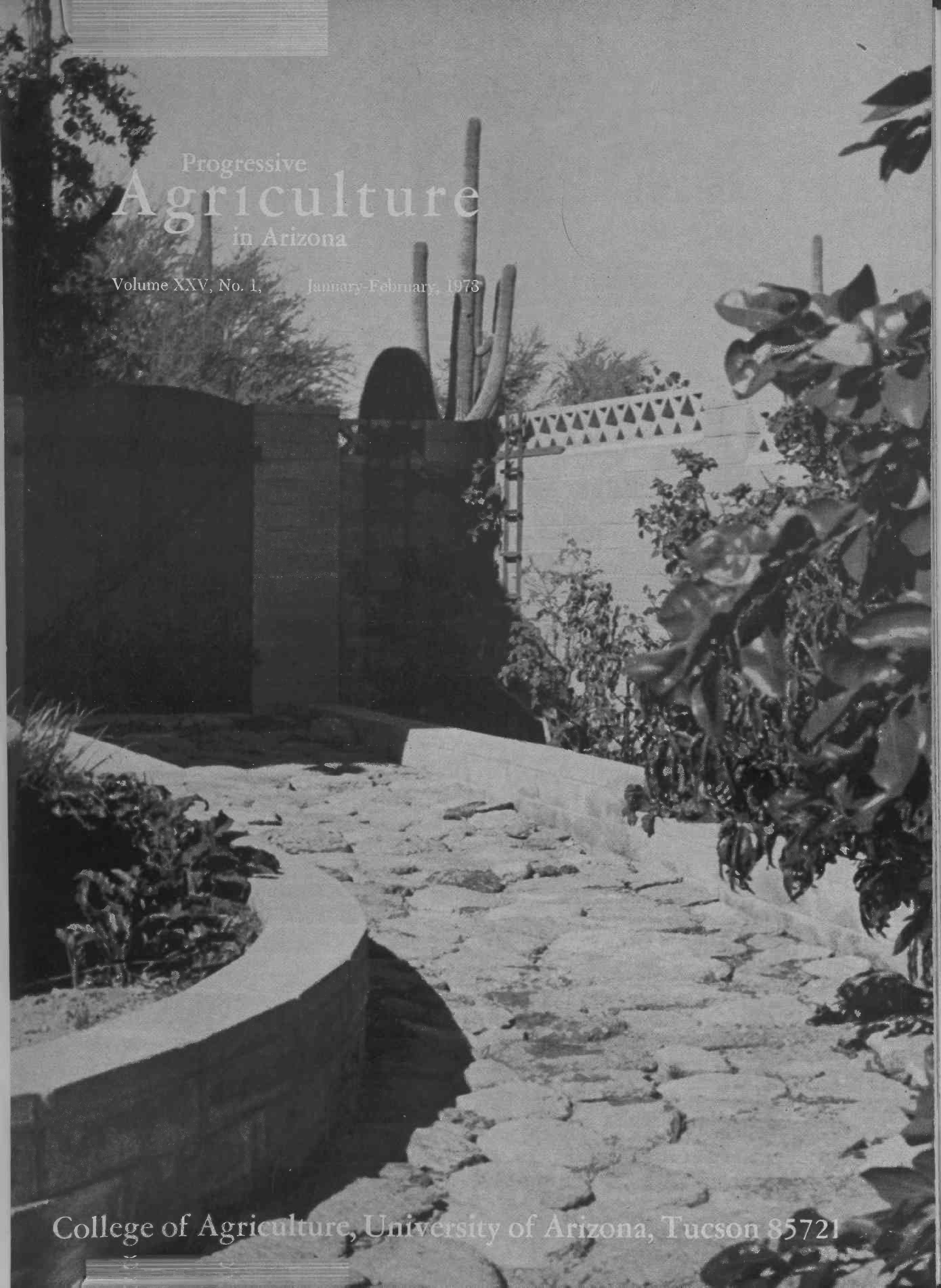
Progressive
Agriculture
in Arizona

Volume XXV, No. 1, January-February, 1973



College of Agriculture, University of Arizona, Tucson 85721

Agriculture Responds to Needs of Society

We believe that individuals in agriculture generally have been responsive to the needs of individuals in society as a whole.

And, those in agriculture have recognized a duty to be involved as a citizen of the community.

Agriculture's social responsiveness is exercised on local, county, state, national, and sometimes international levels; they relate to consumers, producers, processors, handlers, agri-businessmen, general public, minority groups; and they have a long history of practicing conservation, preserving ecology, and enhancing the environment.

Agriculture as a social institution contributes to society in a variety of ways. It provides an abundant, wholesome supply of food and fiber w which to nourish and clothe our f low citizens.

It constantly improves the stan ards of consumer protection. Natu resources of soil, land, water and pl nutrients are carefully guarded.

The grower helps to maintain t quality of the environment.

He offers opportunities to all cluding the disadvantaged minoriti And, he has a strong part in the d veloping of an agricultural technolo which he shares with all mankind.

Agricultural businessmen today b lieve that social responsiveness is area of legitimate concern.

But, they believe also that agricu ture must make a just profit.

For, without profits many of t good works undertaken by many w are in agriculture would be impo sible.

Society, government, agricultu and industry, as dynamic entiti must continue to work together seek better ways to improve the qu ity of life for all men. This does n mean, however, that change, for t sake of change is necessarily good.

Agriculture recognizes its obli tions in the field of social responsi ness. But agriculture shall continue review the order of social priorit and will be ready to adapt and p vide for the changing needs of society as it occurs.

Harold E. Myers

Dean,
College of Agriculture,
School of Home Econom

On Our Cover is a photo sh ing the use of rocks in landsc cover. It provides an excel mulch. See page 8.

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Progressive Agriculture in Arizona

January - February, 1973, Volume XXV, No. 1

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People Are Eating More Lettuce

*by C. Curtis Cable, Jr.**

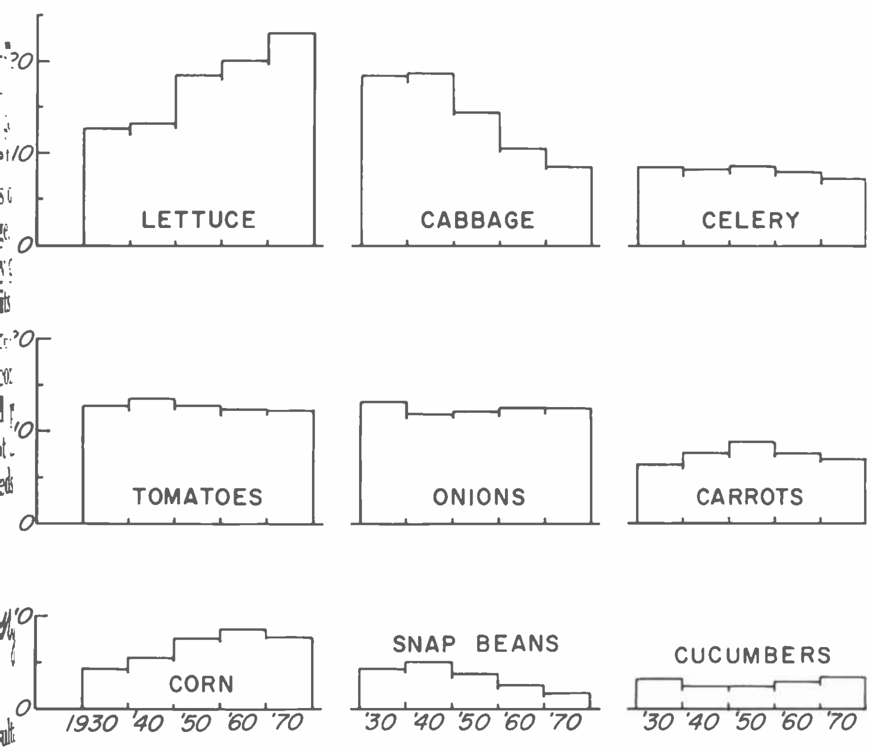
Lettuce is one of the "bright spots" in the long run tlook for fresh vegetables in the United States. Its pularity has been rising since the 1930s, and especially ice the mid-1940s. Consumption of lettuce in the U.S. reased from 13 pounds per person in 1940 to almost 23 unds per person in 1970 (Chart 1).[1]

Other popular fresh vegetables include cabbage, to-atoes, onions, celery, carrots, corn, snap beans and cu-mbers. However, in contrast to the pronounced in-ease in use of lettuce the per capita consumption of ner vegetables in fresh form has remained relatively nstant or been declining during the past 20-40 years.

ttuce Market Expanding

The increase in per capita consumption, along with increase in population, has greatly expanded the rket for lettuce. To supply this expanding market, U.S. tuce production has risen from approximately 32 million ndredweight in 1955 to about 46 million hundredweight 1970.

hart 1. Per Capita Consumption of Principal Fresh Vegetables, U.S.



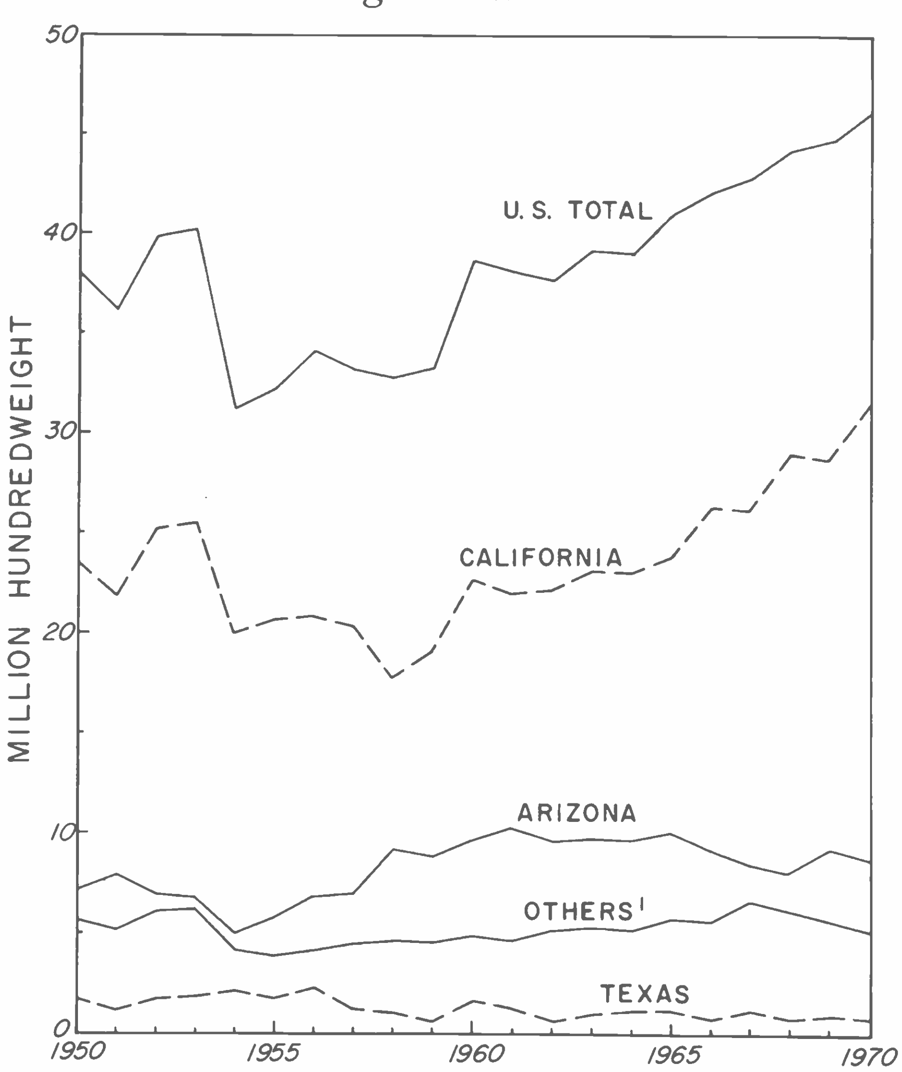
This expanding market for lettuce is of major im-tance to Arizona's fresh vegetable industry. It was nted out in a previous article that lettuce is a 50-60 lion dollar crop in Arizona and accounts for about two-ds of the value of the state's fresh-market vegetales.[2] ıs, Arizona's fresh vegetable industry is based on a duct for which the U.S. market during the past 15 years has increased an average of almost 1 million hun-dredweight or 3 percent per year.

Although lettuce is the backbone of Arizona's fresh vegetable industry, the nation depends primarily on Cali-fornia for about two-thirds of the total yearly lettuce supply. California, the top lettuce-growing state for many years, has been primarily responsible for supplying the *increase in market growth* of 14 million hundredweight during the past 15 years (Chart 2).

In contrast to the continuous expansion in production in California since 1960, annual lettuce production in Arizona remained relatively stable during the early 1960s, and then declined slightly during the late 1960s. As a result, Arizona accounted for less than a fifth of the U.S. supply in 1970, compared to about a fourth in 1965.

In view of the steadily expanding U.S. market and be-cause of the economic importance of lettuce to Arizona's fresh vegetable industry, there is growing concern as to why Arizona's lettuce production is declining, and if this trend can be reversed. This article briefly describes the

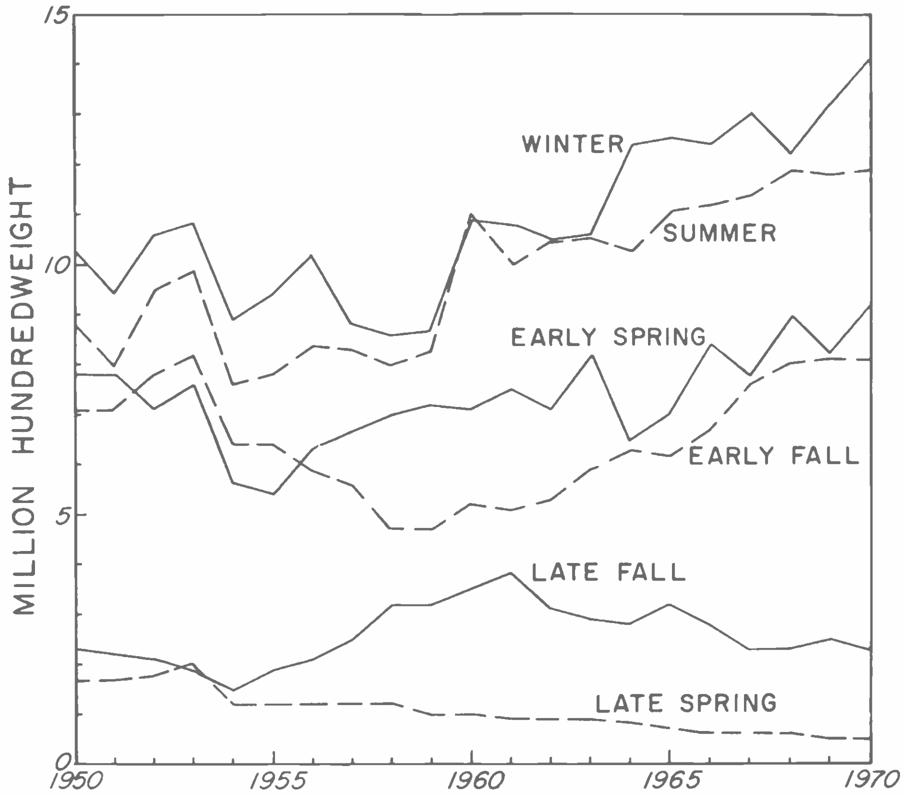
Chart 2. U.S. Production of Lettuce, by Major Producing States.



[1]*Total for all other commercial producing states.*

rking Specialist, Cooperative Extension Service, University of ona.

Chart 3. U.S. Production of Lettuce by Seasons.



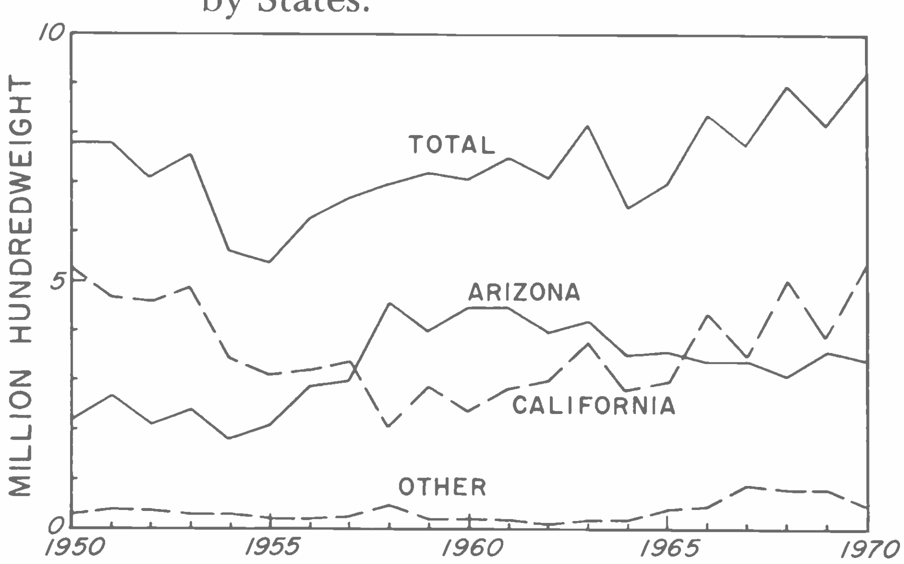
state's lettuce producing industry and explores some of the reasons for the production decline. In turn, this may be helpful in appraising the future outlook for lettuce in Arizona.

A Short-Season Crop

Because it is perishable, and because technologies are not available for preserving it in the desired fresh form, lettuce cannot be stored for a prolonged period like potatoes, apples and grain crops. Fortunately, however, lettuce is a short-season crop, and the year-round demand can be supplied by the "current production" from one or more of the nation's lettuce producing areas. In fact, newly harvested lettuce is being shipped from some point in the U.S. in almost every week of the year.

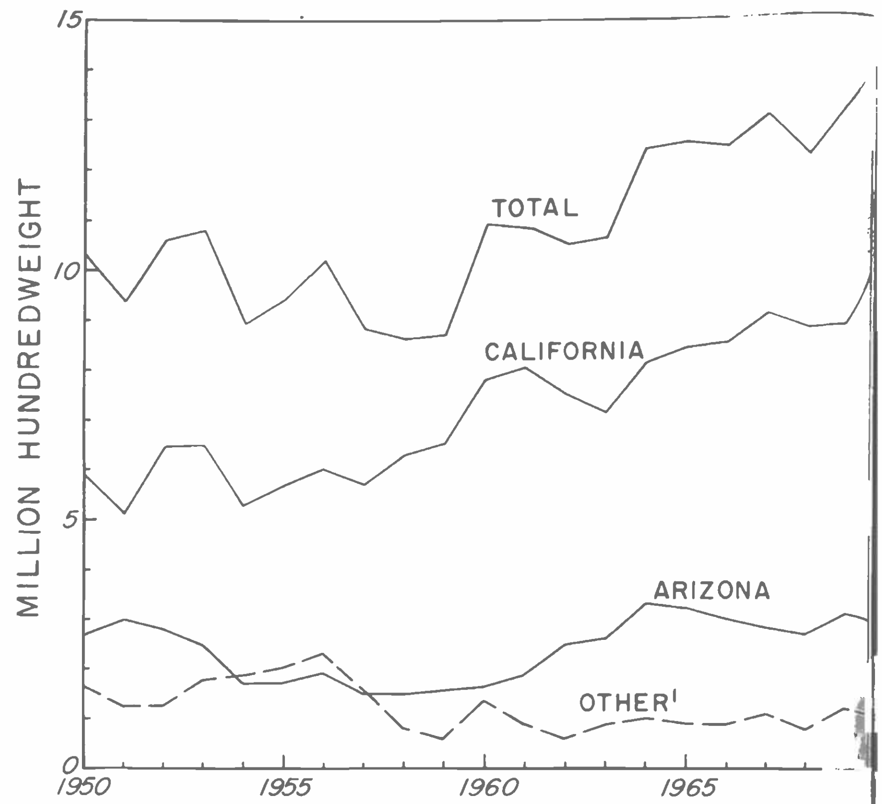
U.S. lettuce production data are available for six different seasons of the year (see Chart 3). The winter and summer lettuce crops are the largest, and the crops in late fall and late spring are the smallest. In addition to being relatively small, the late fall and late spring crops

Chart 5. U.S. Production of Early Spring Lettuce by States.



[1]Total for Georgia, South Carolina and North Carolina for 1950-1955, for these three states and New Mexico for 1956-1961, and for New Mexico and North Carolina for 1962-1970.

Chart 4. U.S. Production of Winter Lettuce States.



[1]Total for Texas and Florida.

have gradually gotten smaller during the past 10 yea Obviously, then, the growth in total lettuce producti was due to increased output during the other growi seasons.

Arizona Production Seasons

Arizona produces lettuce in three of the six differe growing seasons — late fall, winter and early spring. of the nation's late fall lettuce crop is produced in Arizo However, as indicated above, late fall production declined during the past decade — from almost 4 milli hundredweight in early 1960s to less than 2 million hu dredweight in the early 1970s (Chart 3). Apparently th decline is being offset by expanded output during early fall and winter seaons in other producing areas.

Slightly more than a fifth of the 1970 winter lettu crop was produced in Arizona (Chart 4). However, A zona's production has remained relatively stable at 3 million hundredweight since the mid-1960s, altho

Chart 6. Production of Arizona Lettuce Cro

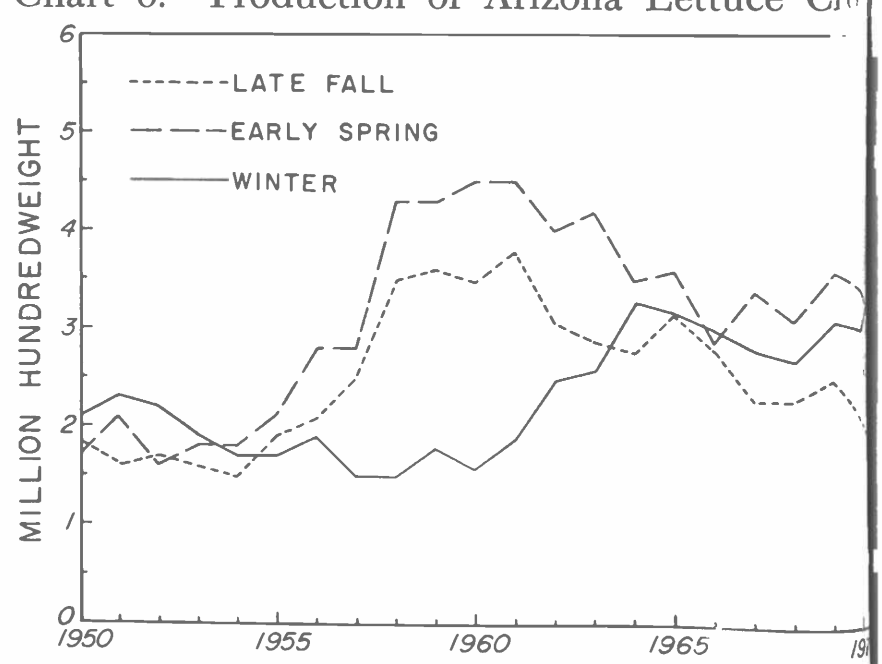
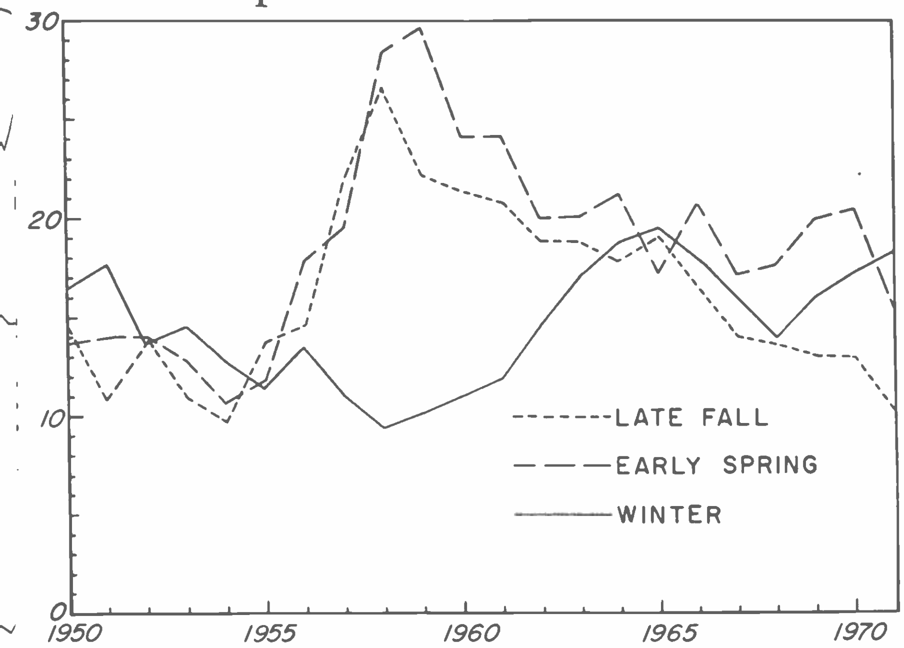


Chart 7. Harvested Acreage for Arizona Lettuce Crops.



otal U.S. output of winter lettuce during this period increased by about 2 million hundredweight. California is he big producer of winter lettuce, accounting for more han 70 percent of the 1970 crop.

For several years the early spring deal was Arizona's argest lettuce crop. There are indications, however, that arly spring production may drop below the state's winter rop in the early 1970s.

During the late 1950s and early 1960s Arizona was he nation's leading producer of early spring lettuce Chart 5). However, the crop in Arizona dropped from approximately 4.5 million hundredweight in the early 960s to about 3.5 million hundredweight by the mid-960s, and has remained near this level up to the present. n contrast, production of early spring lettuce in California as risen from about 2.5 million hundredweight in 1960 to more than 5 million hundredweight by 1970.

In addition to being the top producing state for winter nd early spring lettuce, California is also the leading producer of the early fall and summer lettuce crops. New Jersey is the leading producer of late spring lettuce, although as previously noted the output of this crop is gradually declining. Other lettuce producing states were noted in the second article of this series.[3]

Chart 9. Season Average Price for Arizona Lettuce Crops.

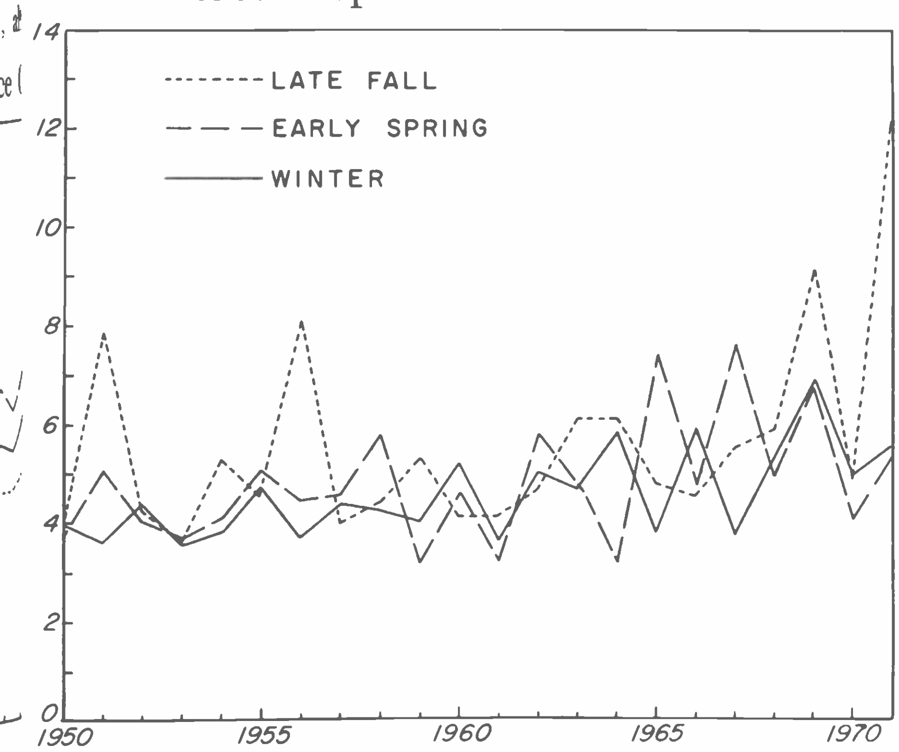
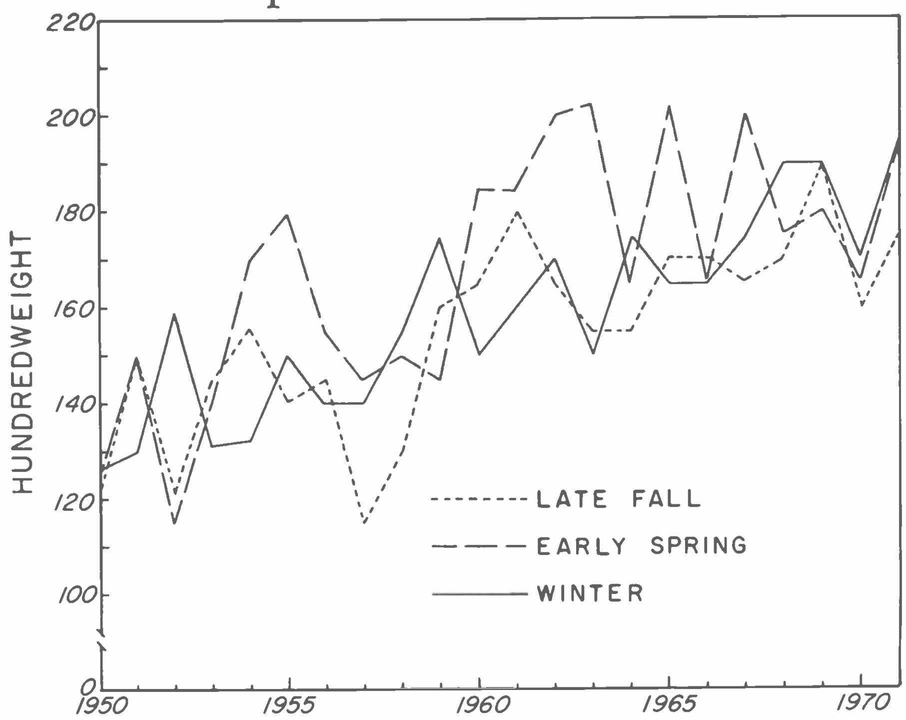


Chart 8. Yield per Acre for Arizona Lettuce Crops.



From these comparisons of production by states and by seasons, it is evident that the drop in total lettuce production in Arizona was due to declines in both early spring and late fall crops (Chart 6). Production of winter lettuce more than doubled during the 1960s; however, a large portion of this increase occurred during the first half of the decade.

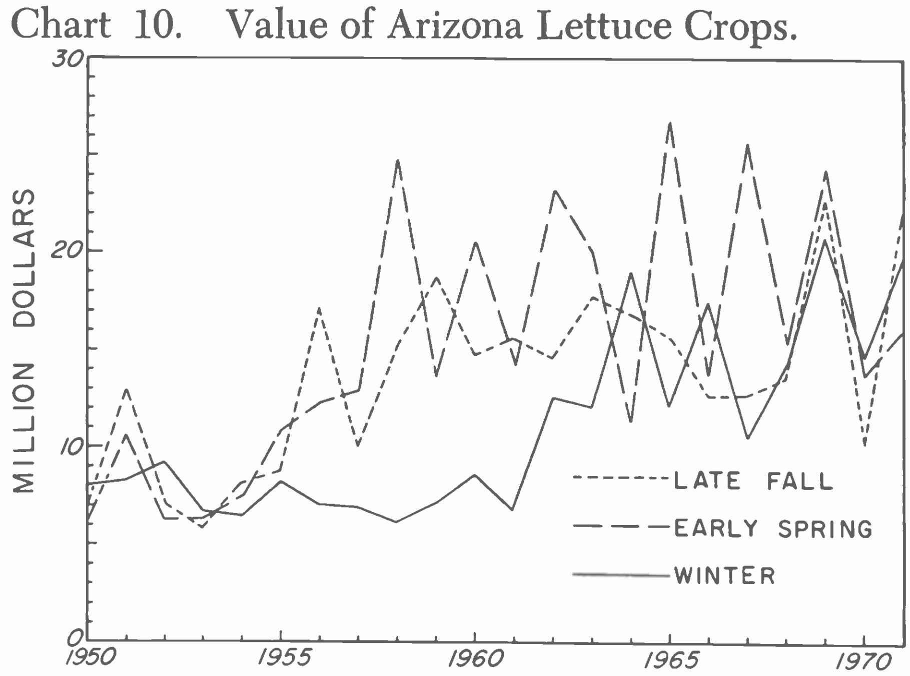
Changes in Arizona's Lettuce Acreage

Changes in lettuce acreage during the past 10-15 years closely parallel the changes in production. The harvested acreage of late fall lettuce has declined approximately 50 percent since the early 1960s — from about 20,000 to 10,000 acres (Chart 7).

Acreage of early spring lettuce reached a peak of almost 30,000 acres in the late 1950s, but has since declined to less than 20,000 acres in the early 1970s. Much of this drop occurred in the early 1960s.

(Please turn to Page 16)

Chart 10. Value of Arizona Lettuce Crops.



Quantification of snowpacks related to inventory-prediction variables may help define forest-snow interactions useful in developing land management systems designed to increase water yields in the ponderosa pine (*Pinus pondersoa* Laws.) type in Arizona. Previous studies (Ffolliott *et al.*, 1965, Ffolliott and Hansen 1968) reported empirical relationships between snowpack conditions at a point in time and inventory-prediction variables, but little work has been directed toward evaluation of snowpack conditions over time.

An exploratory investigation was conducted to evaluate a storage-duration index (Wilm 1948) in relation to inventory-prediction variables. The objective of the investigation was to obtain information for quantifying snowpack storage conditions on site.

The storage-duration index provides an integrated single estimate of initial snow storage and subsequent melt rates. The index is developed for arbitrarily defined time periods by adding together snowpack water equivalent measurements made in successive surveys for the period. Theoretically, maximum index values are obtained with large initial storage followed by slow melting, while low initial storage followed by rapid melting provides minimum index values (Wilm 1948).

Snowmelt is a major source of runoff and water yield for the reservoir systems i central Arizona.

Describing Arizona Snowpacks in Forested Condition with Storage-Duration Index

*by Peter F. Ffolliott and David B. Thorud**

Description of Investigation

The exploratory work discussed herein was designed to evaluate the storage-duration index as related to inventory-prediction variables readily available or easily obtained by the land manager. The variables selected were forest density, potential insolation, and elevation. These variables are important in describing snowpack conditions.

Study Area

The study utilized 75 sample plots located on the Beaver Creek Watershed (Brown 1971) in north-central Arizona.** These plots, located on aerial photographs and then established on the ground, sample a range of forest density and physiographic conditions common to ponderosa pine on the study area. Each plot consisted of 13 sample points systematically arranged within a circular 1/5-acre area.

Ponderosa pine comprises over 85 percent of the forest density, with Gambel oak (*Quercus gambelii* Nutt.) and alligator juniper (*Juniperus deppeana* Steud.) intermingled. The site index (Meyer 1961) is 70 feet at 100 years, and the sawtimber volume averages 5,800 board feet per acre.

Topography varies from essentially level to slopes in excess of 45 percent. Elevation ranges from 7,300 to 7,800 feet. The soils are derived from basalt, with an intermixture of cinders (Williams and Anderson 1967). Annual precipitation averages 24 inches, half of which normally occurs between November 15 and April 15.

Winter precipitation during 1967-6 and 1968-69, the two years of stud was 18.8 and 20.2 inches, respectivel The timing of precipitation event differed between years, however.

Methods

Snowpack water equivalent wa measured with a snow tube and scal at all sample points before and durin the snowmelt-runoff period for bot years of study (Table 1). Durin 1967-68, measurements were made a (1) peak snowpack accumulatio prior to the start of runoff, (2) mid way between peak accumulation an approximate peak daily runoff, an (3) approximate peak daily runof indicated by a nearby stream gag Only the first and last measurement were made during 1968-69, as th snowpack melted at a rapid rat Measurements were not made afte

Table 1 — Snowpack water equivalent measurement dates.

Event	*Year of Study* 1967-68	1968-69
Peak snowpack accumulation, prior to start of runoff	**February 10**	**March 10**
Midway between peak accumulation and approximate peak daily runoff	**February 24**	**(no measurements)**
Approximate peak daily runoff	**March 9**	**March 24**

**Associate Professor and Head, Department of Watershed Management. This study was supported in part by funds provided by the U.S. Department of Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.*

***This study was conducted in cooperation with the Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.*

Table 2 — Regression equations of storage-duration index versus forest density, slope steepness and aspect (potential insolation), and elevation.

ear	Equation	Correlation Coefficient
967-68	$Y = -0.112 - 0.0163X_1 - 0.0433X_2 + 0.0894X_3$	0.56
968-69	$Y = -0.186 - 0.0105X_1 - 0.0488X_2 + 0.0102X_3$	0.53

= storage-duration index
$_1$ = basal area in square feet per acre
$_2$ = potential insolation on index date (February 20) in Langleys (Frank and Lee 1956)
$_3$ = elevation in feet.

pproximate peak daily runoff beause of increasing snowpack depleion.

Snowpack measurements taken at ach point were averaged by plot. hen, storage-duration index was developed for each plot by adding toether the snowpack water equivalent neasurements taken at the abovelefined periods.

Forest density, expressed in square eet of basal area per acre, was estinated by point sampling techniques sing a basal area factor of 25. A subample of five sample points provided he basis for estimating basal area at ach plot.

Potential insolation, in Langleys gram calories/cm^2), received on an ndex date (February 20) was obained from slope steepness and aspect neasurements at each plot (Frank nd Lee 1966). The elevation of each lot was estimated from 7½ minute J.S. Geological Survey topographic naps.

Multiple regression analysis was sed to empirically define relationhips between the storage-duration ndex values and the combine effect f the tested inventory-prediction ariables.

Results and Discussion

Relationships between storage-duraon index values and inventory-preiction variables were similar for both ears of study (Table 2). The useulness of these relationships is not ecessarily in predicting storage-duraon index values *per se,* however, but identifying sites with desired snowack storage conditions.

On the Beaver Creek Study Area, or example, large initial storage folowed by slow melting is associated ith low forest densities, low potenal isolation values, and high elevaons, as sites exhibiting all three haracteristics possess maximum index alues. Low initial storage followed y rapid melting is associated with the pposite site characteristics.

Storage-duration index values and snowpack equivalent at peak seasonal accumulation are similarily associated with forest density, potential insolation, and elevation, as evidenced by this investigation and a previous study of forest-snow relationships on Beaver Creek (Ffolliott and Hansen 1968). This indicates that high initial storage under low forest densities, low potential insolation values, and high elevations is not necessarily offset by accelerated melting, but remains high throughout the melt period. Conversely, low initial storage associated with the opposite site characteristics may not persist due to rapid melting.

The results of this investigation may suggest possibilities for empirically identifying hydrologic strata on a watershed in terms of initial storage and subsequent melt rate criteria. Once identified, land management systems designed to affect snowpack storage conditions may be prescribed. Forest density is the only tested inventory-prediction variable that can be manipulated. Therefore, by decreasing forest densities on high elevation sites with low potential insolation, the storage-duration index values should be increased. Increasing forest densities on low elevation sites with high potential insolation values should have the opposite effect.

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Figure 1. Rock mulch covering this patio slope in Tucson foothills is lain over soil which has been stabilized against wind and rain erosion since 1963.

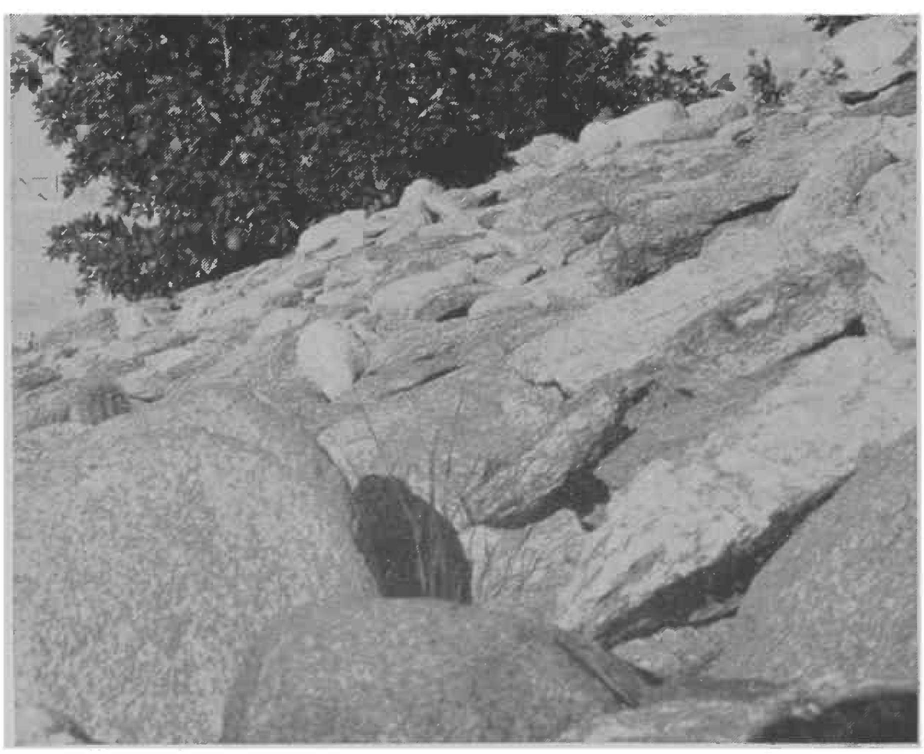


Figure 2. Variability of sizes and textures of rock add interest and beauty to this natural covering.

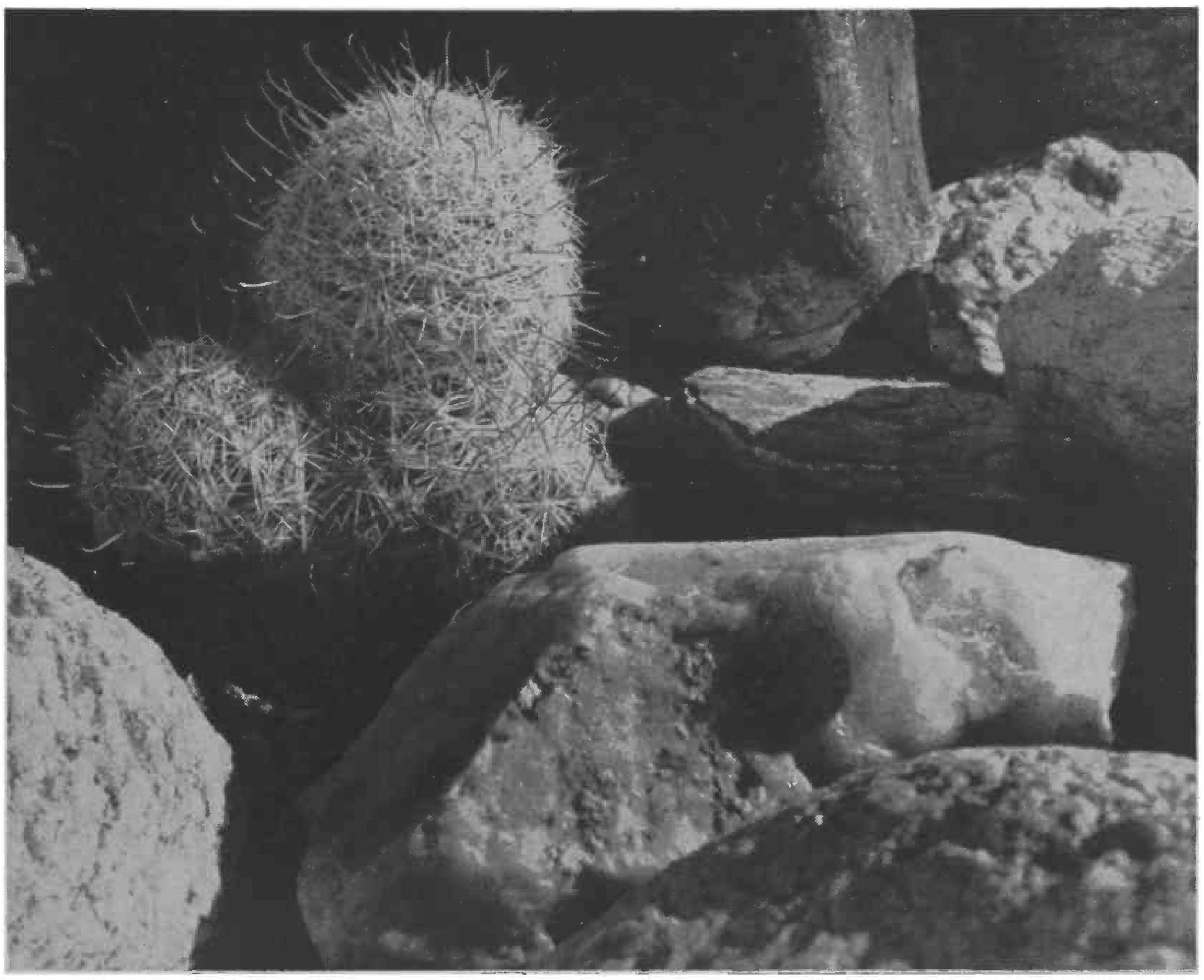
ROCK MULCH
is rediscovered

*by Wallace H. Fuller**

This time in the foothills of the desert Southwest. Th ancient practice, referred to in the Biblical history of th Israelites, is still as attractive today as then. Rock mulch were established to conserve soil moisture for plant grow as well as control soil loss by erosion.

A high proportion of world deserts become pav with stones and rocks naturally. Torrential rains and hi volocity winds, so characteristic of arid lands, remove t finer soil particles (sand, silt and clay) leaving the coar stones and rocks. Eventually the stones and rocks a cumulate to the extent that desert pavement develops cobbles blanket the surface. Soil erosion across th mulched areas becomes minimal. Thus, nature provid a lesson we may use where surfaces require maximu protection from erosion or where rock mulches aesthet cally fit into the landscape design.

**Professor, Soils, Water and Engineering Department.*

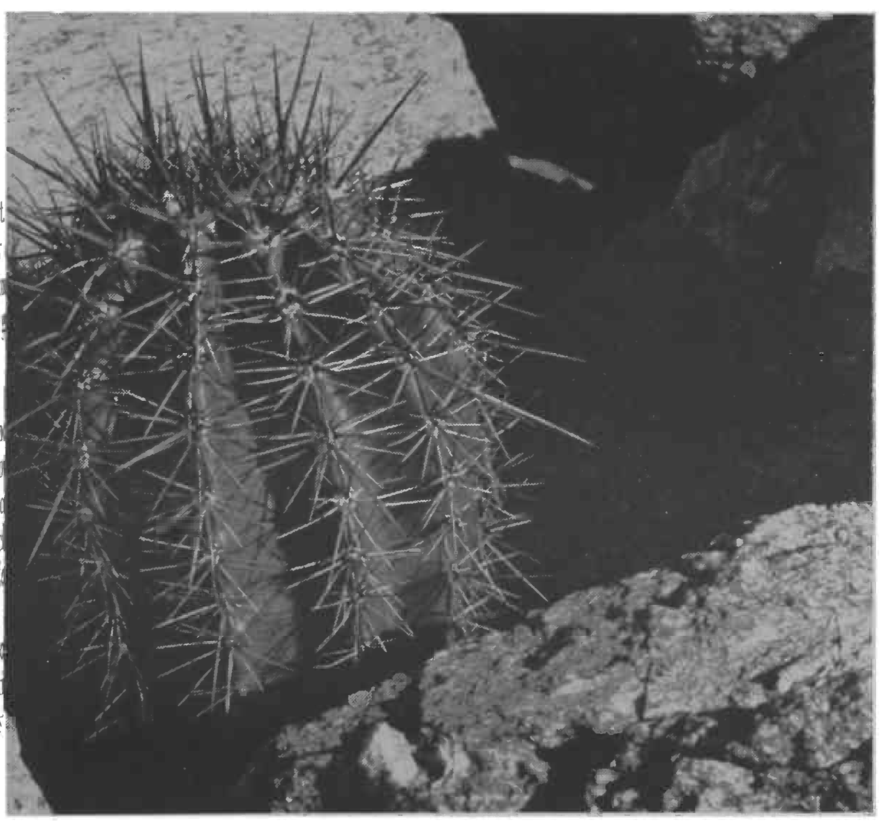


gure 3. Christmas cacti (Opuntia leptocaulis) become well-tablished, naturally, in as short a time as one year in this ck mulch culture.

Figure 4. Pincushion cactus (Mamillaria microcarpus) grows well in the rock mulch. These cacti seed naturally and may grow to maturity in one year.

The desert Southwest erodes severely just as other eserts. The high intensity of rainfal coupled with sparse otection by vegetation and a natural tendency of the ils to disperse upon wetting, makes it necessary to pro-ct all except the flattest of land. Rock mulches effec-vely and efficiently protect even highly sloping land. or a modern example, see the pictures.

gure 5. A young saguaro (Sereus gigantus) ten inches high ows rapidly in the rock mulch. Saguaro seed and grow volun-rily among the rocks. Rates of growth of three to four inches r year occur under these ideal conditions.



The rocks were carried from an adjacent arroyo and placed randomly on the slope as close together as possible. Some weigh as much as 150 pounds and others as little as one pound. The variety in sizes, shapes, and composition adds to the beauty of the patio surface.

The area represented in the pictures has become fully stabilized for 10 years despite the steep slope (15 percent), lack of vegetation, and erodible soil. During this time, rainfalls as intense as 2.5+ inches in one hour occurred two or more times a year. Yet, neither soil nor water eroded into the pool area.

The soil is a loam. Lime and salts are prevalent. Only cactus is permitted to grow among the rocks. Other vegetation is killed either by a weedicide or pulled by hand.

Some advantages of rock mulch are:

1. Soil erosion control
   (Protects your property from eroding away.)
2. Water conservation
   (Saves water otherwise required for turfs.)
3. Aesthetic value
   (Beautiful, textured effects may be attained.)
4. Inexpensive land surface
   (Collect your own rock. Good exercise.)
5. Requires little care
   (No mowing, watering, or fertilizing necessary.)
6. Weed control is relatively easy
   (Paraquat or preemergence weedicide may be used.)
7. Establishment of native plants is easy
   (See pictures of young cacti among the rocks.)
8. Economy of maintenance
   (No sprinkling system or periodic renovating needed.)

Mathematical Modeling of Soil Temperature

*By K. E. Foster and M. M. Fogel**

INTRODUCTION

The range manager is frequently concerned with activity occurring at the soil surface or in the upper 30 centimeters (cm) of the soil profile which may be a function of temperature. A data collection program was initiated in the summer of 1970 at the Santa Rita Experimental Range, Tucson, Arizona, to test a mathematical model developed to simulate soil surface temperature and subsurface temperature profiles to any desired depth on an hourly basis. The approach used was one of solving the basic energy balance equation:

$$R = H + LE + G \qquad (1)$$

where

R = net radiation
H = sensible heat flux
LE = latent heat flux
G = soil heat flux

for the soil surface temperature variation. Assuming then heat flow by conduction, the subsurface temperature variation was calculated from a finite difference form of the heat flow equation using the model simulated soil surface temperature as a time variant upper boundary condition.

Model Development

The surface energy budget for a bare soil can be written by consid[ering] a soil column extending from th[e] surface to that depth where verti[cal] heat exchange is negligible:

$$G = [(Q)\,(1-\alpha)] + I{\downarrow} - I{\uparrow} - H - LE + F_i - F_o \qquad (2)$$

where

G = net rate of the so[il] heat flux
$[(Q)\,(1-\alpha)]$ = incoming solar rad[i]ation absorbed [by] the earth's surface
$I{\downarrow}$ = long wave count[er] radiation
H = transfer of heat wi[th] air (positive wh[en] air is cooler, neg[a]tive when air [is] warmer)
F_i = horizontal transf[er] of heat into the co[l]umn from the su[r]rounding soil
$I{\uparrow}$ = long wave radiati[on] to the atmospher[e]
LE = Evaporation, whe[re] L is the latent he[at] of vaporization (5[..] cal gm^{-1})
F_o = horizonal transf[er] of heat out of th[e] column

The terms $(Q)\,(1-\alpha) + I{\downarrow}-I{\uparrow}$ fo[rm] the radiation balance R, and subsu[r]face heat flux into and out of th[e] column is assumed to be zero, thus th[e] energy balance equation becomes

$$G = R - H - LE \qquad (3)$$

(Terms defined in equation 1)

implying that the net available radi[a]tive energy is used to warm the ai[r,] evaporate water, and warm the so[il.] Equation 3 is applicable to a bare so[il;] however, the need for soil tempe[ra]ture simulation beneath a variab[le] vegetation cover was also desirab[le.] Equation 3 was modified to accou[nt] for the energy partitioning betwe[en] the plant canopy and the soil surfac[e,] thus resulting in an energy balan[ce] equation for both the plant cano[py] and the soil surface.

The energy balance of the pla[nt] canopy may be expressed as:

$$Gp = (-LEp + I{\downarrow} - 2I{\uparrow}p + I{\uparrow}s)\,(I - \Delta I) + Q(1 - \alpha p)\,(1 - X) + Hs - Hp \qquad (4)$$

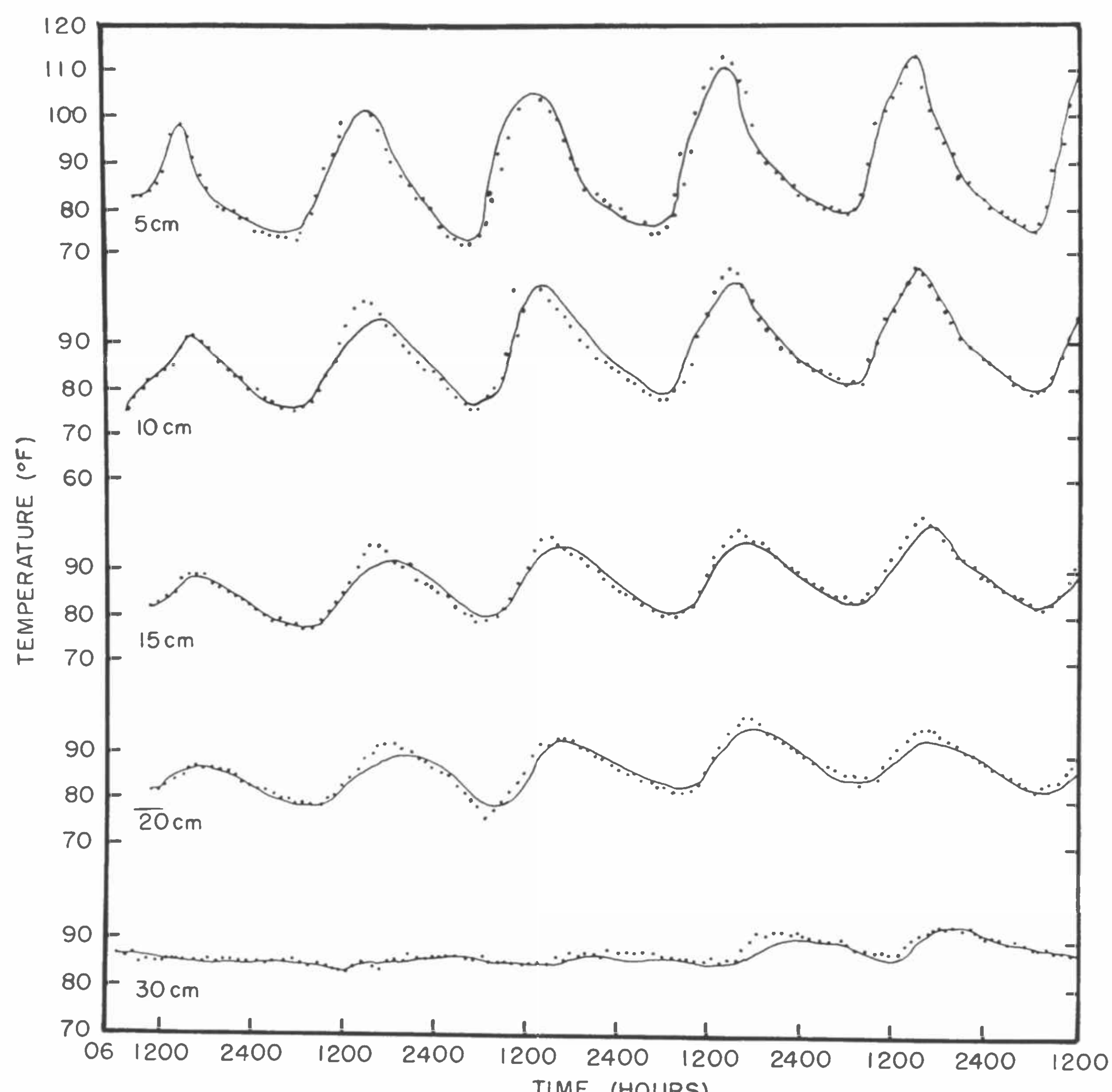


Figure 1. Bare soil temperature variation for a five day period. Dot denotes actual temperature variation and solid line represents the computer simulated temperature variation. (August 8-12, 1970)

*Research Associate, Office of Arid La[nds] Studies, and Professor, Department of W[a]tershed Management, University of Arizo[na] respectively.

ˡ'kewise the energy balance of the
'l beneath a plant canopy can be
'itten as:

$$ = -LEs - Hs + \Delta Q(1 - \alpha s)$$
$$ I^{\downarrow}p\ (1 - \Delta I) + I^{\downarrow}\Delta I - I^{\uparrow}s \quad (5)$$

here

' = the plant heat storage rate
'p = the plant latent heat flux rate
= the counter radiation from the atmosphere
) = the longwave radiation from the plant surface
; = the longwave radiation from the soil surface
= the plant albedo
' = the sensible heat flux from the plant surface
= the sensible heat flux from the soil surface
= the percent of soil surface visible looking vertically through the crop canopy
= the amount of ground receiving incoming solar radiation depending on sun angle (X = ΔI cos Z, where Z = zenith angle of the sun)
= the soil heat flux
'ːs = the soil latent heat flux

In words, Equation 4 states that the t rate at which the heat content of plant is changing is equal to the n of the rates at which heat is be- added by the absorption of solar liation Q(1 - αp), by the absorp- n of counter longwave radiation m the atmosphere $I^{\downarrow}$, by the up- rd transfer of longwave radiation m the soil surface $I^{\uparrow}$s, by the down- rd transfer of sensible heat when air is warmer than the plant - Hp, l by the upward transfer of sensi- heat when the soil is warmer than plant Hs, minus the rates at which at is being lost by longwave radia- n to the atmosphere $I^{\uparrow}$p, by the nsfer of sensible heat to the air en the air is cooler than the plant), and by evaporation LEp.

The net rate Gs at which the heat ntent of the soil column is changing equal to the sum of the rates at ich heat is being added by incom- short wave radiation Q(1 - αs), oming longwave counter radiation m the atmosphere $I^{\downarrow}\Delta$I, and long- ve radiation radiated downward m the plant $I^{\downarrow}$pΔI, minus the rate which heat is being lost by evap- ition LE, sensible heat flux, H, and emission of longwave radiation m the soil surface $I^{\uparrow}$s. For the bare l energy balance solution, Equation 5 may be solved in terms of known variables and the soil surface temperature variation Ts. The soil surface temperature beneath the plant canopy may be calculated by simultaneously solving Equations 4 and 5 for Ts. For method of solution, assumptions, initial conditions, and time series data needed to solve Equations 3, 4, and 5, referral can be made to unpublished dissertation (Foster, 1972).

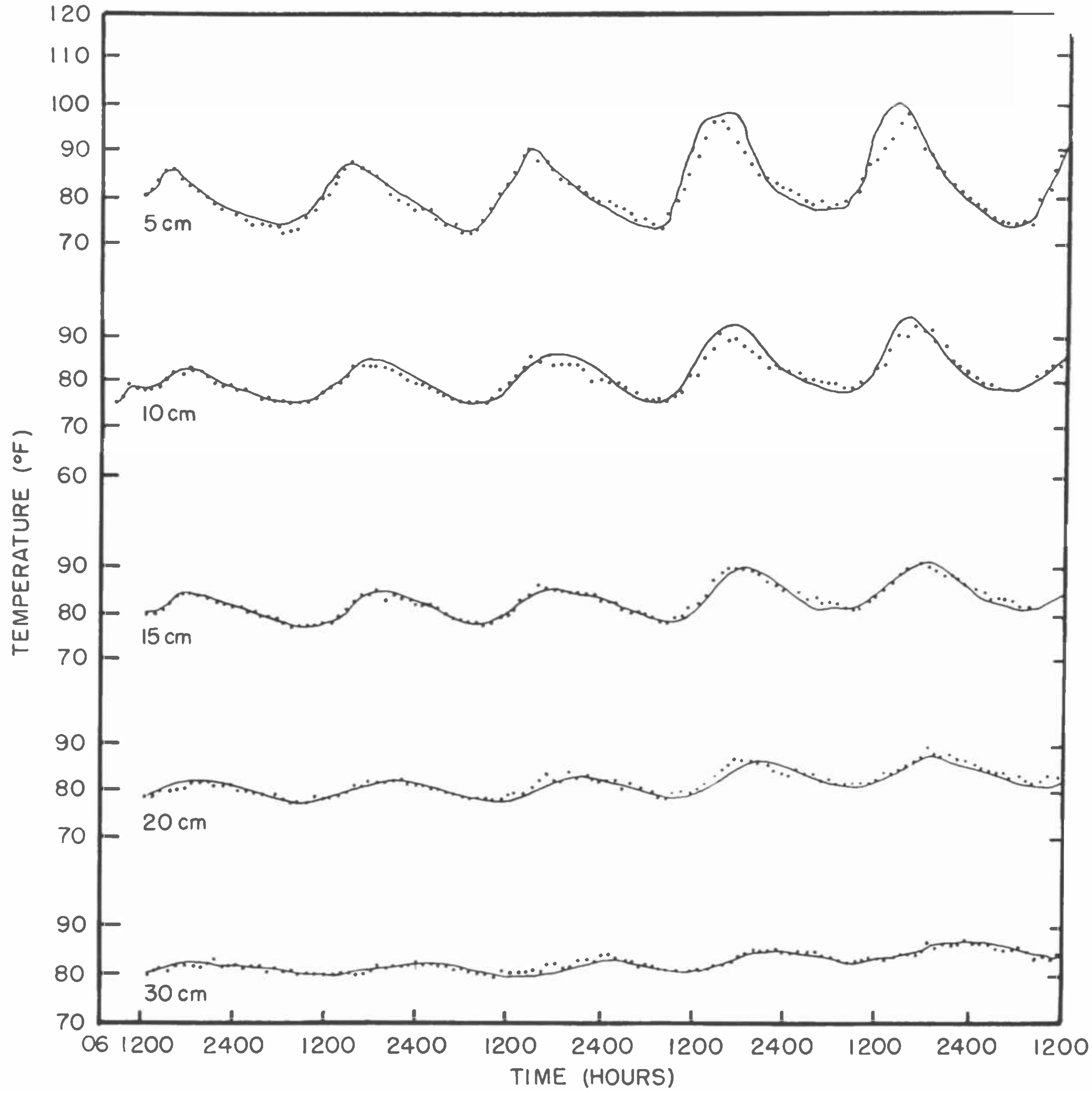


Figure 2. Soil temperature variation beneath a 30 percent plant cover for a five day period. Dot denotes actual temperature variation and solid line represents computer simulated temperature variation. (August 8-12, 1970)

Model Results

Equations 3, 4, and 5 were programmed using the University of Arizona CDC 6400 computer. The hourly soil surface and subsurface temperature variation at 5 cm increments down to 70 cm were calculated. In order to verify model results hourly temperature variation in the field was monitored by *two* honeywell Tektronik 24-channel recorders. Two plots were established on the Range. One plot was left in its natural state of blue grama [Bouteloya gracilis (HBK)] while the other plot was cleared of all existing vegetation.

Figures 1 and 2 show the model output versus measured temperature values for the bare soil plot and the thirty percent grass covered plot for a five day period. Soil temperature variation is shown only down to 30 cm because the maximum temperature variation occurs in this area.

As seen in figures 1 and 2 the observed and calculated temperatures agree in most cases within 2° F. The temperature variation with depth shows about an hour lag in peak temperature occurrence for each 5 cm in depth.

The daily maximum temperature for the 5 cm depth increased the first three days of the test period then remained essentially constant. As the top soil dried out, its heating rate was impeded by the poor conductivity of the soil and the daily maximum tended to stabilize. The lower soil depth from

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10 cm to 30 cm remained moist throughout the observation period and responded to the daily influx of heat by slowly becoming warmer for all time periods.

The most apparent result, when comparing the temperature variation of the two figures, is a temperature damping effect beneath the plant canopy. During the late morning and early afternoon hours the vegetation intercepted at least 30 percent of the incoming solar radiation, thus the peak surface temperature was reduced due to a lower radiation load. At night the vegetation reduced the outgoing longwave radiation from the soil surface thus causing the surface temperature below the vegetation to cool at a slower rate than the bare soil.

The deviation calculated from the actual soil temperatures variation can in most cases be attributed to cloud cover variation between Tucson International Airport, where the data was taken and the study area.

Discussion

The approach used in this study successfully simulates a complex natural phenomena occurring at the earth's surface. The soil temperature variation was the variable measured in the field which was a measure of the model's accuracy. The model also simulated hourly the latent heat flux, soil heat flux, and sensible heat flux. The accurracy with which the simulation occurred for these variables is unknown, and additional equipment would be needed to substantiate model output.

An additional important use of the model would be to simulate the energy budget response under varying plant canopies and initial soil conditions.

Acknowledgements

The authors would like to express their appreciation to Dr. William D. Sellers, Professor, Institute of Atmospheric Physics University of Arizona for model development and to Dr. R. E. Fye, Research Entomologist, USDA, ARS, for making the needed field equipment available.

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PLANTS for irrigated Pastur

*by Clinton W. Renney, R. J. Joy, and M. A. Massengale**

The use of irrigated pasture in ranching and farming programs has been increasing in southern Arizona. Ranchers are realizing the importance of readily available green forage. Also, some producers of annual crops such as cotton are including irrigated pasture in their operations for livestock production.

Increased interest in irrigated pastures has prompted several serious questions about pasture plants and their management. For example, is there a place for cool season perennial grasses in pasture programs? Are there plants that are better suited for irrigated pasture than those commonly grown? Is it practical to grow a perennial grass in a mixture with alfalfa? Are there suitable and productive legumes safer to graze than alfalfa? Which forage species establish quickest and maintain stands longest? What yields can be expected from well-managed irrigated pasture in the hot, desert climate of southern Arizona?

Lack of information on the performance of new improved pasture plants in southern Arizona prompted a co operative 4-year irrigated pastu study by the USDA Soil Conserva tion Service Plant Materials Cente and the University of Arizona Depar ment of Agronomy and Plant Genetic The study was designed to compa the performance of alfalfa with severa legumes that have never been know to cause bloat in livestock. All legume were planted in alternate rows wi tall fescue, a cool season perenni grass.

Three nonbloat legumes: P-49 cicer milkvetch (*Astragalus cicer* L. P-14496 narrowleaf trefoil (*Lot tenuis* Wald et Kit), and A-2130 sai foin (*Onobrychis viciaefolia* Scop. and 'Mesa-Sirsa' alfalfa (*Medicag sativa* L.) were planted in alterna rows with 'Goar' tall fescue (*Festu arundinacea* Shcreb.) October 1 1967. Alfalfa-fescue and trefoil-fesc plots were planted in alternate ro with 6-inch spacing. Milkvetch-fesc and sainfoin-fescue plots were plant in 12-inch alternate row spacing. Ea plot was replicated seven times in randomized complete block desig Treble superphosphate was drill into the surface soil prior to plantin at the rate of 140 pounds P_2O_5 p acre. Nitrogen as ammonium sulfa was broadcast before the first irrig tion at the rate of 35 pounds of

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Table 1 Average percent composition each year of legume and fescue forage in the various mixtures.

	1968 Ave. %		1969 Ave. %		1970 Ave. %		1971 Ave. %	
	legume	*fescue*	*legume*	*fescue*	*legume*	*fescue*	*legume*	*fescue*
Alfalfa-fescue	79	21	86	14	90	10	91	9
Trefoil-fescue	18	82	31	69	22	78	12	88
Milkvetch-fescue	8	92	13	87	19	81	16	84
Sainfoin-fescue	25	75	16	84	10	90	1	99

er acre. Thereafter, all plots were ertilized uniformly three times each ear with 40 to 45 pounds of available N per acre totaling an annual appliation of 120 to 135 pounds. Phoshate was applied yearly at 80 pounds vailable P_2O_5 per acre. Irrigation ater was applied every 10 to 14 days epending upon the consumptive use f the plants. Irrigation intervals were etermined from eight 1-foot long ensiometers (soil moisture measuring nstruments) placed across the plots. lants were irrigated when the averge reading of the tensiometer gauges as between 50 and 60 millibars of ension. Approximately 70 acre-inches f water were applied each growing eason.

Harvests were made to simulate razing. A plot mower was used to lip the plants at 3 to 4 inches above he soil level. Plants at each harvest vere weighed, and representative amples were taken to calculate the

Alfalfa had faster germination and emergence, stronger seedling vigor, faster regrowth after cutting, and over twice the production of the nonbloat legumes when grown in alternate rows with tall fescue.

Based on seeding rate, of the nonbloat legumes, sainfoin and trefoil had comparable emergence. Sainfoin had the strongest seedling vigor, whereas milkvetch had the slowest emergence and the weakest seedling vigor. However, this relationship changed dramatically with time. In the 2nd year the stand of sainfoin was considerably reduced and by the 4th year was essentially gone. Milkvetch started slowly, its stand improved each year, and by the 4th year had the best vigor among the nonbloat legumes. Narrowleaf trefoil established as well as sainfoin and plants persisted well until the latter part of the 3rd year, but the stand was noticeably reduced in the 4th year.

alfalfa completely dominated the tall fescue in the alfalfa-fescue plots. By the 3rd year, tall fescue stands in each plot with alfalfa were greatly reduced. The stand of alfalfa remained good through 3 harvest years but had thinned out somewhat by the start of the 4th harvest year. Data in Table 1 show the percentage of plants in mixture of the various species throughout the study.

Yield data from this simulated irrigated pasture study (Table 2) show a high forage yield for the alfalfa-fescue mixture. An average annual yield of 21,720 pounds of dry forage was obtained. Average annual yield for the trefoil-fescue mixture was 10,297 pounds of dry forage, which was about one half that of the alfalfa-fescue mixture.

Data from 2 years (1969 and 1970) were studied to evaluate season of use, time of peak production, and comparative yields of alfalfa and of

Table 2 Yields of air-fry forage in pounds per acre of alfalfa-fescue, trefoil-fescue, milkvetch-fescue and sainfoin-fescue mixtures grown at Tucson, Arizona from 1968 through 1971.

	1968	*1969*	*1970*	*1971*	*Average per year*
lfalfa-fescue	25,298	23,508	21,773	14,901	21,720
refoil-fescue	15,451	9,378	10,883	5,476	10,297
Iilkvetch-fescue	15,370	9,151	9,053	5,765	9,835
ainfoin-fescue	15,507	8,668	8,606	5,076	9,464

ir-dry weight of the forage mixtures. egume and grass percentages of the orage composition were visually estiated at each harvest. In general, he time of harvests was determined y the maturity of alfalfa and tall escue. This was a disadvantage to e nonbloat legumes since in the ajority of harvests they had little or o bloom when the alfalfa was at 10 50% bloom. The number of arvests varied from 7 to 8 each year epending upon climatic variability. egrowth periods between harvests anged from 28 to 40 days depending pon the season of year. However, verage length of time between harests throughout the study was 32 to 4 days.

Tall fescue established well in all plots though more slowly than most of the legumes. However, by the time of the second harvest, tall fescue was strongly dominating the nonbloat legumes. Tall fescue made up 70 percent or more of the forage in each harvest for the remainder of the trial and suppressed the growth of nonbloat legumes. It is possible that different management systems would improve the performance of the nonbloat legumes. Lengthening the regrowth period may improve the performance of milkvetch. In Montana, milkvetch cut twice gave higher yields and better plant performance than when cut three times.

Contrasted to the above situation tall fescue. Fescue yields peaked in April and had a greater production in the first harvest than did alfalfa. However, fescue production fell off rapidly in subsequent harvests. Alfalfa maintained its high yields into July. These data were similar to the results of other studies involving alfalfa and fescue production in Arizona.

Conclusions

Alfalfa and tall fescue mixtures have the potential for high returns when grown in irrigated pastures in southern Arizona. A good performance of tall fescue with alfalfa could reduce the bloat hazard over alfalfa alone. The nonbloat legumes used in this irrigated forage study had low production when compared with alfalfa.

WEED CONTROL

in perennial grassseed crops

By R. J. Joy[*]

The release of new grass cultivars and the increased demand for seed for range reseeding, irrigated pastures, and roadside beautification have generated interest among growers to produce grass seed commercially. Seed grown for commercial purposes must be weed-free to meet seed certification standards; consequently, the use of chemicals for weed control in perennial grass seed crops has become increasingly important.

The purpose of this study was to select preemergence herbicides that have proven effective on weeds in the Southwest and then to determine their effect on the seed production of established warm-season perennial grasses. Karmex[**] (diuron) and Treflan[**] (trifluralin) were chosen for the trial. They are widely used on cotton and other crops in the Southwest and have proven their effectiveness as herbicides on broadleaf and grassy weeds which establish from seed.

Materials and Methods

Established stands of "Catalina" weeping lovegrass (*Eragrostis curvula* Nees) and P-15630 blue panicgrass (*Panicum antidotale* Retz.) were treated in 1970 and 1971 with Karmex and Treflan applied separately and in combination. The Catalina lovegrass was established in 1969, and P-15630 blue panicgrass in 1965 at the Soil Conservation Service Plant Materials Center in Tucson.

Plants were established in 3-ft rows for seed production. Catalina weeping lovegrass and blue panicgrass were growing on Comoro fine sandy loam and Grabe loam soils, respectively.

The treatments were: (a) Karmex at 1.5 lb/acre, (b) Treflan at 1.25 lb/acre, (c) Karmex at 1.5 lb/acre plus Treflan at 1.25 lb./acre, and (d) untreated check. Herbicides were applied to both plant species in February of 1970 and in March of 1971 by spraying a 3-ft by 50-ft swath directly over the plant row. Immediately prior to spraying, weeds were completely removed from all plots. A Hudson[**] 2-gal. sprayer with a TK-5 nozzle was used to apply the materials at the rate of 63.5 g.p.a. One plant row on either side of the treated row was left untreated to serve as a guard row. Harvested portions of plot rows were 3-ft by 25-ft or .0017 acre. The experimental design was a 4 x 4 Latin square.

Seed was hand harvested when considered ripe for combine harvesting. Heads were cut, hammermilled, and the seed cleaned with a small seed cleaning machine and weighed. From these weights, cleaned seed yields per acre were determined. Seed quality was determined by weighing a 1,000

Table 1. Yield and quality of Catalina weeping lovegrass seed and number of weeds per square foot as effected by herbicides applied preemergence in 1970 and 1971*.

Treatment Year / Herbicide	*Rate (lb./acre)*	*Seasonal cleaned seed yield (lb./acre)*	*Caryopses quality (mg/1,000)*	*Total weeds per sq. ft. per season*
1970 Karmex	1½	**431.09 a**	**135.58 a**	**4.08 a**
Treflan	1¼	**491.63 a**	**125.28 a**	**2.99 a**
Karmex & Treflan	1½ & 1¼	**422.78 a**	**126.69 a**	**0.10 a**
Untreated check		**415.11 a**	**124.00 a**	**16.20 b**
1971 Karmex	1½	**405.30 a**	**129.78 a**	**2.97 a**
Treflan	1¼	**442.03 a**	**171.28 a**	**1.52 a**
Karmex & Treflan	1½ & 1¼	**374.85 a**	**126.99 a**	**1.05 a**
Untreated check		**414.31 a**	**132.38 a**	**10.20 b**

Means within a column and year followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

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[**]Trade names are used solely to provide specific information. Mention of a trade name does not constitute a guarantee of the product by the U. S. Department of Agriculture nor does it imply an endorsement by the Department over comparable products that are not named.

seed sample from each plot at each harvest. Two seed harvests were made each growing season.

Two weed counts per plot of a 9.6 ft^2 quadrat were taken three times during each season. These were at the spring seed harvest, summer forage harvest, and fall seed harvest. An exception to this was in 1970 when weeds were counted only twice (after the spring and fall seed harvests) in the blue panicgrass. Weeds were removed from the plots after each weed count was made.

Catalina weeping lovegrass received approximately 45 and 55 acre-inches of irrigation water in 1970 and 1971, respectively. Blue panicgrass received approximately 35 and 50 acre-inches of water in 1970 and 1971, respectively. The plants were fertilized each season in March with approximately 45 lbs of nitrogen per acre.

Results and Discussion

Catalina weeping lovegrass

The Catalina plants treated with Treflan at 1.25 lb/acre produced the most cleaned seed for both years (Table 1). However, seed yields between treatments were not significantly different for either year. Differences in caryopses quality were not significant.

Karmex at 1.5 lb/acre combined with Treflan at 1.25 lb/acre gave the best weed control. This treatment was followed by Treflan at 1.25 lb/acre and Karmex at 1.5 lb/acre respectively. The herbicide-treated plots had significantly fewer weeds than the untreated check for both years. Winter annuals such as mustard and prickly lettuce that germinated in February and March accounted for most of the weed species in the Treflan-alone plots although some Russian thistle, goosefoot, and grasses were also found. Karmex applied alone was less effective on grasses than Treflan when applied alone. Grasses accounted for most of the weeds observed in the plots treated with Karmex. Weed species most numerous in the untreated plots were mustard, Russian thistle, purslane, pigweed, puncturevine, and grasses. The grassy weeds were mainly red sprangletop, stinkgrass, and reseeded Catalina.

P-15630 blue panicgrass

All blue panicgrass plants treated with herbicides had higher cleaned seed yields than the untreated plants for the 2 years (Table 1). However, there were no significant differences in seed yields among treatments within years. Total seed yields were reduced for blue panicgrass grown under all treatments because of severe shattering of the seed at the fall harvests.

Caryopses quality (mg/1000 seeds) was higher for herbicide-treated plant in 1970 but, again, these differences were not significant. The fall harvests produced lower quality seed than the spring harvests for both years. These data indicated that much of the better quality seed had been shattered by the high fall winds.

In blue panicgrass, weed control was best in the Karmex plus Treflan plots during 1970 and in the plots treated with Treflan alone during 1971. Sow thistle, wild celery, and wild brome accounted for most weeds in the untreated plots. In general, fewer weeds were found in the blue panicgrass than in Catalina weeping lovegrass. This would be expected since blue panicgrass is a much larger plant than Catalina and is better able to compete with weeds.

Table 2. Yield and quality of blue panicgrass seed and number of weeds per square foot as affected by herbicides applied preemergence in 1970 and 1971*.

Treatment: Year	Herbicide	Rate (lb./acre)	Seasonal cleaned seed yield (lb./acre)	Caryopses quality (mg/1,000)	Total weeds per sq. ft. per season
1970	Karmex	1½	249.66 a	598.66 a	0.42 a
	Treflan	1¼	244.47 a	612.65 a	5.22 a
	Karmex & Treflan	1½ & 1¼	180.53 a	616.39 a	0.07 a
	Untreated check		138.49 a	588.30 a	14.93 b
1971	Karmex	1½	194.81 a	566.65 a	0.92 a
	Treflan	1¼	273.27 a	558.39 a	0.48 a
	Karmex & Treflan	1½ & 1¼	224.54 a	606.16 a	0.69 a
	Untreated check		182.85 a	573.38 a	1.74 b

Means within a column and year followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

CONCLUSIONS

Results of this study indicate that Treflan (trifluralin) and Karmex (diuron) safely and effectively controlled weeds in established warm-season perennial grasses grown for seed.

Karmex effectively controlled winter and summer annual broadleaf weeds but was weak on grasses. Treflan effectively controlled summer annual broadleaf and grassy weeds but not winter annuals.

The choice of herbicide treatment depends on which weed complex (summer or winter) was most severe. For example, if only summer annuals are a problem, Treflan applied before weed seed germination in late winter or early spring is enough unless a resistant weed such as Wright groundcherry is present. If winter annuals are also a problem, Karmex could be combined with Treflan in the weed control program. However, a more logical time to apply Karmex is in the late fall or early winter after the crop has become dormant but before most winter annuals have germinated. A surfactant could be added to the Karmex to control emerged weeds if the crop plants are dormant.

Acknowledgements

The author wishes to thank Drs. K. C. Hamilton and A. K. Dobrenz of the University of Arizona Department of Agronomy and Plant Genetics for their technical assistance during this study.

The herbicides used in this study were supplied by Dr. Garry D. Massey of Elanco Products Company and Mr. Larry B. Liggett of E. I. DuPont De Nemours and Company.

LETTUCE Consumption Up

(from Page 5)

Winter lettuce acreage increased from 10,000 acres in the late 1950s to almost 20,000 acres in 1965. Since then, acreage has varied from 14,000 to 18,000 acres annually.

All of Arizona's winter season lettuce is confined to the Yuma production area, the only season this area is in production. Central Arizona is the principal production area for the early spring and late fall lettuce crops. A more complete description of Arizona lettuce production areas and growing seasons, and the changes which have occurred during the past 20-25 years, has been compiled by Firch and Mathews in an Arizona Agricultural Experiment Station Technical Bulletin.[4]

Fluctuating Yields and Prices

During the past 20 years, there has been a gradual but very erratic increase in the yield per acre for all three Arizona lettuce crops (Chart 8). The overall upward trend in yields reflects improved cultural practices and adoption of other production technologies.

The large year-to-year variations may be partially due to weather during the growing-harvesting season. Also, there appears to be a direct relationship between price and yield, especially since the early 1960s. This is logical, since in years when the price for a particular crop is relatively low, it may not be to the growers advantage to harvest the entire crop.

Year-to-year changes in season average prices for all three crops have been relatively large during the past 20 years, and there is no definite indication of an uptrend except possibly for the late fall crop (Chart 9). In addition to prices being highly variable in the 1960s, there was an "up one year, down the next" pattern, especially for the early spring and winter crops.

Uncertainty of Crop Value

Fluctuations in acreages, yields, and prices from year to year result in large year-to-year swings in crop values (Chart 10). This is clearly evident for the early spring crops since the late 1950s, and for the winter crops since the early 1960s.

These large yearly up-and-down swings in value are strong evidence supporting arguments that profits from lettuce are relatively uncertain from one year to the next.

What About the Future?

Perhaps this uncertainty of profits partially explains the declines in acreage and production of late fall and early spring crops. In addition, the western lettuce industry is "constantly seeking the most profitable location for production during each week of the year."[5] As a consequence, those production areas "that have economic advantages displace the older areas."[6]

Apparently, some of the producing areas in California (and perhaps in New Mexico and Texas) possess one or more economic advantages over the late fall and early spring growing areas in Arizona. These economic advantages, if they exist, could involve differences in production, harvesting and marketing costs.

For example, from the late 1950s to the late 1960s, production in the Willcox area declined about 50 percent. Firch and Mathews point out that "Lettuce production during the particular times of the year when the Willcox area is a major shipper has tended to move to New Mexico and western Texas, which have an advantage of lower rail rates to eastern markets than available in the Willcox area."[7]

Another feasible explanation of the decline in production of late fall and early spring lettuce is that some other crop(s) may provide greater certainty and possibly larger net returns. Many farmers may prefer the "year-after-year" certainty of an adequate income rather than gamble on the price risks associated with lettuce and a big monetary loss.

Whether future production and shipments of late fall and early spring lettuce from Arizona continue to decline, or regain the market share enjoyed in the early 1960s, remains to be seen. Innovations and new technologies may swing the economic advantage back to Arizona.

However, it appears that low cost production is the key to the future of Arizona lettuce. The market for lettuce is expanding in the U.S., and there is a large market potential in Western Europe and many other foreign countries. Efficient producers will supply this market growth — inefficient producers will have to find alternative uses for their resources.

Footnotes

1 **Statistical data cited in the text and plotted in the charts were taken from appropriate issues of** Agricultural Statistics **and** Vegetable Situation **published by the U.S. Department of Agriculture, and from** Arizona Agricultural Statistics **compiled by the Arizona Crop and Livestock Reporting Service.**

2 **C. Curtis Cable, Jr., "Arizona's Vegetable and Melon Industry — an Overall View,"** Progressive Agriculture in Arizona, **Vol. XXIV, No. 6, November-December, 1972.**

3 **Ibid.**

4 **Robert S. Firch and Daniel W. Mathews,** The Arizona Lettuce Industry — Competition, Prices, Demand, Supply Control, **Arizona Agricultural Experiment Station Technical Bulletin 188, January 1971.**

5 **Ibid., p. 1.**

6 **Ibid., p. 5.**

7 **Ibid., p. 2.**

PROGRESSIVE AGRICULTURE IN ARIZONA

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Harold E. Myers Dean

to: