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Full Length Research Paper

Influence of cotton plant on development of *Aphis gossypii* Glover (Homoptera: Aphididae)

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Abstract

***Aphis gossypii* Glover (Homoptera: Aphididae) is one of the most important cotton pest in Benin. Experiments were carried out to determine population growth parameters of this pest and to compare its performance when feeding on detached leaves as opposed to the whole plant at constant temperature of 27 ± 1°C and 70 ± 5% of relative humidity. Results indicate that *A. gossypii* developed through four development stages with a mean development cycle of 4.38 ± 0.067 days. The doubling time of the aphid population was higher on whole plants (2.25 ± 0.02 days) than on detached leaves (1.91 ± 0.02 days). Similarly, the reproduction rate (Ro) of *A. gossypii* was lower on whole plants (16.023 ± 1.32) than on detached leaves (33.35 ± 1.68). Development, survivorship and reproduction of the aphid were negatively impacted by whole cotton plants, suggesting the possible induction of defence mechanisms.**

Keywords: *Aphis gossypii*, cotton, life table parameters, induced defence.

INTRODUCTION

Cotton, *Gossypium hirsutum* L. (Malvales: Malvaceae) is the main cash crop in Benin. It contributes to 35% of tax revenues (excluding customs) (Ton, 2004) and to 13% of the gross domestic product (GDP) (PMC, 2008). However, cotton production is limited by high biotic pressure from pests, thereby significantly reducing yields. Together with *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae), *Aphis gossypii* Glover, 1876 (Homoptera: Aphididae) causes serious damage to cotton in African savannahs (Brevault, 2010). It is an extremely polyphagous pest infesting over than 900 plant species of various families (Blackman et al., 2000). In the United States for instance, the economic impact of cotton aphid was ranked sixth and seventh in order of importance in 2002 and 2003, respectively (Williams, 2003; 2004).

This aphid species can infest cotton at different growth stages, and feeds by sucking plant sap (phloem) during the whole cotton development period (Liu et al., 2005). Damage during the boll opening phase affects fiber quality (Almeida and Silva, 1999). According to Shannag et al. (1998), aphid feeding alters the photosynthesis and transpiration rate of plant in proportion with their number and length of infestation period. In Sudan, an infestation of approximately 300 aphids per leaf reduced growth by 38–44%, boll production by 78–80% and cotton seed yield by 60–65% (ripper and George, 1965). Besides the direct damage on crops, *A. gossypii* is responsible for indirect damages related to virus transmission like Cotton Vein Mosaic Virus (CVMV) (Marcos and Busoli, 2006).

Although this aphid species is common to many plants, its performance is highly variable depending on host plant and region (Ekukole, 1990; Wool et Hales, 1997; Liu et al., 2008). This is explained by a specialization of the aphid biotypes to a specific host plant or groups of plants. Kring (1959) showed that aphids established on *Hisbiscus syriacus* (Malvales: Malvaceae) and *Catalpa bignonioides* (Lamiales: Bignoniaceae) can easily develop on cotton but hardly on cucumber plants. Likewise, aphids living on cucumber plants produce little or no offsprings when transferred to other host plants (Guldemond et al., 1994). A strain of *A. gossypii* reared on cotton cannot be established on cucumber plants and vice versa (Williams, 2003; Liu et al., 2008). Genotypic differences within *A. gossypii* populations were evidenced by Carletto et al. (2009) with regard to host plant. Significant differences were reported in the morphological and biological characteristics depending on host plant (Meng and Li, 2001). In Japan, four biotypes in *A. gossypii* population were reported with regard to host plant and life cycle (Inaizumi, 1981).

Aphid development can be affected by cotton plants which evolved direct or indirect mechanisms contributing to their resistance in different ways (Hagenbucher et al., 2013). Subsequently to aphid feeding, plant performs a series of physiological and transcriptional changes triggering plant defence (Kaloshian, 2004). Therefore, several mechanisms are activated. Of these, plant can developed hypersensitive response that induces cell death, a reaction which is elicited by the recognition of aphid insect attack (Morel and Dangl, 1997). This response is perceptible in apple leaves through macroscopic necrosis spots (Awrmack and Leatner, 2002). Aphid feeding is also responsible of metabolic response as direct defence mechanism, which negatively affects life-history parameters such as survival, development time, size, longevity or fecundity (Zangerl and Berenbaum, 1993; Li et al., 2000; Awrmack and Leatner, 2002; Gols et al., 2008). These parameters can also be affected by the cultivar (Satar et al., 1999; Shannag et al., 2007). As an example, Du et al., 2004 showed that *A. gossypii* life span and fecundity was reduced by half after feeding on high gossypol cultivar compared to a cultivar with low gossypol. The purpose of this study was to investigate the occurrence of possible defence mechanisms in cotton plants as mediated by initial feeding by *A. gossypii*. The experiments evaluated development and reproduction of this aphid on both detached leaves and whole plants of cotton variety H279-1.

MATERIAL AND METHODS

Plant material

Cotton variety H279-1 was used in the experiments. It is an improved, late-flowering variety widely used in Benin since 2003 (Sekloka et al., 2009), characterized by excellent vegetative growth and good yields (Sekloka et al., 2008). Four seeds of the cultivar were planted in each plastic pot (4l volume). The growing medium was a potting soil obtained from the field at International Institute of Tropical Agriculture in Benin (IITA-Benin), which was sterilized before use. After germination, seedlings were thinned to one plant per pot. All pots were manually watered daily. The potted plants were placed in a greenhouse to avoid infestation prior to the experiments.

Mass rearing of aphids and experimental conditions

Apterous individuals of *A. gossypii* used in this study were collected from cotton plants, variety H279-1 sown at the field station of IITA-Benin. The aphids were subsequently transferred onto cotton plants placed in the greenhouse as described above. Nymphs were obtained by putting apterous females on cotton leaf disks (5 cm diameter) placed upside down on wet cotton wool in Petri dishes (8.5 cm diameter). The cotton wool in the Petri dishes was soaked daily with water and the aphids were transferred on new leaf disks every week. Aphid rearing was done in the laboratory at 27 ± 1 °C, 70 ± 5% relative humidity and 12 h: 12 h photoperiod in accordance with their physiological requirements (Shannag et al., 2007; Liu et al, 2008). The tests were conducted using apterous individuals. The performance of *A. gossypii* on H279-1 variety was assessed through two experiments described below.

Life table study on detached cotton leaves

The aim of this first experiment was to assess the influence of using detached cotton leaves on life table parameters starting with new-born aphid nymphs. Wingless adult aphids (less than 12 h old) reared on cotton plants in laboratory were placed onto healthy cotton leaf disks for reproduction. Freshly hatched nymphs born within 12 h were individually transferred with a moistened brush onto the underside of a cotton leaf disk (5 cm diameter) which was kept upside on the wet cotton wool in the Petri dishes. The cotton wool in the Petri dishes (8.5 cm diameter) was soaked daily with water to maintain the leaves fresh and every 4 days, the leaf disks were changed. The experiment was performed in laboratory at 27 ± 1 °C and 70 ± 5% relative humidity and 12 h: 12 h photoperiod. A total of 36 individual nymphs were transferred to each Petri dish, 12 Petri dishes were used for this experiment, and repeated 3 times.

Individual nymphs were checked every 12 h and their development and mortality was recorded until they reached adulthood and produced the first parthenogenetic offsprings. The presence of exuviae was used to determine moulting time. After the first

Table 1. Longevity and fertility duration of *A. gossypii* on detached leaves and cotton plants

	Longevity (Mean ± SE) (days)	Oviposition duration (Mean ± SE) (days)	Sex ratio (female) (%)
Detached cotton leaves	18.92 ± 0.42	12.16 ± 0.43	100
Cotton plant	16.67 ± 0.71	11.17 ±0.55	100

parthenogenesis, reproduction of aphids on the leaf discs was checked every 24 hours. Observations continued daily until death of all adults. New-born aphids were counted daily and transferred to other Petri dishes. Leaves in Petri dishes were renewed every 4 days.

Life table study on whole cotton plants

This test evaluated the effect of whole cotton plants of the variety H 279-1 on the development of *A. gossypii*. The experiment was performed using young plants with 8 true leaves grown in laboratory at 27 ± 1℃ with a relative humidity of 70 ± 5% and a photoperiod of 12 h: 12h. Thirty nymphs less than 12 h old were individually transferred with a moistened fine brush on the fourth and fifth leaves of cotton seedlings. Individual nymphs were maintained on the leaves by enclosing them with sleeves made of white fine nylon mesh (18 x 16 cm) attached with a string to the petiole so as to avoid aphid escape. Moulting, fecundity and mortality were monitored every 24 h until death of all adults. At the adult stage, new-born larvae were removed after counting, transferred onto leaf disks in Petri dishes as described above and followed up to adult stage.

Data analysis

Survivorship and fertility life tables were subjected to the Jackknife method for evaluating intrinsic rate of increase (r_m), reproductive rate (R_o), mean lifetime (T_g), doubling time (T_d) and finite rate of increase (λ). Life table parameters of *A. gossypii* were calculated by the equations developed by Maia et al. (2000).

The SAS program (version 9.2) developed by Maia et al. (2000) was used to compute all the above life table parameters. A Student t-test was preformed for comparing life table parameters on plants and detached leaves.

RESULTS

Larval development and sex ratio

The nymph of *A. gossypii* passed through four different instars before reaching adulthood. The average duration for the 1st, 2nd, 3rd and 4th stage on detached cotton leaves was 1.19 ± 0.04, 1.08 ± 0.05, 1.00 ± 0.02 and 1.11 ± 0.04 days, respectively.

Nymphs underwent four subsequent moultings to reach the adult stage. The mean cycle time was 4.38 ± 0.07 days, while the shortest nymphal stage was the 3rd instar. The mean duration of each nymphal stage was about 1 day.

All wingless adults in the population, which were all 100% female biased (because of the parthenogenetic asexual reproduction), had the inherent capacity to produce offspring.

Life cycle and reproduction

The mean life cycle of the aphid, from the birth of the nymph to the death of the insect, was 18.92 ± 0.42 days on detached leaves and 16.67 ± 0.71 days on the whole cotton plant (Table 1). On detached leaves, the reproduction period of *A. gossypii* lasted on average 12.16 ± 0.43 days compared to 11.17 ± 0.55 days on whole cotton plants. The daily fecundity of aphid females increased from day 4 and reached a maximum peak of oviposition on day 10, with an average of 8.34 nymphs for detached leaves and about half that figure for whole plant (Figure 1). Aphid survival remained stable until day 10, and decreased slightly faster on whole plants than on detached leaves (Figure 2).

Effect of cotton plant on the development of *A. Gossypii*

Population growth parameters of *A. gossypii* reared on cotton plants and detached cotton leaves are presented in Table 2. Fecundity of female reared on cotton plants was significantly lower than that of females put on the detached leaves in Petri dishes (P = 0.0013). As a consequence, the net reproductive rate (Ro) of aphids on detached leaves (33.35 ± 1.68 nymphs) was twice as high as that of insects reared using cotton plants (16.023 ± 1.32 nymphs).

Intrinsic and finite rates of increase on detached leaves were significantly higher than those of individuals reared on cotton plants (F = 0.1317, P = 0.0003 and F = 0.5038, P = 0.0003, respectively). The doubling time (Td) of the population of *A. gossypii* on cotton leaves in Petri dishes was significantly lower than that of individuals reared on cotton plants (F = 0.9293, P = 0.0002). The time required for doubling the population of *A. gossypii* was the highest on cotton plants. The mean generation time Tg was statistically the same both on detached leaves and whole cotton plants (F = 0.0399, P = 0.0808).

Table 2. Life table parameters of *A. gossypii* on detached leaves and cotton plants

Parameters	**Estimation de Jackknife**		**Pr>F**	**P**
	Detached cotton leaves (Mean ±SE)	Cotton plant (Mean ±SE)		
Intrinsic rate of increase (r_m) (females/female/day)	0.363±0.00	0.308±0.00	0.5625	0.0003*
Net reproduction rate (R_0) (females/female)	33.35±1.68	16.023±1.32	0.7694	0.0013*
Mean generation time (Tg) (day)	9.65±0.06	8.98±0.21	0.1317	0.0399
Doubling time (T_d) (day)	1.91±0.02	2.25±0.02	0.9223	0.0002*
Finite rate of increase (λ) (females/female/day)	1.44±0.01	1.36±0.00	0.5038	0.0009*

***5% significance level**

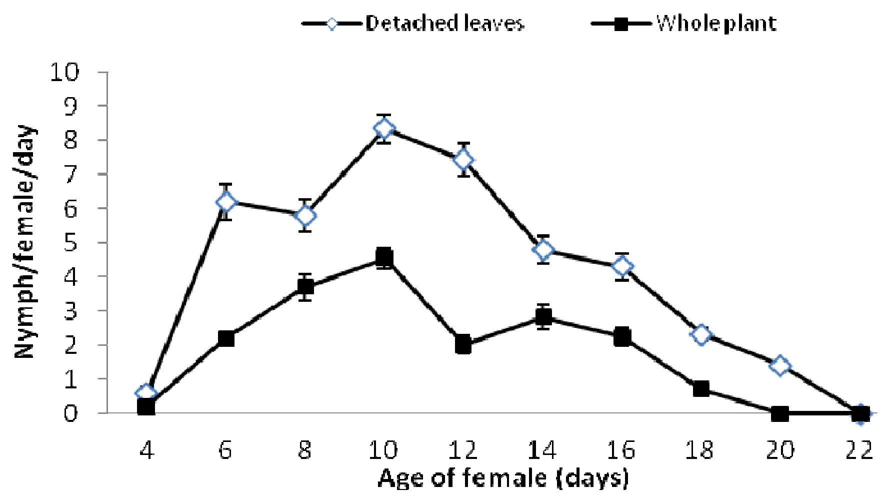

Figure 1. Fecundity of *A. gossypii* on cotton from Jackknife estimates (mean ± SE)

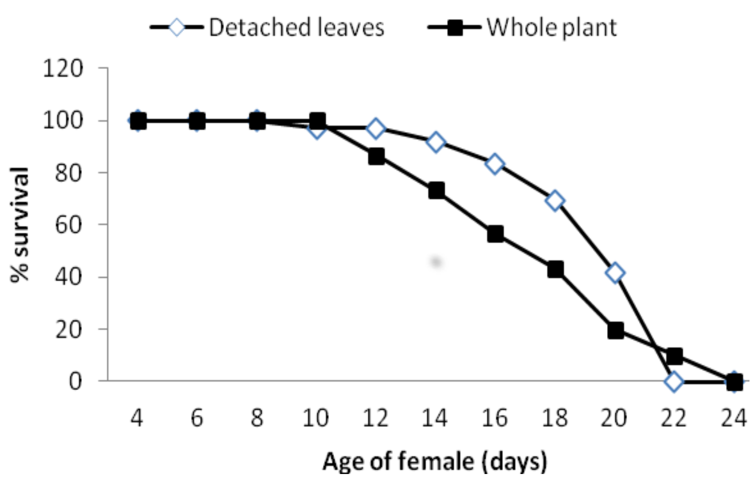

Figure 2. Evolution of adult survival of *A. gossypii* on cotton

DISCUSSION

Wingless individuals of *A. gossypii* are ametabolous insects with almost no change in form but only in size throughout its life cycle. The apterous aphids produce nymphs parthenogenetically. During their development, *A. gossypii* passes through four nymphal instars. Similar observations were reported for this aphid reared on various host plants (Passlow and Roubieck, 1967; Patil and Patel, 2013). The development time of *A. gossypii* from birth to adulthood, reared on cotton H279-1 at 27 ± 1℃ (4.38 days) is close to observations by Henneberry and Forlow Jech (2001) (4.1 days at 26.7℃) and Kersting et al. (1999) (4.5 days at 30℃). This development is slightly shorter than the one reported by Akey and Butler (1989) at 27.5 ℃ (5 days). This difference (less than one day) could be explained either by the time of neonate nymphs observation (every 12 hours in the present work), or by the nutritional quality of the host plant. As inferred by Ramzjou et al. (2006), the variability in the development time of *A. gossypii* can depend on cotton varieties. In their study, development time varied from 4.6 days on Bakhtegan (relatively susceptible cultivar) to 6.3 days on the Saeland (relatively resistant cultivar) at 27.5 ± 1℃. The development duration of *A. gossypii* immature stages on detached leaves observed in the present study corroborates findings by Ramzjou et al. (2006) using the cotton variety Bakhtegan.

The fecundity of *A. gossypii* differed significantly between detached leaves and whole plants. The reproductive rate (Ro) of adults on detached leaves were close to that obtained by Razmjou et al. (2006) on the variety Sahel (29.6 nymphs at 27.5℃). On the other hand, the fecundity of aphids reared on the whole cotton plants was similar to that reported by Razmjou et al. (2006) on the cotton varieties Sealand (15.3 nymphs at 27.5 ° C) and Nimbalkar et al. (2010) (17.32 nymphs at 35℃).

In fact, aphid-plant interactions can result in plant resistance or susceptibility to aphid (Hales et al., 1997). Many studies related to the interaction melon-*A. gossypii* revealed the presence of various resistance mechanisms (Kennedy et al., 1978; Klinger et al., 19998) including tolerance, antixenosis, and antibiosis which can reduce aphid development (Bohn et al., 1972). In the case of cotton, it possesses a wide range of resistance mechanisms against herbivorous arthropods that include morphological traits, and direct defence with secondary metabolites (Hagenbucher et al., 2013). Some morphological features of cotton such as trichomes, spiny structures, okra-shaped leaves, and hairiness provide some degree of resistance to sucking insects. Aphid resistance can also derive from a localized reaction through phloem elements that reduce sap sucking by aphid (Alborn et al., 1996).

In addition to the morphological traits and phloem change, plants activated defence mechanisms such as the synthesis of secondary metabolites to reduce damage by herbivores (Agrawal, 1998). Results from the present study showed that the number of nymphs produced on detached cotton leaves was nearly double as that produced on whole plants suggesting a possible interference with aphid development (Kennedy and Kishaba, 1976). Thus, Klinger et al. (1998) reported a slower aphid development and a reduced reproduction rate (47% of offspring) on resistant plant. Likewise, Alborn et al. (1996) demonstrated that cotton exhibits a local and/or systemic resistance to arthropod under given conditions. In the current work, the higher reproduction capacity observed detached cotton leaves could be attributed to absence of systemic defence involving the synthesis of secondary metabolites.

The intrinsic rate of natural increase (r_m), a parameter that characterizes the growth potential of insects populations (Birch, 1948; Messenger, 1964; Nowierski et al., 1983) was higher (0.363) on detached leaves as compared to whole plants (0.308), suggesting a faster growth of *A. gossypii* on detached leaves. Similarly, the net reproduction rate (Ro) of *A. gossypii* was lower on whole plants than on detached leaves. These observations support the Ro values obtained by Razmjou et al. (2006) which range from 0.272 to 0.382 depending on the cotton variety. On the same vein, the doubling time of the population was higher on whole plants than on detached leaves, which can be attributed to the low reproductive rate of the aphid on whole plants. In summary, this study demonstrates a better performance of *A. gossypii* when reared on detached cotton leaves as compared to the whole cotton plant. Our results suggest that the cotton plant, after the initial attack by colonizing aphids, might evolve defence mechanisms significantly affecting the development and reproduction of *A. gossypii.* These findings will need to be validated by follow-up studies targeting changes in cotton plant physiology and metabolism following exposure to aphid attack.

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