REMOTE SENSING IN CONTROL OF PINK

USING high altitude or space photography to identify crops has long been considered important for land use mapping, crop yield prediction, crop inventory, and disease identification and control. This study evaluates satellite imagery as an aid in controlling pink bollworm infestation through monitoring California's cotton production regulation program in the southern deserts. This was the initial and most obvious objective, but if further studies are successful, the potential of satellite monitoring programs for agriculture is unlimited.

ERTS-1 satellite photographs show (left photo, and cover) the Coachella Valley north of the Salton Sea, and the Imper
the Imperial Valley. The Palo Verde Valley (upper center, right photo), is located along th

Three areas

The three main agricultural areas in the southern deserts of California, the Imperial, Coachella and Palo Verde Valleys, are heavily infested with pink bollworm, which reduces quantity and quality of the cotton produced. To control the population increase and geographical expansion of the pink bollworm, California regulations in 1972 required: (1) that acreage to be planted to cotton be planted in Coachella and Palo Verde Valleys until February 28, and not until February 15 in the Imperial Valley; (2) that all cotton fields must be picked by December 15, and all remaining plant material must be thoroughly shredded and subsequently plowed underground; and (3) that fields must then be left fallow until the following February unless a different crop is to be planted. The "plowdown" procedure ensures that any pink bollworm in the larval or diapause state will have no cotton plant material on which to feed during the winter months.

The threat

The threat of pink bollworm spread in 1972 was even greater than the actual infestation at that time. The desert areas produce 80,000 acres of cotton annually but the State as a whole produces over 1,200,000 acres of cotton, mostly concentrated in the San Joaquin Valley. Although the Federal government, the California Department of Agriculture, and the University of California are all working to ensure that pink bollworm infestations do not spread into this area, the insects have been found in the San Joaquin Valley, and it may sometime become necessary to implement additional regulations that have been prepared but not implemented. These regulations would include monitoring the defoliation, plowdown and replanting dates for the entire San Joaquin Valley cotton acreage. Such a massive management program would be almost impossible without a remote sensing system.

The purpose of these studies was to determine whether or not cotton in the Imperial, Coachella, and Palo Verde Valleys could be identified by sequential aerial photography (see photos). These areas were chosen because they are essentially cloud-free throughout the year.

At present, the only viable means for identifying crops is sequential photography. The Earth Resources Technology Satellite (ERTS) launched in July, 1972 photographed a given area every 18 days. A multispectral scanner (MSS) operating in four spectral bands (.5–.6 μm, .6–.7 μm, .7–.8 μm, .8–1.1 μm; green, red, and two infrared bands, bands 4, 5, 6, 7 respectively) was used to obtain the imagery. An International Imaging Systems optical color combiner was used to combine bands 4, 5, and 7 to simulate color infrared (CIR).

Bare field method

One method used to identify cotton fields was the "bare field" method which is based on the theory that no cotton remains in any field after December 15, and that none can be planted until Feb-

BOLLWORM IN COTTON

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mperial Valley to the south with the international border between Mexico and California visible at the southern end of g the Colorado River bordering Arizona—Imperial Valley is visible in the lower left hand corner.

ruary 15 (Imperial Valley) or February 28 (Coachella and Palo Verde Valleys). Therefore, all bare fields evident in January and February photography might be considered cotton fields, and would be mapped as such. Irrigation would begin in late February and early March, and cotton would begin to appear on the imagery in April. Although sorghum, sudangrass, tomatoes, corn, and onions are planted about the same time, such crops would mature more rapidly and would be harvested long before cotton.

Unfortunately, the winter of 1972–73 was an extremely wet one and not all cotton was plowed under by December 15. Also, fields normally bare in January and February often looked irrigated, and heavy weed growth made fields look cropped when they actually were not. The rains also delayed the planting of cotton, so some fields did not show a crop until midsummer and were not mapped as cotton.

Bare fields

Rather than using January and February photography, it was decided that the March imagery would be mapped for bare fields. These were then checked against May photography in order to determine which fields had begun to show a crop. Since there was no photography after May 23, all bare fields which had become cropped were assumed to be cotton since there was no way to eliminate the other crops mentioned. A field survey of all three valleys was conducted in August to check the accuracy of the maps made from ERTS-1 imagery.

In the Coachella Valley, no fields predicted to be, were in cotton. In the Imperial Valley, 33% of the predictions were accurate and in the Palo Verde Valley, 50% were accurate. These results were poor because there was no imagery after May 23, and a full cotton season was not available for study.

Crop calendar method

The Imperial Valley was studied with cooperation of the Department of Earth Sciences and Geography, U.C. Riverside, using a method based on the crop calendar for all crops grown in the Valley. The ERTS-1 imagery was mapped every 36 days (alternate passes of the satellite) and field surveys were conducted in the valley at 36 day intervals to coincide with the ERTS-1 passes. Mapping consisted of classifying each field according to its conditions—bare, wet, plowed, harvested, or cropped. Using the color combined CIR photographs, the respective colors for each of the above conditions were white, blue or dark lavender, gray-brown or light lavender, yellow, and red. Differentiating between wet and plowed was often a problem, and heavy weed growth (caused by the rains) also caused problems in classifying cropped fields.

Field size, time of year, the crop calendar for the valley and information obtained from the photography were put into a computer, which determined statistically which crops were most likely to be in a given field at a particular time. This information was then checked against the field survey data for accuracy. The correlation between predicted and actual field conditions over four 36-day cycles was 97%; crop identification accuracy varied from 82% for sugar beets to 63% for cotton. The low accuracy rate for cotton was attributed to the fact that a full cotton season could not be studied.

Survey costs

High costs have eliminated ground surveying of cotton fields as an aid in helping control pink bollworm in the Imperial Valley, according to the agricultural commissioner. The sequential coverage provided by ERTS-1 was useful in identifying and mapping cotton fields in these studies. Although the accuracy for cotton field identification by computer was only 63%, accuracy equivalent to that of field mapping was considered probable with a full cotton season available for analysis. With the crop calendar method, identification and mapping of cotton fields has been possible in less time and with less cost. The bare field method does not appear to be useful at this time.

The planimetry of the ERTS-1 imagery is such that a base map prepared from USGS topographic maps can be superimposed on the image with almost perfect accuracy. As such, a base map can be drawn directly from ERTS-1 imagery eliminating the need for tedious cartographic work. High flight imagery such as is possible with U-2 aircraft can be used (if available) for updating field lines, which do change, and which are not always seen on ERTS-1 imagery. However, greater resolution of the ERTS-1 imagery would eliminate the need for high flight photography.

Color combining

Color combining of bands 4, 5, and 7 from the MSS to simulate color infrared provided the best color contrasts for field condition identification, which is vital to actual crop identification. In addition, field size, time of year, and a crop calendar of the area to be studied must be available for crop identification.

Three recommendations for improved results leading to practical application of crop inventory and management findings include: (1) camera system improvements (especially resolution); (2) a longer study period (at least one full cotton season) to minimize such factors as weather, crop conditions, and operator inexperience; and (3) imagery must be received by the user no more than two weeks after the pass is made.

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INFLUENCE OF

and interstocks on the

in Valencia

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THE NUTRITIONAL EFFECTS of the most commonly used citrus rootstocks have been extensively investigated. It is known that the citranges and trifoliate orange rootstocks produce the highest concentration of chloride in the leaves, and that sodium accumulation is higher in trees on mandarin rootstock than those on trifoliate orange hybrid rootstocks. But no information on interstock effects on nutrient concentrations in any citrus scion leaves has been obtained. This paper evaluates the effects of five trifoliate [*Poncirus trifoliata* (L.) Raf.] cultivars used as both rootstocks and interstocks on the accumulation of nutrients in 'Valencia' orange scion leaves. Five of the most commonly used trifoliates were selected for this study, since the literature indicated that trifoliate as a rootstock was not too tolerant to higher amounts of chloride and boron in the soils. Sweet orange *Citrus sinensis* (L. Osbeck) was used as a control rootstock.

Valencia orange was propagated on the following rootstocks: Sweet orange (control), Rubidoux trifoliate (C), Rubidoux trifoliate (A), English small trifoliate, Benecke trifoliate, and Jacobson trifoliate. Rubidoux trifoliate (C) is the same as "UCLA old," and Rubidoux trifoliate (A) is the same as "UCLA young." The same five trifoliates were also used as interstock material between Valencia orange scion and sweet orange rootstock.

Trees were grown for ten years at the South Coast Field Station under uniform cultural practices. Every spring the trees were sprayed with 1 lb of zinc sulfate (36% Zn) and 1 lb of manganese sulfate (28% Mn) per 100 gals of water. The experimental plot was under clean cultivation. Each variation was replicated five times with two trees per plot. In September 1966 and 1967, fifty spring cycle leaves per plot were obtained from non-bearing terminals for chemical determinations of plant nutrients.

Rootstock effects

Nitrogen concentrations in leaves from sweet orange on Rubidoux trifoliate (C) rootstocks were substantially lower than in the leaves from scions on Rubidoux trifoliate (A), English small trifoliate, and Benecke trifoliate rootstocks, but not different in the leaves from trees grown on Jacobsen trifoliate rootstock. The potassium concentration was significantly lower in the leaves from trees on Benecke trifoliate rootstock than in leaves from trees on sweet orange rootstock. Leaves from trees on English small trifoliate had a significantly lower calcium concentration than the leaves from trees on sweet orange. Rubidoux trifoliates (A) and (C), and Jacobsen trifoliate rootstocks, but not different from that found in the leaves from trees on Benecke trifoliate rootstock. Although the concentrations of nitrogen, potassium, and calcium levels in the leaves of trees grown on these different rootstocks varied considerably from each other, these levels were still in the optimal range for citrus production. Substantially lower concentrations of chloride and boron were found in the leaves from