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Acacia mearnsii De Wild. (Fabaceae) reproductive biology II: flowering and fructification phenology

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ABSTRACT - Acacia mearnsii *flowering and fructification were evaluated in trees in an Provenance and Progeny Test and on a commercial plantation in 2001 and 2002. The activity index demonstrated the existence of synchrony in flower bud formation both in the Provenance and Progeny Test (92.8% in 2001 and 70% in 2002) and on the commercial plantation (97% in 2002). Flower opening was synchronized in the Provenance and Progeny Test (85.6% in 2001 and 66% in 2002) and on the commercial plantation (78% in 2002). Fruit formation was synchronic as well and occurred shortly after the peak of flower opening. The development and maturation of the fruits lasted 12 months and was followed by seed dispersion. Morisita´s index confirmed the seasonality of the phenological events.*

Key words: phenophases, seeds, *Acacia mearnsii.*

INTRODUCTION

Black wattle (*Acacia mearnsii* De Wild) is a tree species native to southeastern Australia that has been cultivated in Rio Grande do Sul since the beginning of the last century, when the first plantations were established from imported seeds. It is a species with a great industrial potential for products such as timber, charcoal, pulp for kraft paper, posts, and tannin.

The *Acacia mearnsii* reproductive structure consists of inflorescences on branches with about 50 yellow-colored flowers with a strong smell that is appealing to flower visitors. There are hermaphrodite flowers or functionally male flowers on the inflorescences where the female organ is reduced or absent (Grant et al. 1994). The hermaphrodite flowers show protogyny and the female phase lasts 24 hours. After the stigma loses receptivity, there is a sequence of a three to five-day-long male phase (Moncur et al. 1989). The hermaphrodite structure consists of a stigma with a simple ovary containing about 14 ovules and bilobate anthers that open length-wise in the anthesis period thus releasing the polyad which contains 16 pollen grains (Kenrick and Knox 1989, Grant et al. 1994).

Acacia mearnsii fruits are of the legume type, glabrous and dark in color. A small number of seeds was detected in the legumes, normally five to seven, with low germination vigor and seed defects that lead to seedling abnormalities, such as albinism and etiolation. This may indicate genetic restriction in the population under study, so that a genetic breeding program should be developed for *Acacia mearnsii* De Wild. In this context the strategies for forest species reproduction should contain information on the reproductive biology, including the reproductive phenology (El-Kassaby 2000). Phenophase analysis linked to the reproductive cycle of forest species is an

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indispensable tool in plant breeding, because synchrony in flowering is an important factor for the control of crosses of selected trees.

The phenology of the *Acacia* genus was studied by Milton and Moll (1982), who observed species endemic to Australia (*Acacia cyclops*, *Acacia melanoxylon*, *Acacia longifolia* and *Acacia saligna*) and *Acacia mearnsii* De Wild., introduced into South Africa. This study provided information that enabled the management of these species in the Cape region, where they are considered invader species. Tandon et al. (2001) studied the pollination biology and reproductive system of *Acacia senegal,* a species native to Africa and introduced into North Eastern India, and looked into the phenology and flowering biology. The authors observed the appearance of flower buds, the flowering time, fruit development, maturation and dehiscence, as well as seed dispersion over a three-year period (1994 to 1996).

The objective of the present study was to analyze the flowering phenophases, fructification period and seed dispersal of *Acacia mearnsii* trees through an indicator index of the synchrony of the phenophases associated to a seasonality parameter of the observed events.

MATERIAL AND METHODS

The study was carried out within a Provenance and Progeny Test and on a commercial plantation of the company AGROSETA S.A. on the Fazenda Menezes (lat 30° 7' 12" S, long 51° 57' 45'' W), Butiá county, Rio Grande do Sul State, Brazil. In the study period, the mean temperature was 24.1 °C (2001) and 23.8 °C (2002) in January and 14.0 °C and in 2002, 12.4 °C in July 2001 (Figure 1).

In 2001, 306 trees were studied in the Provenance and Progeny Test. From 2001 to 2002, 11% of this population died, so that 276 trees were assessed. In 2002, 32 trees from the commercial plantation were selected for analysis, sampling the trees at a distance of 50m.

The assessments were carried out on clear days without rain, at 30-day intervals in the stage between flowerings; after the appearance of the first flower buds, the observation interval was reduced to 15 days. The flowering phases were divided into flower bud formation and flower opening. Regarding fructification, fruit formation was observed after fertilization, the maturation period and seed release.

Each phenophase was quantified according to its presence (1) or absence (zero). The activity index, proposed by Bencke and Morellato (2002), was used to estimate the flowering and fructification synchrony in the sampled populations. This analysis method is quantitative at the population level, because it indicates the percentage of individuals that express a certain phenologic event. According to the index, the phenophase was considered asynchronic when manifested by less than 20% of the individuals; little synchronic when the phenophase was observed in 20 to 60% of the individuals and highly synchronic when more than 60% of the individuals were in the phenophase. For the present study the activity index was established at the value reached at the height (peak) of the events linked to flowering. The Morisita index was also used to show the seasonality of the events studied and the rainfall data (Morisita 1959).

$$I\delta = \sum N \frac{ni \times (ni-1)}{n \times (n-1)} \times N \qquad (1)$$

Where ni is the number of individuals in the ith sample, n is the total number of individuals in all samples and N is the number of samples. By this index, events with low values were considered regular, values equal to one were considered random and events with values higher than one were considered aggregated or seasonal. The significance of the Morisita index was verified by the F test.

$$Fc = I\delta \times \frac{(n-1) + N - n}{N-1} \qquad (2)$$

Here I_δ was the Morisita index and n was the total number of individuals in all samples. The value obtained in the significance test (Fc) was compared to the tabulated F at the level of 5% probability.

RESULTS AND DISCUSSION

According to the Morisita index (I_δ), the rainfall values showed the strong seasonality of the study region. The I_δ calculated for rainfall was equal to 1.2, showing the seasonal character of the area. The value obtained by the Morisita index was significant by the significance test (P<0.05).

The activity index detected in the Provenance and Progeny Test in the two years of evaluation showed strong synchrony in flower bud formation (Figure 2). It was equal to 92.8% in 2001. In 2002 there was a decrease

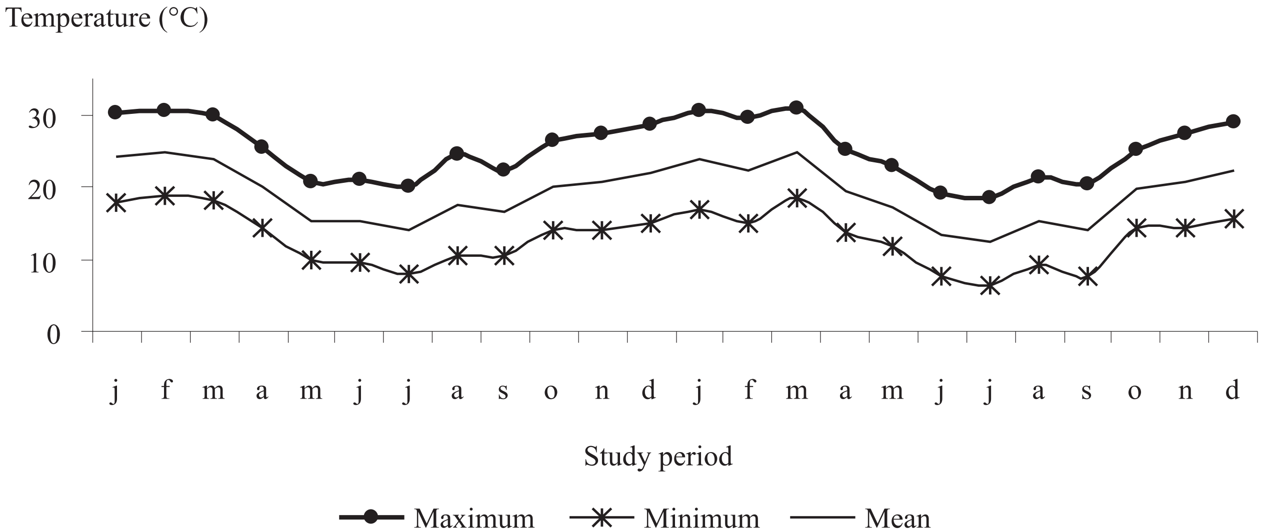

Figure 1. Temperature (°C) observed from January 2001 to December 2002 in the study region. Source: EMBRAPA, 17/04/2003

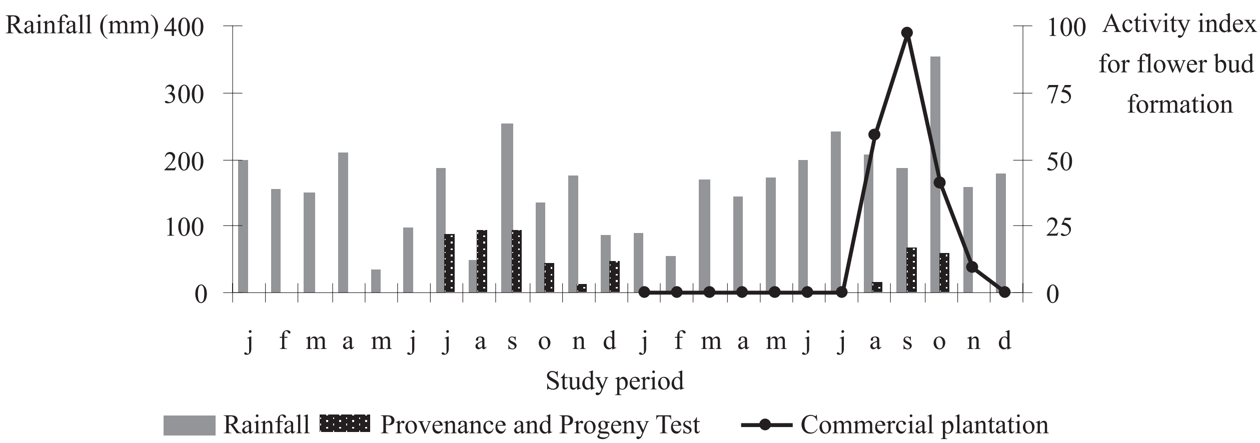

Figure 2. Rainfall (mm) and Activity index (% of individuals in the phenophase) for flower bud formation of the Provenance and Progeny Test (January 2001 to December 2002) and the commercial plantation (January and July 2002). Source: EMBRAPA, 17/04/2003

in the percentage of individuals that formed flower buds (70%). In 2001 flower bud formation in this population was first visualized in July, reaching the peak in the first fortnight of September, decreasing thereafter until there was no further report of this phenophase in November. The I_δ value for the observations was significant and equal to 2.61 ($P<0.05$), showing the seasonality of this event. In 2002, flower bud formation was detected in August and peaked in September. A decline in flower bud production was observed in October while in November there were no individuals with flower buds. The Morisita index value was 4.86 ($P<0.05$).

The beginning of flower bud formation on the commercial plantation was reported in August and the flower bud production peak in the beginning of September 2002 (Figure 2). The activity index was equal to 97%, indicating synchrony in this phenophase. The decline began shortly afterwards and in November no flower bud formation was observed on the commercial plantation. The Morisita index (4.01) was significant ($P<0.05$). It is worth mentioning that this value, as it is superior to one, showed the seasonality of this phenophase for the assessed population.

In both study years the flower buds of the populations under study were formed at the end of the winter. Milton and Moll (1982) studied the phenology of several *Acacia* species in South Africa and observed a similar performance in *Acacia mearnsii*. They further observed that flower bud formation occured in a period with high rainfall. According to the observations of the two populations, the period of this phenophase coincided with an increase in rainfall. In July 2001, when the flower buds began to form, the monthly rainfall was above-average, followed by rainfall shortage in August. The peak of flower bud formation occurred in September of that year during a period of high rainfall and in November, as the rainfall decreased, the intensity of the assessed phenophase decreased. In December a new, less intense peak of flower bud formation was observed in a rainy period. In 2002, in both study populations, flower bud formation was observed in August, peaking in September. In this year, rainfall was above the recorded regional averages in all flowering months, which possibly affected the flower bud production since the duration of this phenophase was shorter compared to the other study years.

Similarly to flower bud formation, flower opening was also highly synchronic in the individuals of the two sampled populations. This phenophase occurred explosively, sweeping and highly visibe. Janzen (1977) explained the value of this by the attraction of flower visitors that would localize the plant in their search for food.

Flower opening was observed in the Provenance and Progeny Test in the first week of August in 2001. Figure 3 shows that there were two flower opening peaks, the first in the last week of September and the second in some trees at the end of November. The activity index verified that the flower opening peak (first peak) was 85.6 % indicating phenophase synchrony. The activity index was 47.4% for the second flower opening, indicating little synchrony in the event. No open flowers were observed after this period. The value of the Morisita index calculated for flower opening in this population was 3.4 ($P<0.05$). In the Provenance and Progeny Test in 2002 flower opening began in September and peaked in October.

The activity index verified for flower opening was 66%, indicating synchrony of the events in the individuals of this population. Unlike the previous year, only one peak of full flower opening was observed, with an immediate decline thereafter. The result obtained by the Morisita index was significant and equal to 5.59 ($P<0.05$). According to the Morisita classification, this value expressed the strong seasonality of the event. An explanation for the decrease in the number of trees with open flowers in 2002 were the strong winds stated in the flower opening period that contributed significantly to the pronounced flower drop.

Flower opening in 2002 also began in August in the population of the commercial plantation and coincided with that of in the Provenance and Progeny Test (Figure 3). The flower opening peak occurred in September. The activity index was 78%, showing synchrony in flower opening. Then there was an immediate decline in this phenophase. A flower opening peak was observed in 2002 but strong winds reduced the number of trees that expressed the phenophase. The Morisita index was 3.83 ($P<0.05$).

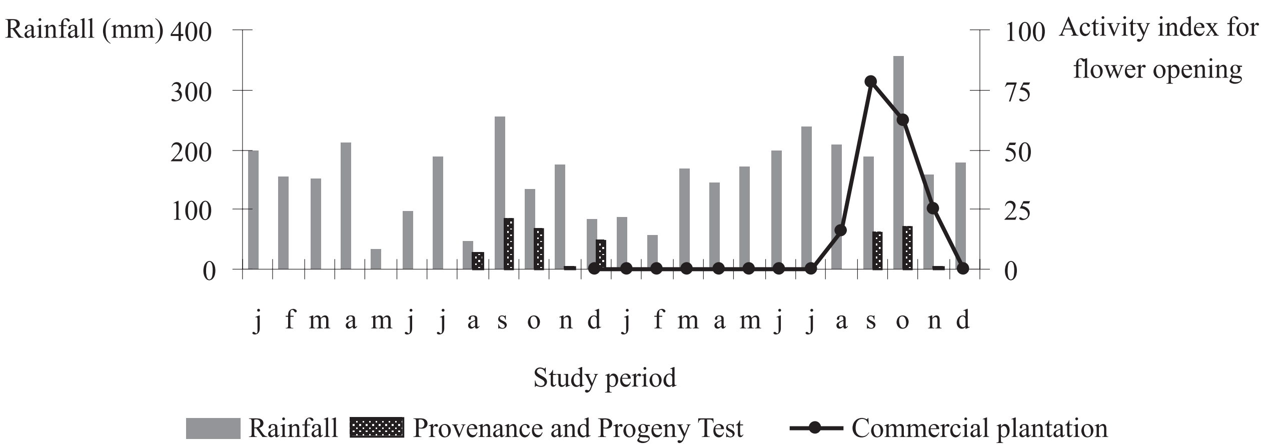

Figure 3. Rainfall (mm) and activity index (% of individuals in the phenophase) for flower opening in the Provenance and Progeny Test (January 2001 to December 2002) and the commercial plantation (January and July 2002). Source: EMBRAPA, 17/04/2003

The flower bud opening was clearly synchronized in the assessed populations. Milton and Moll (1982) observed the occurrence of maximum flowering at the end of the winter and in spring. The adaptation of the species to greater rainfall may have occurred because of the advantages that this period would bring to the region under study, with an increase in floral visitors and the improved soil nutrient cycling from litter decomposition. According to Morellato (1992a) and Pedroni et al. (2002) an increase in temperature and rain occurrence would anticipate the litter decomposition process, making the nutrients available to the vegetation.

During the flower bud formation and flower opening period there was a period of temperature increase accompanied by rain (July, August and September). Then there was a reduction in rainfall and high temperatures (mean temperature around 25 °C) in the fruit opening and seed dispersion period. It could be suggested that the adaptation of the species to the study region was pressured by the need to disperse the seeds in a dry and hot period. This theory was reinforced by the dispersion form, which requires a dry period to reduce fruit moisture content to open and disperse the seeds.

Some authors (Frankie et al. 1974, Janzen 1977, Morellato 1992a, 1992b, Pedroni et al. 2002) commented that the strong synchrony and seasonality in the events linked to flowering, both at the intra and inter population levels, could be the result of factors that act decisively on flower production synchrony, such as nutrient offer, need for cross-pollination, flowering in periods of greater pollinator activity, fructification in the dry period and satiety of flower and fruit eating animals.

The seed dispersion pattern in *Acacia mearnsii* is autochoric, with brown fruits and seeds, indicating a tactic to imitate seeds on the forest floor. Janzen (1977) stated that this form of dispersion would involve little investment on behalf of the plant.

In 2001 fruit formation in the Provenance and Progeny Test became visible in August (Figure 4) and lasted approximately 12 months. Maturation was first observed in September 2002. Seed dispersion began in mid-November and continued to December. The fruits formed during flowering in 2000 were fully developed in July and August 2001, and their seeds were dispersed in December 2001 and January 2002. In the commercial plantation population, the development of the fruits formed in 2001 was observed from January 2002 on. Fruit formation began in September 2002 and the fruit

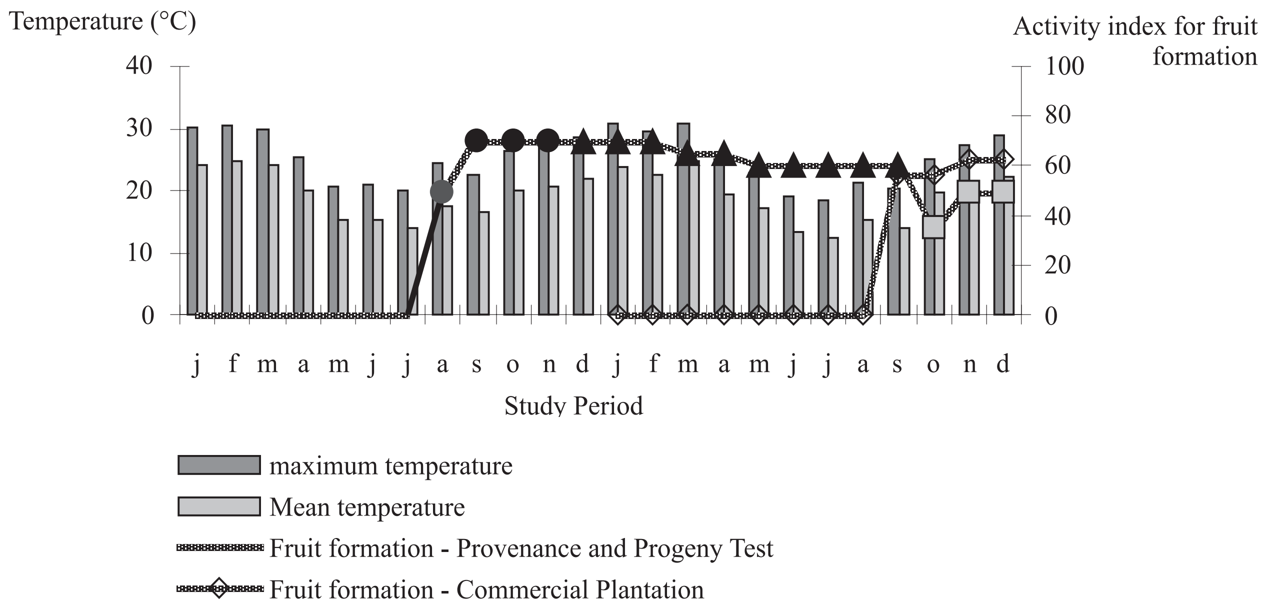

Figure 4. Maximum and mean temperatures (°C) and activity index (% of individuals in the phenophase) for fruit formation in the Provenance and Progeny Test (January 2001 to December 2002) and the commercial plantation (January and July 2002). Provenance and Progeny Test: ●- fruit formation/2001; ▲- development of the fruits formed/2001; □- fruit formation/2002. Source: EMBRAPA, 17/04/2003

maturation and seed dispersion phases were identical as in the Provenance and Progeny Test.

In the 2002 flowering, fruit formation began to be recorded in the Provenance and Progeny Test when the flowering peak decreased at the beginning of October; on the commercial plantation, the phenophase was detected in September. The synchronic behavior of fructification of the species suggested the occurrence of selective pressures towards reducing the damage caused by fruit and seed predators. According to some authors (Frankie et al. 1974, Janzen 1977) synchrony of the fructification phase would be associated to species under attack of fruit pre-dispersion. Unlike the peaks detected in the flowering-related phenophases, fructification peaks were not observed.

The observations confirmed that fructification set in shortly after the flowering peak in a period of rising temperatures and humidity. According to Morellato (1992a), humidity and heat conditions benefit nutrient cycling in forests, favoring nutrient availability. The energetic cost of fruit formation is considerable, requiring nutrient availability for the development of this event. *Acacia mearnsii* delayed fruit maturation for a period of one year, beginning dispersion in the dry season in December and January in Rio Grande do Sul. Frankie et al. (1974) observed that several tropical species retained their fruit for a period of six to 12 months after formation. Crestana et al. (1992) studied *Genipa americana* L. (Rubiaceae) and detected a 12-month development period where increase in fruit length, diameter weight and volume was recorded.

Synchrony and seasonality were observed in the present study in the *Acacia mearnsii* flowering and fructification phases. Flower bud formation and flower opening were observed in a period of rising temperatures accompanied by rainfall, when the availability of flower visitors and nutrient cycling increased. There was a 12-month period between the beginning of fruit formation and their full development. These phenophases were synchronic, suggesting a strategy to reduce the damage caused by seed predators. Fruit opening was synchronic and seasonal in the *Acacia mearnsii* study populations and was observed in a high temperature period with reduced rainfall, an appropriate period for the autochoric form of dispersion of the species.

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Biologia reprodutiva de *Acacia mearnsii* De Wild. (Fabaceae) II: fenologia do florescimento e da frutificação

RESUMO - *O florescimento e a frutificação de* Acacia mearnsii *De Wild. foram analisados em árvores de teste de procedências e progênies e em plantio comercial nos anos de 2001 e 2002. Pelo índice de atividade verificou-se a existência de sincronia na formação de botões florais, tanto no teste de procedências e progênies (em 2001, 92,8% e em 2002, 70%) quanto no plantio comercial (em 2002, 97%). A abertura das flores também foi sincrônica no teste de procedências e progênies (em 2001, 85,6% e em 2002, 66%) e no plantio comercial (em 2002, 78%). A formação dos frutos foi sincrônica e ocorreu logo após o pico da abertura das flores. O período de desenvolvimento e maturação dos frutos se completou em doze meses, seguido pela dispersão das sementes. O índice de Morisita confirmou a sazonalidade dos eventos fenológicos.*

Palavras-chave: fenofases, sementes, *A. mearnsii*.

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