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Suitability of pollen sources for the development and reproduction of *Coleomegilla maculata* (Coleoptera: Coccinellidae) under simulated drought conditions

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Abstract

Laboratory experiments compared the nutritive value of various pollen sources for the development of *Coleomegilla maculata* DeGeer under conditions of continuous water availability and simulated drought. When water was continuously available, larval survival was not different from 100% on diets of frozen eggs of *Ephestia kuehniella* Zeller, corn pollen, sorghum pollen, or pulverized bee pollen, whereas survival of larvae was significantly reduced on the latter three diets in the simulated drought treatment. Pollen of cultivated sunflower, *Helianthus annus* L., proved fatal to both larvae and adults; its surface structure caused clumping and accumulation on the insect cuticle that led to death from exhaustion/desiccation in petri dishes. The *Ephestia* egg diet yielded shorter developmental times and heavier adult weights than any pollen diet in both treatments. The drought treatment increased developmental time on all diets with a significant treatment–diet interaction. Drought reduced the adult weight of females on the sorghum pollen diet, and that of both sexes on the bee pollen diet, again with a significant treatment–diet interaction. Initial water content was highest in corn pollen (36.8%), followed by *Ephestia* eggs (29.2%), sorghum pollen (25.3%), sunflower pollen (8.7%), and bee pollen (4.6%), but did not appear correlated with *C. maculata* larval survival on pollen sources under drought conditions. Reproductive adult females that received corn or sorghum pollen as a supplement to *Ephestia* eggs did not differ in fecundity or fertility from those fed only *Ephestia* eggs.

Keywords: *Coleomegilla maculata*; Development; Drought; *Helianthus annus*; Pollen; Reproduction; *Sorghum bicolor*; *Zea mays*

1. Introduction

Agriculture in the High Plains of the United States is dominated by cereal crops such as wheat, *Triticum aestivum* L., corn, *Zea mays* L., and sorghum, *Sorghum bicolor* (L.). Of secondary importance are oilseed crops such as soybeans and sunflowers. The primary pests of cereal crops are aphids, including the greenbug, *Schizaphis graminum* Rondani, the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) and the bird cherry-oat aphid, *Rhopalosiphum padi* (L). Recently, the soybean aphid, *Aphis glycines* Matsumura, has emerged as an adventive pest of soybeans in the American Midwest, renewing interest in biological control of aphids in oilseed crops (Fox and Landis, 2003). Suppression of aphid populations by natural enemies is especially important in these crops because their relatively low market value renders most control tactics non-economic. Biological control is typically provided by a complex of parasitoids (Aphidiidae, Aphelinidae), and predators (mostly Chrysopidae, Coccinellidae, and Syrphidae).

The twelve-spotted ladybeetle, *Coleomegilla maculata* DeGeer, is a native coccinellid species that, along with

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other species such as *Hippodamia convergens* Guerin and *Coccinella septempunctata* L., contributes significantly to biological control of cereal aphids in the High Plains (Elliott and Kieckhefer, 1990). *C. maculata* is renowned for its polyphagous habits (Hodek and Honek, 1996) and the ability of the larvae to develop successfully on an exclusive diet of pollen (Hodek et al., 1978). However, pollen may have relatively low water content compared with insect prey, especially aphids, raising the question of how a pollen diet might affect the water requirements of larval stages in an arid environment such as the High Plains.

It has been noted that the abundance of *C. maculata* in sweet corn tends to peak around the time of anthesis (Groden et al., 1990). Ostrom et al. (1997) used analysis of stable isotopes to demonstrate that *C. maculata* adults field-collected in California had obtained a large portion of their carbon and nitrogen budget from pollen sources, primarily alfalfa and corn. However, whether pollen availability improves or decreases the efficacy of *C. maculata* as a biological control agent has been the subject of some debate. The availability of pollen may serve to attract adult *C. maculata* into a crop, potentially improving biological control if beetles or their progeny remain beyond flowering to feed on insect prey (Harmon et al., 2000). However, if beetles focus on pollen consumption at the expense of insect prey, the impact of predation on pest populations may be reduced. For example, Pfannenstiel and Yeargan (2002) concluded that the availability of sweet corn pollen during anthesis reduced predation of *Helicoverpa zea* eggs by *C. maculata*, similar to the conclusion of Cottrell and Yeargan (1998). On the other hand, the presence of pollen as an alternative food source has been postulated to ameliorate intraguild predation between *C. maculata* and *Harmonia axyridis* Pallas and promote their co-existence in corn fields, presumably facilitating improved biological control (Musser and Shelton, 2003).

Much of the research on *C. maculata* pollen consumption has focused on corn, especially since it was discovered that the *Bacillus thuringensis* endotoxin can be expressed in the pollen of certain transgenic maize cultivars such as event MON863 (Duan et al., 2002; Lundgren and Wiedenmann, 2002; Wold et al., 2001). In western Kansas, *C. maculata* is known to be an important component of the predator guild that contributes to biological control of greenbug (Rice and Wilde, 1988). Adult *C. maculata* and other coccinellid species enter sorghum fields in early summer when plants are in the whorl stage to feed on colonies of *Rhopalosiphum maidis* (Fitch) (Kring and Gilstrap, 1986; J.P. Michaud, pers. observation). Although these aphid colonies normally disappear prior to flowering, *C. maculata* adults can also be found in flowering sorghum fields consuming pollen. Thus, both corn leaf aphids and sorghum pollen could serve to retain *C. maculata* adults within this crop and facilitate subsequent functional and numerical responses to greenbugs that can develop large and damaging colonies on sorghum plants in later stages of development. *Coleomegilla maculata* can also be found in multispecies aggregations of adult coccinellids on juvenile sunflower plants where they appear to ingest plant sap although they are rarely present on the sunflower blooms despite their production of abundant pollen (J.P. Michaud, unpublished data).

Given the potentially important role of pollen in the life history of *C. maculata* on the High Plains, and the ephemeral availability of different types of crop pollen seasonally, we conducted a series of experiments to assess the relative suitability of various pollen types for *C. maculata* larval development and adult reproduction. We compared the development of larvae raised on exclusive diets of the various pollen types to maximize resolution of nutritional differences and compare development to that obtained on a standardized diet of animal protein (eggs of *Ephestia kuehniella* Zeller). Since the High Plains is an arid region, we examined larval development on pollen under regimes of both limited and unlimited access to water, as some pollen sources can have relatively low water content relative to insect prey.

Adults also engage in pollen consumption, raising the question of how feeding on various pollen sources might affect reproductive performance. It has been shown that *C. maculata* fecundity is greater when animal protein is provided in addition to pollen (Riddick and Barbosa, 1998). However, pollen might serve as a dietary supplement that improves adult reproductive performance if available insect prey are of low nutritional value. Alternatively, if pollen feeding diminishes the consumption of more nutritious insect protein sources, adult reproduction could be adversely affected. Since adult beetles are capable of dispersal over considerable distances and unlikely to feed exclusively on pollen without access to animal protein, we provided three different crop pollens to ovipositing females as dietary supplements in addition to *Ephestia* eggs and assessed their reproductive performance.

2. Materials and methods

2.1. Insects

Adults of *C. maculata* were collected in Hays, KS in April, 2003 and used to initiate a stock colony that was maintained on a diet of frozen *Ephestia* eggs (Beneficial Insectary, Oak Run, California) supplemented with bee pollen. All insects in stock colonies and experiments were held in a climate-controlled growth chamber at a constant temperature of 24 ± 2 °C under 'cool-white' fluorescent lights set to 18 h day length. Relative humidity averaged $42 \pm 5\%$ throughout the course of experi-