



Research Article

Phenological Record over Five Continuous Years of the Flora in the Ñacuñán Ecological Reserve, Department of Santa Rosa, Mendoza, Argentina

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Abstract

The phenology of the flora of the Ecological Reserve of Ñacuñán was recorded, located in the center of the Phytogeographical Province of Monte, in Santa Rosa, Mendoza. It has a semi-arid climate with an average rainfall of 310 mm/year, with a markedly summer distribution. The soil is sandy to sandy-loam. The objective was to determine a phenological pattern of growth and development stages that would include the largest number of species in the Monte community. After 54 years of closure, with monthly observations over five vegetative cycles (1979-1984), the stages of vegetative growth, flowering, fruiting, fruit maturation, or spiking were recorded for 106 species. On an observation trail, each species had a minimum of 10 observation specimens; when 50% showed signs of growth or development, the corresponding stage was recorded. There were 41 herbaceous species, including grasses. 36 of them are perennial grasses, 25 are woody, and 4 are succulent. 36.8% of the species manifest growth and development during the late spring, summer, and autumn months, coinciding with the concentration of rainfall.

Keywords

Phenology, Vegetative Growth, Flowering, Fruiting

1. Introduction

The vascular flora of the Ñacuñán Reserve was originally described by Roig, who identified 122 taxa, with dominance of *Larrea cuneifolia* shrublands and open woodlands of *Neluma flexuosa* [1]. Following the establishment of perimeter fencing in 1972, the area was excluded from grazing, allowing significant vegetation recovery. Subsequent evaluations after 25 years of exclusion reported no substantial increase in species richness, although several new taxa were detected in specific microhabitats. *Eleocharis macrostachya*, *Hordeum stenostachys*, *Melilotus albus*, *Avena barbata*, *Gnaphalium*

gaudichaudianum, *Lepidium spicatum*, *Glandularia flava* [2].

Plant phenology refers to the periodic production of vegetative and reproductive structures resulting from interactions between biotic and abiotic factors that regulate the timing of growth and reproduction [3]. It constitutes the study of recurring life-cycle events and their environmental controls [4]. Seasonal sequences can therefore be identified in relation to climate, vegetative dormancy, growth activity, flowering, and fruiting [5].

Climate change is currently altering phenological patterns

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worldwide; however, generalized models explaining rates and mechanisms of phenological shifts across spatial and temporal scales remain limited [6]. In eastern Mendoza, long-term meteorological records (1919–2004) indicate an average annual precipitation of approximately 310 mm, with only five years registering values below 150 mm. Although projections suggest potential increases in rainfall in the plains, no clear floristic shifts have yet been documented in the reserve [7]. For a meteorological record of 86 continuous years in Ñacuñán (Years 1919–2004), with an annual average of 310 mm/year, there were only 5 cases of average precipitation below 150 mm/year (Year 1923: 108 mm, Year 1924: 147.1, Year 1935: 134.5 mm, Year 1948: 116 mm and 2003: 90.8 mm) that is, a marked decrease in precipitation below the annual average, of close to 6% [8]. If we consider that rainfall in the plains is going to increase, some floristic changes may occur in the reserve, which are not currently observed.

Phenology is a fundamental component of the plant “regeneration niche” and plays a central role in species coexistence within plant communities [9]. Phenological knowledge contributes to ecological characterization, grazing management, agricultural decision-making, and understanding plant–animal interactions such as pollination and herbivory. Given the high interspecific variability and microhabitat influence on phenological expression, long-term systematic observations are essential. Having phenological knowledge of the vegetation contributes to characterizing plant species and their variations through ecotypes, improves decision-making for livestock management of fields, and in agriculture leads to detecting the different most appropriate stages of cultivation, the dynamics of faunal movements, identifying changes in vegetation in relation to climate modifications [10]. It is known that the incidence and intensity of vegetation flowering selectively modulates variables such as the abundance of fauna (pollinators and their predators), as well as intra- and interspecific competition of insects for pollen and nectar [11].

There is great phenological variability, which may be due to the particular responses of the species that make up the community and depending on how they are in certain microhabitats [12]. This forces us to select areas where it is possible to observe a certain number of specimens per species. In general, an ideal calendar that signals seasonal changes and plant development requires long-term observations of phenological events, along with concise microenvironmental measurement [13].

In the Eastern Plain of Mendoza, a bioclimatic map has been prepared based on foliar phenology using satellite images, differentiating the degrees of aridity of this region. The distribution of rainfall determines the geographical distribution of plant communities [14].

The objective of this study was to qualitatively evaluate the phenological behavior of the entire vascular flora of Ñacuñán over five consecutive years, identifying general patterns and species-specific dynamics.

Working hypothesis:

- 1) The plant community exhibits definable species-specific phenological patterns.
- 2) The tree stratum, particularly *Neltuma flexuosa*, displays phenological behavior partially independent of short-term precipitation variability.

2. Materials and Methods

2.1. Study Area

The Ñacuñán Biosphere Reserve is located in the Santa Rosa Department, Mendoza Province, Argentina (34°03'S; 67°58'W), at approximately 540 m a.s.l., covering 12,300 ha. Established in 1971 and incorporated into the UNESCO MAB Network in 1986, the reserve represents the Central Monte phytogeographic province (Figure 1). Its geographical coordinates are: 34°03'S and 67°58'W. It was created in 1971 and is representative of Monte Central. It emerged as a Forest Reserve and became part of the UNESCO MAB Network in 1986 and its main objective was to protect the carob forest and conserve the soil and the native plant and animal species in natural conditions [15].

It has a semi-arid climate with an average precipitation of 310 mm/year, with a markedly summer distribution [15]. Belonging to the Llanura de la Travesía, the soils are very deep, originating from recent sedimentary materials, with a sandy to sandy loam texture with variations in the different plant communities [16].

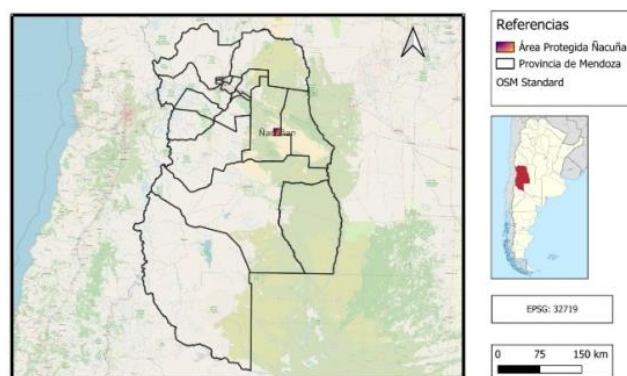


Figure 1. Location of the Ñacuñán Ecological Reserve, Santa Rosa Department, Mendoza, Argentina.

The observation of the phenological phases of the vascular flora was carried out with monthly visits to the Ñacuñán Reserve for five years (1979–1984), which were part of other research projects. To record the species, two circuits were created with a length of approximately 500 m: one in the South field of the Reserve and the other in the North field. This allowed, through a trail, the observation and recording of the species in a number of no less than 10 specimens of each one. As the observations were monthly, two stages were recorded:

1. Vegetative growth.

2. Reproductive phase, including flowering (or panicles in Poaceae), fruit development, maturation, and seed persistence.

The vegetative state is the active growth phase, while the reproductive phase includes flowering in broadleaf and woody plants or panicles of grasses, with the emission and opening of the flowers or anthesis of the grasses until their maturation and the permanence of the seeds in the inflorescences or panicles and spikes.

The frequency of observation did not allow establishing differences between the flowering, fruiting and fruit release phase, so a continuum of these stages was recorded.

When at least 50% of the specific specimens showed the expression of growth, flowering or fruiting, the beginning and end of the phenological stage was considered.

At all times, the measurement of species in different sites was avoided, such as depressions or under the tree canopy of carob and chanar trees, where they manifested a different phenology, either earlier or more persistent. For this reason, the evaluation was always located in the same site under the conditions of the jarillal community of *L. cuneifolia* and *L. divar-*

icata, with or without direct sunlight according to the requirements of the species. During the route of field N, a sector of dunes was included for psamphilous species.

Of the total Flora of Ñacuñán, the following species were not recorded:

Bromus catharticus, *Senna aphylla*, *Habranthus jamesonii*, *Rhodophiala mendocina*, *Polygala stenophylla*, *Parietaria debilis*, *Lycium chilense* var. *petiolatum*. Among the naturalized exotics: *Sonchus oleraceus*, *Salsola kali*, *Bassia scoparia*, they were excluded from the analysis due to their low presence or sporadic occurrence.

3. Results and Discussion

A total of 106 species and varieties were recorded: 41 annual herbaceous species, 36 perennial herbaceous species, 25 woody species, and 4 succulents. Annexes [Figure S1, Figure S2, Figure S3, Figure S4, Figure S5, Figure S6, Figure S7].

The precipitation of the place during the years of observation [8] is seen in Figure 2.

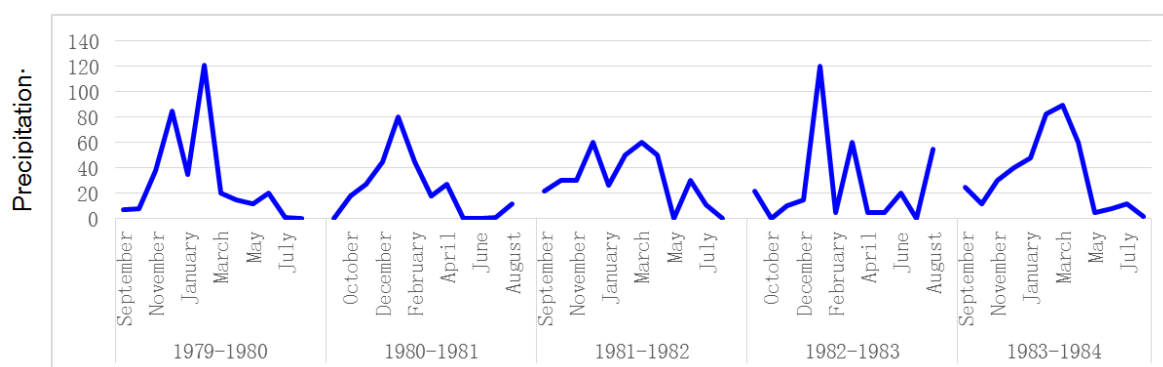


Figure 2. Precipitation record from the Ñacuñán Meteorological Station (ÑME) during the cycles 1979-80 (355.6 mm), 1980-81 (265.2 mm), 1981-82 (369.8 mm), 1982-83 (304.6 mm) and 1983-84 (410.0 mm).

Across the five-year period, 36.8% of species exhibited vegetative growth and reproductive activity from late spring through autumn, coinciding with the seasonal precipitation peak. Additional groups showed spring–summer (19.8%), summer–autumn (17.9%), or strictly summer (15.1%) phenological patterns (Figure 3).

Attempts to correlate phenophase onset with precipitation events were inconclusive due to spatial variability in rainfall distribution relative to the meteorological station.

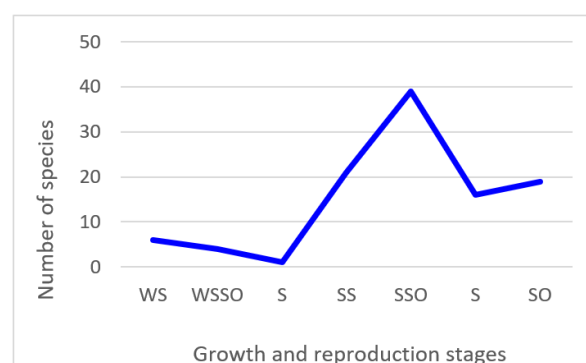


Figure 3. Manifestation of growth and reproduction of the Ñacuñán vegetation WS: winter-spring; WSSO: winter-spring-summer-autumn; S: spring; SS: spring-summer; SSO: spring-summer-autumn; S: summer and SO: summer-autumn.

Braun Rolando et al. carried out for three years a synthesis of phenological observations of some woody and herbaceous species, of the latter mainly grasses. The recorded species behaved like summer manifestations [26].

Neltuma flexuosa exhibited a remarkably stable phenological cycle. Leaf emergence typically began in mid-October, immediately followed by flowering. Fruit maturation occurred between January and February, with occasional persistence into March–April. Interannual variation in vegetative onset was limited to 1–3 weeks. This species behaves as a phreato-phytic or vadose-zone exploiting tree, accessing subsurface moisture retained in clay–sandy lenses. Its phenological cycle appears largely independent of short-term rainfall pulses [17, 18]. Leaf senescence contributes significantly to litter accumulation and nutrient cycling, improving soil nitrogen availability beneath the canopy and favoring the natural establishment of grasses and herbaceous plants [19].

When foliation begins, the specimens were always without leaves from the previous year, probably for temperature reasons. This differentiates it from the behavior observed in Chancani, Cordoba [20], where 40% of the trees still have a remnant of foliation. A plant may possess more than one phenological state at a given time, depending on the timing of its reproductive activity [21]. Specimens of *N. flexuosa* were also observed in incipient flowering stages when others were in advanced fruiting.

It is known that in our country, the probability of obtaining a greater quantity of fruits increases the drier and warmer the environment is at the time of flowering. Furthermore, the species behaves like a “vecera” with years of high and low production. Sometimes the occurrence of hail in the area leads to great loss of fruits [22].

Annual herbs responded rapidly to winter–spring rainfall and maintained reproductive activity through summer depending on moisture availability, while for forest vegetation, maximum flowering and fruiting occurs during the dry period [23, 24].

Atriplex lampa begins early flowering in the month of September and concentrates ripening in the month of December. It may show vegetative growth during summer and fall, sometimes also some growth in early winter.

Atamisquea emarginata, an evergreen species, shows periods of growth and reproduction in spring, summer and autumn, with foliar loss during the winter.

Evergreen species such as *Larrea divaricata* and *L. cuneifolia* showed a vegetative and productive behavior similar to a piedmont in the Luján de Cuyo department, with lower precipitation levels, of 220 mm/year [25].

Among herbaceous perennials, *Sphaeralcea miniata* manifests itself with reproductive phenology during the spring, summer and autumn seasons; no fruiting was observed during the winter period. Another observer recorded winter behavior for *S. miniata* when precipitation conditions are favorable [26]. During the five years of observation, only a brief vegetative manifestation was recorded in the month of June.

Winters are generally dry, this makes species like *Panicum urvilleanum* behave like spring–summer–autumn. However, this species in Payunia, Malargüe, grows at any time of the year when it has moisture, with a preference for gleanings in spring–summer (personal obs.). Something similar happens with *Lycium* spp. that grows, flowers and bears fruit all year round if they have moisture [27, 28].

If there is precipitation in spring and summer, almost all of the grasses are available.

The presence of *Salsola Kali* has advanced in recent years on disturbed land, edges and centers of roads and footprints, with ingressions on the margins of the jarilla communities.

Perennial grasses (mostly C4 species) responded speedily to spring–summer precipitation. Certain species (e.g., *Nassella tenuis*) exhibited marked interannual population fluctuations. Introduced species such as *Eragrostis lehmanniana* and *Bromus catharticus* showed opportunistic behavior linked to wetter years.

Bromus catharticus was recorded as present in rainy years and in dry periods it is not observed, so it is deduced that it behaves as a falsely perennial.

Eragrostis lehmanniana, introduced in the Reserve, manifests itself in years with average rainfall, however, in dry seasons it is not observed, remaining in the seed bank that is expressed when precipitation conditions improve.

Winter-active species such as *Schismus barbatus* (exotic naturalized) were consistently present despite limited winter rainfall.

All succulent species displayed a single annual reproductive period, peaking during summer.

We worked with almost all the plant species present. This allowed us to understand the phenological spectrum over the 5 years of observation. Based on these measurements, future research will require working with a smaller number of species considered valuable, preferably with phenological records in relation to rainfall.

In previous observations in the Monte province, the phenological manifestation of *N. flexuosa* has been discussed as independent of rainfall. Carob trees normally complete their phenological stages, even during periods when the upper soil layers are very dehydrated [29]. It was found that the records over the 5 years show that the delay in the onset of vegetative growth only varied by 1 to 3 weeks between years.

4. Conclusions

The majority of species concentrate vegetative and reproductive activity between late spring and autumn, coinciding with the seasonal precipitation regime.

Annual herbaceous species respond rapidly to rainfall pulses and maintain extended reproductive phases during favorable summers.

Climbing perennial herbs exhibit growth in response to rainfall pulses, primarily during the summer.

Perennial grasses (predominantly C4) depend strongly on

spring–summer precipitation. C3 plants, such as *Jarava ichu*, show early spring growth [30].

Shrubs initiate growth early in spring, even under low rainfall conditions. They exhibit different behaviors; for example, *Atriplex lampa*, with scarce spring rainfall, vegetates and fruits in November and December of each year, releasing bracts, and by January, the plants do not yet have seeds.

Neltuma flexuosa demonstrates a relatively stable phenological cycle with limited interannual variation, largely independent of short-term rainfall fluctuations, begins to grow in October, and flowering and fruiting extend, with variations between individuals, until February sometimes reaching early March.

Bulnesia retama and *Geoffroea decorticans* respond to spring and summer rainfall.

The five-year continuous dataset provides a comprehensive phenological spectrum for the Monte ecosystem and establishes a baseline for future quantitative studies examining rainfall–phenology relationships under climate change scenarios.

Abbreviations

IADIZA	Argentine Institute for Arid Zone Research
CONICET	National Council for Scientific and Technical Research, Argentina
UNCUYO	National University of Cuyo
ÑME	Ñacuñán Meteorological Station
WS	Winter- Spring
WSSO	Winter- Spring- Summer- Autumn
S	Spring
SS	Spring- Summer
SSO	Spring- Summer- Autumn
S	Summer
SO	Summer- Autumn

Supplementary Material

The supplementary material can be accessed at <https://doi.org/10.11648/j.ijnrem.20261101.17>

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Author Contributions

Antonio Daniel Dalmasso: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflicts of interest.

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