distinguishable from other plant species on aerial photos. This information would be useful to locate its endemic areas, to monitor its spread, and to delineate areas needing control.

Our objective was to evaluate the use of conventional color and color-infrared (CIR) aerial photography for detecting infestations of camphorweed on south Texas rangelands.

MATERIALS AND METHODS

This study was conducted from August to October in 1982 and 1983 at sites located near Raymondville, Falfurrias, Encino, and Hebbronville, in south Texas. All study sites were located in sandy soil rangeland areas. The Hebbronville and Raymondville sites are approximately 120 km apart. Aerial photographs and ground truth observations were taken on all study sites in October 1982. Additional photos were taken near Encino, Texas, in August 1982 and September 1983. Field spectral measure-

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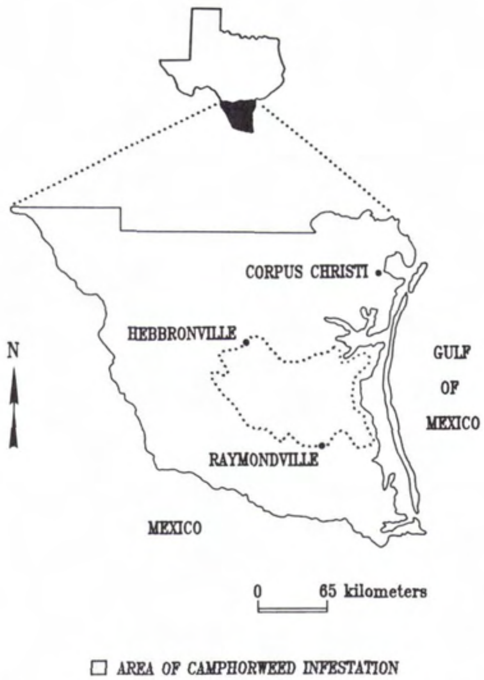

FIG. 1. Location of sandy range sites in south Texas where camphorweed has increased in abundance within recent years.

ments were made in October 1982 and 1983 near Encino, Texas.

Kodak* Aerochrome conventional color (0.40- to 0.70-μm waveband [WB]) type 2448 and CIR (0.50- to 0.90-μm WB) type 2443 films were used for all aerial photographs. Photos were taken with two Hasselblad cameras (150-mm lens, 5.7- by 5.7-cm format) mounted vertically in the floor of a fixed wing Cessna airplane. Hasselblad 4 × 0-2 and 3.5 × CB 12-1.5 filters were used on the camera containing CIR film while a clear haze filter was used on the camera containing conventional color film. The camera containing CIR film had its aperature set at *f*8 with a shutter speed of 1/500 sec. Photographs were taken at scales of 1:2,000, 1:4,000, 1:6,000, and 1:10,000. Photographs were taken in strips with a forward overlap of 60 percent. There was little distortion in the photographs due to the camera's optics. Photos of camphorweed near Encino were taken on 19 August and 15 October 1982 and on 2 September 1983. Photographs near Falfurrias and Hebbronville were taken on 15 October 1982, while photos near Raymondville were taken on 19 October 1982. All aerial photos were taken between 1200 and 1400 hrs under clear and sunny conditions.

Spectroradiometric plant canopy measurements were made in the field on camphorweed, live oak (*Quercus virginiana*), honey mesquite (*Prosopis glandulosa*), Bermudagrass (*Cynodon dactylon*), mixed grasses, mixed grasses and forbs, and broom groundsel (*Senecio spartioides*). Live oak and honey mesquite are common woody plant species that occur in association with camphorweed. Bermudagrass, stands of mixed grasses, and stands of mixed grasses and forbs are typical herbaceous species or mixtures of species that occur with camphorwed. Broom groundsel is a perennial weed that occasionally occurs with camphorweed, and also produces a profusion of bright yellow flowers at the same time as camphorweed. Reflected radiation of seven randomly selected plant canopies of each species or mixtures of herbaceous species were measured with an Exotech-Model 20 spectroradiometer at 0.05-μm increments over the 0.45- to 0.90-μm WB (Leamer *et al.*, 1973). Measurements were made with a sensor with a 15-degree field-of-view (0.5 m^2) placed 3.0-m above each of the plant canopies under clear sunny conditions between 1100 and 1430 hrs during the first two weeks of October in 1982 and 1983.

Ground truth reconnaissance was conducted on 21 October 1982, near Encino, Falfurrias, and Hebbronville, Texas, and on 24 October 1982, near Raymondville, Texas for 22 widely separated sites, each thought to contain camphorweed after viewing single conventional color positive transparencies of these areas on a light table. Sites were photographed at random, usually adjacent to or near roads and highways so they could be accessible for ground truth. Road maps and/or conventional color prints made from the transparencies were used to help locate sites. Observational data relative to plant species, density, and cover were recorded at the various locations.

Optical density measurements were made on conventional color film with a Joyce Loebl automatic recording microdensitometer. The measurements were made using white light (no filter) on film exposed on 15 October 1982. The microdensitometer output has been described by Everitt *et al.* (1980). One scan line was run for each of five plant canopies of camphorweed, live oak, honey mesquite, mixed brush species, and mixed grasses and forbs on 1:2,000 scale film transparencies. Optical density measurements were not made around the edge of the transparencies in order to avoid the effects of lens distortion, and measurements were not made on the smaller scale transparencies because not all of the selected species' area on film was large enough to make microdensitometric measurements on. Measurements were made on mixed brush canopies because they were typical of brush infestations on rangeland. Measurements were not made on Bermudagrass, broom groundsel, and mixed grasses because they could not be distinguished on the transparencies or their stands were too sparse.

* Mention of company name or trademark is the readers' benefit and does not consititute endorsement of a particular product by the U.S. Department of Agriculture over others that may be commercially available.

Canopy reflectance data for the visible (0.45- to 0.75-μm) and near-infrared (0.75- to 0.90-μm) WBs were analyzed using analysis of variance techniques. The visible WB data was comprised of the six 0.05-μm increment readings from the 0.45 to 0.70-μm wavelengths. Because the near-infrared region of the spectrum commences at about the 0.75-μm wavelength, the near-infrared WB data included the four 0.05-μm increment readings from the 0.75- to 0.90-μm wavelengths. Optical film density data were also subjected to analysis of variance. Duncan's multiple range test was used to test statistical significance at the 0.05 percent probability level among species' means (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Field spectroradiometric canopy reflectance measurements over the 0.45- to 0.90-μm WB for camphorweed and the six other associated species and mixtures of species are shown in Figure 2. Conspicuously yellow flowered camphorweed and broom grounsel plants had significantly higher ($p \leq 0.05$) visible (0.45-to 0.75-μm WB) reflectance than the other plant species or mixtures of species (Table 1). The outer canopies of both species were comprised of a profusion of bright yellow flowers that were oriented horizontally, which apparently resulted in their spectral charateristics being essentially the same in the visible WB. The foliage of the other species varied in color from light to dark green, which gave them lower visible reflectance values than those of camphorweed and broom groundsel. The near-infrared (0.75- to 0.90-μm WB) reflectance of camphorweed, live oak, and Bermu-

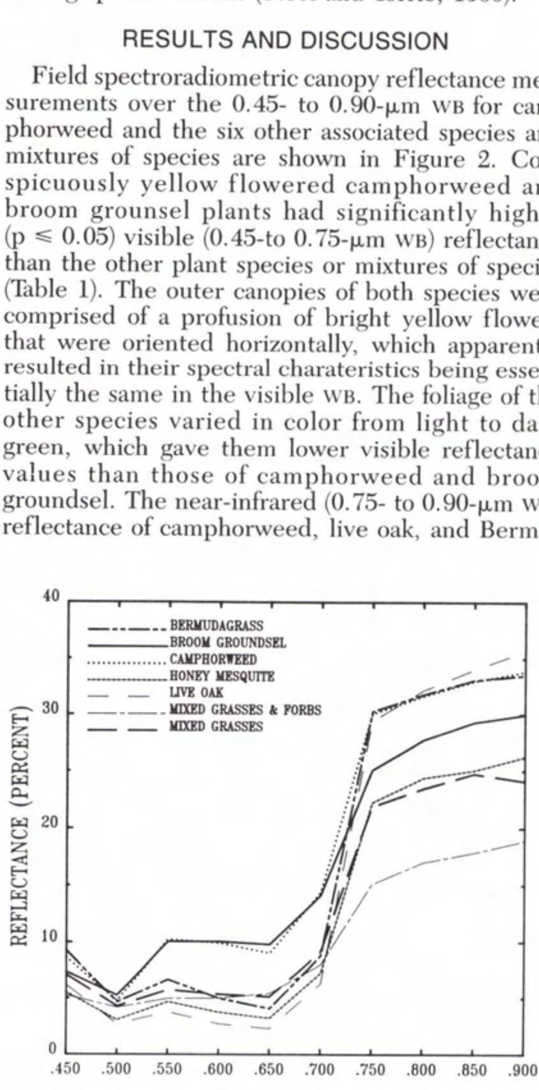

FIG. 2. Field measured canopy light reflectance over the 0.45- to 0.90-μm waveband for camphorweed and six other assocaited rangeland species or mixtures of species on south Texas rangelands in October.

TABLE 1. CANOPY LIGHT REFLECTANCE OF CAMPHORWEED AND SIX OTHER RANGELAND SPECIES OR MIXTURES OF SPECIES IN OCTOBER FOR THE VISIBLE AND NEAR-INFRARED WAVEBANDS.

	Wavebands	
Plant Species or Mixture	Visible[1] (0.45- to 0.75-μm)	Near-infrared (0.75- to 0.90-μm)
Bermudagrass	6.5 b	32.2 a
Broom Groundsel	9.4 a	28.0 b
Camphorweed	9.5 a	32.1 a
Honey Mesquite	4.6 cd	24.5 bc
Live Oak	4.0 d	32.8 a
Mixed Grasses & Forbs	5.5 bc	17.2 d
Mixed Grasses	6.1 b	23.6 c

[1] Values within columns followed by the same letter do not differ significantly at the 0.05% probability level according to Duncan's multiple range test.

dagrass was significantly higher ($p \leq 0.05$) than that of the other species; however, the three species could not be distinguished from each other in the near-infrared WB. Overhead views of the canopies of the different species showed that camphorweed, live oak, and Bermudagrass had greater leaf density within the canopy than did the other species, while mixed grasses and forbs had more openings and less leaf density within their canopies than the other species. The higher leaf density of the camphorweed, live oak, and Bermudagrass canopies yielded higher near-infrared reflectance (Allen and Richardson, 1968).

Plate 1 shows typical CIR (upper photo) and conventional color (lower photo) positive prints of a rangeland area near Hebbronville, Texas. Both prints are 6X enlargements of original 70-mm aerial photos (original scale 1:10,000). Arrows on both prints point to a dense stand of camphorweed. Notice that camphorweed is easy to distinguish on the color print because it retains its conspicuous yellow color and that the denser, more vigorous stands of camphorweed near the arroyo (diagonal strip) have a brighter yellow color than some of the sparser, less vigorous stands on the more upland sandier areas. The denser stands of camphorweed were nearly impenetrable with plant canopy covers of approximately 90 percent, whereas some of the sparser stands had canopy covers of about 20 percent. On the CIR photo, camphorweed has a light magenta image that is similar to that of the dense stand of mixed grasses and forbs which are predominant in the arroyo. Moreover, only the denser stands of camphorweed can be detected on the CIR photo. Sparser stands of camphorweed are difficult to distinguish from the associated soil background and litter. Because arroyos occur sporadically throughout this area, plant canopy reflectance measurements were not made on mixed grasses and forbs growing in these areas. Consequent-

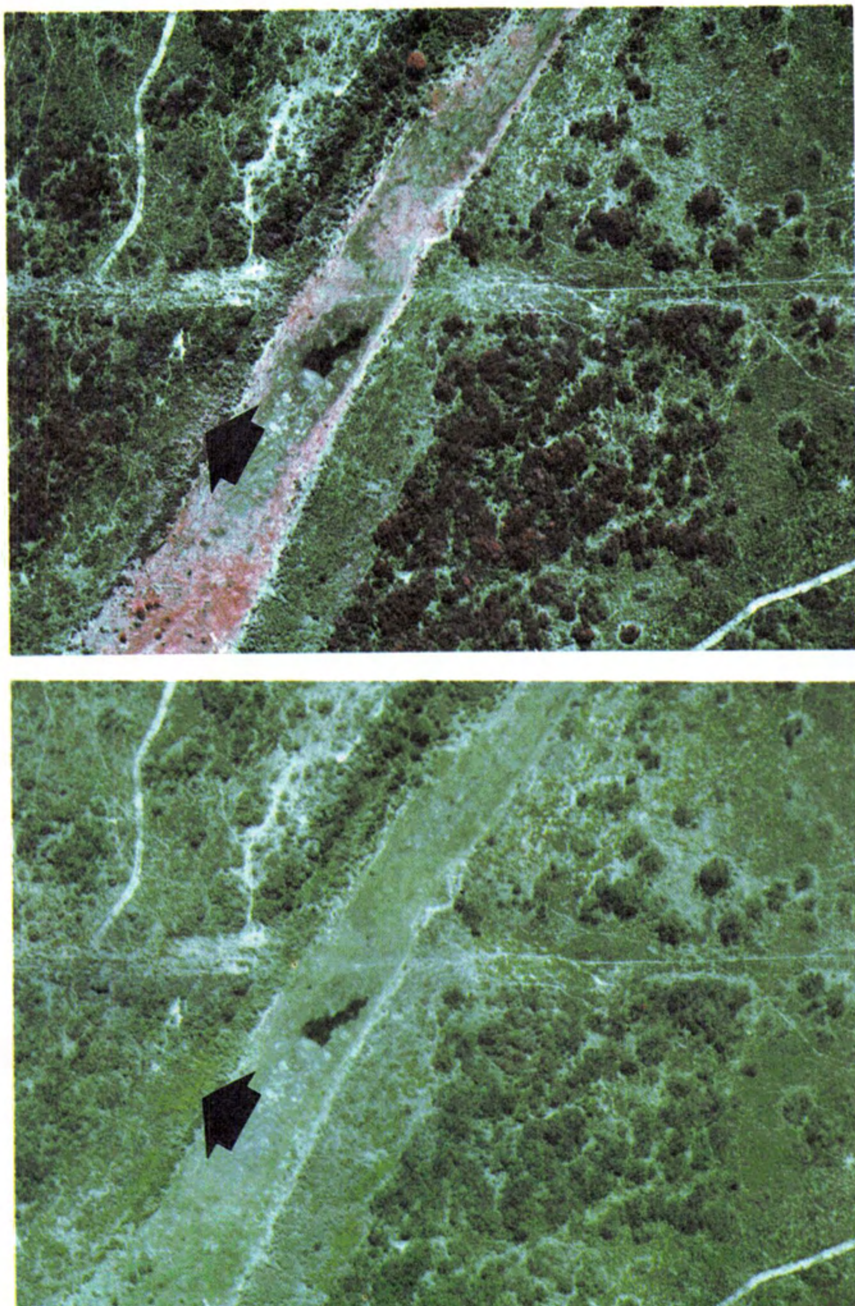

PLATE 1. Upper photograph shows a typical color-infrared (CIR) positive print of a rangeland area near Hebbronville, Texas. The lower photograph shows a typical conventional color print of the same area. Both prints are 6X enlargements of original 70-mm aerial photos (1:10,000 original scale) taken on 15 October 1982. The arrows on both prints point to a dense stand of camphorweed. Camphorweed is easy to distinguish on the conventional color photo because it retains its conspicuous yellow color, with the denser stands having a brighter yellow color than some of the more sparse stands. Camphorweed is difficult to distinguish on the CIR photo.

ly, reflectance data presented for mixed grasses and forbs (Figure 2 and Table 1) are indicative of less vigorous stands of these herbs growing on sandy soils. Arroyos receive runoff from the surrounding terrain; thus, vegetation growing in these areas is usually more vigorous than that on the more upland areas. Previous research has shown that more vigorous stands of mixed grasses and forbs have higher visible and near-infrared reflectance, and that their image response on CIR film can be various shades of magenta (Everitt *et al.*, 1984). Camphorweed's visible reflectance and image response on CIR film is also very similar to that of silverleaf sunflower (*Helianthus argophyllus*) which occurs on sandy soils in south Texas (Gausman *et al.*, 1977). Although silverleaf sunflower is usually dead by October, small stands may remain into fall in some years (Correll and Johnston, 1970).

Ground truth reconnaissance for 22 sites selected near Raymondville, Encino, Falfurrias, and Hebbronville, Texas from conventinal color transparencies of rangeland areas resulted in visual correct identification of camphorweed on all sites; however, small infestations (≤ 0.10 ha) of broom groundsel were found mixed in with camphorweed at three locations. Broom groundsel occurs in loose sandy soils throughout the western half of Texas (Correll and Johnston, 1970). Broom groundsel is considered a weedy species on rangelands and is also poisonous to livestock (Kingsbury, 1964; Sperry *et al.*, 1968). The bright yellow color of broom groundsel could not be distinguished from camphorweed on color aerial photos. The inability to distinguish broom groundsel from camphorweed on color photos supports the canopy reflectance data in Figure 2.

Aerial photos taken of camphorweed (vegetative stage) infestations on 19 August 1982, and 2 September 1983, revealed that camphorweed could not be visually distinguished from many other rangeland species on either conventional color or CIR aerial photos. These findings substantiate that camphorweed's identification on aerial photographs is confined to its flowering period.

Microdensitometric measurements made on 1:2,000 scale conventional color transparencies of rangeland areas on 15 October 1982 showed that camphorweed could be distinguished quantitatively from other associated rangeland vegetation (Table 2). Camphorweed had significantly lower ($p \leq 0.05$) optical film density than honey mesquite, live oak, and mixed brush species and higher optical film density than mixed grasses and forbs.

TABLE 2. MICRODENSITOMETER (OPTICAL DENSITY) MEASUREMENTS WITH WHITE LIGHT ON AERIAL CONVENTIONAL COLOR (0.40- TO 0.70-μM) FILM (SCALE 1:2,000) FOR CAMPHORWEED AND FOUR ASSOCIATED PLANT SPECIES OR MIXTURES OF SPECIES FOUND ON SOUTH TEXAS RANGELANDS.

Plant Species or Mixture	Optical Density[1]
Camphorweed	2.32 c
Honey Mesquite	2.90 b
Live Oak	3.15 a
Mixed Brush	3.03 ab
Mixed Grasses & Forbs	0.92 d

[1] Mean values within columns followed by a common letter do not differ significantly at the 0.05% probability level, according to Duncan's multiple range test.

CONCLUSIONS

This study showed that conventional color photography can be a useful tool to monitor the spread of camphorweed on rangelands when this troublesome weed is flowering. This technique should be useful to ranchers and range managers to delineate areas needing control.

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