regulating the spacing, according to these test results. The closer the spacing, the lower the weights per plant, the smaller the diameter of heads and butts, and the later the average maturity. Maximum yields were obtained at spacings of from 8 to 11 inches, depending on the season and the variety grown. The relationship between spacing and total yield indicates that it is safer to err in the direction of spacings that are slightly greater than optimum rather than in the other direction.

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BIOLOGICAL CONTROL OF PUNCTURE VINE

with imported weevils

C. B. HUFFAKER, D. W. RICKER, AND C. E. KENNETT

Puncture vine, *Tribulus terrestris*, was sufficiently abundant to attract attention as a pest in California around 1912–1915. The weed became so troublesome by 1925 that a basic plan for its control was developed by the California State Department of Agriculture and was adopted in most sections of the state. Expenditures by county governments alone, from 1927 to 1930 inclusive, totalled more than half a million dollars.

Substantial sums were still being spent to control this pest in the early 1950's by county weed control officials. The Association of County Agricultural Commissioners passed a resolution in 1956 requesting research on the possibilities of biological control. Prior to this, Dr. G. W. Angalet of the U. S. Department of Agriculture had been in India exploring for parasites of the oriental fruit fly. He noted the rarity of puncture vine in India and made extensive observations on two species of weevils he found attacking it. His tests and additional research conducted at Albany (by Huffaker) and later in France and Italy by Drs. Angalet and Lloyd Andres established the safety in introduction of both the stem boring weevil, *Microlarinus lypriformis*, and the seed weevil, *Microlarinus lareyniei*. These insects were shown to be entirely incapable of breeding on any plants other than puncture vine and possibly its very close relative, *Kallstroemia* sp. Officials of both the federal and state governments then approved introduction of these insects.

It is much too early in the research program to even guess at how well the weevils imported last summer will work to eventually control puncture vine in California. But limited samples of seed pods and stems taken this fall have already indicated 30 to 50 per cent infestation on some plants at release sites in counties from San Joaquin to Riverside. Next year, if the weevils get off to a good start, it is expected that all interested counties can be supplied with initial stocks for wider distribution of the stem boring weevil, Microlarinus lypriformis, or the seed weevil, Microlarinus lareyniei. Both insects breed only on puncture vine.

Importation

Importation and establishment of these biological control agents were initiated during the summer of 1961. Because of the need to be certain that only these species would be introduced, rather small-scale importations were planned. Since positive identification of each specimen had to be made while it was alive, it was not practical to handle large numbers of the imported weevils. From 800 to 1,000 insects of each species were to be imported, with approximately half of these to be released in California.

The first shipment from Dr. Andres was received on July 11, 1961 and colonizations from this and subsequent shipments were made in July and August, 1961. Seed weevil distributions of about 100 adult insects were made in San Joaquin County near Manteca, Kern County near Bakersfield, and Los Angeles County near Castaic. Two larger colonies of 200 adults each were released near Hughson in Stanislaus County and at Riverside. Stem weevil colonies of 100 adults each were released near Clovis in Fresno County, near Woodville in Tulare County, near Moreno in Riverside County, and at Madera.

Weevils were in egg deposition when the releases were made. In general, half of each colony was released in a cage over a field stand of puncture vine and the other half released outside the cage. After about one month, at which time progeny were beginning to emerge, the cages were removed. While these cages were intended to provide protection to the beetles, they actually proved to be an impediment.

Progress varied

Progress of the weevil colonies has varied greatly. Multiplication from the small numbers of seed weevils released at the Hughson plot in Stanislaus County has been phenomenal. Most of the multiplication came from the first release of 100 weevils on July 13, because a later release of 100 was too late to accomplish a marked reproduction. At this site adult weevils could readily be found in early September beneath the large puncture vine plants at distances 50 to 60 yards from the exact release spot. A conservative guess is that from 25,000 to 100,000 weevils were produced during the two-month period involved, predominantly from the 50 females of the original release. While minimal developmental time was only 22 to 23 days during July and August, since the egg-laying females are long-lived, two full generations were not completed during the time involved, even though some of the population may be of the F_3 generation.

Seed weevils

The Riverside colony of the seed weevil also progressed almost as well. But due to a much more limited supply of host plants, the total multiplication appears to have been less than at the Hughson location. However, reproduction continued approximately one generation longer at this more southern location and higher rates of pod infestation were encountered. Eight hundred weevils emerged from one large plant after it was dug up and caged. Progress of this species was also promising at the Los Angeles County site but

was somewhat less promising at the Kern County location.

Progress of the stem weevil colonies has been less striking. There is less potential for reproduction per plant and as a result, this species appears to be more subdued in reproductive expression due to competition with its own kind when densities are even moderate on a given plant. However, this species too has shown encouraging indications of tolerance to our California conditions and, with more time, it may develop with increasing success.

The greatest hazard facing these tiny weed control experts at present is the passing of the winter period, much of it in the absence of its host plant. During this time the weevils hide out in sheltered spots, but they may move about considerably, dispersing widely from the areas where liberations were made. If the females succeed next spring in locating the new stands of puncture vine, they should be off to a much more promising season of multiplication. They will have a full season of reproduction ahead of them, rather than only the last half, as was the case this first summer in California.

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The foreign exploration, specificity testing, and importation were made in cooperation with the Entomology Research Division, Agriculture Research Service, USDA.

F. E. Skinner assisted with tests conducted in the quarantine facilities.

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Aerial Photographs Show Ran

When taken to proper specifications, photos aid in estimating anim

R. N. COLWELL

The volume and species composition of herbage on a range are major factors governing its animal-carrying capacity—the number of animals of any given type that can be grazed on the range for a given period of time. Important differences in range herbage can be detected on small-scale aerial photographs, mainly on the basis of differences in photographic tone or color.

The accuracy of such photo classification of rangeland conditions depends on the scale of the aerial photography, the film-filter combination employed, and the seasonal stage of development of the forage. Viewing the aerial photographs as stereo-pairs (as illustrated here) makes differences even more obvious.

Rangeland conditions in several areas of Contra Costa County were analyzed after they had been classified by aerial photo interpretation. When checked on the ground, areas classified as "A" on the photos included here were found to have a per-acre carrying capacity nearly three times greater than "B" areas and eight times greater than "C" areas. These differences were consistently significant at the 95 per cent level of probability. Total acreage within each of the three photo classifications was also readily determined photogrammetrically. The three classifications were adequate for delineating significant differences, as well as being consistently recognizable on the photos. Outcroppings of rock ("R") were obvious on the photos because herbage was totally absent or unavailable on such areas.

Photo specifications

In developing the photo specifications, photographs of representative areas were taken at four seasonal stages in the development of the vegetation—spring, summer, fall, and winter. On each date, photographs were taken at four scales, ranging from 1:2,000 to 1:20,000. Each of the following film-filter combinations was used: panchromatic film with a light-red (25A) filter; infrared film with a dark-red (89A) filter; aerial ektachrome (color) film with a haze-cutting (HF-2) filter; and camouflage detection (color) film with an orange (15) filter. Ground-level photographs were also taken, using the same film-filter combinations to record range condition details for comparison with aerial photos of the same date.

Timing

The optimum time for aerial photography of rangelands in most of the foothill country of California is in the late spring, according to these tests. At that time, areas of sparse vegetation (including shallow soil) exhibit brown foliage and areas of denser vegetation (including deeper soil) exhibit green foliage. About one month after the first soaking rains in the fall, the new annual vegetation is very apparent on shallow-soil areas but is still obscured by ungrazed vegetation on the deep-soil areas. Photos taken at this time are next best in terms of tone or color contrast and general interpretability. At other seasons, photo classification of range conditions is difficult, because the entire area appears uniform—green in winter, brown in summer.

Scale

The optimum scale for aerial photography, when cost must be balanced against useful information, is about 1:5,000, although spot coverage of a few representative areas at a scale of 1:2,000 also is desirable.

Film-filter combinations

Of the four film-filter combinations tested, aerial ektachrome film with a haze filter gave the best results and panchromatic film with a light-red filter next best. The photographs should not be taken on hazy days because of the likelihood that tone or color contrasts between the range