Phenology of some herbaceous and woody species in central, semiarid argentina

(with 9 figures)

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Abstract. Phenological stages of several grasses, shrubs, trees or herbaceous dicots are described at a site typical of rangelands in the Monte Phytogeographical Province. High soil water levels determined an extension of tillering during summer in the autumn-winter-spring perennial grasses, and during late-spring and summer in the spring-summer perennial grasses. This cautions about strictly classifying these grasses as either cool-or warm-season species. Stem elongation, flowering, fructification and/or seed dispersal in several perennial grasses, and the boot stage, flowering and/or the reproductive stage of development in some woody species occurred earlier in drier than wetter springs. However, reproductive phenological phases in other perennial grass and woody species were either advanced or extended later into the season as years become wetter. During wet summers, sprouting can extend even until early autumn in the woody species. The temporal plasticity in the phenology of the grass, herbaceous dicots or woody species suggests that they are well adapted to the great intra- and interannual variation in rainfall which can occur in the studied region.

Key words: phenology, semiarid Argentina, annual and perennial grasses, annual herbaceous dicots, shrubs and trees.

Running title: Phenology of herbaceous and woody species.

Resumen. Se describen los estadios fenológicos de especies de gramíneas, arbustos, árboles o dicotiledóneas herbáceas en un sitio típico de pastizales naturales en la Provincia Fitogeográfica del Monte. Altos niveles de agua en el suelo determinaron una extensión del macollaje durante el verano en las gramíneas perennes otoño-inverno-primaverales, y durante fines de primavera y verano en las gramíneas perennes estivales. Esto nos alerta a clasificar estrictamente estas especies como otoño-inverno-primaverales o estivales. La elongación de tallos, floración, fructificación y/o dispersión de semillas en varias especies de gramíneas perennes, y los estadios de botón floral, floración y/o reproductivo en algunas especies de leñosas ocurrieron antes en las primaveras más secas que en las más húmedas. Sin embargo, las fases fenológicas reproductivas en otras especies de gramínes perennes y leñosas se adelantaron o extendieron más tarde en la estación cuando los años fueron más húmedos. Durante los veranos húmedos, el rebrote de las especies de leñosas puede extenderse aún hasta principios del otoño. La plasticidad temporal en la fenología de las especies de gramíneas, dicotiledóneas herbáceas o leñosas sugiere que éstas especies están bien adaptadas a la gran variación intra e interanual de la lluvia en la región estudiada.

Palabras claves: fenología, región semiárida de Argentina, gramíneas anuales y perennes, dicotiledóneas herbáceas anuales, arbustos y árboles.

Título abreviado: Fenología de especies herbáceas y leñosas.

Knowledge of when a certain plant species will reach a specific developmental stage can assist range managers in timing their management practices, and vegetation scientists in choosing the optimal time for sampling in different regions. Phenology, for example, is essential to determine the appropiate time for grazing as to minimize negative herbivory effects on desirable components of rangeland vegetation (9). Comparative phenological development has received some attention in herbaceous and woody species in the Southern Caldenal, a Phytogeographic Region of about 40000 km^2 in central, semiarid Argentina (20, 13, 37, 14). However, these studies have only provided some general information on the phenology of these species or been limited to a few species.

Rangelands in the Monte Phytogeographical Province, south of the Southern Caldenal, cover about 528000 km^2 in central Argentina and experience low and highly variable rainfall (long term range 100-400 mm per year) (41). Since precipitation can be a critical factor in plant phenology in arid and semiarid areas (5), species commonly found in these rangelands will have reproductive strategies that enable them to survive these conditions. It is also important to determine the extent of temporal plasticity in the phenology of the studied species because it might contribute to explain their persistence in the community. This descriptive paper therefore focuses on providing a more detailed analysis or additional information of phenological events in several herbaceous and woody species at the Monte Phytogeographical Region.

MATERIALS & METHODS

Area description

The study was conducted at a site typical of rangelands at the Monte Phytogeographical Province, Pcia. Bs. As., Argentina. The study site (40° 39'S, 62° 54'W; 40 m a.s.l.) was 22 km away from Carmen de Patagones.

The general climate, vegetation and soil characteristics of the region have been reported by Cabrera (11), De Fina (18) and Parodi (41). The climate is temperate semiarid, mean annual temperature is 14.6 °C, and mean monthly temperatures of the coldest (July) and warmest (January) months varie between 3-12 °C and 19-27 °C, respectively. Absolute minimum and maximum temperatures have varied between -5 to -17 °C and 35 to 46 °C. The mean relative humidity is 60%. Winds have an annual mean of 13 km h^{-1}. Long-term average rainfall is 331 mm/year (28). Annual rainfall is concentrated during spring and fall. Air temperature, water vapor tension, and rainfall were provided by a meteorological station located at the study site during 1983-1986 (Fig. 1). Evapotranspiration was calculated following Papadakis (40). Mean annual water deficit varies between 400 to 800 mm.

The community is characterized by an open shrubby stratum which includes herbaceous species of different value for cattle production. Cattle grazing on natural vegetation is the most important economic activity in the region (11). In this study, annual or perennial grass and forbs species of the herbaceous layer were categorized into desirable (highly preferred), intermediate (grazed when desirable species are not available) or undesirable (only accepted when a better forage species is not available) on the basis of their acceptability by cattle. Woody species were classified as either evergreen or deciduous.

Grass, forb and woody species selected for the study are common to rangelands in the Monte Phytogeographical Province. Dominance of any of these species groups in a particular area, however, would be determined at least in part by fire and grazing history as has been recently described by Distel & Bóo (21) in their state-and-transition model of vegetation dynamics. Under exclosure or light grazing conditions, *Stipa clarazii* Ball.* and *Poa ligularis* Nees ex Steud. are an example of dominant, C3 desirable perennial grass species in the community; both species are highly competitive in the absence of grazing and thought to be part of the pristine vegetation (13, 36). At sites where moderate grazing has been continuous, however, these species have been replaced by other C3 desirable perennial grasses, mainly *Stipa tenuis* Phil. and *Piptochaetium napostaense* (Speg.) Hack (21). Other common perennial grasses in the region include the desirable C3 *Bromus brevis* Nees, *Stipa neaei* Nees ex Steud. and *S. papposa* Nees, and C4 *Pappophorum subbulbosum* Arechav. and *Sporobolus cryptandrus* (Torr.) A. Gray. The intermediate C3 *S. speciosa* Trin. & Rupr. and *Melica bonariensis* Parodi, and C4 *Aristida pallens* Cav., *A. spegazzinii* Arechav. and *A. trachyantha* Henrard are also present. If exposed to heavy, continuous grazing, desirable perennial grasses have been replaced by undesirable perennial grasses like the C3 *S. trichotoma* Nees

*Even though *S. clarazii* and *S. longiglumis* Phil. have been cited sometimes as synonymous, Torres (52) has advised use of *S. clarazii* instead of *S. longiglumis* until further studies confirm if these are either different or the same species. Except in original references, only *S. clarazii* will thus be used throughout this manuscript.

(21). Continuous lack of fire or low fire frequency, heavy grazing, availability of shrub propagules and conditions favouring shrub seedling establishment have determined that sites previously dominated by desirable perennial grasses are now converted to a shrubland. Under these conditions, desirable grasses have been replaced by annual grass (*Bromus mollis* L.) or forb species (*Medicago minima* (L.) Grufberg and *Erodium cicutarium* (L.) L'Her. ex Aiton)(24, 21). At this stage of ecosystem degradation, dominant components of the woody layer are deciduous tree species [e.g., *Geoffroea decorticans* (Gill. ex Hook. & Arn.) Burkart]; evergreen, perennial shrubs [e.g., *Brachyclados lycioides* Don, *Condalia microphylla* Cav., *Chuquiraga erinacea* D. Don, *Larrea divaricata* Cav. and *Schinus fasciculatus* (Griseb.) Johnston], and deciduous, perennial shrubs [e.g., *Lycium chilense* Miers, *Prosopidastrum globosum* (Gill. ex Hook. & Arn.) Burkart and *Prosopis alpataco* Phil.] (21).

Regional topography is typically a plain. Soil texture varies from loamy and loam-sandy to loam-clay-sandy. Several physical and chemical characteristics at the study site have been reported by Giorgetti et al. (28).

Phenological observations

Phenological determinations were made on the grass, forb and woody species listed in Figs. 2 to 9. Observations were performed every 7-40 days from May 1983 to May 1986. They were taken within exclosures (15 ha) more than one-year-old to domestic herbivory at both sites, following the phenological keys reported by Distel & Peláez (20). At each sampling time, careful annotation was made of all existing phenological stages within each species by walking through the exclosures. Variability in the occurrence of any given phenological stage among years will only be reported after comparison of similar sampling dates in these years.

RESULTS AND DISCUSSION

Perennial grasses

With the exception of *Pappophorum subbulbosum*, *Sporobolus cryptandrus* and *Aristida* species, perennial grasses listed in Figs. 2 to 5 have usually been classified as been autumn-winter-spring species because of vegetating during these seasons (13). *Pappophorum subbulbosum*, *S. cryptandrus* and the *Aristida* species have often been categorized as spring-summer species because they remain vegetative during these periods (13). However, high rainfall values during December 1984-January 1985 (354 mm, Fig. 1) or February and March 1984 (280 mm, Fig. 1) may have contributed to the extension of tillering during summer in the autumn-winter-spring species or towards the end of spring, summer and even autumn in the spring-summer perennial grasses, respectively (Figs. 2-5). A similar extension of tillering during summer was observed by Distel & Peláez (20) in *P. napostaense*, *S. tenuis* and *P. subbulbosum*, and Dalmasso (17) in *Pappophorum* *caespitosum.* Tillering was not observed during January and the first half of February in *S. papposa* in 1986; rainfall during this period was < 15% of that during the same period in 1984 and 1985 (Fig. 1). In accordance with this observation, Bertiller et al. (7) reported that phenological development was interrupted and the reproductive period did not start or failed shortly after initiation in *P. ligularis, S. speciosa* and *S. tenuis* when water content in the upper soil was depleted in late spring and summer in an arid ecosystem of the southern portion of the Monte Phytogeographical Province. The extent of tillering on an annual basis in these grasses may thus be highly tighted to rainfall. Dickinson & Dood (19) cautioned about classifying species as strictly cool- or warm-season since some species exhibit characteristics of both groups. Pulses of activity synchronic with water inputs have also been reported for several grasses in plant communities of northern Patagonia (48, 6). Additional tillering during wet years could potentially add to the forage available to grazers. Olson & Richards (38) reported that in wet years or at sites with higher soil moisture availability into summer, the contribution of axillary tillers to late spring and summer production would have been considerably greater than what they observed in *Agropyron desertorum* (Fisch. ex Link) Schult.

Periods of flowering, fruit production, seed dispersal or dormancy in the perennial grasses are similar to the general patterns given by Aramayo et al. (3), Cano (13) and Distel &

Peláez (20) in these species. However, a drier period during April-June in 1985 (41.3 mm) than in 1984 (160.5 mm) and 1983 (127.7 mm) may have contributed to an advancement of the plant dormancy stage in *P. subbulbosum* in 1985 (Figs. 1-3). Dormancy appears to be a major mechanism for coping with seasonal drought and extended water deficits in mid-continental regions such as the North American Great Basin (30, 46). As such, it reduces exposed leaf surfaces to water loss and heat gain during periods of water deficits (10). Also, stem elongation in *P. napostaense* and *P. subbulbosum;* flowering in *S. papposa, S. speciosa* and *S. tenuis;* fructification in *P. subbulbosum, P. ligularis, S. clarazii, S. papposa* and *S. speciosa,* and seed dispersal in *A. pallens, M. bonariensis, P. subbulbosum, S. cryptandrus, S. clarazii, S. neaei, S. papposa, S. speciosa* and *S. trichotoma* occurred earlier in the drier springs of 1983 and/or 1985 compared to that in 1984 (Figs. 2-5). Rainfall was 104 mm in 1983, 160 mm in 1985 and 300 mm in 1984 between September and December (Fig. 1). Maintenance of high soil water potentials by irrigating throughout the growing season has also retarded phenological development by about 10 days in *Bromus tectorum* L. and *Poa sandbergii* Vasey (32). Knowledge of the advancement of these phenological stages during dry periods in these species is important for range managers who should adjust grazing management accordingly if natural reseeding wants to be favored.

Our results, however, disagree with those of Jones (31), who reported that water deficits tended to delay flowering in perennials. Adaptive shifts in the timing of flowering are well known to occur in annuals as a result of water stress conditions (47, 43, 4, 31, 49). For example, water stress accelerated the transition to flowering in *Bromus fasciculatus* C. Presl. (by 1-2 days) and in *Brachypodium distachyon* (L.) Beauv. (by 4-6 days), and diaspore maturation in these species (4), and advanced flowering by up to a week in *Triticum aestivum* cv. Gabo (2). Time to heading was also 3.5 days shorter on average under rainfed than under irrigated conditions in *Triticum aestivum* L. in a Mediterranean environment (53). Under terminal drought, other studies have shown a positive correlation between early heading and grain yield in *Pennisetum americanum* (L.) Leeke and *Hordeum vulgare* L. (8, 54). The ability of plants to alter the phenotypic expression of their genotype in response to the environment may enhance the individual plant's capacity to survive and reproduce (50).

Flowering in *M. bonariensis* and *S. trichotoma*, on the other hand, was advanced as the spring became wetter in 1984 in comparison to that drier in 1983 or 1985 (Figs. 4 and 5). Gibbens (27) found that inflorescence exsertion in *Sporobolus flexuosus* (Thurb.) Rydb. was delayed by about 2 months partially as a result of 38 mm less rainfall at one of his research sites.

A wetter spring in 1984 also extended the periods for stem elongation in *P. subbulbosum*, *S. papposa* and *S. speciosa*, flowering in *A. pallens* and *S. papposa*, and fructification in *A. pallens* in comparison to the extent of these phenological phases in the drier 1983 and/or 1985 (Figs. 2-5). On the other hand, low rainfall between November and February in 1985/6 (76.3 mm) when compared to rainfall in the same period in 1984/5 (419.4 mm) and 1983/4 (259.9 mm) may have contributed to shorten the extent of seed dispersal in the drier period in *A. pallens*, *P. subbulbosum* and *P. ligularis* (Figs. 1-5).

Woody **species**

Similar to results of Cano (13) and Distel & Peláez (20), sprouting started by early to mid spring in the woody species shown in Figs. 6 to 9. Soriano (48) and Bertiller (6) reported that activity of deep-rooted woody species was triggered when temperatures began to increase in early spring by using the water stored in the deep soil during the precipitation period. During wet summers (December 1984-January 1985 and February-March 1984: Fig. 1), however, sprouting extended until the end of this season or even early autumn in the caducifolious (*Geoffroea decorticans*, *Lycium chilense*, *Prosopidastrum globosum*, *Prosopis alpataco*) or evergreen (*Brachyclados lycioides*, *Condalia microphylla*, *Chuquiraga erinacea*, *Larrea divaricata*, *Schinus fasciculatus*) species (Figs. 6-9). Timing for the vegetative stage of development may thus go well beyond limits given by Cano (13) and Distel & Peláez (20) for these species. Our results agree with those of Fisser (23) in *Artemisia tridentata* and Caldwell (12) in shrubs of the Great Basin where a longer leaf development period was obtained with increased soil moisture levels. Low precipitation amounts have suppressed vegetative activity in *Larrea tridentata* (Sesse & Moc. ex Dc.) Cov. (45), although temperature appears to be a major environmental variable controlling biological activity in this species when water is not limiting (15, 16). On the other hand, summer rains can trigger summer growth in this species in the Mojave Desert if precipitation is > 25 mm (5). This can be attributed to its lateral shallow roots in addition to its deep main root (33).

The sensitive response of lateral roots to small amounts of precipitation allows the plant to take advantage of increased moisture supply at the soil surface following precipitation. An additional active growth period in *L. tridentata* was observed in late fall (November and December) associated with an unusually warm and moist December (45). It appears that *Larrea* may have the genetic potential for multiple patterns of growth, depending on climatic conditions; shifts of growth activity towards early spring or late summer can depend on favourable temperatures and the timing of precipitation (16). A strong relationship between soil moisture and phenological events has also been reported for *Lycium andersonii* (1). Production of vegetative structures has been fostered by higher levels of water availability in the desert shrubs *Jatropha cinerea* (Ortega) Muell. Arg. and *J.*

cuneata Wiggins & Rollins (35). Leaf flushing of 49 woody species (either evergreen or semideciduous or fully deciduous) also commenced following the attainment of seasonal minima in pre-dawn leaf water potential (55).

The reproductive stage has been reported to occur during spring and/or summer in these species (20, 13, 3, 34). Cano (13) and Distel & Peláez (20), for example, confined flowering to December in other *Prosopis* species. In our study, the boot and flowering stages occurred during the previous 2 months in *P. alpataco* (Figs. 8 and 9). The reproductive stage for the species shown in Figs. 8 and 9 occurred thus at some additional times other than those given by Aramayo et al. (3), Cano (13) and Distel & Peláez (20). Drier conditions during early spring (September and October) in 1983 (58.5 mm) than in 1984 (137 mm) and/or 1985 (115.6 mm) may have contributed to advance the occurrence of the boot stage in *P. globosum*, the boot, flowering and reproductive phases of development in *L. chilense*, and the reproductive stage in *B. lycioides* (Figs. 1 and 6-9). These results are similar to those obtained by Caro et al. (14) in *Prosopis chilensis* (Mol.) Stuntz which advanced the boot developmental stage as the growing season became drier in semiarid Argentina. Production of flowers in the desert, spiny shrub *Fouquieria diguetti* (Tiegh.) I.M. Johnstone was greater during the dry season (35); these authors suggested that this species can optimize resource use through differentially translocating water for vegetative and sexual structures when it is available, and for sexual structures when it is not, thereby assigning energy to reproduction mechanisms. *Jatropha cinerea* and *J. cuneata* have interrupted flowering and fructification by a reduction in soil moisture in the desert scrub community in Mexico (35). This response has also been observed in trees and tall shrubs of the tropical semi-arid vegetation of Venezuela where the short rainy season seems to be responsible for the initiation and synchrony of flowering (29). Tropical trees of Costa Rica and *Tabebuia neochrysantha* A. Gentry, a deciduous forest species, have shown the same pattern (39, 44).

On the other hand, the fructification stage in spring was advanced in the wetter 1984 when compared to the drier 1983 in *S. fasciculatus* (Figs. 6 and 7). The desert tree *Bursera microphylla* A. Gray needed a soil moisture threshold to produce flowers, but it showed abundant flowering when high soil moisture was available (35). Aramayo et al. (3) reported the period for the earliest and lattest flowering dates during a 3-year-period in *G. decorticans*, *L. chilense* and *P. globosum* in semiarid Argentina. Although they recognized variability in the flowering date of these species among years, they did not relate this variability to climatic variables.

The beginning of autumn (March and April) was wetter in 1984 (155.5 mm) than in 1985 (93.3 mm) (Fig. 1). This may have contributed to extend the reproductive phase of development during this period in 1984 in *P. globosum* (Figs. 8 and 9).

Drier conditions during August and September in 1983 (22.5 mm) than in 1984 (75.8 mm) and 1985 (44.3 mm) may have contributed to extend the period of leaf fall in *C. microphylla* in the drier period (Figs. 1, 6 and 7). Leaf fall occurred in *L. divaricata* during at least May and June in 1983 and 1985 but it was not observed in these months in 1984 (Figs. 6 and 7); lower rainfall during this period in 1983 (59.2 mm) and 1985 (28.0 mm) than in 1984 (118.5 mm) may then contribute to explain this observation (Fig. 1). Leaf shedding occurred as soon as soil moisture decreased in *Fouquieria diguetti*, a desert perennial scrub community species (35). Williams et al. (55) also reported that leaf fall in 49 evergreen, semideciduous or fully deciduous woody species was coincident with the attainment of seasonal minima in leaf water potential.

Overall, phenological development in *Geoffroea decorticans* is similar to that reported by Mújica et al. (37) in an area with a long-term mean rainfall (583 mm) higher than that at our study site (455 mm). Sprouting in this species was initiated by the end of October in 1984 and 1985 (Figs. 8 and 9), a month when rainfall was similar in both years (Fig. 1). However, Mújica et al. (37) in *G. decorticans*, Distel & Peláez (20) in *Prosopis flexuosa* and *P. caldenia*, and Caro et al. (14) in *P. chilensis* reported that the beginning of sprouting in these species does not appear to be influenced by rainfall. This partially could be due to the deep and extensive root system found in these species (51, 22, 42, 14). *Condalia microphylla,* however, is a shrub with a relatively shallow root system (42), and it showed sprouting initiation by early August during 1983-1985 (Figs. 6 and 7). Rainfall during the previous month (July), however, had been 0.0 mm in 1983, 67.0 mm in 1984 and 112.5 mm in 1985 (Fig. 1).

Annual grass or dicots species

High rainfall during early 1984 and 1985 (> 210 mm in January and February: Fig. 1) contributed to the germination of *Medicago minima* and *Erodium cicutarium* at the beginning of March in both years (Figs. 8 and 9). Germination of these species occurred later in 1986 than in the two previous years very likely because of lower rainfall amounts during January-March of that year (Fig. 1). Fresnillo Fedorenko et al. (26) did not observe germination until early May in both species when rainfall during the period January-April was lower than 30 mm in central, semiarid Argentina. Germination regulation mechanisms of winter annuals thus restrict the germination of seeds to periods of comparatively abundant moisture coinciding with favourable temperature regimes (5). Previous to germination, seeds of these species are scarified by high daily temperature oscillations at the soil surface during summer, and freezing and thawing cycles during autumn at the study site (25).

Mid-spring (October-November) was wetter in 1984 (106.5 mm) and 1985 (90.6 mm) than in 1983 (61 mm) (Fig. 1); this may have contributed to the extension of the boot and flowering stages later in the season in the wetter years in *M. minima* (Figs. 8 and 9). Flowering was also observed during mid-spring in *M. minima* in an area with rainfall concentrated during autumn and spring during a yearly cycle, and an annual average rainfall of 574,9 mm (3).

Plant death in *M. minima* and *E. cicutarium* had not occurred by the end of November in 1984 and 1985. The earlier plant death reported for these species by Fresnillo Fedorenko et al. (26) could be attributed, at least in part, to the drier mid-spring in their study (30 mm rainfall in both October and November) than in ours (>90 mm rainfall in the same period). In annuals, the onset of plant senescence can be induced and accelerated by water stress resulting in a shorter growth cycle (4). Other than germination time and timing of plant death, the phenological development shown in Figs. 8 and 9 for *M. minima* and *E. cicutarium* is similar to that reported by Cano (13), Distel & Peláez (20) and Fresnillo Fedorenko et al. (26) in these species in the Southern Caldenal. Germination and seedling establishment in *Bromus mollis* started by early or mid-summer if this season is wet; this was observed for this species during the wet summers in 1984 and 1985 (Figs. 1, 8 and 9).

Bertiller et al. (6) demonstrated species-specific responses of plant phenology to soil moisture, small precipitation events, air temperature, and soil nutrient availability for main plant components of an arid ecosystem in north-eastern Patagonia. In our study, air temperatures were very similar among years during the studied period (Fig. 1) and rainfall appeared to be a major environmental factor affecting plant phenology. However, the interaction among several abiotic factors which can potentially exert some control on plant phenology (i.e., 7) may distinctly affect phenological development among years within each species. This could help to explain the interannual variation of phenological events on each of the studied species.

A species must be able to cope with extended periods of intra-seasonal drought (i.e., 28) to be successful in the environment of the Monte Phytogeographical Province. The temporal plasticity in the phenology of the perennial or annual grass, herbaceous dicots or woody species suggests that they are well adapted to this environment. This plasticity has been maintained when the phenology of some of these species has been reported for much drier regions in Argentina (mean annual precipitation: 175 mm: 7). Although the phenology of the studied species was compared for years with total annual rainfall similar to or above the long-term mean, it must be emphasized that both wetter and drier years are part of the normal, long-term weather pattern in the Monte Phytogeographical Province (28).

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Figure Legends

Fig. 1. (a) Absolute monthly maximum and minimum, and mean monthly air temperatures, and (b) monthly rainfall and mean monthly evapotranspiration at a meteorological station located at the study site during 1983-1986.

Fig. 2. Phenological stages in desirable perennial grasses at a site typical of rangelands in the Monte Phytogeographical Province in semiarid Argentina during 1983 and 1984. Phenological stages are: oooo seed, ▩ germination, ☐ sprouting for woody species, vegetative for grasses and forbs, ▨ stem elongation, ░ boot stage, ▥ flowering, ▧ fructification (incipient, green and/or mature fruits), ▤ seed dispersal/fruit fall, xxxx leaf fall/senescence, ■ dormancy. Sampling dates within each year are shown as vertical lines right above the month line in the abscissa. The number of phenological stages at any sampling date can be obtained in the Y axis by summing up the number of different shadings on that date. N.D.=Not Determined.

Fig. 3. Phenological stages in desirable perennial grasses at a site typical of rangelands in the Monte Phytogeographical Province in semiarid Argentina during 1985 and 1986. Meaning of shading for the different phenological stages are as in Figure 2. Sampling dates within each year are shown as vertical lines

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Fig. 4. Phenological stages on intermediate and undesirable perennial grasses at a site typical of rangelands in the Monte Phytogeographical Province in semiarid Argentina during 1983 and 1984. Meaning of shading for the different phenological stages are as in Figure 2. Sampling dates within each year are shown as vertical lines right above the month line in the abscissa. The number of phenological stages at any sampling date can be obtained in the Y axis by summing up the number of different shadings on that date. N.D.= Not determined.

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Fig. 6. Phenological stages on evergreen shrubs at a site

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Fig. 7. Phenological stages on evergreen shrubs at a site typical of rangelands in the Monte Phytogeographical Province in semiarid Argentina during 1985 and 1986. Meaning of shading for the different phenological stages are as in Figure 2. Sampling dates within each year are shown as vertical lines right above the month line in the abscissa. The number of phenological stages at any sampling date can be obtained in the Y axis by summing up the number of different shadings on that date. N.D.= Not determined.

Fig. 8. Phenological stages on deciduous shrubs or trees and desirable annual grasses or forbs at a site typical of rangelands in the Monte Phytogeographical Province in semiarid Argentina during 1983 and 1984. Meaning of shading for the different phenological stages are as in Figure 2. Sampling dates within each year are shown as vertical lines right above the

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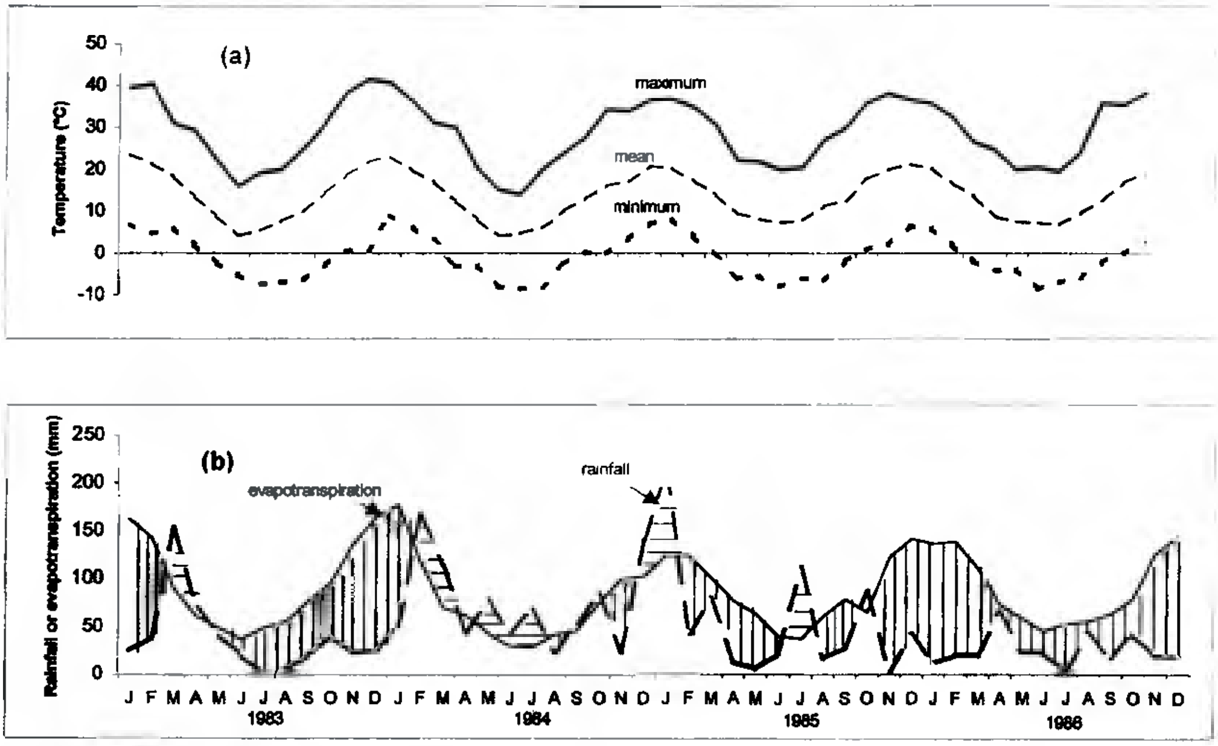

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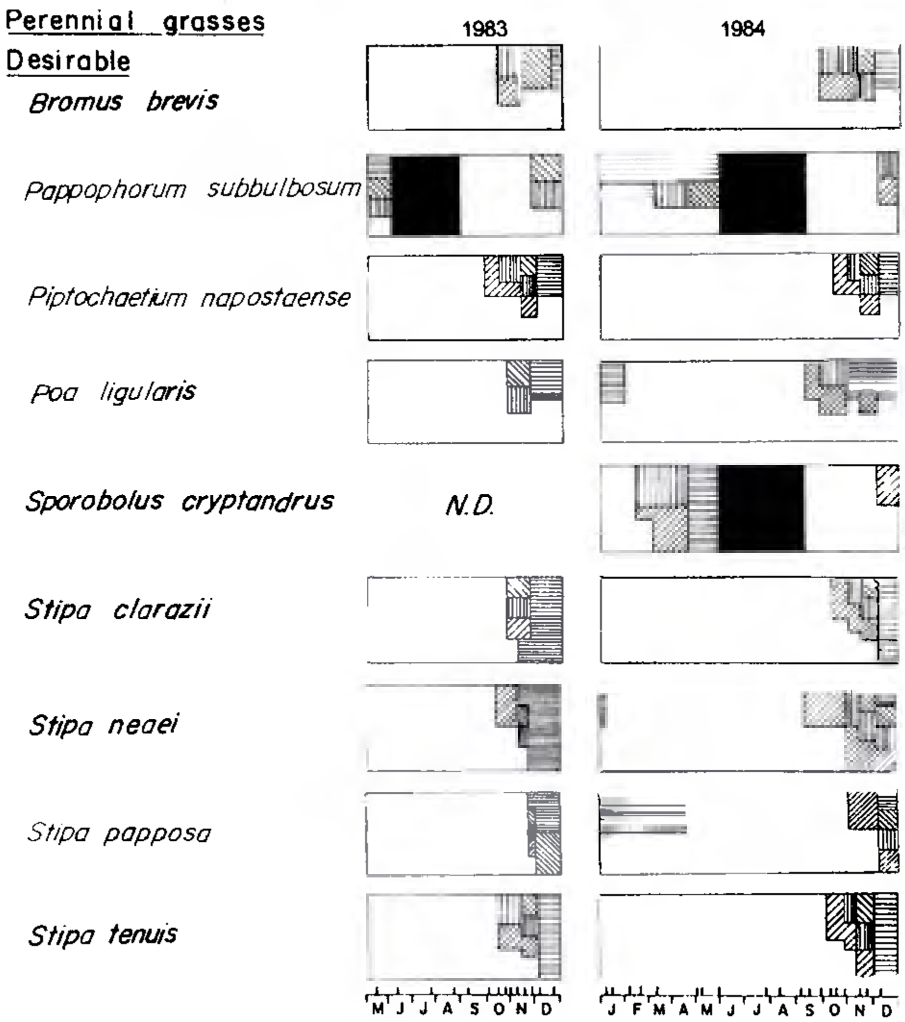

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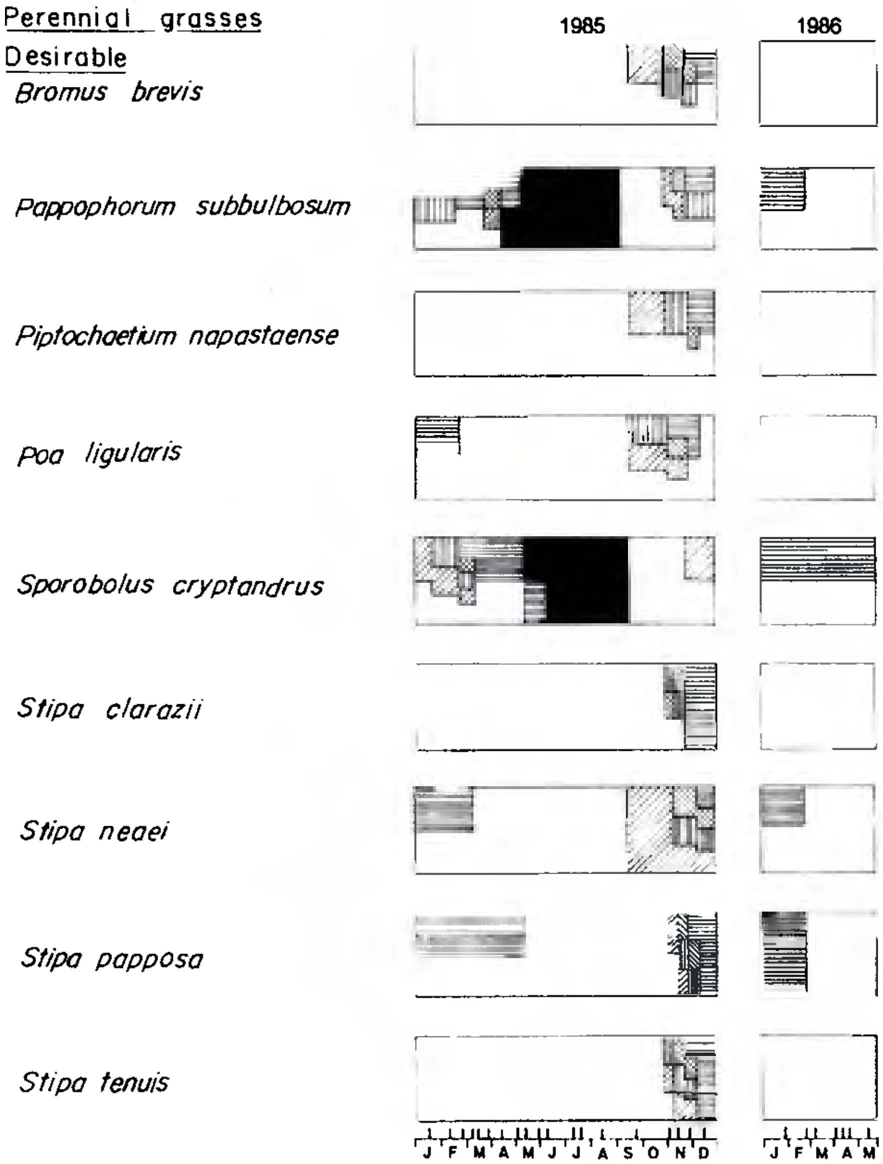

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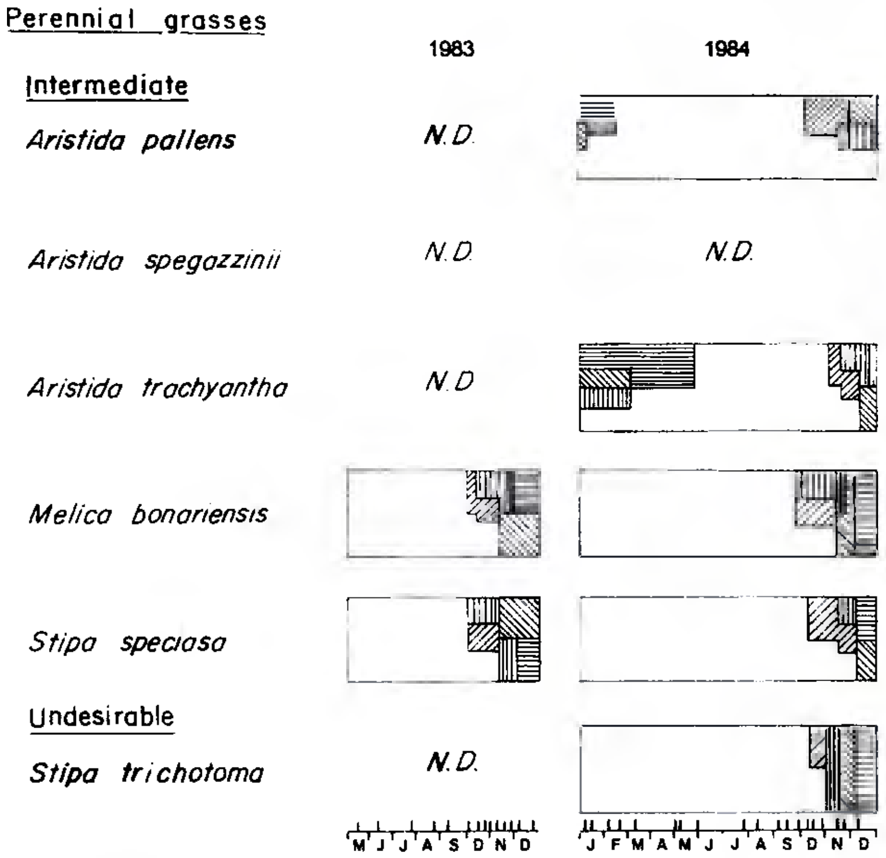

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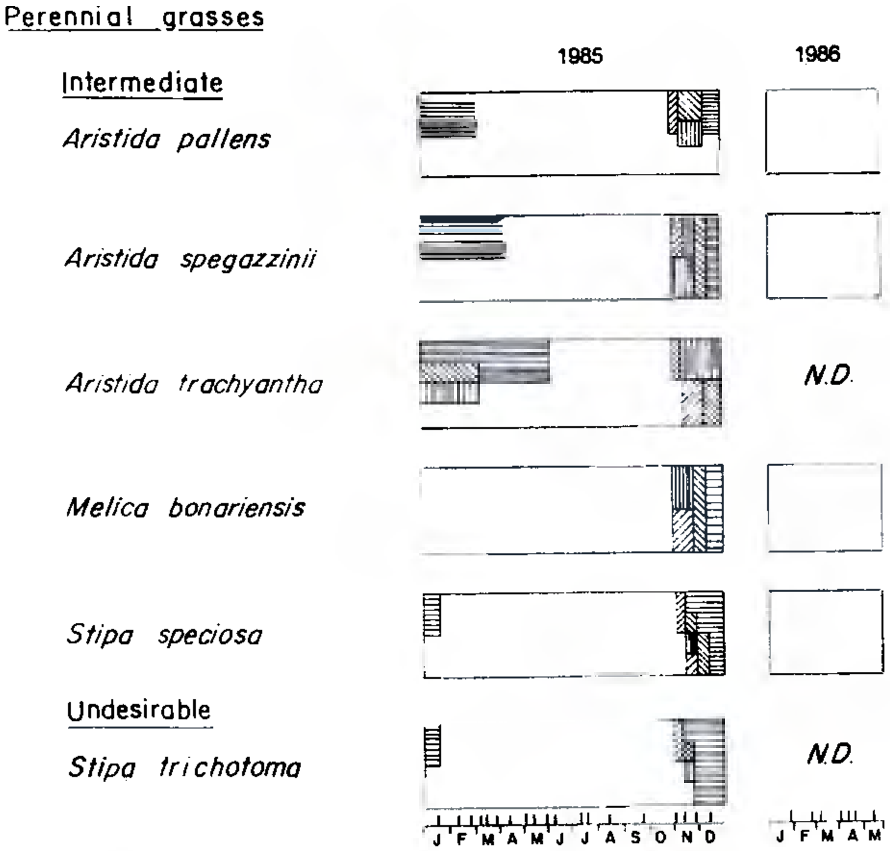

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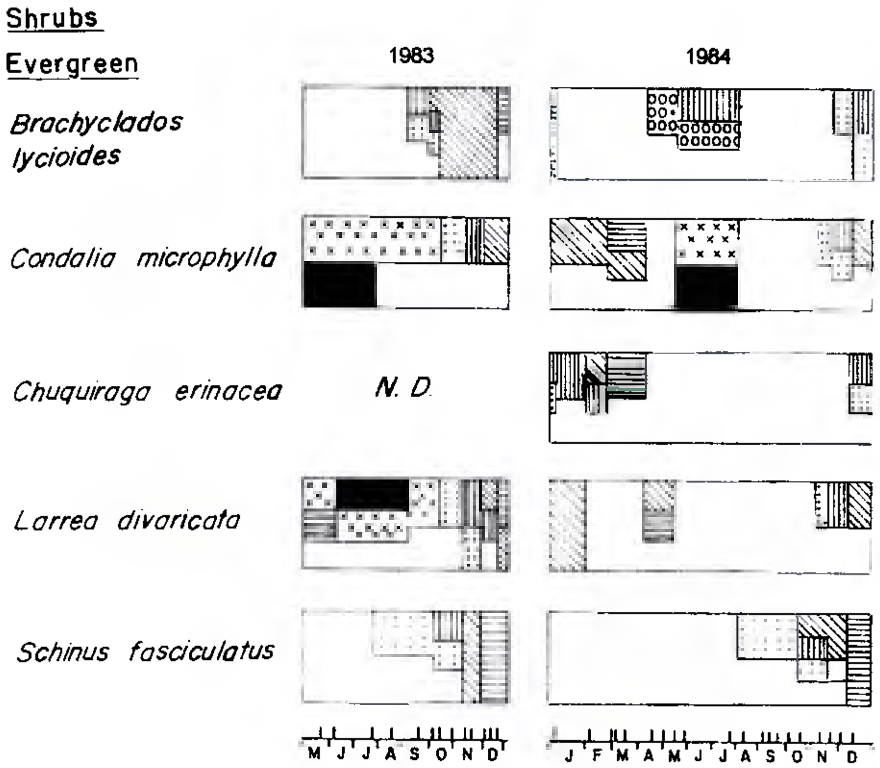

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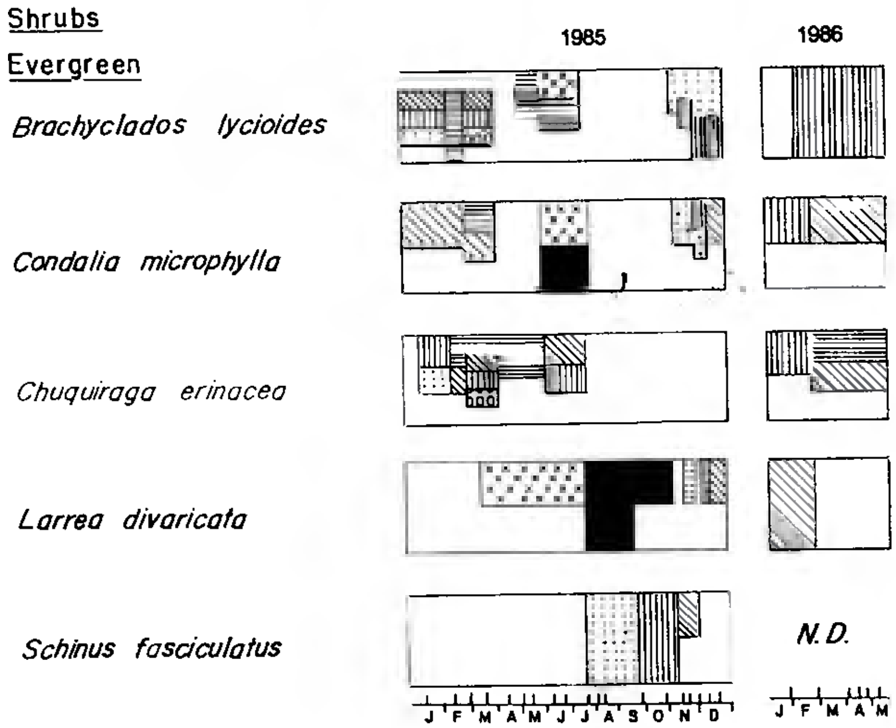

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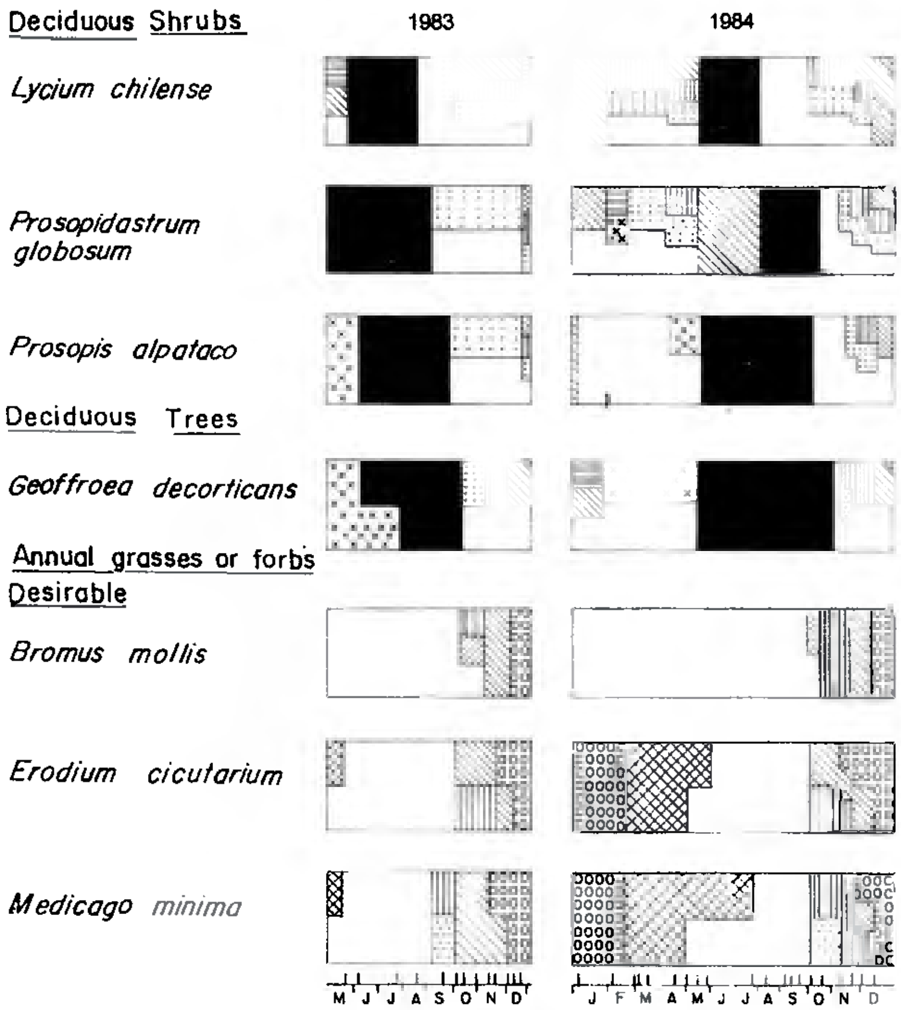

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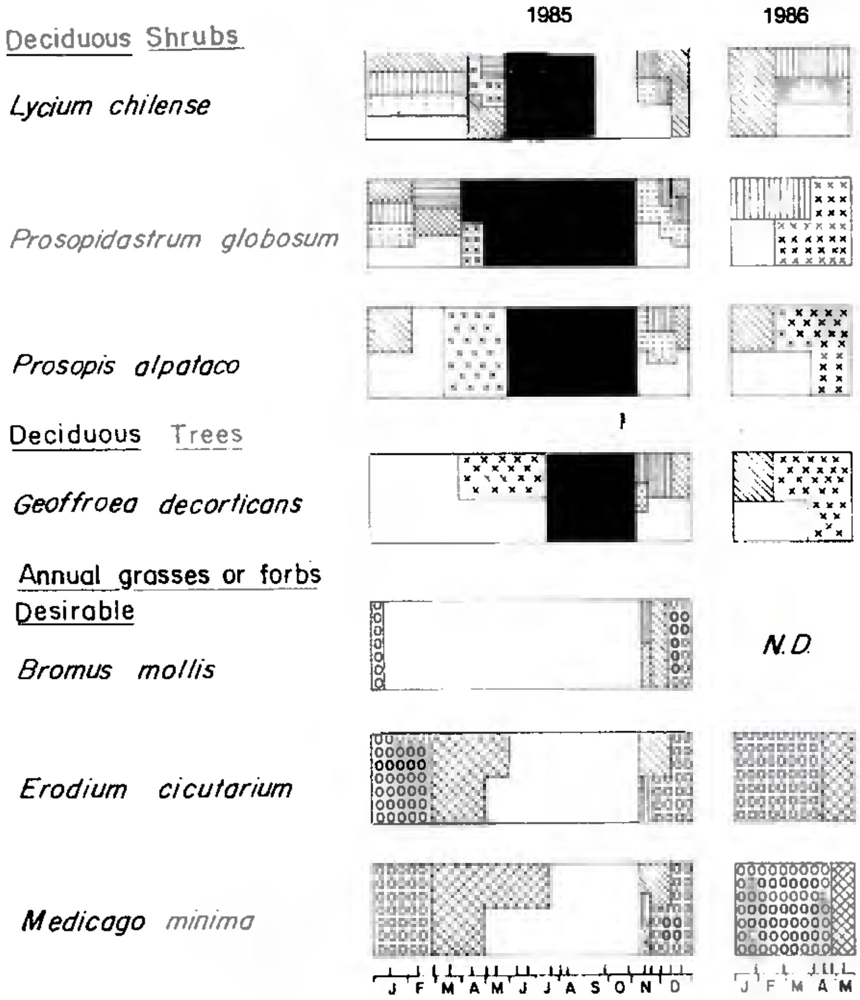

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