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Pollination ecology of *Citrullus lanatus* at Yatta, Kenya

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Abstract. Pollination ecology was investigated in *Citrullus lanatus* (Thunb.) Matsum. & Nakai, which is a species vulnerable to pollinator loss. It was found that this species depends heavily on the honeybee, *Apis mellifera* L., as the main pollinator. Other pollen vectors identified include *Xylocopa* bees, halictid bees, *Hypotrigona* bees, flies and beetles. Phenologically, the plant was found to promote male fitness by producing numerous male flowers, which serve as pollinator attracting structures. Blooming sequence and *A. mellifera* visitation rates to these flowers are presented. This will enable farmers and pollination managers to better understand visitation patterns and to safeguard pollinators during pesticide application schedules.

Key words: *Citrullus lanatus*, Cucurbitaceae, watermelon, pollination ecology, phenology, *Apis mellifera*, pollinators conservation, integrated pest management

Résumé. L'écologie de la pollinisation a été étudiée chez *Citrullus lanatus* (Thunb.) Matsum. & Nakai, qui est une espèce sensible à la diminution de la pollinisation. On a montré que cette espèce est très dépendante de l'abeille domestique, *Apis mellifera* L. qui est son principal pollinisateur. D'autres pollinisateurs ont été identifies, tels que des abeilles des genres *Xylocopa* et *Hypotrigona* et de la famille des Halictidae, des mouches et des scarabés. Phénologiquement, on a montré que la plante favorise la reproduction mâle en produisant de nombreuses fleurs mâles qui attirent les pollinisateurs. Le rythme de floraison et la fréquences des visites de ces fleurs par Apis mellifera sont présentés. Cela devrait permettre aux fermiers et aux apiculteurs de mieux comprendre les rythmes de visite des pollinisateurs et ainsi les protéger lors des traitements insecticides.

Mots clés: *Citrullus lanatus*, Cucurbitaceae, melon d'eau, écologie de la pollinisation, phénologie, *Apis mellifera*, protection des pollinisateurs, lutte intégrée

Introduction

The immobility of the plant kingdom requires that reproduction is usually assisted by other agents—wind, water or animal vectors. The majority of flowering plants require pollen vectors to effect successful reproduction, which is both key to their genetic diversity and indication of their dependence on services provided by other taxa within the ecosystem. There is a growing interest at present in conservation of pollinators (Buchmann and Nabhan, 1996), as it is recognized that the productivity

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of many crops depends on the services of key pollen vectors. Insufficient pollinator service is a concern in fruit production because when the plant receives too few visits by the pollinators, pollen limitation may result in reduced yields. Pollinator decline has been associated with increased/improper pesticide use, as well as habitat loss for pollinators.

This research is aimed at exploring the pollination ecology of *Citrullus lanatus* (Thunb.) Matsum. & Nakai. This species belongs to the family Cucurbitaceae Juss., which is predominantly tropical, having 90% of the species in three main areas namely: Africa and Madagascar, Central and South America and Southeast Asia and Malaysia (Jeffrey, 1990). Economically, the family has many cultivated species. In addition, a number of wild species are found to be of importance in Kenya (as elsewhere) as sources of food, medicine and fodder (Njoroge, 1992; Njoroge and Newton, 1994).

Citrullus lanatus is one of the cultivated cucurbitaceous species thought to have their origin in Africa (Cobley, 1965; Masefield *et al.*, 1969; Kirkbried, 1993). Its cultivation began in ancient Egypt and India and spread from there to other countries via the Mediterranean, Near East and Asia. In 1857 Livingstone reported the existence of a large wild species of watermelon in Botswana. As a result of prolonged cultivation and selection, new forms of table watermelon have evolved that have no resemblance to the ancient African forms (Fehe'r, 1993).

The plant is grown in Kenya for fleshy fruits that are extremely refreshing during the dry hot season because they contain abundant water and minerals. The fruit is also rich in α and β-carotene. In some other parts of Africa, especially West Africa, *Citrullus lanatus* is grown for its seeds, which contain high levels of unsaturated linoleic acid and various amino acids (TCN, 1996).

Although the cultivation of this crop is gaining popularity in Kenya, no data are available on pollination patterns of watermelon in the region. Studies in other regions (Corbet *et al.*, 1997) have shown that pollinator visitation contributes positively to productivity. We have sought in this study to investigate when the plant has most visitations by the main pollinator(s) so as to furnish farmers and pollination managers with data that can be applied in integrated pest management for pollinator safety and conservation. This was especially necessary because watermelons are susceptible to a range of pests and diseases and locally farmers were seen to spray pesticides continuously in order to guarantee pest control with little regard to the essential pollinators. The main fungal diseases of this crop are anthracnose, powdery mildew (*Sphaerotheca fuliginea*) and downy mildew (*Pseudoperonospora cubensis*). Other production problems are as a result of insect attacks, e.g. melon ladybird (*Henosepilachna elateri*), aphids (*Aphis gossypii* Glover), melon fly (*Dacus cucurbitae*), red spider mite (*Tetranychnus* sp.) and thrips (*Cerathothripoides cameroni*). Aphids are a major threat in the early stages of the plants' growth (R. R. Schippers, pers. comm.).

Materials and methods

The study was carried out at Yatta National Youth Service farm, Thika District, Kenya. Plants were sown in nursery beds and transplanted when they reached a height of 16 cm, on ridges with planting distance of $3 \times 2\,m^2$. A total of 1000 plants were sown in early December so that flowering and fruiting could coincide with the dry months of January and February. The plants were top-dressed with calcium ammonium nitrate (C.A.N.) fertilizer when the plants began to spread, and again just before flowering. Drip irrigation was used every other day. Pesticides were used to control different pests and diseases but application was done after 1100 h to avoid bee poisonings.

Phenological changes in this plant were observed and the number of male and female flowers recorded every other day throughout the growing period.

To estimate the approximate time of the day when anthers dehisce, the anthers were stroked gently with a small paintbrush. At every stroke the brush was examined for the presence of any pollen grains adhering on it. From 0630 h the anthers were stroked every 30 min until some pollen grains were observed on the paintbrush. At the same time the stigmas were observed for receptivity every 30 min until a glassy liquid was observed.

In this study, documentation of flower visitors paid special attention to discrimination between pollinators and mere floral visitors. Those insects that had contacts with anthers and stigmas were recorded as pollinators. Representatives of pollinators observed brushing the anthers or stigmas were captured and killed in a jar using ethyl acetate fumes. Voucher specimens were prepared, insects identified and then preserved in insect boxes, deposited in the Botany Department of Jomo Kenyatta University.

Observations of insect foraging were made for 6–8 h per day. These observations began at 0600 h and ended at about 1300 h. Occasional visits were made to establish if there were any insects visiting these flowers after this time. Observations were based on $1\,m^2$ plots of the flowering crop and the number and types of pollinators coming into the flowers recorded over 10-min observation periods. The number of visits to the plots was correlated to time of the day.

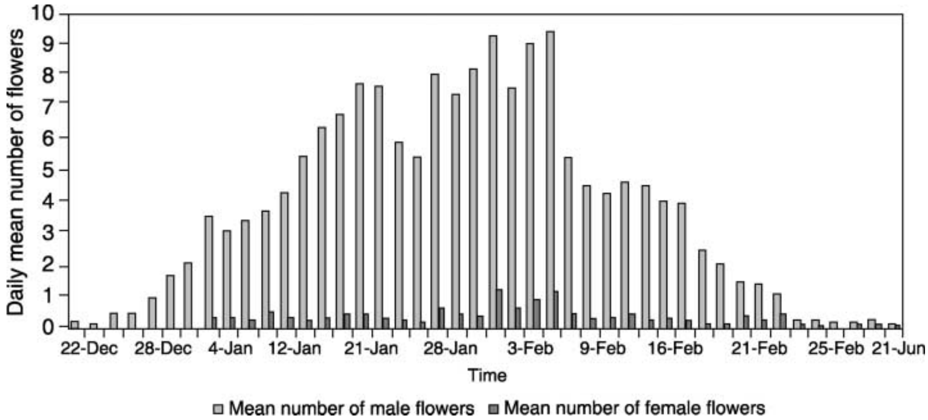

Fig. 1. Comparison of production of male and female flowers in *Citrullus lanatus*

The relative periods of time (in seconds) spent by *Apis mellifera* while foraging on male and female flowers were recorded and compared.

Any fauna that reduced pollination effectiveness was documented as enemies of pollination in this plant. This included predators of pollinators or any fauna reducing attractiveness of the flowers to the pollinators, by for example, gnawing on the floral parts.

Results

The flowering period lasted 8–11 weeks. At all times there were more male flowers per plant than female flowers. The ratio of male to female flowers when worked out for the whole growing period was found to be 13:1 (Fig. 1). The anthers dehisced from 0830 h, with most pollen being released at 1000 h. The stigmas became receptive from 1030 h.

The main pollinator was found to be *Apis mellifera* (21,22). However, other insects were found to visit flowers of *Citrullus lanatus* in the study area. These include the Lepidoptera *Danaus chrysippus* (3), *Eurema brigitta* (4), *Neocoenyra gregorii* (1) and *Junonia hierta* (2), and two Cleoptera species, *Aphthona marshalii* (20) and *Leptaulaca fissicollis* (19). The other Hymenoptera are *Xylocopa lataritia* (17), *Anthophora bipartita* (16) and *Braunsapis* sp. (9.10,11,12,13). Halictid bees and meliponine bees were also observed, but not captured. Dipteran visitors included *Chrysomya* sp. (6), *Cosmina* sp. (8) and *Phytomia* sp. (15). (Numbers in brackets refer to the voucher specimen numbers). Visits by these visitors were not as predictable and stable as were honeybee visits, and thus we focused on honeybee visitation patterns; however, they did appear to carry pollen and effectuate pollination, and merit closer investigation.

No foragers were observed before 0700 h. It was observed that only butterflies made occasional appearances after 1200 h. On days when it was cloudy or rainy few visitors were observed in these flowers, these comprising flies and halictid bees. At such times the *Apis mellifera* was absent in these flowers.

The visitation rate across the day for *Apis mellifera* is shown in Figs 2 and 3. Visitation rate is low in the early morning but increases steadily later, reaching a peak at 1000 h. After this, the rate of *Apis mellifera* visitation to *Citrullus lanatus* decreases and by 1200 h they have essentially stopped visiting the crop.

SAS software was used for all the subsequent data analysis. A linear positive relationship was found between time of the day (0700 to 1200 h) and visits to the flowers by *Apis mellifera* ($r = 0.72478$, $P < 0.0001$). Although there is a peak in the late morning, visits to male flowers drop off earlier in the morning than do visits to female flowers. More time per flower is spent on female flowers by *Apis mellifera* (Fig. 4). The mean times were 0.56 s per male flower and 1.49 s per female flower, which was significantly higher by the Tukey Studentized range (HSD) test. However the overall time spent on male flowers per plot

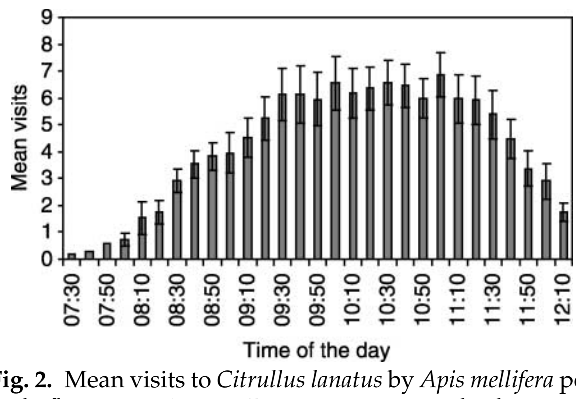

Fig. 2. Mean visits to *Citrullus lanatus* by *Apis mellifera* per male flower per 10 min. Bars represent standard error

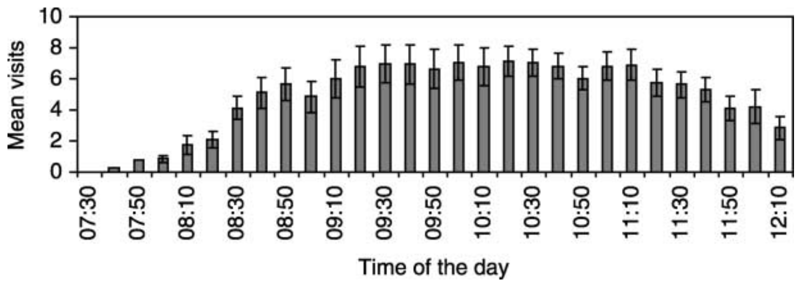

Fig. 3. Mean visits to *Citrullus lanatus* by *Apis mellifera* per male flower per 10 min. Bars represent standard error

was significantly more than that on the female flowers (male = 6.52 s and female = 5.36 s), as there were more male flowers in each plot, and each was visited more frequently than the female flowers.

The time spent visiting both male and female flowers decreased over the morning, although more drastically in female flowers than male flowers. Both flowers receive lengthier visits from pollinators at a time when pollination is unlikely to be effective, but more frequent visits once anthers have dehisced and stigmas are receptive.

Some wasps and the crab spider were found to be enemies of pollinators of *Citrullus lanatus*. The crab spider (*Araneae*) has a unique camouflage in that it has the same shade of yellow as the petals of the *Citrullus lanatus* flowers. Through this camouflage, they are able to trap bees coming to visit the flowers. Some wasps were observed to be acting as bee pirates, lurking among the flowers and attacking bees as they foraged.

Discussion

Pollination managers and farmers need adequate understanding of the blooming sequence of this crop. The data presented are a pointer to farmers and pollination managers to bring in pollinators in hives to the fields or by managing native vegetation adjacent to fields, so that pollinators will be present at the time of flowering of the crop. Such timing will ensure that fruit failure, which would otherwise occur due to insufficient pollinator service, will be curbed.

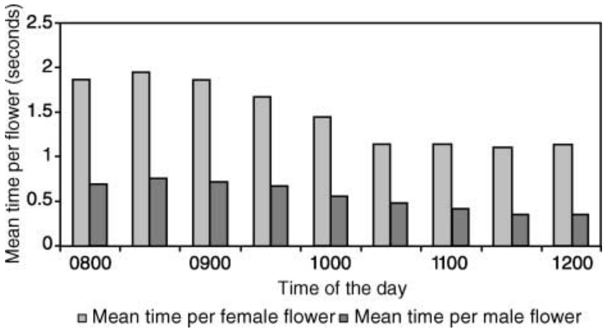

Fig. 4. Mean time (per flower) spent by *Apis mellifera* on male and female flowers of *Citrullus lanatus*

In pesticide application it would be necessary to understand when highest numbers of blooms are expected so that pesticides can be applied before or after these peaks. Farmers and pollination managers need to 'read' the seasons and keep in close contact to coordinate their activities to ensure maximum pollination.

Proximity of many flowers reduces pollinator flight costs (Harder and Barret, 1996). Pollen grains are usually more numerous and individually inexpensive to produce than the ovules. The occurrence of a far greater number of staminate flowers (Fig. 1) promotes male fitness in this crop.

The pollination strategy of *Citrullus lanatus* in this region of Kenya can be described by the following characteristics:

- The numerous staminate flowers of *Citrullus lanatus* serve to keep *Apis mellifera* foraging on them, hence ensuring that plenty of pollen sticks to their bodies.
- The ovaries have very many ovules, at times reaching 1000 ovules in one ovary. Considerable pollen deposits may be required for sufficient fertilization of ovules.
- The fact that maximum anther dehiscence time coincides with maximum *Apis mellifera* visitations and time of stigma receptivity acts to facilitate pollination success. This also makes this pollinator species well adapted to carry out effective pollination in this crop.
- More visits are made to male flowers than to female flowers. This ensures transmission of ample pollen loads to the female flowers.

The pollination strategy of *Citrullus lanatus* in Kenya, as described above, can act as a guide to show what time of the day agricultural chemicals may be applied so as to minimize detrimental impacts on pollinators. It is recommended that pesticides can be applied late in the evening when these bees have left the flowers. Since the flowers for that day will have closed and new flowers will emerge the following morning, the bees stand some chance of escaping poisoning. The fresh flowers and nectar produced the following morning will have less direct contact with the pesticides sprayed the previous day than would flowers that were open when sprayed.

Apis mellifera spent more time on each female flower than on a male flower. This may be beneficial for effective pollination, as pollen removal from anthers to the bee body parts takes a short time. To accumulate a large pollen load, an individual bee must make multiple visits to many male flowers. This accounts for the greater time spent overall on male flowers per plot than female flowers. When the bee comes to harvest nectar from the female flowers it has to struggle getting it from the nectar cup below the style. This allows contact of the already loaded pollen bags with the stigma and consequently the pollen is dislodged.

The set of insects profiting from visiting pollinators to *Citrullus lanatus*, including predatory wasps and crab spiders, highlights the fact that pollinator webs are complex; just as pollinators depend on the plant, and plants depend on the pollinators, a number of other taxa contributing to the agroecosystems depend upon the pollinators as well. The impact of agrochemicals throughout these foodwebs remains largely unknown and requires further study.

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