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REPRODUCTIVE AND VEGETATIVE GROWTH PATTERNS IN *YUCCA ELATA* ENGELM. (LILIACEAE)

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ABSTRACT. Biomass allocated to reproductive structures in *Yucca elata* was compared to net leaf growth over a three year period (1971–1973) on two sites in southern New Mexico. Reproductive effort in *Y. elata* is dependent on the pattern of precipitational inputs, with significant inputs in the spring and previous winter having the greatest effect. Vegetative growth is curtailed during periods of reproductive growth, probably due to the large amount of energy allocated to reproductive structures. Thus, intervening periods of good vegetative growth may be necessary before a high energy cost inflorescence stalk can be produced. Cattle were found to have a major grazing impact on inflorescence stalks of smaller plants.

Soaptree yucca (*Yucca elata* Engelm.) is a succulent perennial occurring on the mesas, small arroyos and playa edges of the Chihuahuan desert (Kearney and Peebles 1969). It occurs singly or in pure stands, with the most vigorous stands occurring in well drained soil with a deep caliche layer (Cannon 1911). The distribution of *Y. elata* also appears to be influenced by livestock disturbance (Wallmo 1955).

Yucca elata varies from 1 to 9 m in height, and is one of the few arborescents of the Chihuahuan desert (Kearney and Peebles 1969). It has the xerophytic adaptation of water storage in its above ground and subterranean caudex (Robison 1961). It also has narrow leaves forming a rosette that may resist excessive transpiration loss. The inflorescence is long exserted, 1.5 to 4 m in length, and is an open panicle (McKelvey 1947).

McCleary and Wagner (1973) and Arnott (1962) found as high as 96% germination in *Y. elata* seeds. However, reproduction by seed has been found to be limited in southern New Mexico due to rare seedling esablishment (Campbell and Keller 1932). Although they conclude

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that *Y. elata* reproduces almost entirely by vegetative means, they observed high sexual reproductive effort in favorable years. One of the purposes of this study was to quantify reproductive effort in *Y. elata*. Furthermore, our observations indicate that *Y. elata* exhibits little or no vegetative growth during periods of sexual reproduction. This indicates the possibility of cyclic patterns in reproductive growth with intervening periods of vegetative growth. Another purpose of this study was to examine reproductive and vegetative growth patterns of *Y. elata* in relation to precipitation patterns.

STUDY AREA. This study was conducted from 1971 to 1973 at two sites on the New Mexico State University College Ranch adjacent to the USDA Jornada Experimental Range in southern New Mexico. One site is a 25 ha alluvial fan (bajada) area at the base of the Doña Ana Mountains. On this site, *Y. elata* has an estimated average density of 123 individuals / ha, with most of them occurring in the numerous small arroyos dissecting the site (Whitford and Ludwig 1973). The small arroyos have well drained, course sandy soil with a deep caliche layer. Creosotebush, *Larrea divaricata* Cav., is the most abundant perennial plant on the entire site.

The second site in a 36 ha ephemeral lake (playa) area approximately 2 km north of the bajada site. *Yucca elata* only occurs around the 23 ha fringe of the 13 ha playa bottom, with an estimated average density of 152 individuals / ha of fringe (Whitford and Ludwig 1973). Mesquite, *Prosopis glandulosa* Torr., is the most abundant large perennial on the playa fringes. The soils are sandy loam to clay loam in texture. The playa bottom receives runoff from the surrounding fringes, usually flooding in late summer or early fall due to localized convective storms.

METHODS. Leaf production was monitored from 1971 to 1973 on 8 and 10 randomly chosen *Y. elata* plants on the playa fringe site and bajada site, respectively. For each plant, number and total length of new leaves were measured once a month. Off-site harvest and regression analysis were used to obtain oven-dry leaf biomass as a function of leaf length. A second-order polynomial equation was found to have a good fit ($r^2 = 0.99$), based on criteria suggested by Draper and Smith (1966). The equation and its fit to the observed data, along with the 95% confidence limits, are shown in Fig. 1.

Several times during the potential reproductive season, observations were made to find the percentage of *Y. elata* plants producing an inflorescence stalk. If present, the length of each stalk and basal diameter were recorded. Off-site harvests were made to obtain regression equations for predicting inflorescence biomass (oven dry) given inflorescence height and basal diameter. A second-order polynomial equation was again found to have a good fit ($r^2 = .93$). This equation and its fit to the observed data, along with the 95% confidence limits are shown in Fig. 2. Observations on fruit production and fruit harvests were made later in the reproductive season to determine biomass of the fruits and seeds. The biomass data were converted to energy units using "Oxygen Bomb" calorimetry techniques.

RESULTS AND DISCUSSION. Biomass fluctuations of *Y. elata* reproductive structures are compared to new leaf growth and precipitation inputs on each site in Fig. 3; reproductive data are given in Table 1. In the dry year of 1971, only two plants on each site produced an inflorescence stalk, with no fruit set. In 1972, stalks began appearing in early April on the bajada and mid-April on the playa. Nighttime minimums in air temperature are lower on the playa site due to it being a basin for cold air drainage off the surrounding higher elevations.

On the playa in 1972, 58% of the *Y. elata* stalks were destroyed by cattle from the New Mexico State University College Ranch (Table

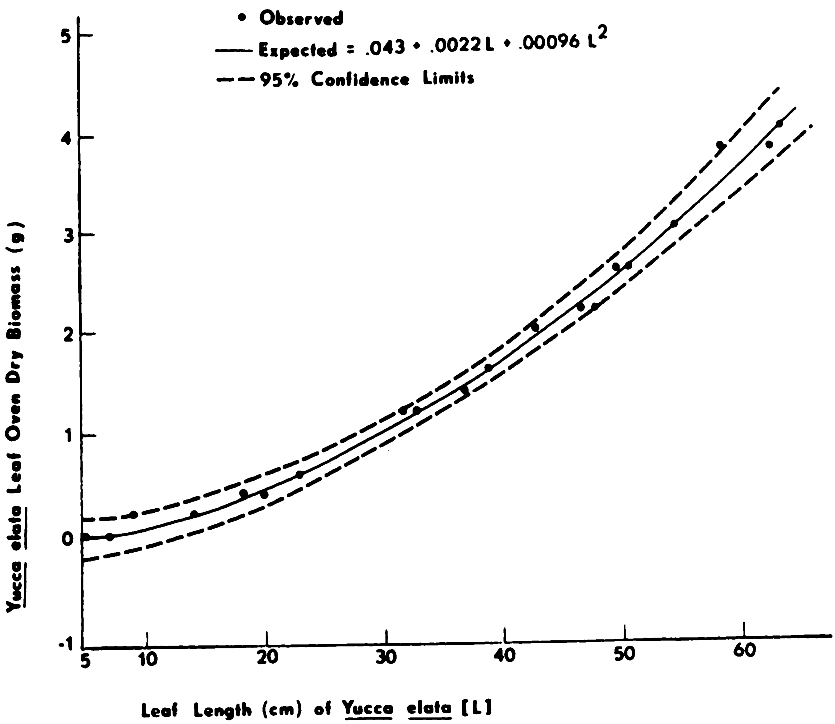

Fig. 1. Regression analysis to estimate oven dry leaf biomass from leaf length. A second-order polynomial equation has a good fit to the observed data as indicated by the 95% confidence limits.

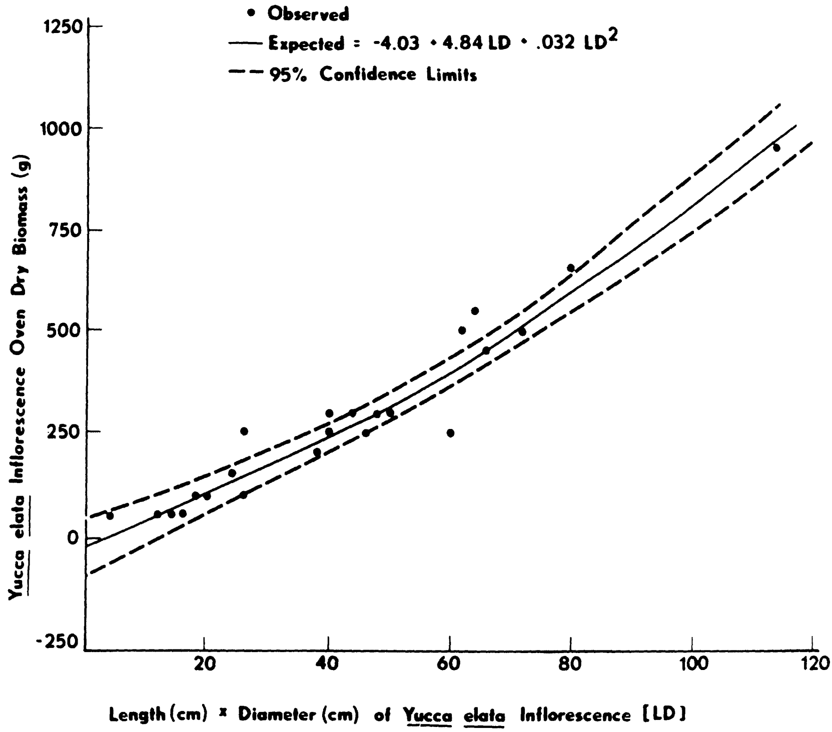

Fig. 2. Regression analysis to estimate oven dry inflorescence biomass from inflorescence stalk length and basal diameter. A second-order polynomial equation has a good fit to the observed data as indicated by the 95 % confidence limits.

1). The cattle primarily graze the playa bottom, which is covered with vine-mesquite grass, *Panicum obtusum* H. B. K. However, in 1972 they entered the fringe areas of the playa to eat the young inflorescence stalks of *Y. elata*, which they relish in dry periods (Benson and Darrow 1944). Herbel and Nelson (1966) have shown that in periods of extreme drought *Y. elata* constitutes up to 70% of the diet of cattle on the Jornada Experimental Range. On the playa, fruit data biomass was unreliable due to continued grazing on the fruits throughout the summer. One bull entered the bajada site and consumed 75% of the stalks (Table 1).

In 1973, stalks emerged in the first week of May on the bajada and in late May on the playa. The month delay in 1973 over 1972 was probably due to a wetter, cooler winter and spring in 1973. Both sites were protected from cattle in 1973. On the bajada about 67% of the plants produced inflorescences, with about 84% of these forming an

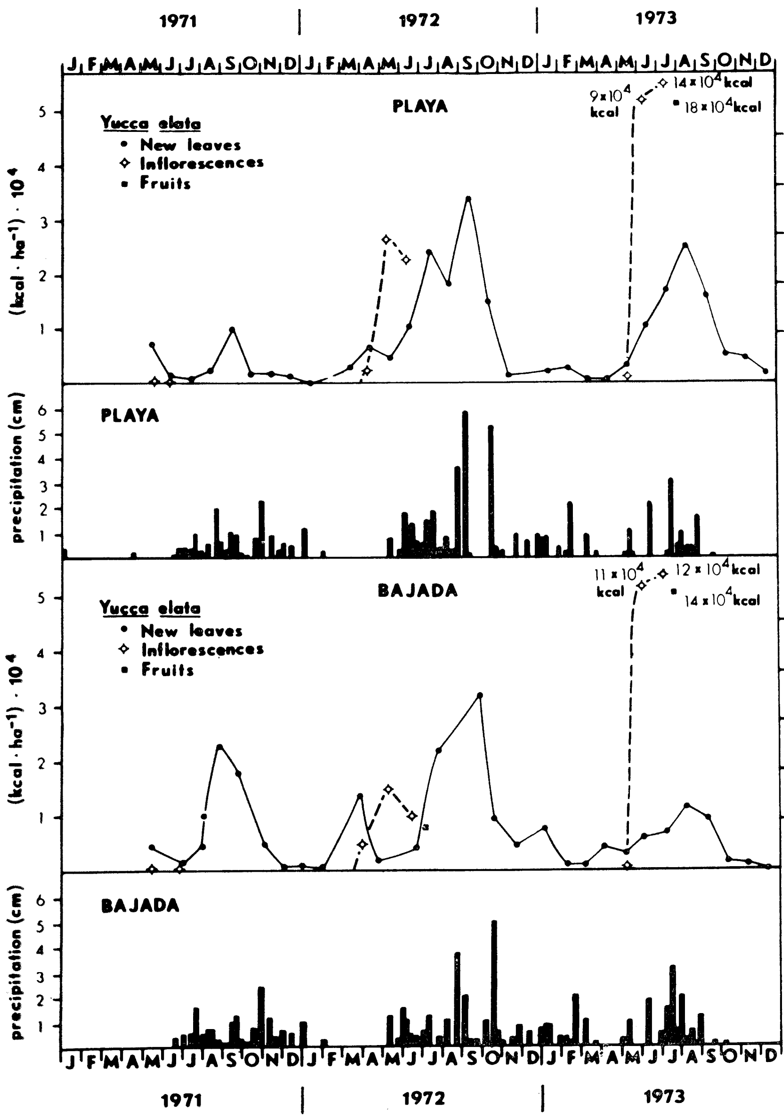

Fig. 3. Reproductive and vegetative growth patterns of *Yucca elata* compared to precipitation patterns on the playa and bajada sites.

average of 13 fruits (Table 1). The playa site had fewer plants producing inflorescences (41%), but 90% of these produced an average of 25 fruits per stalk.

One hundred fruits were harvested at maturity in late August 1973

TABLE 1

Reproduction growth data for Y. elata *in 1971, 1972 and 1973 on two sites in the Chihuahuan desert of southern New Mexico.*

	% Plants with stalks		% Stalks Fruiting		Mean Fruits per stalk	
Date	Playa	Bajada	Playa	Bajada	Playa	Bajada
71 Jul 01	.1	.1	0	0	0	0
72 Apr 15	19	52	0	0	0	0
May 01	8*	13*	0	0	0	0
June 01	†	†	‡	90	‡	27
73 May 01	8	12	0	0	0	0
Jun 01	30	66	0	0	0	0
Jul 01	41	67	90	84	25	13
Aug 01	†	†	†	†	17	9

* Reduction due to cattle destruction

‡ Cattle destruction too severe to give reliable estimates

† Fruit survey only

and yielded 10 g of seed per fruit, which is about 350 seeds. The biomass of each fruit is about 60% seed. On many plants the weight of the fruit causes the stalk to bend down so that with partial dehiscence most of the seeds fall to the ground. Fruits collected in October showed that 15% of the seeds were still present in the fruits.

The pattern of precipitation appears to have the greatest effect on reproductive effort and vegetative growth in *Y. elata*. When little or no rainfall occurred before the spring of 1971, there was less than 100 Kcal of inflorescence per hectare produced (Fig. 3). Under these dry conditions, new leaves were not produced until the summer rains. In contrast, when the spring of 1972 was preceded by good moisture conditions the previous fall, there were about 30,000 and 20,000 Kcal of inflorescence per hectare produced on the playa and bajada, respectively. With summer rains in 1972, about 35,000 Kcal of new leaves per hectare were produced on each site. Also as shown in 1972, during the spring reproductive period new leaf production was reduced, since only those plants without an inflorescence stalk produced new leaves. In fact, during the three years of this study no new leaf growth was observed on an individual plant during the period in which energy was being allocated to reproductive structures. No plant was observed to produce an inflorescence stalk two years in succession. A *Y. elata* individual may have a year of primarily reproductive growth followed by one or more years of strictly vegetative growth. After a moist fall in 1972 and a moist winter and spring in 1973, *Y elata*'s reproductive effort was about 140,000 and 120,000 Kcal of inflorescence per hectare for the playa and bajada respectively. Thus, the greatest spring reproductive effort occurred when all the previous seasons were moist and vegetative growth was good the previous summer and fall.

The timing of precipitation is probably less critical for *Y. elata* than for other life forms in the desert, since it is a succulent and can store water in its large root and caudex. Water storage could be an important adaptation for *Y. elata* in the Chihuahuan Desert, since if it can store water before the spring season, which is normally low in precipitation (Houghton 1972), then the plant will flower normally. Shrubs, such as *Larrea*, cannot store large amounts of water and must wait for significant precipitation inputs before flowering (Ludwig and Whitford 1975).

Herbivore stress had a marked effect on the reproductive structures in 1972, but this probably has little influence on the population as a whole due to the high amount of asexual reproduction in the species (Campbell and Keller 1932). *Yucca elata*'s survival pattern appears to be the establishment of seedlings in rare very favorable years with asexual reproduction in other years. This survival pattern has also been hypothesized for *Agave lecheguilla* Torr. (Freeman 1973). Most of the damage done by cattle was to young plants that did not have an above ground caudex of significant height, since most of the *Y. elata*'s with tall caudices have inflorescence stalks unavailable to cattle. A possible long range effect of cattle grazing could be an increase in the number of large clonal individuals.

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