Flowering Phenology of River Red Gum (*Eucalyptus camaldulensis* Dehnh.) Associations in Homs Province, Syria

[1]**Mays Maaaz;** [2]**Mohammad Suliman Abido;** and [1]**Ahmad Haj**

[1]Dept.Renewable Natural Resources and Ecology, Faculty of Agriculture, Damascus University, Syria
[2]Desert and Arid Zone Sciences Program, College of Graduate Studies,AGU, Bahrain

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Correspondent Author:
Mohammad Suliman Abido
mohammadsaa@agu.edu.bh

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ABSTRACT

Flowering phenology, ecology and stand characteristics of *Eucalyptus camaldulensis* Dehnh. were described in response to rainfall and temperature at a plantation site in Northwestern province of Homs, Syria. Flowering observations were carried out for one year on a bi-monthly basis as time of flowering, duration and intensity were recorded. Analysis of 30-year rainfall and temperature revealed that the area has a typical Mediterranean climate of cool thermal variant. The area experiences a decreasing trend in rainfall with a recurrent 6- months climatic drought. Trees registered 9.6 m in heights and 18.4 cm in diameter at 29 years of age. Trees started to set flower buds in the first week of June where cumulative annual rainfall (CAR) and mean temperature were 391 mm and 24.2ºC, respectively. Flowering occurred in two periods with varying percentages of flowering trees in each. Autumn flowering started in the first week of November and extended for 107 days. On the other hand, Spring flowering commenced in the first week of April and continued for 92 days. A significant negative relationship (r = -0.39) was observed between the percentage of flowering trees and average monthly rainfall. However, a weak but positive correlation (r = 0.33) existed between the percentage of flowering trees and average monthly temperature. The percentage of flowering trees were higher in dry months compared to wet months because of low temperature associated with wet period. Flowering intensity was ranked 0.7 in December and 3.3 in June. Fruit setting started in the onset of January and mid June for Autumn and Spring flowers, respectively. Knowing timing and duration of flowering contribute significantly towards understanding the species biology, managing associated fauna and rearing of honey bees in the area.

فينولوجيا الإزهار لتجمعات الأوكاليبتوس الأحمر(*Eucalyptus camaldulensis* Dehnh.) في محافظة حِمص، سوريا

[1]**ميس المعاز**، [2]**محمد سليمان عبيدو**، و [1]**أحمد الحاج أحمد**

[1]قسم الموارد الطبيعية المتجددة وعلوم البيئة، كلية الزراعة ، جامعة دمشق، ، سوريا
[2]برنامج علوم الصحراء والأراضي القاحلة، كلية الدراسات العليا، جامعة الخليج العربي، مملكة البحرين

المُستلخص

دُرست فينولوجية الإزهار والبيئة وخصائص تجمعات الأوكاليبتوس الأحمر(*Eucalyptus camaldulensis* Dehnh) واستجابة إزهار أشجاره للأمطار ودرجات الحرارة في موقع تشجير حرجي شمال غرب حمص، سوريا. تم مراقبة إزهار الأشجار لمدة سنة بشكل نصف شهري؛ حيث سُجلت مواقيته ومدته وكثافته. أظهر تحليل بيانات 30 عاماً لكميات الهطول ودرجات الحرارة وقوع المنطقة ضمن المناخ المتوسطي النموذجي اللطيف' مع تناقص في كميات الأمطار وفترة جفاف مدتها ستة أشهر تتكرر سنوياً. سجلت الأشجار ارتفاعاً قدره 9.6 م و18.4سم قطراً عند عمر29 عاماً. بدأت الأشجار بتكوين براعم زهرية في الأسبوع الأول من شهر يونيو؛ حيث سجل المجموع المطري التراكمي ومعدل درجات الحرارة 391 مم و24.2ºم على التوالي. حدث الإزهار على فترتين مع اختلاف في نسبة الأشجار المُزهِرة في كل منهما. بدأ إزهارالخريف في الأسبوع الأول من نوفمبر واستمر لمدة 107 يوماً. بالمقابل بدأ إزهار الربيع في الأسبوع الأول من أبريل واستمر لمدة 92 يوماً. لُوحِظ علاقة سلبية (r= -0.39) بين نسبة الأشجار المُزهِرة ومعدل الأمطار السنوي؛ إلا أنه قد وُجِد ارتباط موجب وضعيف (r= 0.33) بين نسبة الأشجار المُزهِرة ومعدل درجات الحرارة الشهرية. كانت نسبة الأشجار المُزهِرة في الأشهر الجافة أعلى منها في الرطبة بسبب ترافق الأخيرة ودرجات الحرارة المنخفضة. كما كانت كثافة الإزهار 0.7 في ديسمبر مقارنة مع 3.3 في يونيو. بُدِء في تكوين الثمار مع بدء يناير ومنتصف يونيو لتلك التي تشكلت في الخريف والربيع على التوالي. يُسهم معرفة مواقيت الإزهار وفتراته بشكل ملموس في فهم بيولوجية النوع وإدارة الفونا المرافقة وتربية نحل العسل في المنطقة.

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بريد الكتروني:
mohammadsaa@agu.edu.bh

الكلمات الدالة

كثافة الإزهار، الهطول التراكمي، الأوكاليبتوس، سوريا

Introduction

River red gum (*Eucalyptus camaldulensis* Dehnh.) is an evergreen tree belongs to the genus Eucalyptus and the family Myrtaceae. The genus is complex and comprises of more than 800 species (Chippendale, 1988). It is mainly native to Australia and forms 80% of its forest cover (Department of the Environment and Water Resources, 2007). With its 7 subspecies, the river red gum is considered the most widespread species of the genera in the world; displaying a wide ecological amplitude (Soerianegara, *et al.,* 1994); Pokaeo, 2008); and (McDonald*, et al.,* 2009). The species was introduced to the Mediterranean countries including; Syria in late 19th century for forestation purposes and environmental protection. Since then, its plantation acreage is ever increasing due to its fast growth and species ability to survive different environmental conditions (FAO, 1973); (Lacaze, 1978); (Merwin, 1983); (Nahal, 1989); and (Abido, 2000).

The study of plant phenology is an effective tool to understand plant response to climate variability, plan for agricultural operations and understand the biological relationships among species (Broadhead, *et al.,* 2003); (Milla, *et al.,* 2010). Phenology is defined as, "the study of the timing of recurring biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species." (Leith, 1974). Phenological events of plant species are primarily controlled by climatic conditions of which temperature and rainfall are the most varied (Schwartz, 2000); (Snyder, *et al.,* 2001); (Van Vliet, 2008); and (Semple and Koen, 2010). Yet, these two factors are crucial for plant growth especially in arid and semi arid environment. To this end, many authors believe that temperature by virtue is the most important factor that controls phenological events in plants (Sparks, *et al.,* 2000); (Gordo and Sanz, 2005); and (Lu, *et al.,* 2006). Number of researchers reported on the species phenological response to temperature variants with varying results from species to another (Keatley, *et al.,* 2002); (Pederson, *et al.,* 2004); (Barry *et al.,* 2009); (Vitasse, *et al.,* 2009); (Rousi, *et al.,* 2011); and (Richardson, *et al.,* 2013). (Keatley and Hudson, 2010) pointed out that the increase in temperature had no effect on flowering time; as only 19% of the 68 Australian tree species studied flowered earlier than usual due to temperature increase. For instance, the increase in temperature forces trees like *E. polyanthamos* and *E. microcarpa* to bloom early than expected (Keatley, *et al*., 2002). However, in earlier study; (Keatley and Hudson, 1998) stated that the onset of flowers in eucalypt trees is linked to flower bud size with a significant effect of temperature on flowering intensity. In addition to the effect of temperature on flowering date; (Kim, *et al*., 2009) reported contradicting results on the effect of rainfall on a flowering intensity where an inverse relationship was found in *E. camaldulensis* and *E. melliodora* contrary to positive one in *E. tricarpa* and *E. leucoxylon* with a threshold amount of rainfall for setting flowers in affected species. (Jensen, *et al.,* 2007) stated that flower budding is cyclic process where buds initiate in January and February, flower in November and peaks in December with variation between years due to rainfall and temperature in the previous year. Other researchers pointed out to the complexity of timing of flowering in eucalyptus as rainfall, daily temperatures, soil moisture, the intensity of solar radiation, and genetic factors as well as physiological effects are driving forces (Bolitin, 1975); and (Wilczek, *et al.,* 2010).

River red gum is a species of wide amplitude of tolerance towards environmental conditions however, its biology and response to environmental factors remain unclear in many regions of Syria. This research was undertaken to characterize river red gum ecology and flowering phenology in response to annual rainfall and temperature at plantation site of Homs province, Syria.

Materials and Methods

(1) Study Area

The study area is located in the Northwestern province of Homs (E 36° 28' 37", N 34° 41' 22") at an altitude of 517 m above sea level. Topography is relatively flat with boulders scattered in and around the site. Soil falls within the orders of inceptisols of basaltic parent rock, poor in calcium carbonate and of dark to brown color (figure 1). The site is occupied with a linear eucalypt plantation as trees were planted 30 years ago and spaced 3 m within and between rows.

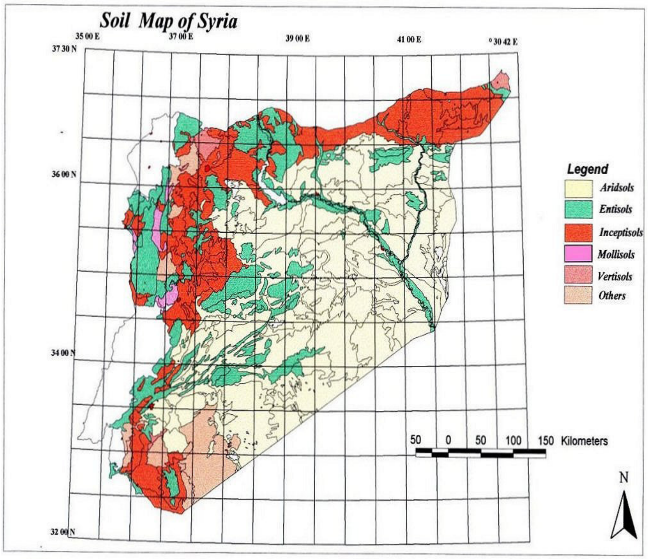

Figure 1: Soil Map of Syria (Ilaiwi, 2001).

(2) Methodology

30-year rainfall and temperature data set for Homs station were obtained and analyzed to characterize the environmental setting of the research site. 5-year moving average was computed for the period 1950-2010. Pluviothermic quotient of Emberger (Q_2) was calculated according to the formula:

$$Q_2 = \frac{2000\,P}{M^2 - m^2},$$

where P is the annual rainfall (mm); M is average maximum temperature of the hottest month of the year (ºK) and m is the average minimum temperature of the coldest month of the year (Daget, 1977).

Ombrothermic diagram was drawn to delineate drought period using the relation (P≤2t); where P is annual rainfall (mm) and t, is the mean temperature of the year (°C) (Bagnouls and Gaussen, 1953).

Total heights of trees and overbark diameter at breast height were measured using clinometers and diameter tape accordingly in plots of 400 m^2 replicated 3 times. Flowering observations were carried out for one year on a bi-monthly basis (Koch, *et al.,* 2003). Flowering onset, duration and intensity were recorded for dominant and co-dominant trees. Flowering intensity was score ranked as values between 0 and 5 according to (Wilson, 2003); (Keatley, *et al.,* 2004); and (Keatley and Hudson, 2007) taking into consideration flowering abundance of (Semple, *et al.,* 2007). A correlation was made between annual rainfall, temperature and percentage of flowering trees using SPSS program.

Results and Discussion

(1) Climatic Conditions

Analysis of climatic data indicated that the climate of the study area falls within the cool thermal variant of semi-arid bioclimatic zone of Emberger's climagram (*Q2* = 44.4, m= 2.7 ºC). Average annual precipitation reaches 428 mm with variations from year to year and between same months of the years, scoring 256 mm in January 1950 and 10.7 mm in the same month of 2010. The 5-year moving average of rainfall in study area showed a decreasing trend in rainfall (figure 2).

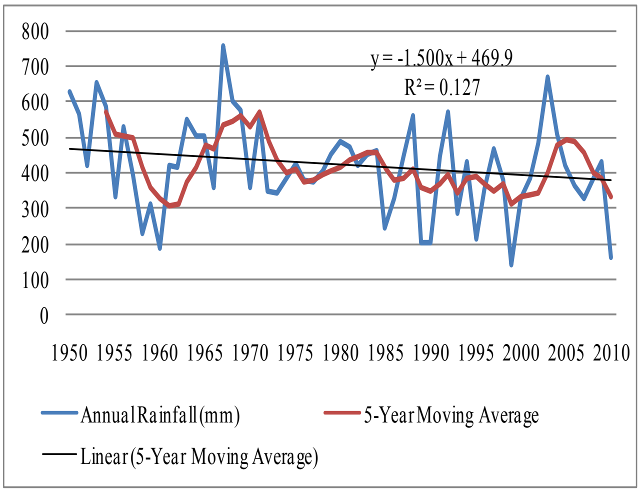

Figure 2: Total and 5- Year Moving Average of Rainfall in the Study Area.

Rainfall was less than average in 48% of the year's record and climatic drought lasts for more than 6 months; starting from mid April to the first of November (figure 3). Rainfall regime is of a type: Winter-Spring-Autumn-Summer as 58% of precipitation falls in Winter, 23% in Spring, 16% in Autumn and 3% in Summer.

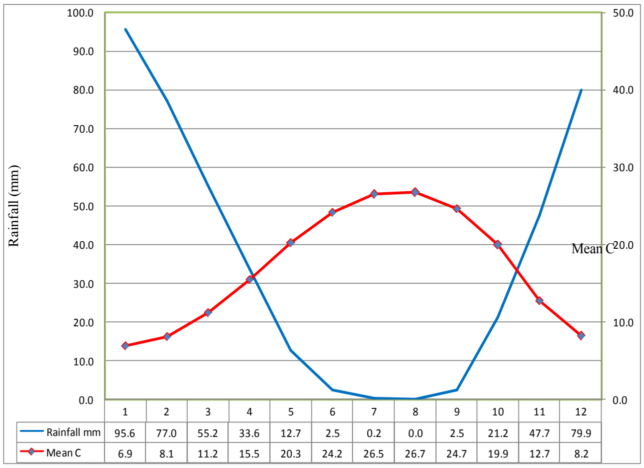

Figure 3: Ombrothermic Diagram of Bagnouls and Gaussen for Study Area.

The effects of drought is intensified on trees by hot dry wind blowing from Syrian desert, reaching a speed of 5 m/sec. that coincides with high temperature season causing leaf desiccation and leaf fall off. Nevertheless, the amount of rainfall fulfills requirement of trees as extension of roots has the capacity to access water stored in bottom of soil profile and fissures of rocks.

(2) Stand Characteristics

Average tree heights in the plots registered 9.6 m at age 29 yrs. where, mean annual height growth attained 32 cm yr-¹. Dominant and co-dominant trees in the stand numbered 350 tree ha-¹ with an average height of 12.9 m and average diameter of 24.4 cm. Average stand diameter reached 18.4 cm, equaling to an average growth of 6 mm yr-¹ in width. Average basal area of the trees in the stand reached 31.2 m² ha-¹ whereas, density reached 1175 tree ha-¹. This is in contradiction with results of (Abido, 2000) as he reported average tree height of 13.3 m and a diameter of 20.7 cm in stand of same age grown in similar climatic conditions in the country. Furthermore, mean annual volume increment of trees is 3.19 m³ ha-¹ yr-¹ which is 2- 3 times less than similar rates reported by (Lamprecht, 1990) in different countries of the World.

(3) Flowering Phenology

Flower buds in trees developed on current season's shoots in clusters of 7 on the average. Trees started to set flower buds in the first week of June where sums of sunshine duration reached 12 hours, cumulative annual rainfall (CAR) totaled 391 mm. and mean temperature was 24.2ºC. The flowering buds by that time measured (1×0.5 ×1) cm³ in size (figure 4).

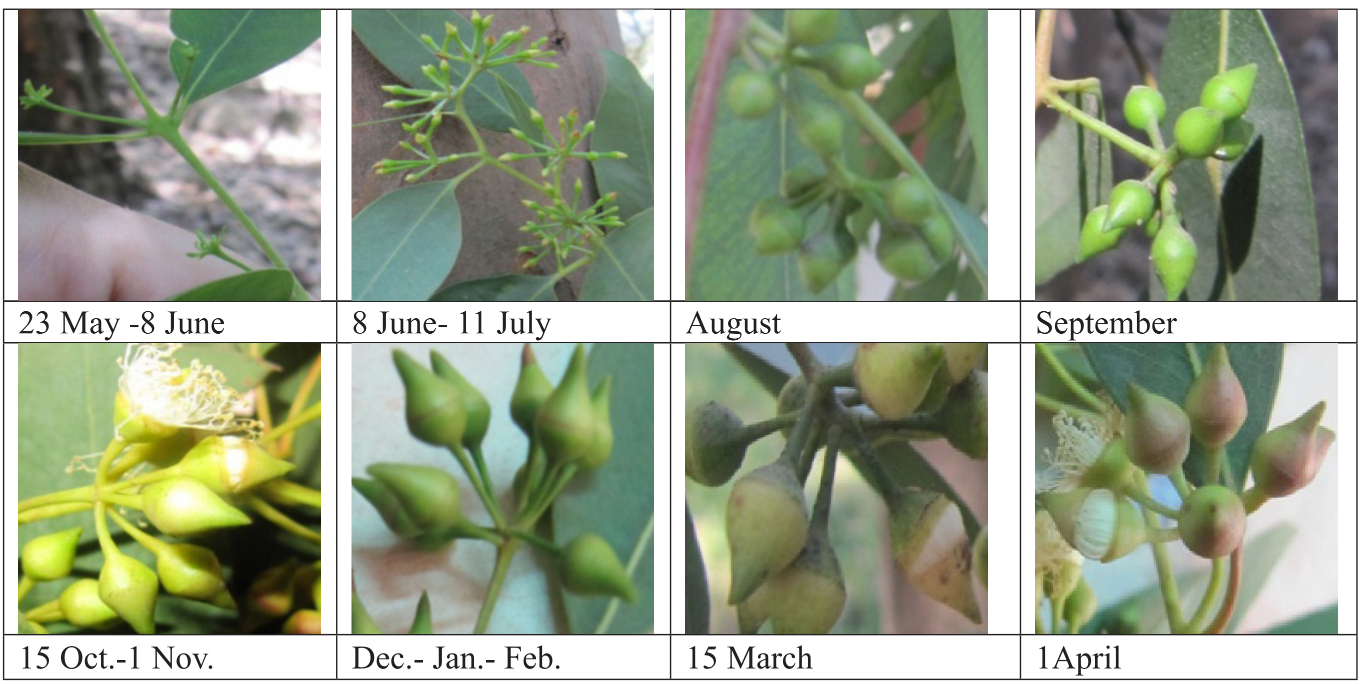

Figure 4: Flower Buds Development in *Eucalyptus camaldulensis* in the Study Site.

The set buds developed into flowers in two periods; Autumn and Spring. Autumn flowering started in the first week of November where bud age was 147 days and sums of sunshine duration reached 6.4 hours. In the meantime, average temperature and cumulative annual rainfall (CAR) registered 18.8ºC and 72 mm, respectively. The percentage of flowering trees was 6% of total dominant and co-dominant trees in the stand reaching 19% in mid November. The effect of low temperature (8˚C) and cumulative annual rainfall (CAR) (298mm) was clear on flowering as 1.1% was recorded in February. Autumn flowering could be attributed to varieties or ecotypes within the plantation site or to location of the trees in the stand where most of bloomed trees received 10 hours of direct sunlight. On the other hand, Spring flowering began in the first week of April; 298 days after buds' setting, where average temperature and cumulative annual rainfall (CAR) were 15.6˚C and 376mm, respectively. Same percentage of flowering trees was recorded for the beginning of Spring blooms, however flowering peaked in the first week of June as percentage of bloomed trees attained 63.7%. By that time, average temperature and cumulative annual rainfall (CAR) were 24 ˚C and 391mm, respectively compared to 6.3% in April where temperature was 15.6 ˚C and cumulative annual rainfall (CAR) totaled 376mm. The duration of Autumn flowering extends for 107 days started 1st of November to 15th of February compared to 92 days for Springs' that started 1st of April lasting to1st of July (figure 5 and figure 6).

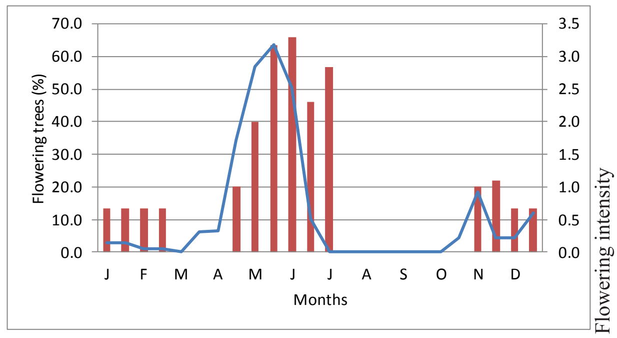

Figure 5: Flowering Intensity and Percentage of Flowering Trees.

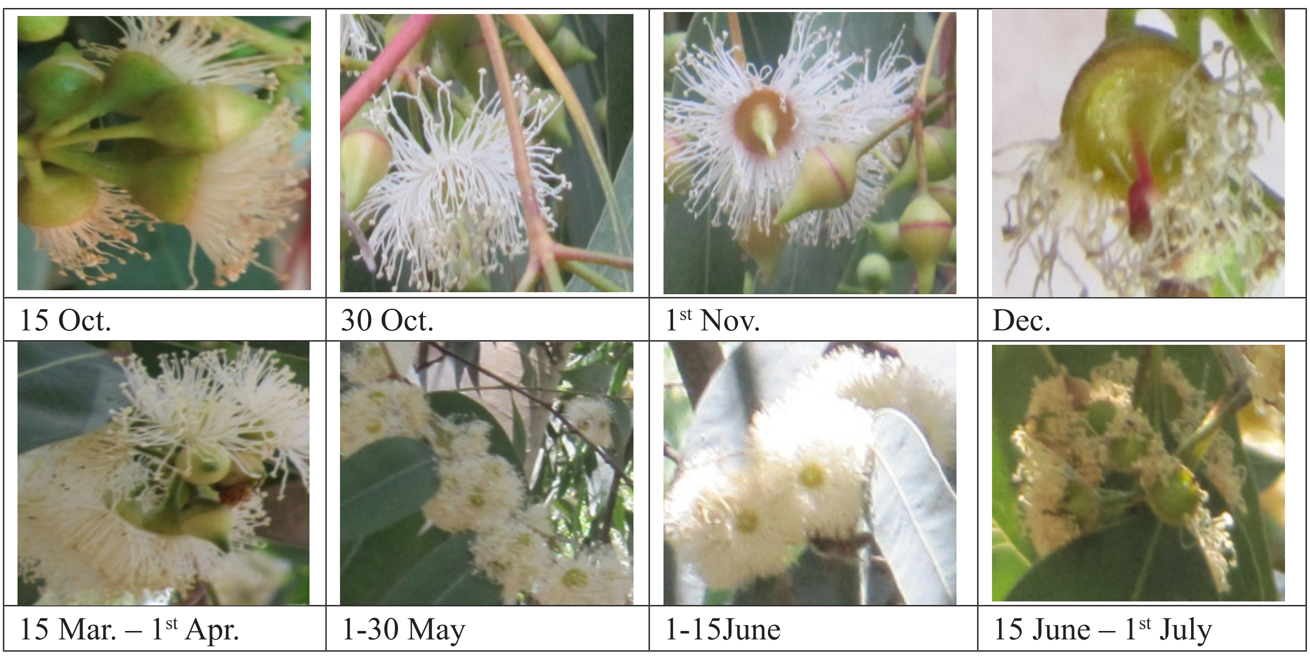

Figure 6: Phenological Development of Flowers from Set to Fruit Formation

Flowering intensity was ranked 3.3 in June, where average temperature was 24˚C and the cumulative annual rainfall (CAR) 391 mm, while the lowest value (0.7) was registered in December and January as the average temperature dropped to 8˚C and CAR reached 137mm. This is in line with results of (Keatley, *et al.,* 2007); and (Hudson, *et al.,* 2009, 2010), where they recorded similar results in Australia. On the other hand, (Dexter, 1978) reported variable flowering intensity and unpredictability from year to year.

A significant negative relationship (r = -0.39) was found between the percentage of flowering trees and average monthly rainfall. Nevertheless, a weak but positive correlation (r = 0.33) existed between the percentage of flowering trees and average monthly temperature. It was found that the percentage of flowering trees were higher in dry months compared to wet months because of low temperature associated with wet months. This result complies and contradicts with other results of species behavior in its native homeland as the species displays one flower period, but various dates of flowering. Flowering of trees occurred from 19 November to 2nd February in 1998 and from 2nd of December to 16 January in 1999 in Box-Ironbark area of central Victoria compared to flowering period from November to December in southern Australia and in September in Murray area (Jensen, *et al.,* 2007). Other studies reported flowering in most years from July to February (Brooker and Kleinig, 1999) and from December to February (Boland, 1984).

Fruit setting started after flowers were pollinated in the onset of January for Autumn flowers whereas, fruit setting began in mid June for Spring flowers and reached its maximum in July. The percentage of fruit-setting trees in August reached 63 compared to14 in December. Fruits remain close on trees for 1-2 years and open in Summer temperature where seeds are released.

Conclusions

In sum, floral buds of river red gum trees are formed in late May or early June in the study area where bioclimatic regime is semi-arid Mediterranean with cool variant. Trees set flowers in Autumn and Spring with varying percentages in the same period due to variations in temperature and precipitation. Autumn and Spring flowering extends 137 and 109 days, respectively. Flowering intensity differs between Spring flowering as ranked 3.3 compared to 0.7 in Autumn period. Fruit setting started in January and in mid June for Autumn and Spring flowers, respectively. Fruits remain close on trees for 1-2 years and open in Summer temperature. Knowing timing and duration of flowering of river red gum trees in the area contribute significantly towards understanding the species biology, managing associated fauna and rearing of honey bees.

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