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Performance of four species of phytoseiid mites on artificial and natural diets

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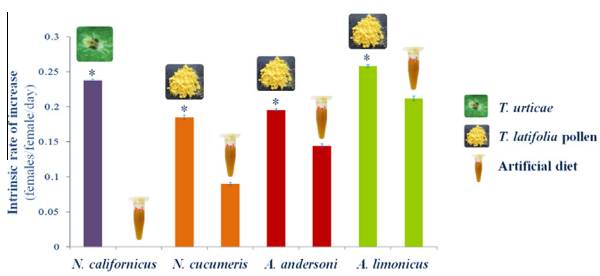
HIGHLIGHTS

- Population growth of four phytoseiids was studied on natural and artificial diets.
- A liquid artificial diet was enriched with extract of *Artemia franciscana* cysts.
- Growth rates were lower on artificial diet than on natural food, but survival was similar.
- The more generalist predators performed better on the artificial diet.
- The artificial diet has potential for the mass rearing or for use in the crop.

GRAPHICAL ABSTRACT



* Asterisks indicate significant differences among diets within a species (P < 0.05)

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ABSTRACT

The phytoseiid mites *Neoseiulus californicus* (McGregor), *Neoseiulus cucumeris* (Oudemans), *Amblyseius andersoni* Chant, and *Amblydromalus limonicus* Garman & McGregor (Acari: Phytoseiidae) are being used on a commercial scale as biological control agents of spider mites, thrips and whiteflies in protected crops. The present laboratory study was conducted to determine the life table parameters of these predatory mites when presented with a liquid artificial diet (consisting of honey, sucrose, tryptone, yeast extract and egg yolk) enriched with extract of dry decapsulated cysts of the brine shrimp *Artemia franciscana* Kellogg (Anostraca: Artemiidae), as compared to feeding on two-spotted spider mites *Tetranychus urticae* Koch (*N. californicus*) or *Typha latifolia* L. pollen (*N. cucumeris*, *A. andersoni* and *A. limonicus*). Diet had no influence on the immature survival rate, ranging from 92% to 98% for all species. Female developmental times were significantly shorter for predators offered spider mites or pollen than for those fed the artificial diet, except in *A. limonicus.* The fecundity of *N. californicus*, *N. cucumeris* and *A. limonicus* females given spider mites or pollen was significantly higher than that of females presented with the artificial diet, whereas no differences among diets were observed in *A. andersoni.* When *N. californicus* females were fed on the artificial diet, none of their offspring succeeded in reaching adulthood. Our findings indicate the potential of this artificial diet for use as a supplemental food source to maintain populations in the crop after release or for use in the mass production, especially for the more generalist predatory mites *A. andersoni* and *A. limonicus*.

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1. Introduction

Phytoseiid predatory mites are important biocontrol agents of tetranychid mites and small, soft-bodied insects like thrips and whiteflies (Chant, 1985). In augmentation biological control, large numbers of predaceous mites are released in the field (Collier and Van Steenwyk, 2004; Stinner, 1977). Hence, a cost-effective method for their mass-rearing is an essential prerequisite (van Lenteren, 2003). Rearing phytoseiid mites on plant materials infested with natural prey has several disadvantages, such as large space requirements, inconsistent yields of predators, harvesting difficulties and variable results with different species (McMurtry and Scriven, 1965). Rearing procedures based on factitious prey like storage mites (Bolckmans and van Houten, 2006; Zhang, 2003) also involve space and labor to maintain large parallel cultures of the factitious prey. Further, there may be health risks for workers in production facilities or releases in the crop caused by allergens associated with the factitious mite prey (Bolckmans and van Houten, 2006; Fernandez-Caldas et al., 2007). The availability of an adequate artificial diet could eliminate many of the above-mentioned problems associated with the mass production of predatory mites (Kennett and Hamai, 1980). In addition, these artificial diets may be useful as food supplements to support predator populations after release in the crop (Wade et al., 2008).

Several artificial diets have been developed for phytoseiid mites, but the results were mostly inferior to those on natural or factitious prey. McMurtry and Scriven (1966) reported longer developmental times and lower oviposition rates when four phytoseiids (*Amblydromalus limonicus* Garman and McGregor, *Amblyseius hibisci* (Chant), *Typhlodromus occidentalis* Nesbitt and *Typhlodromus rickeri* Chant) (Acari: Phytoseiidae) were fed on various artificial diets compared with mite prey and pollen as food sources. Shehata and Weismann (1972) tested three artificial diets for the specialist spider mite predator *Phytoseiulus persimilis* Athias-Henriot. Their results indicated that the larvae could develop to adults but the females failed to produce viable eggs. Kennett and Hamai (1980) investigated oviposition rate and developmental capacity of 9 predaceous mites (*A. hibisci*, *A. limonicus*, *Amblyseius largoensis* (Muma), *Metaseiulus pomoides* Schuster & Pritchard, *T. occidentalis*, *Typhloseiopsis arboreus* (Chant), *Typhloseiopsis pyri* Scheuten, *P. persimilis*, and *Iphiseius degenerans* (Berlese)) fed on artificial and natural diets. The authors reported that complete development and oviposition occurred for seven out of nine species when fed on an artificial diet consisting of bee honey, sugar, yeast flakes, yeast hydrolysate, enzymatic casein hydrolysate and fresh egg yolk. Oviposition rates of all species fed on the artificial diet were lower than those on a natural diet. Ochieng et al. (1987) reported that *Amblyseius teke* Pritchard and Baker could complete more than 25 generations when reared on a liquid diet composed of bee honey, milk powder, egg yolk and Wesson's salt. Abou-Awad et al. (1992) noted that the predacious mites *Amblyseius gossipi* El-Badry and *Amblyseius swirskii* Athias-Henriot developed and reproduced successfully on artificial diets composed of yeast, milk, cysteine, proline, arginine, sucrose, glucose, streptomycin sulfate and sorbic acid. However, fecundity of both species fed on the artificial diet was lower than on natural prey, although the eggs showed no abnormalities. Shih et al. (1993) conducted experiments to investigate the responses of *Euseius ovalis* (Evans) to natural food resources and two artificial diets. Immature development was successful in the first generation but offspring was not able to complete its life cycle when maintained on the artificial diets. The females of *E. ovalis* fed on artificial diets showed a shorter oviposition period, lower daily and total reproductive rates, and shorter longevity than those fed on natural diets. Ogawa and Osakabe (2008) investigated the development and survival of *Neoseiulus californicus* (McGregor) on an artificial diet. The phytoseiid successfully developed on the artificial diet, but only few eggs were deposited.

In our previous studies we found that artificial diets enriched with an extract of dry decapsulated cysts of the brine shrimp *Artemia franciscana* Kellogg (Anostraca: Artemiidae) or pupal hemolymph of the Chinese oak silkworm (*Antheraea pernyi* (Guérin-Méneville)) supported development and reproduction of the generalist predatory mite *A. swirskii*. The females fed on these two artificial diets displayed higher intrinsic rates of increase than those fed on several natural prey and performed as well as those reared on the factitious prey *Carpoglyphus lactis* L. (Acari: Carpoglyphidae), which is routinely used in the mass rearing of this phytoseiid (Nguyen et al., 2014a, 2013). The objectives of the present study were to assess the suitability of the artificial diet enriched with *A. franciscana* as an alternative food for several other economically important predatory mites by performing full life table studies under controlled laboratory conditions. The phytoseiids selected for testing belong to different types based on their level of food specialization (McMurtry et al., 2013): *N. californicus* is a selective predator of tetranychid mites (type II), whereas *A. andersoni* Chant, *N. cucumeris* (Oudemans), and *A. limonicus* are more generalist predators (type III).

2. Materials and methods

2.1. Stock colonies of predatory mites

Laboratory cultures of *N. cucumeris* and *A. limonicus* were initiated with specimens supplied by Koppert B.V. (Berkel en Rodenrijs, The Netherlands) and *A. andersoni* was supplied by Biobest N.V. (Westerlo, Belgium). The mites were reared on green plastic arenas ($10 \times 10 \times 0.3$ cm) (Multicel, SEDPA, France), placed on a wet sponge in a plastic tray containing water (Nguyen et al., 2013). The edges of the arenas were covered with tissue paper immersed in the water to provide moisture and deter the mites from escaping. Every two days the mites were fed with fresh cattail pollen (*Typha latifolia* L.), which was also supplied by Koppert B.V. and stored at -18 °C. For the experiments, pollen was thawed and kept in a refrigerator at 5 °C for max. 1 week. A small piece of sewing thread was placed on the arenas to serve as an oviposition substrate. Every two days the eggs were collected and transferred to new arenas.

A culture of *N. californicus* was initiated with mites acquired from Koppert B.V. and was reared on kidney bean leaves heavily infested with two-spotted spider mites (*Tetranychus urticae* Koch). The leaves were placed upside down on a layer of water-saturated cotton in a glass petri dish (ϕ 133 mm), with an extra cotton layer on the leaf edges to provide free water and prevent the mites from escaping.

Predatory mites were cultured in a growth chamber set at 25 ± 1 °C, 70 ± 5% RH and a 16:8 h (L:D) photoperiod.

2.2. Preparation of artificial diet

Artificial diets were prepared according to Nguyen et al. (2014a): 80% basic artificial diet supplemented with 20% (w/w) extract of dry decapsulated *A. franciscana* cysts, which were provided by the *Artemia* Reference Center of Ghent University (Ghent, Belgium) and originated from the Great Salt Lake (Utah, USA). The basic artificial diet was composed of 5% honey (Meli N.V., Veurne, Belgium), 5% sucrose (MP Biomedicals LLC, Illkirch, France), 5% tryptone (a pancreatic digest of casein; Fluka Analytical, Sigma–Aldrich Co., St. Louis, USA), 5% yeast extract (Duchefa, Haarlem, The Netherlands), 10% fresh hen's egg yolk, and 70% distilled water, and was prepared according to Nguyen et al. (2013). The diet was dispensed into 2 ml Eppendorf tubes and stored at -18 °C.