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Phenology and Function of Sonoran Desert Annuals in Relation to Environmental Changes

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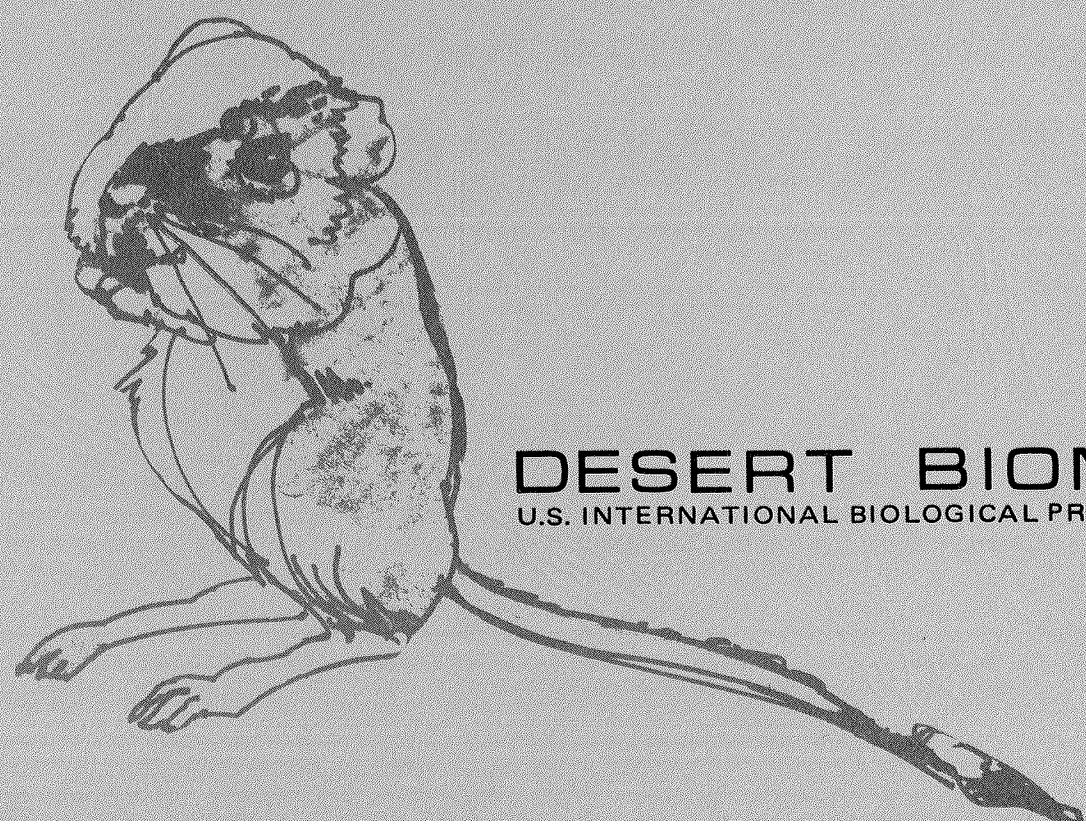

DESERT BIOME

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1972 PROGRESS REPORT

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INTRODUCTION

Perennial grasses, shrubs, trees and succulents are usually considered the characteristic plants of the Sonoran Desert; however, the annual herbs may significantly contribute to the desert vegetation cover and biomass during years when there is adequate moisture. The Sonoran Desert has both winter and summer periods of precipitation, each producing a different annual flora. Winter annuals are generally dicotyledons while summer annuals are monocotyledons.

The winter annual vegetation begins to develop shortly after the first winter rains which usually occur in December. If late winter rains do not follow the early rains, the annual herbs may not flower or fully develop. Development of winter annuals during good moisture years may produce more new photosynthetic material than the shrubs. However, as the weather warms, the shrubs far surpass the annuals in total biomass production.

Summer rains occur in late July and August stimulating annual grass production. In lower elevations of the Sonoran Desert, summer rainfall may be irregular and annual plant development may therefore be quite limited. At higher elevations, wet years cause annual grass production to be 80% of the total grass biomass while during dry years annual grass production may be lacking (Martin, 1966).

Germination and development of annuals have been shown to be related to rainfall and temperature (Went, 1949) as well as to the relative position to shrubs (Went, 1942; Müller, 1953). Annual growth also may occur in clumps with high densities in some areas (e.g., 250 plants per dm^2) and few plants elsewhere. These irregularities in growth occurrence along with variations in response to environmental stimuli among different annual plant species create an interesting problem for the researcher of desert vegetational development and productivity.

OBJECTIVES

The primary objectives of this study are to relate the growth and development of desert annual plants to environmental parameters in order to determine which factors most influence annual vegetation productivity. Closely correlated with these objectives is the determination of the relationship between the phenological stages of the annuals and the past and present environments of the plants. Productivity of the desert annuals can be measured through field sampling as well as CO_2 exchange analyses. A comparison of these processes shows the relationship between environmental responses of field growth and

ABSTRACT

Desert annual plants may contribute a high percentage of biomass during "good" years. This study proposes to determine those factors that influence the productivity of desert annuals by 1) monitoring desert microenvironmental conditions in various habitats, 2) periodically measuring biomass accumulation of desert annuals, 3) determining phenological stages of annuals in relation to time and environment and 4) measuring CO_2 exchange functions of annuals in relation to environments.

In 1972, desert annual biomass accumulation did not begin until October, winter rains were lacking and summer rains were apparently insufficient. Biomass accumulation since October has been concentrated under the shrubs, the area of apparent optimum environment. Continual monitoring of annual plant biomass relative to shrub and open habitats is beginning to show the factors necessary for annual plant development in the Sonoran Desert. Growth has been limited to the vegetative stage so flowering, seed set and dispersal, and mortality have not been related to specific environmental variables. This relationship plus CO_2 exchange analyses should help predict productivity rates of desert annuals.

physiological function. All of the measured processes of growth and productivity of the annuals are considered relative to the perennial plants which greatly influence the microenvironments of the desert.

METHODS

A study site near Cave Creek, Arizona, at an elevation of about 2100 feet was selected because it had similar vegetation and rainfall to the Silverbell Validation Site near Tucson, Arizona. Vegetation is typical of the *Larrea-Franseria* desert association with scattered *Cercidium*, *Opuntia* and *Cereus*. This site was mapped and randomly sampled (21 10 x 10 m quadrats) for composition.

Microenvironmental stations were set up in two locations in the study site in order to measure abiotic conditions prior to, during and after annual plant germination, growth, flowering, seed set and dispersal, and mortality. Microenvironmental conditions were measured, starting in April, 1972, in the open and in relation to the canopy of various shrub species, especially *Cercidium microphyllum*, *Larrea divaricata*, and *Franseria deltoidea*. Abiotic parameters measured include: solar radiation by pyrheliograph (Data Set A3UPB05), precipitation by recording rain gauge (Data Set A3UPB06), air temperatures and calculated vapor pressure deficits at 15 and 120 cm by recording hygrothermographs (Data Set A3UPB07), air temperatures at 1.5 cm by Moeller distance recording thermographs (Data Set A3UPB08), wind velocity at 15 and 120 cm in the open and 15 cm under shrubs by totalizing anemometers (Data Set A3UPB09), soil temperatures at 1.5 and 7.5 cm depths by Moeller thermographs (Data Set A3UPB10), and soil moisture at 0-7.5 cm and 15-22.5 cm depth by gravimetric means (Data Set A3UPB11), and at 1.5, 7.5, 15, and 30 cm by Colman soil moisture blocks (Data Set A3UPB12). Most of the abiotic data have been collected on a weekly basis; however, when periods of rainfall occur and plant growth is stimulated, daily microenvironmental data are recorded.

Annual plants were sampled under shrubs and in the open with 2 x 2 dm quadrats. Under large shrubs sampling was at four aspects (N, S, E, W) from the shrub stem near the stem and under the canopy overhang. Sampling under small shrubs was limited to the north and south sides near the shrub base. Densities of annual plants and total biomass (dry weight) for each sample (2 x 2 dm) were measured under *Cercidium microphyllum*, *Larrea*, *Franseria deltoidea* and in the open (Data Set A3UPB13). Densities and biomass of individual species of annuals, when they could be identified, were measured under *Cercidium*, *Larrea*, *Franseria* and in the open (Data Set A3UPB14). During the sampling, phenological stages of the various species of annuals were also determined.

CO_2 exchange measurements were not made during 1972 because the annual plant vegetation did not develop until near the end of the year, thus the amount of photosynthetic surface was limited.

RESULTS

Vegetation

The relationship between shrubs and the growth and development of annuals is considered important enough that vegetational composition of the study area might be used to ultimately determine productivity of annuals in the area. Table 1 shows that the study area is dominated by *Franseria deltoidea* (I.V. over 100); however, influence of shrub cover probably is more significant when considering annual plant growth. *Cercidium microphyllum* with lower density than *Franseria* practically equals the cover of *Franseria* and thus is probably very important to annual productivity. Many of the perennials produce cover within the canopy of a bigger shrub or tree and thus may not independently influence the annual plant microenvironment.

Abiotic environment

Macroclimate of the study area is represented by temperature data from a standard weather shelter at 120 cm and precipitation data from the open (Fig. 1). The study site is typical of the Sonoran Desert with hot summers and cool winters. 1972 was an unusual year in the study area in that the first half of the year was dry, the normal winter rains never occurring, while the second half of the year was abnormally wet with heavy rains in October. The abnormal rainfall pattern caused a lack of annual plant development in the winter and spring and a lush annual plant development in late fall.

Germination, growth and development of desert annual plants is influenced more by conditions near the ground than at 120 cm; thus microenvironment near the ground, in the open and under shrubs, has been intensively monitored. Proper temperature and moisture conditions initiate annual plant development and maintain growth. Figure 2 shows temperature conditions in the open and under *Cercidium* at 1.5 cm above the ground surface and 1.5 cm in the soil, along with soil moisture conditions in the upper 7.5 cm of soil in the open and under *Cercidium*. In the summer, conditions were extremely hot with subsurface soil temperatures reaching over 50 C. Soil moisture was very low until the July rains, after which soil moisture was not maintained due to evaporation. Not until after the late fall rains did the soil temperature drop in conjunction with a more or less continual maintenance of soil moisture. The influence of the shrubs can be readily seen (Fig. 2). Temperatures near the ground and in the soil subsurface are moderated by the shrub canopy. Soil moisture is also maintained for a longer period under the shrubs.

Growth and development of the annual plants after germination is a function of soil moisture and temperature, but the microenvironment in the area of foliage development must also have some influence. Figure 3 shows the temperature and vapor pressure deficit (VPD) differences at 15 cm above the ground in the open and under the canopy of *Cercidium*. VPD is high during the drought periods and moderate during rainy periods. Only on days of rainfall does VPD drop to zero. From April through December, 1972 temperature and VPD conditions in the open and under the shrubs were not too different except for the slight expected variations due to the influence of shrubs. At times, the VPD under the south-side canopy of *Cercidium* was higher than in the open. This probably was due to the south-side canopy creating a heat pocket.

Table 1. Cover percentages and importance values (IV) of the perennials at the Cave Creek study site

Species	Aerial Cover (%)	I.V.
Franseria deltoidea	32.3	115.9
Larrea divaricata	23.9	42.6
Cercidium microphyllum	31.3	41.0
Opuntia acanthocarpa	5.3	20.2
Opuntia bigelovii	0.7	15.3
Mammillaria microcarpa	*	10.2
Opuntia leptocaulis	1.9	10.7
Echinocereus engelmannii	*	7.8
Opuntia fulgida	0.6	6.4
Cereus giganteus	*	4.5
Trixis californicus	*	6.0
Opuntia phaeacantha	*	1.6
Prosopis juliflora	1.5	3.4
Fouquieria splendens	0.9	2.3
Krameria grayi	*	1.5
Ferocactus acanthodes	*	4.0
Opuntia arbuscula	*	1.9
Simmondsia chinensis	*	1.4
Acacia greggii	*	0.9
Zizyphus obtusifolia	*	1.0
Calliandra eriophylla	*	0.7
Porophyllum gracilis	*	0.7

*Cover = less than 0.5%.

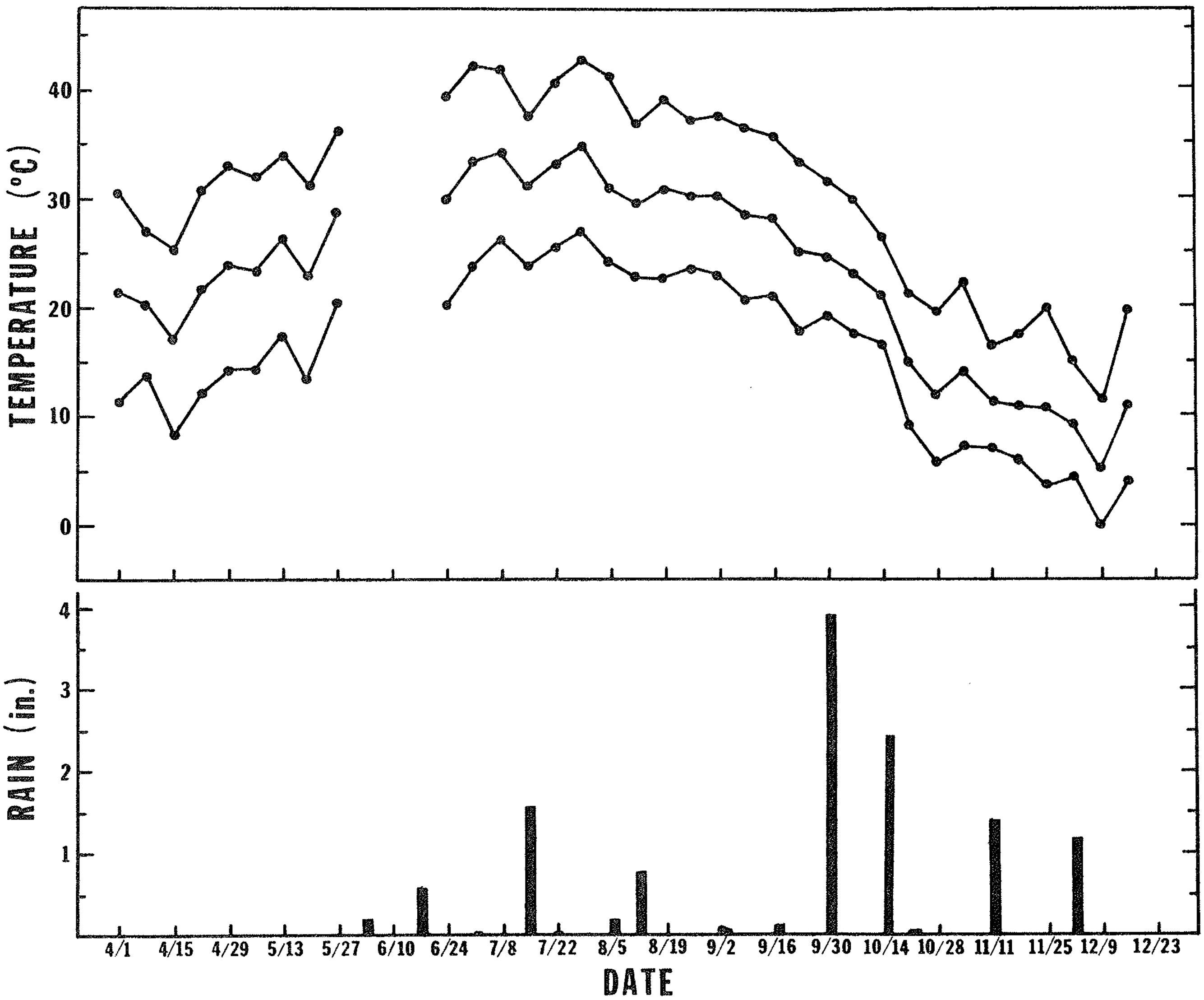

Figure 1. Weekly mean maximum, mean and mean minimum temperatures at 120 cm above the ground, and total weekly precipitation at the Cave Creek study site. Dates indicate the first day of the averaged weekly period. (DSCODES A3UPB06 and A3UPB07)

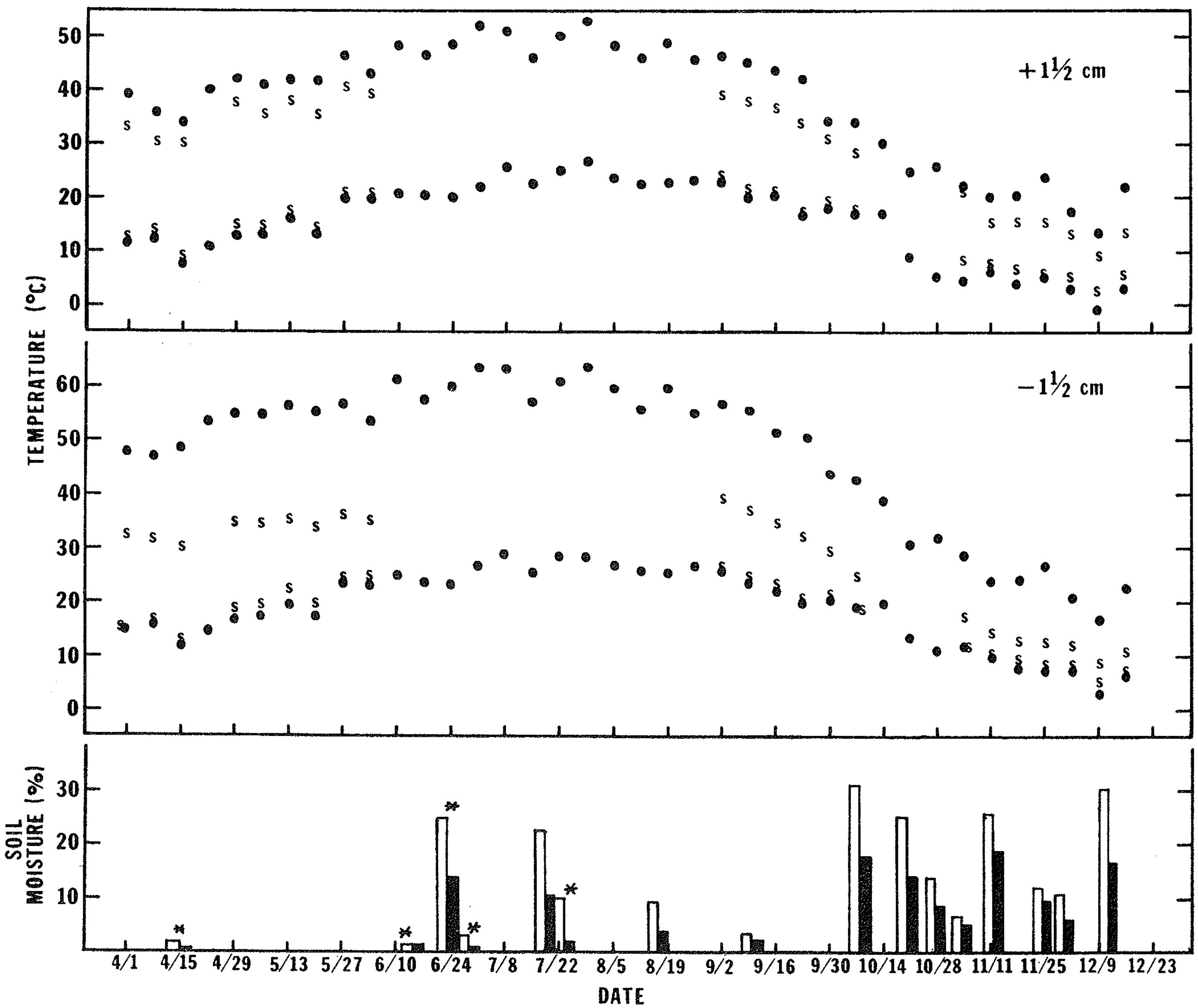

Figure 2. Weekly mean maximum and mean minimum temperatures at 1.5 cm above the ground and 1.5 cm in the soil in the open (solid dots) and under the north side of *Cercidium* (s). Soil moisture (rock corrected) at 0 - 7.5 cm in the open and under *Cercidium* (dark bar) for the date indicated (*not corrected for rocks). (DSCODES A3UPB08, A3UPB10 and A3UPB11)

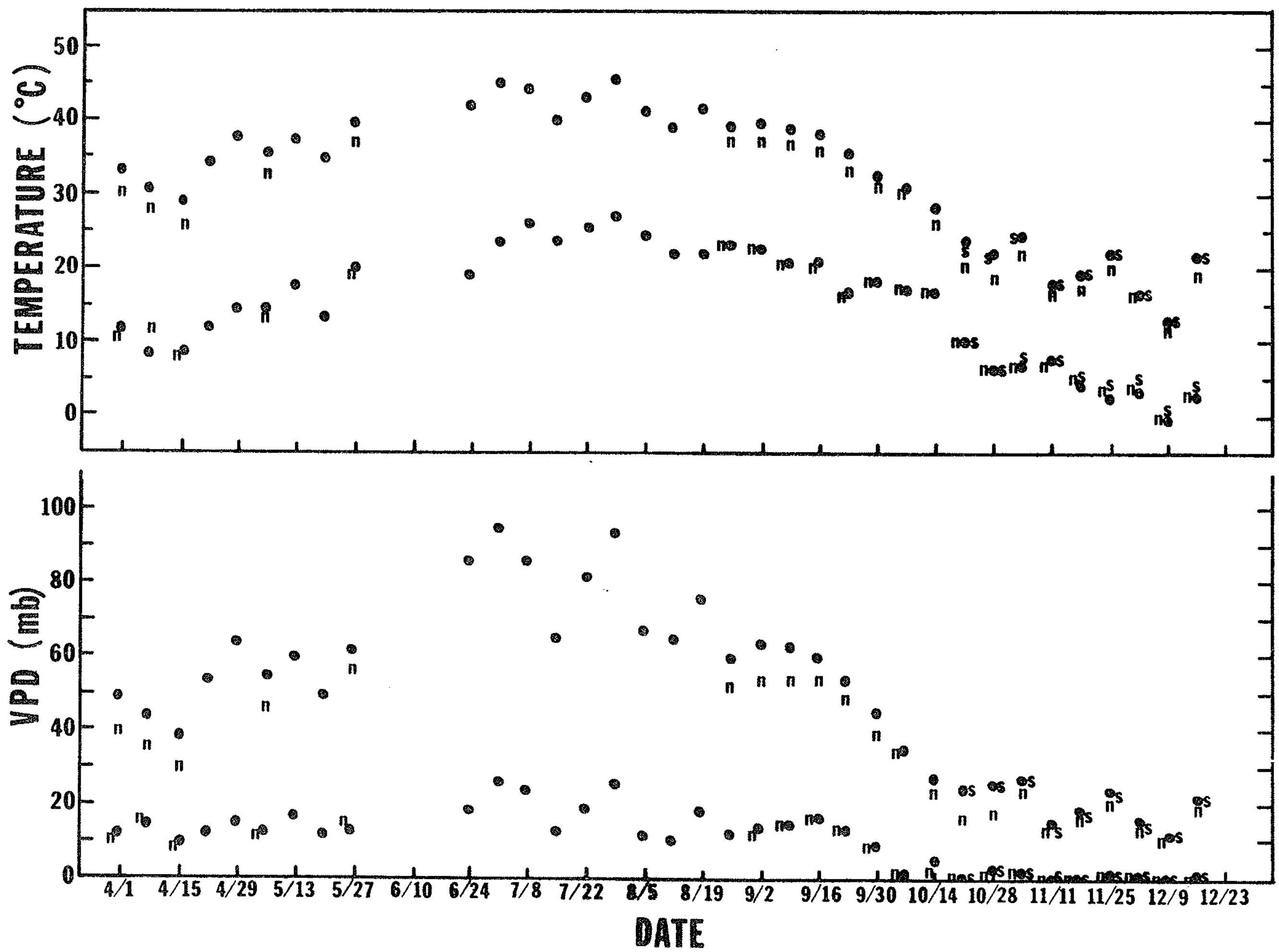

Figure 3. Weekly mean maximum and mean minimum temperatures and mean maximum VPD's at 15 cm in the open (dot), and under the north (n) and south side (s) of canopies of *Cercidium*. (DSCODE A3UPB07)

Biomass

In 1972 there was no annual plant development until following the early October rains. Figure 4 (A) shows biomass accumulation of the annual plants in the open and under the influence of various shrub species. This Figure presents only totals and does not break the totals down into biomass quantities under various aspects of the shrub canopy. Germination and measureable annual plant biomass development occurred first under *Cercidium*, followed by growth under *Larrea, Franseria* and out in the open. The second surge in growth was probably due to additional moisture input from later rains followed by clear sunny days. The difference in biomass accumulation between under the shrubs and in the open is great even at an early stage of annual plant development. The amount per unit area is nearly four times greater under *Cercidium* than in the open.

Totaling biomass does not indicate the significance of various aspects under the shrub canopy. Figure 4 (B) shows that the edge of the southside of the canopy of *Cercidium* is very similar to totals in the open shown in Figure 4 (A). On the other hand, biomass accumulation of annuals under the southside of the canopy near the base of the tree is as high as any of the northside canopy figures (Fig. 4 (B)). Position under the shrub thus appears to be important for maximum annual plant growth and development.

Phenological stages of the characteristic annual species are being followed but in most cases germination and vegetative growth is all that has been recorded. A few individuals of a few species show signs of beginning to flower.

The following is a list of the identified annual plant species at the Cave Creek study site following the fall, 1972, rains:

Bowlesia incana
Parietaria floridana
Draba cuneifolia
Eucrypta chrysanthemifolia
Lotus salsuginosus
Lotus tomentellus
Astragalus nuttallianus
Poa bigelovii
Pectis papposa
Pectis prostrata
Erodium cicutarium
Sisymbrium irio
Pterostegia drymarioides
Lotus humistratus
Calandrinia ciliata
Tillaea erecta
Erodium texanum
Schismus barbatus
Sonchus sp.
Thelypodium sp.
Plantago spp.
Amsinckia spp.
Spermolepis echinata
Plagiobothrys spp.
Filago sp.
Lepidium sp.
Descurainia sp.

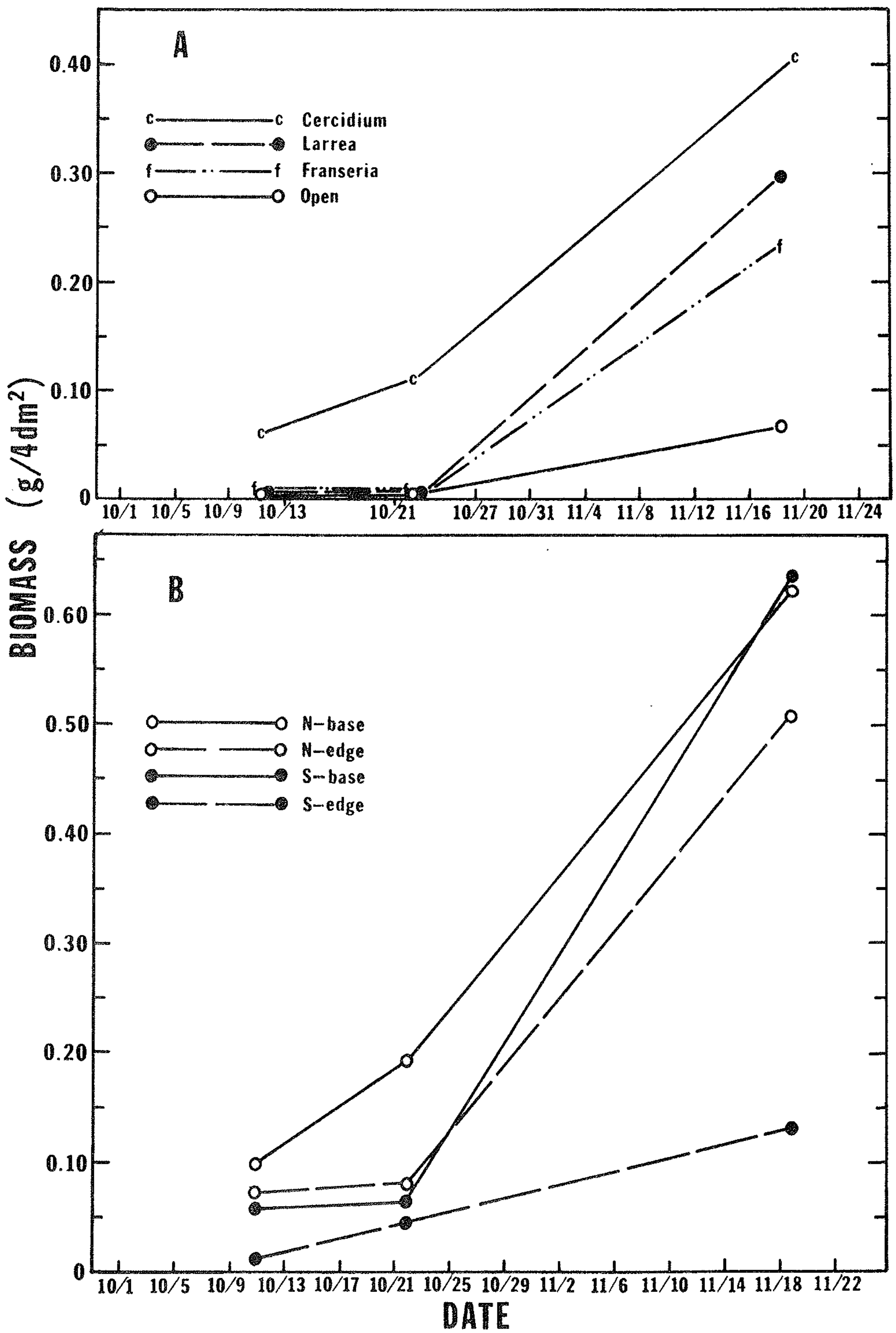

Figure 4. A. Total annual plant biomass (dry weight) in the open and under *Cercidium, Franseria* and *Larrea* in relation to time. (DSCODE A3UPB13)

B. Total annual plant biomass under the north and south canopies of *Cercidium* near the canopy edge and near the base of the tree, in relation to time. (DSCODE A3UPB13)

DISCUSSION

Many factors influence the germination and growth of desert annual plants. Probably the most important are moisture and temperature or the combination of these two. No annuals developed in the study site in July when the moisture was non-limiting. Extremely high ground temperatures or the lack of seeds from heat-requiring species probably accounted for this. However, the rains that occurred in October brought on the development of many annual plants; some are considered to be summer annuals. October soil temperatures were not as high as July but they were hot. Soil moisture was maintained longer in October and high soil temperatures did not last as long. These could be factors permitting annual plant seed germination and growth.

Once conditions were generally right for development of annuals in all areas, they were optimum in certain areas under the shrubs. That these areas under the shrubs produced more annual plants and biomass than in the open is probably due to microenvironment but it may also be due to a greater seed reserve under the shrubs; a product of greater annual plant survival in these areas.

EXPECTATIONS

The production of biomass of desert annuals in late 1972 is only the beginning of the potential biomass accumulation that should occur into 1973. Continuation of monitoring of the macro- and microenvironment will indicate what factors most influence the biomass accumulation and developmental stages of the annuals. Factors which will be looked at more closely will be VPD and low temperatures (frost damage).

In late 1972, the annual species were beginning to be identifiable. When certain identification is possible, biomass accumulation will be separated as to species and totalled. In the winter and spring of 1973 as annual plants flower and begin to die, microenvironment will be followed very closely to determine the conditions influencing each stage of each species.

With the development of enough plant volume to permit measureable gas exchange, CO_2 exchange analyses will be made on clumps of annuals in the field in different locations (shrubs, open, etc.). The measurements will be compared with the actual biomass accumulation data to enable estimates of productivity rates.

Phenological studies of annuals will be continued in 1973 until all the plants have set seed and died.

Laboratory analyses of germination requirements of annuals will be made after an adequate seed reserve is collected. Germination tests will also be made using the desert soil after the annuals at the study site have completed seed development and dispersal.

A comparison of the various microenvironmental regimes where annuals germinate, grow and flower with the relative biomass accumulation rates of the species and CO_2 exchange rates, should give a composite picture of the environmental spectra in which productivity is possible for each annual plant species and the annual plants as a whole.

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