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Influence of sublethal abamectin exposure on development, reproduction, and population growth of the predatory mite *Amblyseius swirskii* (Acari: Phytoseiidae)

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ABSTRACT

The predatory mite *Amblyseius swirskii* is widely used as a biological control agent against spider mites, thrips, and whiteflies. This study examined the sublethal effects of two abamectin concentrations (LC_{10} and LC_{20} for *A. swirskii*) on life history traits and demographic parameters of the F_1 generation derived from treated parents under controlled laboratory conditions (25 ± 1 °C, 75 ± 5% RH, 16:8 [L:D] photoperiod). Using the age-stage, two-sex life table approach with *Tetranychus urticae* Koch as prey, results showed that total longevity was shortest in progeny of LC_{20}-treated parents (males = 13.42 days; females = 13.94 days) compared with LC_{10} progeny (males = 15.06 days; females = 15.50 days). Fecundity, oviposition period, and net reproductive rate (R_0) declined significantly with increasing acaricide concentration. Intrinsic and finite rate were reported to be increased in the treatments (r: 0.159 vs. 0.199 day^{-1}; λ: 1.172 vs. 1.221 day^{-1}). Age-specific survival (l_x), fecundity (m_x), and reproductive value (v_{xj}) curves indicated pronounced adverse effects of sublethal exposure on population performance. These findings demonstrate that even low concentrations of abamectin can compromise key life history traits of *A. swirskii*, potentially limiting its effectiveness in biological control programs. Thus, evaluating acaricide compatibility with natural enemies is critical for successful IPM implementation.

KEYWORDS

IPM, life table, side effect, sublethal effects, *Tetranychus urticae*

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INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae* (Prostigmata: Tetranychidae), is a highly polyphagous pest that threatens a wide range of crops, including vegetables, fruits, ornamentals, and fiber plants, causing significant economic losses worldwide (Zhang 2003; Xu *et al.* 2012). Its rapid reproductive cycle, adaptability to diverse environmental conditions, and ability to develop resistance to chemical pesticides make it a persistent challenge in both greenhouse and open-field cropping systems (Nicholas *et al.* 1998; Naher *et al.* 2006). Excessive use of synthetic acaricides has led to environmental pollution, reduction of non-target beneficial species, resistant mite populations, and contamination of food products (Dettbern *et al.* 2006; Sinha *et al.* 2012; Lozowicka 2015). These factors have emphasized the need for Integrated Pest Management (IPM) strategies that prioritize environmentally friendly approaches, particularly biological control. Among biological control agents, the predatory mite *Amblyseius swirskii* (Phytoseiidae) is widely used due to its efficiency against whiteflies, thrips, and spider mites. It can persist on alternative foods such as pollen when prey densities are low, supporting its establishment in diverse cropping systems (Castagnoli and Simoni 1999). Since its commercialization in 2005, *A. swirskii* has become a key component of greenhouse pest management worldwide (Van Lenteren and Woets 1988; Fathipour *et al.* 2017). Chemical acaricides, such as Agrimec Gold, which contains 8.4% abamectin derived from *Streptomyces avermitilis*, are widely used to control spider mites. Unlike many persistent acaricide formulations, Agrimec Gold is characterized by rapid photodegradation and strong adsorption to soil particles, leading to low environmental persistence and minimal residue accumulation (Escalada *et al.* 2008; European Food Safety Authority (EFSA) 2020). However, sublethal exposure can adversely affect non-target beneficial organisms such as predatory mites (Schausberger *et al.* 2010). These characteristics distinguish Agrimec Gold from other abamectin formulations and highlight the need for careful evaluations in integrated pest management programs. Life tables, particularly the age-stage, two-sex model, provide a robust framework to assess developmental stages, survival, reproduction, and population growth of predatory mites (Chi *et al.* 2020, 2023). Understanding how sublethal exposure affects these parameters is essential for designing effective and sustainable IPM strategies.

In this study, we hypothesized that sublethal exposure to Agrimec Gold would reduce fecundity, longevity, and key population parameters of the F_1 generation of *A. swirskii*. Testing this hypothesis allows for a clearer assessment of the compatibility between chemical and biological control agents in IPM.

MATERIAL AND METHODS

Host plant cultivation

The common bean, *Phaseolus vulgaris* L., was chosen as the host plant to rear colonies of the two-spotted spider mite (TSSM) *Tetranychus urticae* Koch. Prior to planting, the seeds underwent a 24-hour soaking period in moist cloth to promote optimal germination. Afterwards, several seeds were sown into plastic containers measuring 14 cm in diameter and 12 cm in depth, filled with a standard potting mixture composed of equal parts soil, sand, and peat (totally 30 kg). To ensure a constant availability of fresh host plants during the study, new seeds were planted.

Rearing of two-spotted spider mite

Specimens of the two-spotted spider mite *T. urticae* were initially gathered from a strawberry greenhouse located at the Faculty of Agriculture, University of Kurdistan, Sanandaj, western Iran, during 2024. To establish infestations on healthy common bean plants, leaves carrying mites were directly placed onto the foliage, facilitating natural mite transfer. The infested plants were then kept under controlled conditions in a growth chamber set at 25 ± 1 °C temperature, 75 ± 5% relative humidity, and a photo-period of 16 hours light followed by 8 hours darkness to allow the colonies to develop and expand.

Phytoseiid rearing

The cohort of the predatory mite *Amblyseius swirskii* used in this research was sourced from specimens provided by Berg Sabz Engineering Company in 2024. Rearing was carried out in the Entomology Research Laboratory at the University of Kurdistan, utilizing cylindrical plastic containers measuring 20 cm in diameter and 18 cm in height. Each container housed common bean leaves infested with two-spotted spider mites, serving as prey for the predatory mites. Fresh infested leaves containing a range of developmental stages of TSSM were introduced into the rearing arenas thrice weekly. To ensure consistency and reduce effects related to diet or intrinsic factors, the predator populations were maintained for two successive generations feeding solely on TSSM. The duration from egg deposition to adult emergence was recorded under the previously mentioned controlled environmental settings.

Acaricide

Agrimec Gold acaricide was prepared for use. This pesticide targets various pests, including mites, across multiple crops. Its active component is 8.4% abamectin. It is formulated to provide enhanced dispersion and efficacy due to its fine particle composition. This acaricide was selected to evaluate its potential compatibility with biological control agents within Integrated Pest Management programs.

Toxicity bioassay

Agrimec Gold acaricide (commercial formulation containing 8.4% abamectin) was used in the bioassays. Initial range-finding tests were conducted to determine concentrations causing minimal (< 15%) and maximal (> 85%) mortality. A logarithmic dilution series was then prepared to establish test concentrations. The leaf-dip method was employed for toxicity assessment. Leaf discs (diameter: 2 cm) from *P. vulgaris* plants were submerged in the acaricide solution for 15 seconds and then air-dried under laboratory conditions for three hours. Cohorts of twenty 24-hour-old adult female and male *A. swirskii* (equal sex ratio), reared in pesticide-free conditions, were transferred onto each treated leaf disc. Control leaf discs were dipped in distilled water under the same conditions. Each disc was placed in a Petri dish lined with moistened cotton to maintain humidity and prevent mite escape, with daily rehydration of the cotton. Five concentrations plus a control were used, each with three replicates, and the entire assay was independently repeated three times. Mortality was assessed at 24, 48, and 72 hours post-exposure. LC_{50} values were estimated using probit analysis, and sublethal concentrations (LC_{10} and LC_{20}) were calculated based on mortality at 72 hours post-treatment, which were then used for subsequent demographic studies (Table 1).

Use of previously validated control data (external control)

The control data used in this study were obtained from our previously published research (Rahimi *et al.* 2022) conducted under identical laboratory conditions using the same methodology. Therefore, this dataset served as a reliable external control, avoiding unnecessary repetition of experiments while maintaining scientific rigor.

Life history parameters at sublethal concentrations

Transgenerational sublethal effects of abamectin were evaluated using life-table parameters of F1 cohorts derived from treated *A. swirskii* parents (F_0 generation). Leaf discs (diameter: 2 cm) of common bean (*P. vulgaris*) were used for egg collection and mite rearing. To obtain eggs for each treatment, 60 pairs of adult *A. swirskii* were individually placed on leaf discs previously treated with LC_{10} and LC_{20} concentra-tions of Agrimec Gold. Control cohorts were treated with distilled water, and corresponding life-table data were obtained from Rahimi *et al.* (2022) under identical laboratory conditions. After 24 hours, surviving individuals were transferred to fresh, untreated leaf discs for oviposition. Eggs laid were counted daily, and developmental duration, egg hatchability, and daily mortality were monitored. Seventy F_1 eggs laid within 24 h were collected for the life-table study and maintained individually in cylindrical plastic containers with acaricide-free common bean leaves. The predatory mites were reared on all developmental stages of the two-spotted spider mite (TSSM), which served as prey throughout the experiment. Observations were made at 24 h intervals using a stereomicroscope (Olympus Optical Co., Ltd., Tokyo, Japan). The development time from egg to adult emergence of the F1 generation was recorded under laboratory conditions (25 ± 1 °C, 75 ± 5% RH, 16:8 h L:D photoperiod). Upon adult emergence, each female was paired with one male. In cases where extra individuals emerged and a balanced pairing was not possible, surplus males or females were excluded from the reproductive study. Female reproductive parameters including pre-oviposition, oviposition, postoviposition periods, daily and total fecundity and longevity were recorded daily until death. The number of individuals per treatment used for life-table analysis was 70 F_1 eggs, fully monitored as independent trajectories. Data for control cohorts were included from Rahimi *et al.* (2022) for comparison.

Statistical Analysis

The life history raw data of all individuals were analyzed using the age-stage, two-sex life table procedure (Chi and Liu 1985; Chi 1988). Data were collected on the life table parameters including the age-stage specific survival rate (s_{xj}) (where x = age in days and j = stage); the age stage-specific fecundity (f_x) (daily number of eggs produced per female of age x); the age-specific survival rate (l_x); the age specific fecundity (m_x); the adult pre oviposition period (APOP, the length of the pre-oviposition period beginning from adult emergence); and the total pre-oviposition period (TPOP; the length of the pre oviposition period beginning from birth). The population growth parameters, including the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and mean generation time

(*T*) were also calculated. According to Chi and Liu (1985), age-specific survival rate was calculated.

The standard errors of the developmental times, fecundity, reproduction period and population parameters were estimated using the bootstrap method (Efron and Tibshirani 1994; Huang and Chi 2012), with 100,000 bootstraps to obtain stable estimates of standard errors (Akca *et al.* 2015). The paired bootstrap test was used to compare differences (Efron and Tibshirani 1994). The computer program TWOSEX-MSChart (Chi 2024) was used for the raw data analysis and calculation of population parameters.

RESULTS

The sublethal effects of the acaricide Agrimec Gold on the demographic parameters of *A. swirskii* were evaluated. Acaricides often exhibit stage-specific toxicity, affecting certain developmental stages rather than causing broad-spectrum lethality. This selective action underlies their widespread use in mite management programs. In this study, Agrimec Gold was applied to adult *A. swirskii*, allowing assessment of its sublethal impacts on life-table parameters (Table 1).

Table 1. Mean lethal concentrations (LC_{10}, LC_{20} and LC50, µg a.i./ml) of Agrimec Gold for *Amblyseius swirskii*.

Treatment	Slope ± SE	χ^2 (df [b])	LC_{10}	LC_{20}	LC_{50}
Agrimec Gold	2.536 ± 0.260	5.183	9.643 (5.239–14.913)	21.343 (13.611–30.123)	97.571 (72.613–134.623)

Table 2 summarizes the duration of developmental stages and total longevity of *A. swirskii* exposed to sublethal concentrations (LC_{10} and LC_{20}) of Agrimec Gold, alongside control data from Rahimi *et al.* (2022). The egg stage duration was not significantly affected by the treatments, indicating minimal impact on embryonic development. The larval stage was slightly shortened, lasting 1.04 days under LC_{10} and 1.00 day under LC_{20}, compared with 1.11 days in the control. The total development time from egg to adult emergence averaged 6.42 and 6.51 days in females, and 6.59 and 6.42 days in males under LC_{10} and LC_{20}, respectively, showing no significant differences from control values (female: 7.32 days; male: 5.75 days). Adult longevity was significantly affected by treatments: female lifespan decreased from 20.03 days in the control to 9.08 days (LC_{10}) and 7.43 days (LC_{20}), while male longevity decreased from 13.38 days in the control to 8.47 days (LC_{10}) and 7.00 days (LC_{20}), indicating pronounced effects on post-embryonic stages.

Table 2. Development time of different stages and longevity (days ± SE) of *Amblyseius swirskii* (male and female) treated with Agrimec Gold (LC_{10} and LC_{20}).

Stage	Control (Rahimi *et al.* 2022)		LC_{10}		LC_{20}	
	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE
Egg	70	1.6 ± 0.06a	70	1.43 ± 0.06a	70	1.36 ± 0.06a
Larva	65	1.11 ± 0.04a	70	1.04 ± 0.02a	70	1.00 ± 0a
Protonymph	58	1.91 ± 0.04a	70	1.06 ± 0.03a	70	1.07 ± 0.03a
Deutonymph	58	2.14 ± 0.08a	68	2.99 ± 0.04a	68	3.04 ± 0.03a
Female preadult	34	7.32 ± 0.08a	36	6.42 ± 0.12a	35	6.51 ± 0.10a
Male preadult	24	5.75 ± 0.09a	32	6.59 ± 0.09a	33	6.42 ± 0.10a
Female adult	34	20.03 ± 0.75a	36	9.08 ± 0.14b	35	7.43 ± 0.12c
Male adult	24	13.38 ± 0.52a	32	8.47 ± 0.10b	33	7 ± 0.14c
Female total	34	27.35 ± 0.77a	36	15.50 ± 0.18b	35	13.94± 0.15c
Male total	24	19.12 ± 0.52a	32	15.06 ± 0.10b	33	13.42 ± 0.17c

n = number of individuals per stage. Means followed by the same lowercase letter within a row indicate no significant difference among treatments (paired bootstrap test, $P < 0.05$). Standard errors were estimated using the bootstrap technique with 100,000 resampling. Control data were obtained from Rahimi *et al.* (2022) under identical laboratory conditions and are included for comparison.

Age-specific survival curves (Fig. 1) demonstrated stage- and sex-dependent effects. Female survival consistently exceeded that of males across treatments. Under LC_{10}, larval survival probability was ~0.58, slightly increasing to 0.61 under LC_{20}. Adult female survival was 0.43 (LC_{10}) and 0.42 (LC_{20}), while males showed ~0.41 survival at both concentrations.

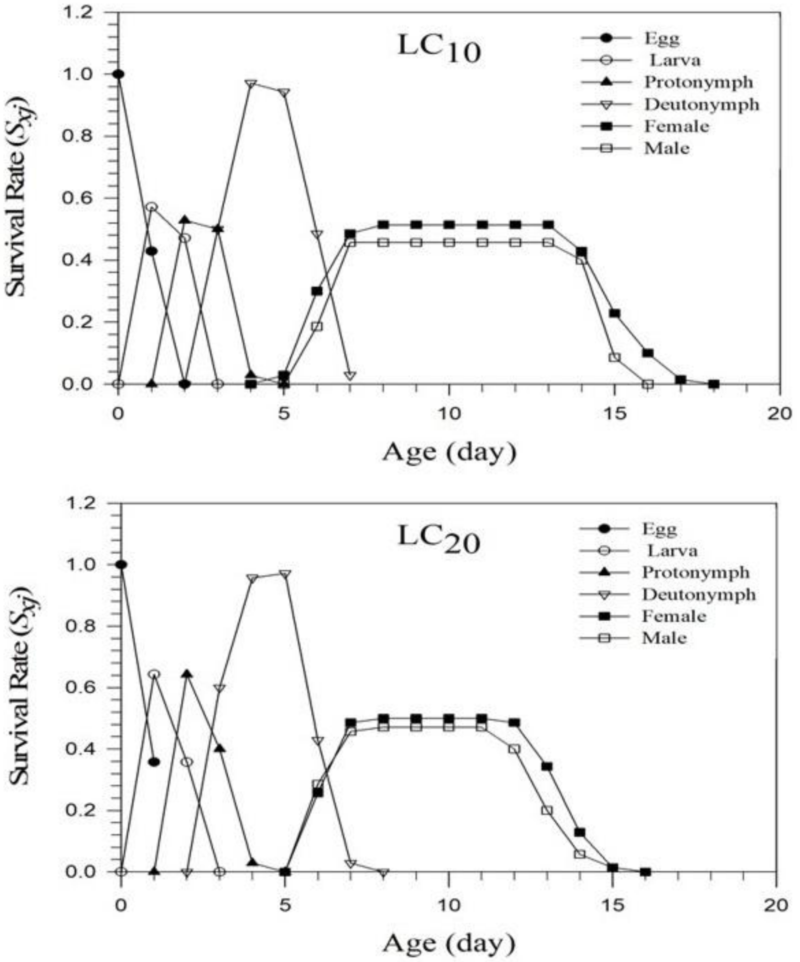

Figure 1. Age-specific survival rate (S_{xj}) of *Amblyseius swirskii* treated with Agrimec Gold (LC_{10} and LC_{20}).

Reproductive parameters are summarized in (Table 3). Pre-oviposition periods (APOP and TPOP) did not differ significantly among treatments (Control: APOP = 2.32 days, TPOP = 9.65 days; LC_{10}: APOP = 0.44 days, TPOP = 6.86 days; LC_{20}: APOP = 0.43 days, TPOP = 6.94 days). In contrast, fecundity and oviposition duration were significantly reduced with acaricide exposure. Total eggs per female decreased from 27.24 in the control to 17.17 at LC_{10} and 11.94 at LC_{20}, and oviposition duration shortened from 16.15 days (control) to 7.64 days (LC_{10}) and 6.00 days (LC_{20}), highlighting strong negative effects of sublethal exposure on reproductive output.

Table 3. Adult pre-oviposition (APOP), total pre-oviposition period (TPOP), fecundity (eggs/female) and oviposition days (day) of *Amblyseius swirskii* treated with Agrimec Gold (LC_{10} and LC_{20}).

Stage	Control (Rahimi *et al.* 2022)		LC_{10}		LC_{20}	
	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE
APOP	34	2.32 ± 0.08a	36	0.44 ± 0.08b	35	0.43 ± 0.08b
TPOP	34	9.65 ± 0.1a	36	6.86 ± 0.17b	35	6.94 ± 0.14b
Fecundity (*F*)	34	27.24 ± 0.93a	36	17.17 ± 0.47b	35	11.94 ± 0.31c
Oviposition days	34	16.15 ± 0.54a	36	7.64 ± 0.17b	35	6.00 ± 0.14c

Standard errors were estimated by using the bootstrap technique with 100,000 resampling. Means followed by the same letter in a row indicate no significant difference between cultivars (paired bootstrap test, $P < 0.05$).
Control data were obtained from Rahimi *et al.* (2022) under identical laboratory conditions and are included for comparison.

Life expectancy (e_{xj}) curves of *A. swirskii* under sublethal concentrations of Agrimec Gold confirmed a concentration-dependent decline in expected lifespan (Fig. 2). These values are reflected in the life-expectancy curves: under LC_{10} females show substantially reduced remaining life expectancy relative to the control (consistent with the 15.5 d mean total longevity), and under LC_{20} this expectancy declines further (consistent with the 13.94 d mean total longevity). Male life expectancy follows the same pattern, with smaller absolute values than females in all treatments. Immature stages (egg, larva, protonymph, deutonymph) exhibit short, stage-specific expectancies that fall to zero within the first ~5–6 days, as shown in the stage-specific curves. Overall, life-expectancy profiles and total-longevity statistics both indicate that Agrimec Gold causes a pronounced, dose-dependent reduction in adult survival.

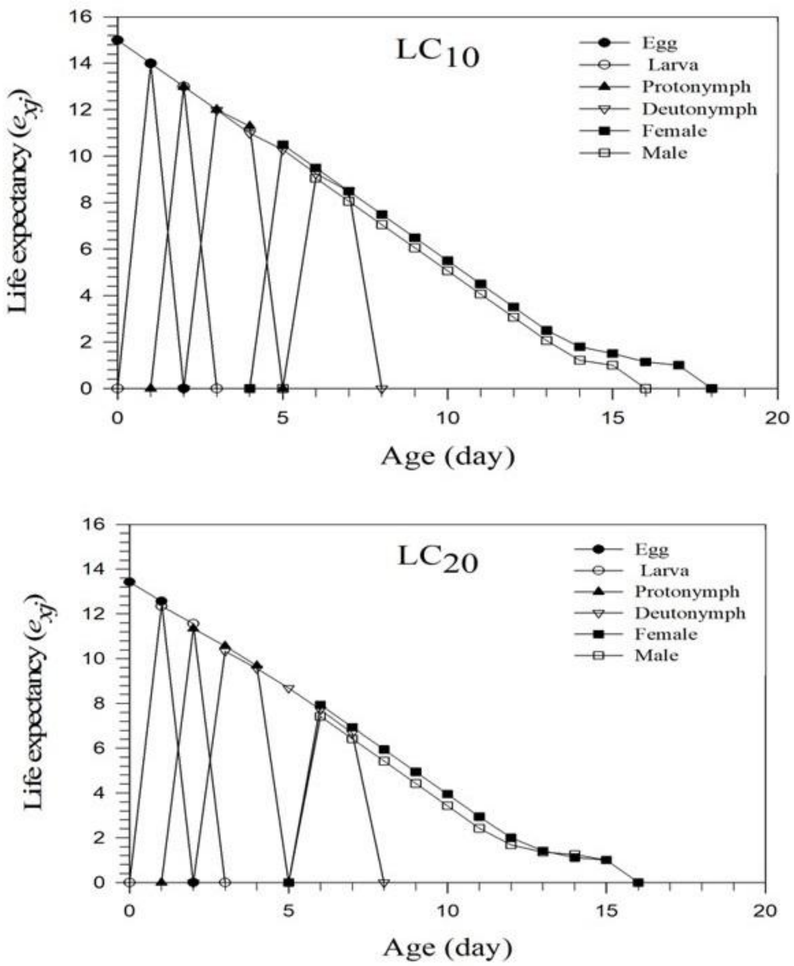

Figure 2. Age-specific life expectancy (e_{xj}) of *Amblyseius swirskii* treated with Agrimec Gold (LC_{10} and LC_{20}).

Life expectancy of *A. swirskii* was markedly reduced under sublethal concentrations of Agrimec Gold (LC_{10} and LC_{20}) in a concentration-dependent manner. Compared with the control at 25 °C (Rahimi *et al.* 2022), exposure to both concentrations substantially shortened life expectancy, particularly in the adult stage. Females exhibited higher life expectancy than males across treatments, yet this difference was more evident at LC_{20}. These results indicate that sublethal exposure to Agrimec Gold accelerates mortality and disproportionately affects post-embryonic stages.

The age-stage-specific reproductive value (v_{xj}) showed a clear concentration-dependent pattern, peaking at the early adult stage and declining sharply thereafter. Sublethal concentrations accelerated the attainment of peak reproductive value compared to optimal conditions, with the highest values observed earlier under LC_{20}. Although the timing of reproduction advanced, overall reproductive potential was truncated at higher concentrations, resulting in a shorter reproductive window. These findings highlight the negative, concentration-dependent impact of Agrimec Gold on population growth parameters of *A. swirskii*.

Life table analyses (Table 4) confirmed concentration-dependent effects. The intrinsic rate of increase (*r*) was 0.205 day^{-1} at LC_{10} and 0.177 day^{-1} at LC_{20}, compared with 0.15 day^{-1} in the control, reflecting higher reproductive capacity at LC_{10}. The finite rate of increase (λ) was 1.227 day^{-1} at LC_{10} and 1.194 day^{-1} at LC_{20}, compared with 1.17 day^{-1} in the control. The net reproductive rate (R_0) declined from 13.22 in the control to 8.828 at LC_{10} and 5.971 at LC_{20}. Mean generation time (*T*) was 16.41 days (control), 10.60 days (LC_{10}), and 10.05 days (LC_{20}). These findings indicate that higher sublethal concentrations significantly reduce demographic fitness, while LC_{10} exerts a moderate effect, emphasizing the importance of considering concentration-dependent impacts when assessing acaricide compatibility with predatory mites.

Table 4. Life table parameters (mean ± SE) of *Amblyseius swirskii* treated with Agrimec Gold. R_0, net reproductive rate; *r*, intrinsic rate of increase; λ, finite rate of increase; *T*, mean generation time.

Parameter	Treatment		
	Control (Rahimi *et al.* 2022)	LC_{10}	LC_{20}
R_0 (offspring/individual)	13.22 ± 1.69a	8.828 ± 1.054b	5.971 ± 0.728c
r (day^{-1})	0.15 ± 0.008a	0.205 ± 0.012b	0.177 ± 0.012ab
λ (day^{-1})	1.17 ± 0.009a	1.227 ± 0.015b	1.194 ± 0.015ab
T (day)	16.41 ± 0.21a	10.60 ± 0.161b	10.05 ± 0.112c

Control data were obtained from Rahimi et al. (2022) under identical laboratory conditions and are included for comparison.

DISCUSSION

Increasingly, agricultural producers recognize the importance of eco-friendly practices and integrated pest management (IPM) strategies to meet the growing global demand for safe and sustainable products. Implementing such strategies not only reduces the frequency and intensity of pesticide applications but also enhances the competitiveness of crops in international markets (Cuthbertson and Murchie 2006). Concurrently, with the world population continuing to rise, ensuring food security remains a critical societal challenge. Effective IPM programs rely on a thorough understanding of the interactions between chemical pesticides and beneficial organisms in agroecosystems. By integrating pesticide-tolerant natural enemies with selective chemical applications that minimize non-target effects, pest populations can be managed efficiently while preserving ecological balance (Tommy and Robinson 2009).

While traditional lethal dose assessments provide information on mortality by categorizing individuals as either alive or dead, they often overlook the broader spectrum of sublethal effects. Many pesticides may exert minimal immediate lethality on beneficial organisms but can substantially impair key life-history traits, particularly reproductive performance (Sanatgar *et al.* 2011). Consequently, demographic toxicological approaches, especially those employing age-stage, two-sex life table analyses, offer a more comprehensive evaluation of pesticide impacts. These methods allow for simultaneous assessment of survival, fecundity, and population growth parameters, yielding a more complete understanding of the potential ecological consequences of chemical exposure (Marcic 2003).

The results of this study indicated that the duration of the egg stage of *A. swirskii* was not significantly affected by LC_{10} and LC_{20} concentrations of Agrimec Gold, suggesting negligible impact on embryonic development. These findings are consistent with the control data reported by Rahimi *et al.* (2022), where egg stage duration remained stable under identical laboratory and dietary conditions. Helle and Sabelis (1985) also reported that egg development in mites is primarily influenced by food quality rather than chemical exposure, supporting the observation that the embryonic stage is less sensitive to acaricides. In contrast, significant reductions were observed in the larval stage, indicating a detrimental effect of Agrimec Gold on this more vulnerable developmental phase, likely due to its higher mobility and greater exposure compared to relatively protected eggs.

In the present study, the lifespan of both male and female *A. swirskii* decreased markedly under LC_{10} and LC_{20} concentrations of Agrimec Gold compared with the untreated control reported by Rahimi *et al.* (2022). As expected for phytoseiid mites, females consistently lived longer than males across all treatments. This pattern is well documented in predatory mites and has been attributed to the more active mate-searching behavior of males, which increases their energy expenditure and mortality risk (Amano and Chant 1986). In contrast, females typically exhibit higher physiological tolerance to stressors, including pesticides, partly due to their greater lipid reserves, which facilitate detoxification processes and enhance survival relative to males. The sharper decline in female longevity at LC_{20} compared with the control, however, indicates that although females are naturally more resilient, elevated sublethal concentrations of Agrimec Gold can still significantly compromise their survival potential and long-term contribution to population growth.

The laboratory observations demonstrated that the average number of eggs laid per day differed significantly among treatments, confirming a clear decline in daily oviposition following exposure to Agrimec Gold. Compared with the untreated control reported by Rahimi *et al.* (2022), both sublethal concentrations (LC_{10} and LC_{20}) substantially reduced reproductive output, indicating that even non-lethal doses can impair reproductive physiology in *A. swirskii*. A primary explanation for this reduction is that the oviposition rate of predatory mites is closely linked to their feeding activity; exposure to acaricides often reduces mobility, foraging efficiency, and prey consumption, ultimately lowering fecundity (Gotoh *et al.* 2004). Furthermore, reproductive output is highly dependent on prey quality. As reported by Park *et al.* (2011), predatory mites produce significantly more eggs when feeding on live, high-quality prey compared with pollen or low-quality diets. Therefore, any pesticide-induced decline in prey-handling efficiency or feeding rate is expected to translate into reduced oviposition, consistent with the patterns observed in the present study.

Comparison of the fertility rate of *A. swirskii* females across the two sublethal concentrations (LC_{10} and LC_{20}) revealed a clear and significant reduction, confirming the detrimental effect of Agrimec Gold on reproductive capacity. When compared with the untreated control values reported by Rahimi *et al.* (2022), it becomes evident that both concentrations suppressed total fecundity and shortened the oviposition period, demonstrating that Agrimec Gold disrupts normal reproductive investment even at non-lethal doses. This reduction in fertility is likely linked to the acaricide's adverse effects on feeding behavior and energy allocation. Sublethal pesticide exposure often reduces mobility, prey-handling efficiency, and overall feeding rate, which subsequently limits the energy available for oogenesis and egg production. Comparable findings were reported by Mousavi *et al.* (2023), where exposure to *Euphoria* toxin significantly reduced reproductive output in predatory mites. These consistent patterns across studies emphasize that sublethal doses of chemical compounds can meaningfully interfere with the reproductive performance of beneficial arthropods, potentially diminishing their biocontrol efficacy in integrated pest management programs. Although the present study focused on a single formulation (Agrimec Gold), future research should compare the sublethal effects of different abamectin-based acaricides on biological parameters of *A. swirskii* to determine whether the observed reproductive suppression is formulation-specific or common to the active ingredient.

The intrinsic rate of population increase (*r*) is a fundamental demographic parameter that reflects a population's capacity to grow under ideal conditions and is highly sensitive to environmental disturbances, making it a reliable indicator for evaluating sublethal pesticide effects on beneficial arthropods. In the present study, *r* differed notably between the two sublethal concentrations, with values of 0.205 at LC_{10} and 0.177 at LC_{20}. When compared with the untreated control value reported by Rahimi *et al.* (2022) ($r = 0.15$), it becomes evident that both concentrations altered population growth dynamics, although the impact was concentration-dependent. The reduction in *r* at LC_{20} highlights a substantial decline in population growth potential, indicating that higher sublethal exposure compromises reproduction and survival. The *r* value at LC_{10} (0.205 day^{-1}) was not significantly different from the control value (0.15 day^{-1}), whereas at LC_{20} (0.177 day^{-1}) it showed a notable reduction. Overall, these results demonstrate that increasing sublethal concentrations of Agrimec Gold diminish the demographic fitness of *A. swirskii*, underscoring the importance of dose-dependent evaluation when determining pesticide compatibility with biological control agents.

According to Stark and Banks (2003), sublethal pesticide exposure can lead to substantial reductions in the intrinsic rate of increase (*r*), even when mortality is low, highlighting the importance of incorporating life table analyses into ecotoxicological assessments. Takahashi and Chant (1994) reported that in phytoseiid mites, the intrinsic rate of increase is closely linked to feeding rate and prey availability. Canlas *et al.* (2006) further demonstrated that the developmental stage of prey affects the demographic performance of predatory mites, explaining the variability in *r* values across studies. Moreover, Gotoh *et al.* (2004) emphasized that variations in feeding behavior, prey quality, and environmental conditions are key factors contributing to differences in *r* among predatory mite species. Therefore, the observed decline in *r* at higher concentrations of Agrimec Gold in this study indicates a negative impact of the acaricide on population growth potential. However, comparing demographic parameters across studies is challenging, as differences may arise from variations in mite species, experimental methods (including size and type of setup), food sources, environmental conditions (relative humidity, temperature, and photoperiod), and calculation methods (De Vasconcelos *et al.* 2008).

Pesticides significantly affect the population growth parameters of both herbivorous and predatory mites (Marcic 2005, 2007; Hamedi *et al.* 2011). Effective pest control requires an integrated approach, as relying solely on a single method—particularly without the strategic use of chemical control—can reduce the overall success of pest management programs (Dent 2000). Careful and informed selection of pesticides, taking into account minimal side effects on natural enemies and the environment, is crucial for maintaining the balance of agricultural ecosystems. The use of sublethal doses of pesticides in combination with biological control agents not only preserves beneficial organisms but also enhances pest control efficiency and reduces the risk of resistance development in pest populations (Marcic 2007). Furthermore, repeated or improper use of chemical pesticides can lead to pest resistance and decreased control efficacy, highlighting the importance of integrated pest management strategies (Alzoubi and Çobanoğlu 2007). Overall, targeted and integrated approaches are essential for achieving sustainable agriculture and protecting environmental health. A limitation of this study was the use of an external control from previously published data (Rahimi *et al.* 2022). Although the experimental conditions were identical, a concurrent control would have been more reliable. Future studies should include a concurrent control to avoid potential discrepancies.

CONCLUSION

The results of this study demonstrate that sublethal concentrations of Agrimec Gold negatively affect the survival, reproduction, and population growth potential of *A. swirskii*. While low concentrations may induce mild hermetic effects, higher sublethal doses significantly reduce demographic fitness, emphasizing the need for careful pesticide selection. Integrating compatible chemical applications with biological control agents is essential to preserve beneficial mite populations, enhance pest management efficiency, and promote sustainable agricultural practices.

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تأثیر غلظت‌های زیرکشنده آبامکتین بر رشد، تولیدمثل و رشد جمعیت کنهٔ شکارگر *Amblyseius swirskii* (Acari: Phytoseiidae)

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دریافت
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چکیده

هِرِنای شکارگر *Amblyseius swirskii* یکی از عوامل مؤثر مهار زیستی است که برای مهار هرناهای تارتن، تریپس‌ها و سفیدبالک‌ها به کار می‌رود. در این پژوهش، اثرهای زیرکشندگی دو غلظت آبامکتین (LC_{10} و LC_{20}) را روی ویژگی‌های زیستی و پراسنجه‌های جمعیتی نسل F_1 حاصل *A. swirskii* (حاصل از والدین تیمارشده) در شرایط کنترل‌شده آزمایشگاهی (دمای ۱±۲۵ درجهٔ سلسیوس، رطوبت نسبی ۵±۷۵ درصد و دوره نوری ۱۶:۸ ساعت روشنایی: تاریکی) انجام گرفت. با استفاده از روش جدول زندگی ویژه سن–مرحله دو جنسی و با تغذیه از کنه تارتن دولکه‌ای (*Tetranychus urticae*) به عنوان طعمه، نتایج نشان داد که طول عمر کل در فرزندان حاصل از والدین تیمارشده با LC_{20} (ماده‌ها ۹۴/۱۳ روز؛ نرها ۴۲/۱۳ روز) در مقایسه با نتاج LC_{10} (ماده‌ها ۵۰/۱۵ روز؛ نرها ۱۵/۰۶ روز) به میزان زیادی کوتاه‌تر بود. باروری، دورهٔ تخم‌ریزی و میزان خالص تولیدمثل (R_0) با افزایش غلظت آفت‌کش به طور معنی‌داری کاهش یافت. کاهش در میزان ذاتی افزایش جمعیت (r= ۰/۲۰۵ در مقابل ۰/۱۷۷) و میزان متناهی افزایش جمعیت (λ = ۱/۲۷۷ در مقابل ۱/۱۹۴ در روز) مشاهده شد، اگرچه این تفاوت‌ها از نظر آماری معنی‌دار نبودند. منحنی‌های زنده‌مانی ویژه سن (l_x)، باروری ویژه سن (m_x) و ارزش تولیدمثلی (v_{xj}) اثرات منفی بارز غلظت‌های زیرکشنده را بر عملکرد جمعیت نشان دادند. این یافته‌ها نشان می‌دهد که حتی غلظت‌های پایین آبامکتین می‌تواند ویژگی‌های کلیدی تاریخچه زندگی *A. swirskii* را مختل کند و به طور بالقوه کارایی آن را در برنامه‌های مهار زیستی محدود سازد. بنابراین، ارزیابی سازگاری کنه‌کش‌ها با دشمنان طبیعی برای اجرای موفق مدیریت تلفیقی آفات ضروری است.

واژگان کلیدی: مدیریت تلفیقی آفات، جدول زندگی، اثر جانبی، غلظت‌های زیرکشنده، *Tetranychus urticae*

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