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Effects of three different host plants on two sex life table parameters of the fall armyworm *Spodoptera frugiperda*

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The fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is a major phytophagous pest that invaded China in late 2018, posing a serious threat to local agricultural production. Therefore, we investigated the effects of maize, soybean, and sweet potato on the growth, development, and reproduction of *S. frugiperda* under laboratory conditions. The developmental period of the egg-larval stage was significantly longer when *S. frugiperda* fed on sweet potato (28.94 days) compared to maize (16.19 days) and soybean (17.82 days). Sweet potato feeding significantly prolonged the pupal period, but this effect was not observed in the adult stage. *Spodoptera frugiperda* larvae fed on sweet potato had the lowest pupal weight (116.18 mg) and pupation rate (68.19%). The mean fecundity of females significantly differed among the plants, with egg production being highest for insects fed on maize (996.17 eggs) and lowest for those fed on sweet potato (319.28 eggs). *Spodoptera frugiperda* fed on sweet potato exhibited the smallest net reproductive rate (47.892), lowest intrinsic rate of increase (0.083 day^{-1}), lowest finite rate of increase (1.086 day^{-1}), and longest mean generation time (46.806 days). Overall, *S. frugiperda* can survive and complete its entire life cycle on all three host plants.

Keywords Fall armyworm, Life table, Host plant, Development, Reproduction

The fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is a notorious agricultural pest native to tropical and subtropical regions of the Americas[1,2]. It is a highly polyphagous herbivore that reportedly can consume more than 350 plant species from 76 plant families, causing serious damage to economically important cultivated crops such as maize, wheat, rice, sorghum, cotton, tobacco, millet, beans, vegetables, and pasture grasses[3–7]. In early 2016, this invasive pest was officially reported for the first time in West and Central Africa[8]. Subsequently, it rapidly spread to more than 80 countries worldwide[9]. Unfortunately, by the end of 2018, *S. frugiperda* was discovered in Yunnan Province, China, and it rapidly expanded its range to other regions. By October 2021, the pest had invaded 27 provinces (municipalities and autonomous regions), such as Guangdong, Guangxi, Fujian, Sichuan, Guizhou, Shanxi, Gansu, Hainan, Hebei, and Taiwan[10–13], damaging more than 1.32 million hectares and posing a grave threat to Chinese agricultural production and ecological security.

Based on host plant preferences, mating behavior, and pheromone compositions, *S. frugiperda* is classified into two morphologically identical strains: the corn strain and the rice strain[14,15]. As the names suggest, the corn strain prefers maize, sorghum, and cotton, whereas the rice strain prefers rice, millet, and grasses. According to previous studies, the *S. frugiperda* population that invaded China is likely a peculiar "corn strain" originating from the hybrid offspring of a corn strain male and a rice strain female[16,17]. Notably, the host plant range of this special "corn strain" likely expanded with its spread. It is widely known that differences in host plants can influence the development and population dynamics of phytophagous insects[18]. For instance, compared with *S. frugiperda* fed on maize and wheat, those fed on tomato and cotton had longer larval developmental stages, lower larval survival, and lower fecundity[19]. Similarly, the larval developmental duration and mean fecundity of *S. frugiperda* fed on pepper, tomato, and eggplant were significantly different from those fed on maize[6]. However, studies have found that *S. frugiperda* fed on various host plants can complete development and reproduction. Based on these findings, we speculate that this invasive pest is likely to cause significant economic losses among food and fiber crops. Therefore, analyzing the potential risk posed by *S. frugiperda* to different host plants, especially cultivated crops, is essential.

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Maize, soybean, and sweet potato are important economic crops for grain, oil, and feed in China, and their collective planting area accounted for 35.59% of the country's total agricultural crop sown area in 2022. Because of the overlap of the growing regions for these crops, pests that prefer different host plants can cause trans-boundary harm. For example, *Spodoptera litura* (Lepidoptera: Noctuidae), a major pest of soybean, has caused damage to maize[20], and *Ostrinia nubilalis* (Lepidoptera: Pyralidae), a principal pest of maize, can also feed on soybean[21]. *S. frugiperda* is an invasive pest that prefers to feed on members of the grass family. However, whether this new corn strain of *S. frugiperda* is likely to cause trans-boundary damage to soybean and sweet potato is a key area of concern. Furthermore, the effects of soybean and sweet potato feeding on the biological characteristics of *S. frugiperda*, such as developmental duration, survival rate, pupation rate, emergence rate, and fecundity, are not yet fully understood in the Chinese populations.

In this study, we investigated the growth attributes, developmental cycle, and reproduction of *S. frugiperda* fed on soybean and sweet potato in comparison to maize under laboratory conditions. The age–stage, two-sex life table method was applied to obtain the life table parameters of *S. frugiperda*. Our results should help clarify the growth attributes and developmental cycle of *S. frugiperda* in its expanded range, facilitating the implementation of effective management programs for this invasive pest.

Materials and methods

Host plants

Seeds of maize (variety: Jingnuo 10) and soybean (cultivar: Zhonghuang 57) were purchased from the market. Sweet potato seedlings (cultivar: 19 − 7) were donated by the Institute of Biotechnology, Guizhou Academy of Agricultural Sciences. The three host plants were planted in the experimental field of Kaili University without pesticide exposure. Healthy and undamaged plant leaves were collected for testing.

Insect rearing

The initial population of *S. frugiperda* larvae was obtained from maize fields at Gechong Village, Kaili City, Guizhou Province, China, in June 2022. The larvae were transferred to an artificial climate incubator at 25℃ ± 1℃ and 70% ± 5% relative humidity (RH) under a 16-h/8-h light/dark photoperiod in the laboratory[6,12]. To maintain culturing conditions, the insects were reared on each of the aforementioned plants for four consecutive generations. The fifth-generation eggs were then used to perform the following experiments.

Life table study

At least 200 eggs laid within 6 h were collected from each plant and placed on a new leaf in each plastic Petri dish (8 × 1.5 cm^2). After hatching, the neonates were randomly selected and transferred individually to a 12-hole hyaline culture plate (12.5 × 8.5 × 2.3 cm^3; single hole: 2.3 × 1.7 cm^2). Two 12-hole hyaline culture plates with fresh leaves were prepared for each plant, and five replications were performed for each plant. Culture plates with fresh maize, soybean, and sweet potato leaves were replaced every 24 h to avoid contamination by microorganisms. Until the third instar, individual larvae were transferred from the culture plates to a 500-mL plastic cup and provided fresh leaves daily to ensure adequate nutrition. The incubation times of the eggs, developmental periods, and survival rates of larvae were recorded daily. Furthermore, we quantified the pupal weight on the second day after pupation. Following the eclosion of *S. frugiperda*, one female and one male reared on the same host were paired in a 500-mL plastic cup lined with fresh leaves of the same host for oviposition. All adults were fed a 10% (v/v) honey solution. Subsequently, parameters such as adult lifespan, number of eggs laid per female, pre-oviposition period, and egg-laying period were recorded. The aforementioned experiments were conducted under constant conditions of 25℃ ± 1℃, 70% ± 5% RH, and a 16-h/8-h photoperiod.

Life table data analysis

Based on the age–stage, two-sex life table principle[22]and the method described by Chi[23], the life history raw data of all individuals were recorded and pooled, and the computer program TWOSEX-MSChart[24,25] was used to calculate all life table statistics. Thus, we obtained population and life table parameters for each experiment, including the age–stage-specific fecundity (f_{xj}, x is age and j is stage); age-specific survival rate (l_x); age–stage-specific survival rate (s_{xj}); age-specific fecundity (m_x); age–stage-specific life expectancy (e_{xj}); age–stage-specific reproductive value (v_{xj}); adult pre-oviposition period of female adults (APOP); total pre-oviposition period of females counted from birth (TPOP); oviposition period (OP); and the net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), and mean generation time (T).

Statistical analysis

All experimental raw data were recorded using Microsoft Excel 2007 (Microsoft, Redmond, WA, USA). Life table parameters were analyzed using TWOSEX-MSChart, and means and standard errors (SEs) for all parameters were estimated using the bootstrap method with 100,000 replicates. Differences among the various treatments were assessed using the paired bootstrap test at a significance level of $P < 0.05$. Pupal weight and pupation rate were tested via one-way analysis of variance using SPSS 13.0 (IBM Inc., Armonk, NY, USA), with significant differences determined using the Duncan's multiple range test. Graphs were generated using OriginPro 2023 (OriginLab Corp., Northampton, MA, USA).

Results

Effect of different hosts on the developmental period of *S. frugiperda*

The effects of the three tested plants on the developmental period of *S. frugiperda* are presented in Table 1. *S. frugiperda* completed its life cycle on all tested plants. The egg stage was longest on sweet potato (2.58 days,

Parameters	n	Maize	n	Soybean	n	Sweet potato
Egg stage (days)	120	2.34 ± 0.04b	120	2.38 ± 0.05b	120	2.58 ± 0.05a
First instar (days)	118	1.95 ± 0.07c	97	2.37 ± 0.08b	120	4.58 ± 0.09a
Second instar (days)	111	1.70 ± 0.06b	87	1.97 ± 0.06b	120	3.38 ± 0.07a
Third instar (days)	107	1.53 ± 0.05b	86	1.80 ± 0.07b	120	2.57 ± 0.05a
Fourth instar (days)	103	2.10 ± 0.06b	84	2.11 ± 0.07b	119	3.14 ± 0.08a
Fifth instar (days)	101	2.86 ± 0.07b	81	2.74 ± 0.08b	103	4.82 ± 0.08a
Sixth instar (days)	100	4.36 ± 0.10b	79	4.30 ± 0.10b	68	7.72 ± 0.14a
Egg-larva (days)	100	16.19 ± 0.19b	79	17.82 ± 0.19b	68	28.94 ± 0.26a
Prepupa (days)	88	1.81 ± 0.08b	60	1.55 ± 0.07b	46	2.22 ± 0.06a
Pupa (days)	73	8.56 ± 0.13b	48	8.71 ± 0.13b	37	10.51 ± 0.14a
Pre-adult (days)	73	27.21 ± 0.29b	48	27.90 ± 0.29b	37	41.27 ± 0.44a
Adult (days)	73	8.16 ± 0.23a	48	8.62 ± 0.27a	37	8.03 ± 0.33a
Total longevity (days)	73	35.37 ± 0.38b	48	36.52 ± 0.43b	37	49.30 ± 0.54a

Table 1. Developmental period and total longevity of *S. frugiperda* fed on three tested plants. Note: Values (mean ± SE) followed by different lowercase letters within the same row were significantly different at $P < 0.05$ when analyzed using the paired bootstrap test.

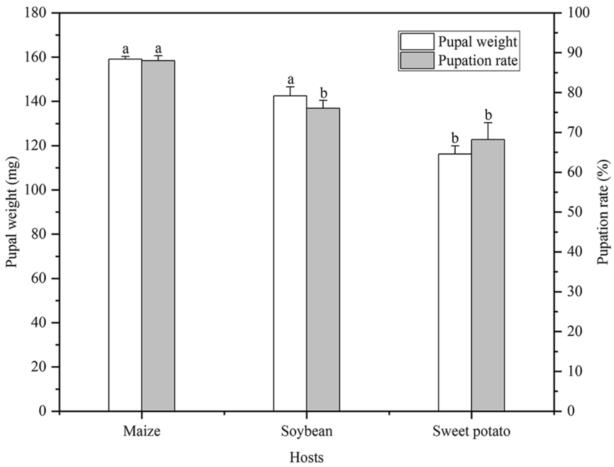

Fig. 1. Effect of maize, soybean, and sweet potato feeding on the pupal weight and pupation rate of *S. frugiperda*. The data are presented as the mean ± SE. Different lowercase letters above the error bars indicate a significant difference by Duncan's multiple range test ($P < 0.05$).

$P < 0.05$). The first–sixth instar larvae that fed on sweet potato had a longer developmental duration than those fed on maize and soybean (both $P < 0.05$). In total, the developmental period of the egg-larval stage was shortest on maize (16.19 days) and longest on sweet potato (28.94 days), indicating that *S. frugiperda* had significantly reduced development on maize. The prepupal period was significantly shorter for *S. frugiperda* fed on maize (1.81 days) and soybean (1.55 days) than for those fed on sweet potato (2.22 days, both $P < 0.05$). The pupal stage was 1.95 days longer for sweet potato feeding compared to maize and 1.8 days longer compared to soybean feeding. The pre-adult stage was significantly longer for insects fed on sweet potato than for those fed on maize and soybean (both $P < 0.05$). There were no significant differences in the adult stage among the tested plants.

Effect of different hosts on the pupal weight and pupation rate of *S. frugiperda*

The pupal weight and pupation rate of *S. frugiperda* fed on three host plants are presented in Fig. 1. In particular, the pupal weight of *S. frugiperda* fed on sweet potato was 116.18 mg, which was significantly lower than that of insects fed on maize (159.14 mg) and soybean (142.49 mg; both $P < 0.05$). The pupation rate of *S. frugiperda* fed on maize was significantly higher than that of insects fed on soybean and sweet potato (both $P < 0.05$).

Effect of different hosts on the reproductive parameters of *S. frugiperda*

The reproductive parameters of *S. frugiperda* varied depending on the host plants (Table 2). APOP for *S. frugiperda* females fed on maize was 1.73 days, which was significantly shorter than that recorded on soybean ($P < 0.05$) but similar to that recorded on sweet potato. TPOP for *S. frugiperda* females fed on sweet potato was 43.33 days, which was 14.38 and 12.68 days longer than that for insects fed on maize and soybean, respectively.

Parameters	*n*	Maize	*n*	Soybean	*n*	Sweet potato
Pre-oviposition	40	1.73 ± 0.09b	26	2.35 ± 0.12a	18	2.22 ± 0.17ab
Total pre-oviposition	40	28.95 ± 0.42b	26	30.65 ± 0.44b	18	43.33 ± 0.64a
Oviposition period (days)	40	7.00 ± 0.19a	26	7.00 ± 0.18a	18	6.06 ± 0.15a
Fecundity (eggs/female)	40	996.17 ± 15.96a	26	671.96 ± 16.93b	18	319.28 ± 10.84c

Table 2. Reproductive parameters of *S. frugiperda* fed on three plants. Note: Values (mean ± SE) followed by different lowercase letters within the same row were significantly different at $P < 0.05$ when analyzed using the paired bootstrap test.

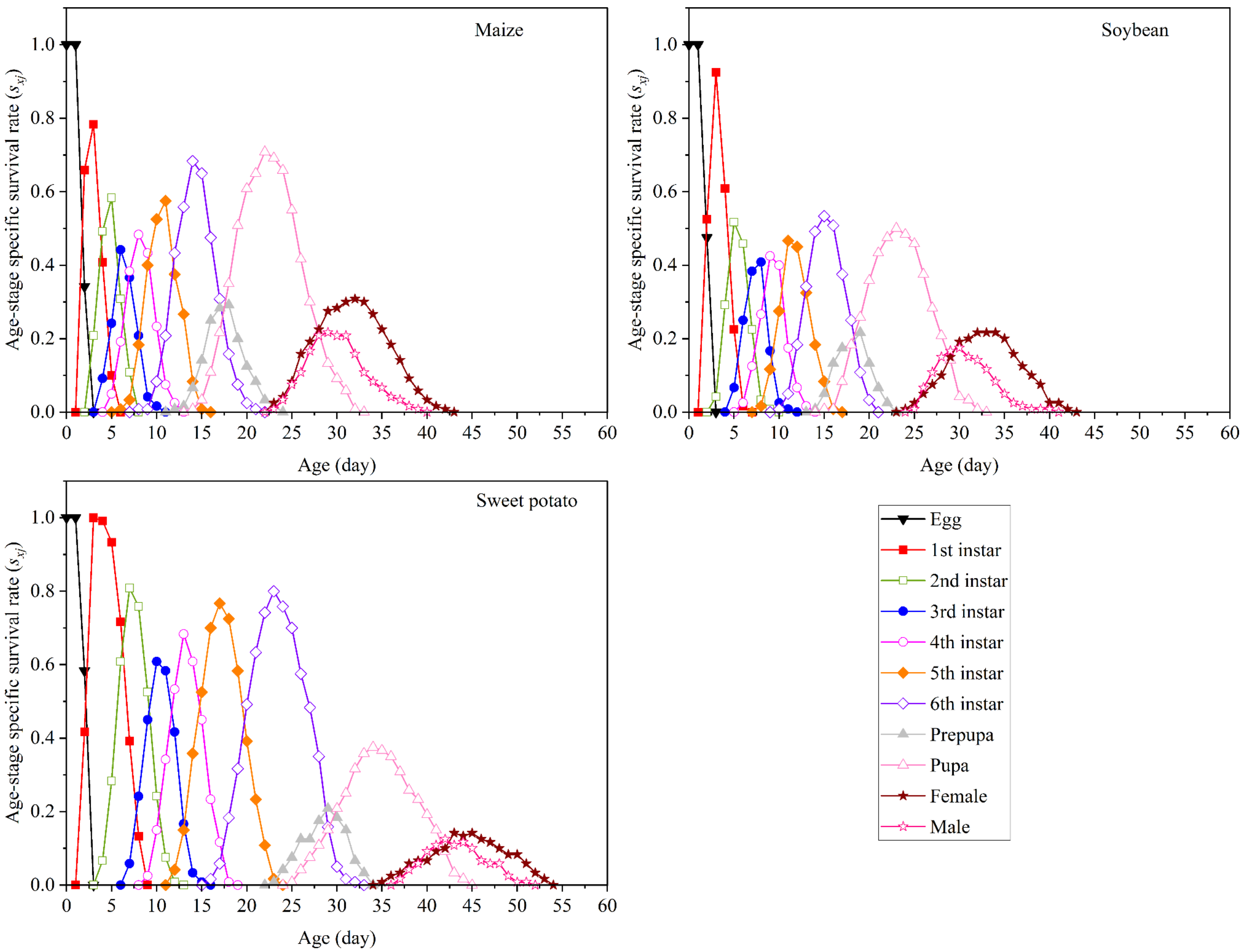

Fig. 2. Age-stage specific survival rate (s_{xj}) of *S. frugiperda* fed on three plants.

No significant differences were observed in OP ($P > 0.05$). The mean fecundity was highest on maize (996.17 eggs), followed by soybean (671.96 eggs, $P < 0.05$) and sweet potato (319.28 eggs, $P < 0.05$).

Effect of different hosts on the survival rate of *S. frugiperda*

s_{xj} indicates the probability that a newborn individual will survive to age x and stage j (Fig. 2). s_{xj} of *S. frugiperda* eggs exceeded 0.90 on all three tested host plants. From egg development to sixth instar larvae, s_{xj} was highest for *S. frugiperda* fed on sweet potato (0.80), exceeding the values for insects fed on maize and soybean by 0.1167 and 0.2667, respectively. s_{xj} of pupa was considerably higher on maize (0.7083) than on soybean (0.50) and sweet potato (0.3750). For the adult stage, s_{xj} of females and males fed on maize (0.3083 and 0.2167, respectively) were higher than those of insects fed on soybean (0.2167 and 0.1750, respectively) and sweet potato (0.1417 and 0.1250, respectively).

The l_x curves of *S. frugiperda* fed on different host plants exhibited a downward trend over time (Fig. 3). The l_x curve of *S. frugiperda* fed on maize slowly decreased, reaching 0.70 by day 25. The l_x curve of *S. frugiperda* fed

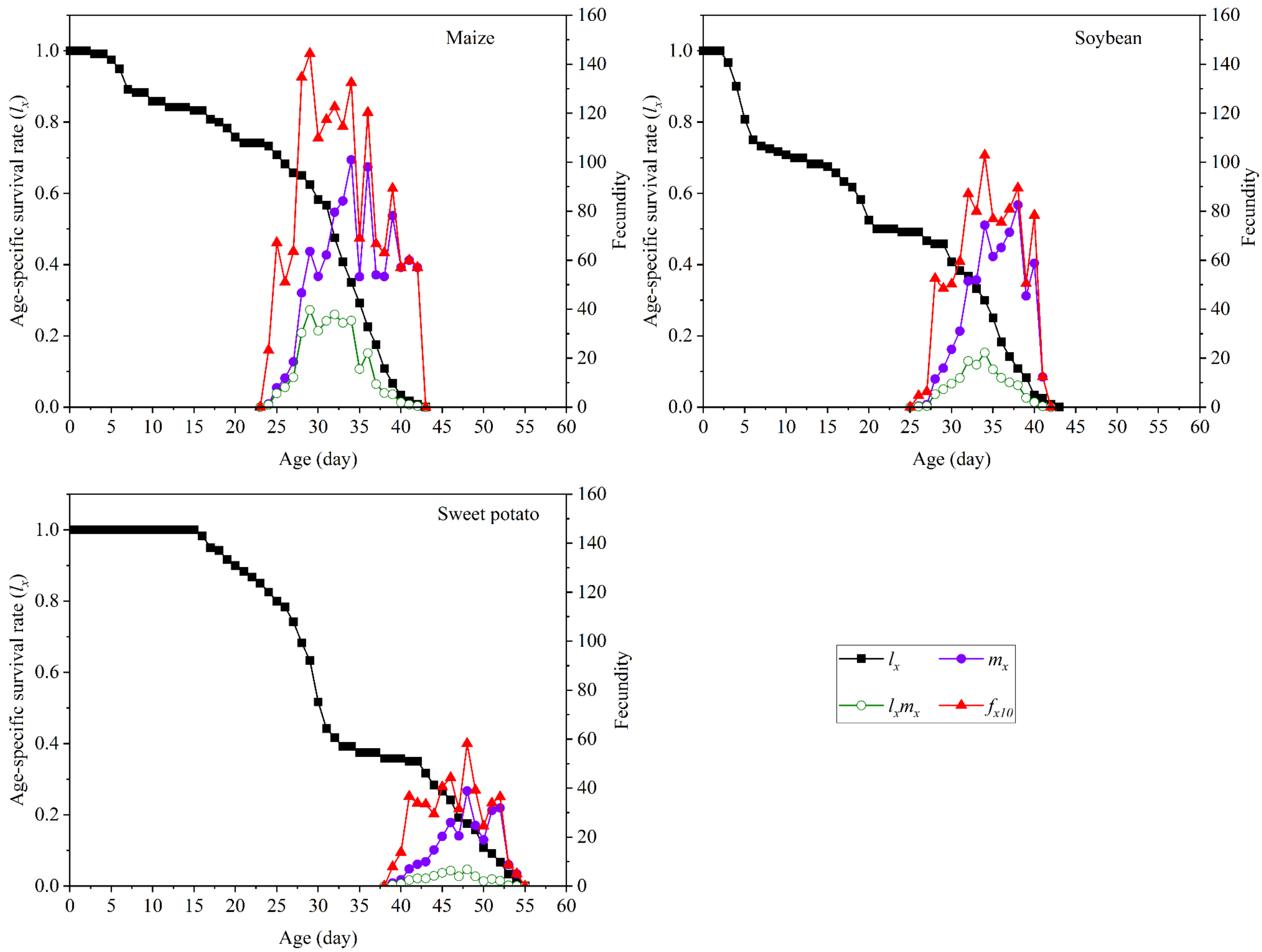

Fig. 3. Age-specific survival rate (l_x) and fecundity of *S. frugiperda* fed on three plants.

on soybean rapidly decreased, and the survival rate decreased by > 0.3 between days 3 and 10. Surprisingly, the l_x curve for *S. frugiperda* fed on sweet potato declined rapidly starting on day 16.

Effect of different hosts on the fecundity of *S. frugiperda*

The larval diet significantly affected f_{x10}, m_x, and population age-specific maternity (l_xm_x) in *S. frugiperda* (Fig. 3). In general, f_{x10}, m_x, and l_xm_x of *S. frugiperda* fed on all three tested host plants increased initially before decreasing. f_{x10} of females fed on maize, soybean, and sweet potato peaked on days 29, 34, and 48, respectively, with mean fecundities of 144.36, 102.81, and 58.21 eggs, respectively, for insects fed on these plants.

Effect of different hosts on the life expectancy of *S. frugiperda*

The e_{xj} of *S. frugiperda* fed on three host plants is presented in Fig. 4. The results indicated that the e_{01} values for *S. frugiperda* fed on maize, soybean, and sweet potato were 28.22, 22.75, and 34.77 days, respectively. Further, e_{xj} declined over time for insects fed on all three plants (Fig. 4).

Effect of different hosts on reproduction in *S. frugiperda*

The different host plants markedly affected v_{xj} in *S. frugiperda* (Fig. 5). At age zero (v_{01}), the v_{xj} values of *S. frugiperda* fed on maize, soybean, and sweet potato were 1.20, 1.16, and 1.09, respectively. v_{xj} gradually increased with successive developmental stages, peaking after the adults laid eggs. The highest reproductive values for *S. frugiperda* fed on maize, soybean, and sweet potato were observed at 28, 31, and 41 days, reaching 565.6, 368.6, and 248.2 eggs, respectively.

Effect of different hosts on the life table parameters of ***S. frugiperda***

Significant differences were observed among the life table parameters of *S. frugiperda* fed on the three host plants (Table 3). R_0 of *S. frugiperda* fed on maize (332.058) was significantly higher than that of insects fed on soybean (145.592) and sweet potato (47.892, both $P < 0.05$). The differences in r and λ were significant for *S. frugiperda* fed on the three tested host plants ($P < 0.05$). More importantly, r and λ were > 0 and > 1, respectively, indicating that *S. frugiperda* could survive on all three host plants. Conversely, T was highest for *S. frugiperda* fed on sweet potato (46.806 days), followed by soybean (33.958 days) and maize (31.766 days).

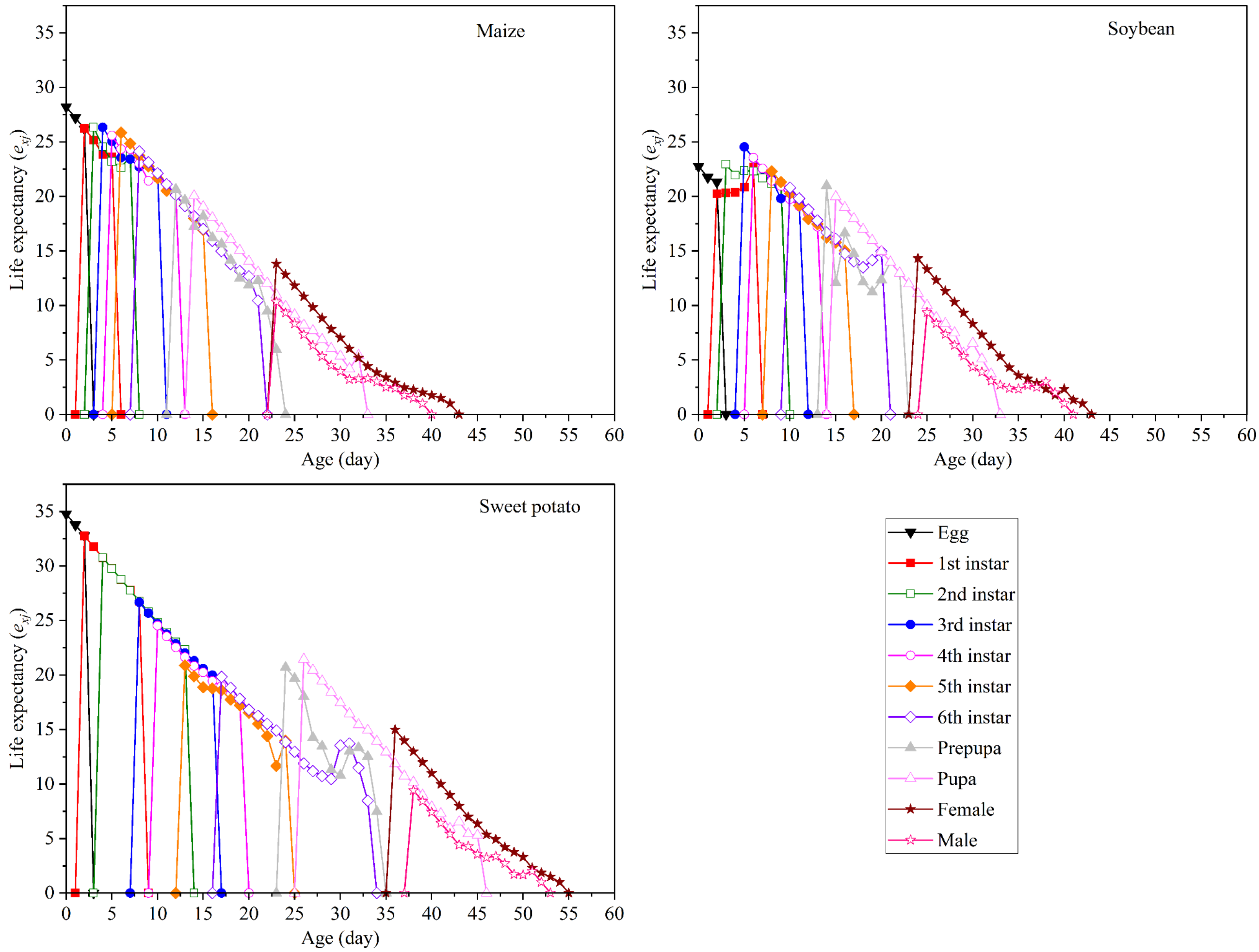

Fig. 4. Age-stage specific life expectancy (e_{xj}) of *S. frugiperda* fed on three host plants.

Discussion

It is known that phytophagous insects prefer the most suitable host plants for feeding. The primary reason is that a preferred host plant can best meet the water and nutritional requirements necessary for insect growth and development[18,26]. Hence, biological indicators of insects, such as a shorter developmental period, higher survival rate, and greater reproductive capacity, are often used to measure the adaptability of insects to host plants[27]. For example, Guo et al.[28] reported that *S. frugiperda* larvae fed on maize exhibited a shorter larval developmental time, higher survival rate, greater longevity, and a higher number of eggs per female than those fed on potato and tobacco. Zhang et al.[29] studied the feeding adaptability of *S. frugiperda* on different maize varieties (three special and three common varieties) and found significant differences in larval developmental duration, pupal weight, and fecundity among the different maize varieties, with *S. frugiperda*fed on common maize varieties showing better adaptability. According to previous studies[28,29], the adaptability of invasive pests differs both among various host plants and among different varieties of the same host plants. In this study, we empirically verified the effects of different host plants on *S. frugiperda* development. The results clearly indicated that *S. frugiperda* could complete its developmental cycle on maize, soybean, and sweet potato; however, the three tested plants significantly affected larval development. The duration of the larval stage was shortest and the survival rate highest when *S. frugiperda* fed on maize. Conversely, when the pest fed on soybean, they experienced a prolonged larval period and a lower survival rate. These results align with previously reported findings of a longer larval development time and lower survival rate for *S. frugiperda*fed on soybean compared to maize[4,13,19,30,31]. During the test, we found also that soybean leaves with thinner mesophyll lose water faster than maize and sweet potato leaves with thicker mesophyll, which might be responsible for the lower survival rate on soybean plants. On the other hand, The differences in the developmental duration and survival rate of *S. frugiperda* may be attributed to the chemical characteristics of plant species[26]. Generally, the extension of the larval stage and increased mortality result from reduced feed intake due to one or more inhibitors in host plants, nutritional inadequacies of the host plants[32], or the production of defense metabolites that impair the growth and development of insects[33,34].

The characteristics in the pupal stage reflect the fitness of larvae to a specific host plant. Pupal weight and pupation rate are critical indicators of an insect's physiological condition and serve as the mirror for its

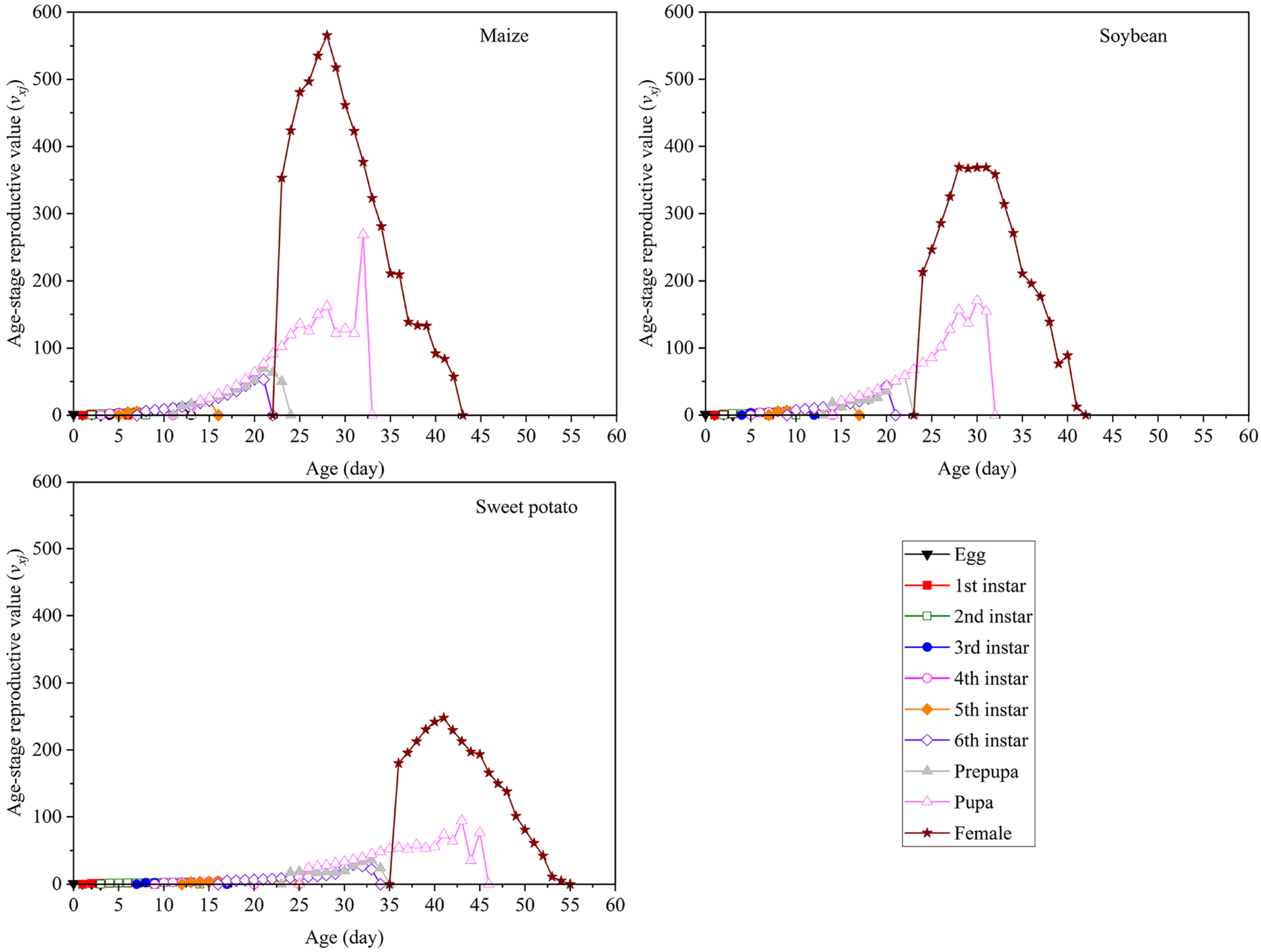

Fig. 5. Age-stage specific reproductive value (v_{xj}) of *S. frugiperda* fed on three plants.

Hosts	Parameters			
	Net reproductive rate (R_0)	Intrinsic rate of increase (r, day^{-1})	Finite rate of increase (λ, day^{-1})	Mean generation time (T, day)
Maize	332.058 ± 43.273a	0.183 ± 0.005a	1.201 ± 0.006a	31.766 ± 0.399b
Soybean	145.592 ± 25.518b	0.147 ± 0.006b	1.158 ± 0.007b	33.958 ± 0.426b
Sweet potato	47.892 ± 10.560c	0.083 ± 0.005c	1.086 ± 0.006c	46.806 ± 0.647a

Table 3. Life table parameters of *S. frugiperda* fed on different host plants. Note: Values (mean ± SE) followed by different lowercase letters within the same column were significantly different at $P < 0.05$ when analyzed using the paired bootstrap test.

overall nutritional status and health during the larval stage[35,36]. In the present study, we found that both pupal weight and pupation rate were lower for larvae fed on sweet potato than for those fed on maize and soybean. Our results were consistent with those reported by Silva et al.[31] and Chen et al.[4]. A plausible explanation for these findings may be the reduced intake of host plants by the larvae, leading to less efficient food assimilation and, consequently, lower pupal weight and pupation rate[37,38]. Furthermore, pupal weight is also an important predictor of an insect's ability to withstand environmental stressors and complete its development successfully. Heavier pupae, with their greater energy reserves, are generally more likely to survive to adulthood and have a higher probability of successful mating and oviposition[39,40].

The host plant can affect the growth and development of herbivorous insects as well as the reproductive capacity of adult insects[26,31–43]. In the present study, the OP did not significantly differ among insects fed on maize, sweet potato, and soybean, which contradicts the findings of Xu et al.[44]. However, *S. frugiperda* larvae fed on sweet potato and soybean laid significantly fewer eggs per female than those fed on maize. Similarly, a previous study found that *S. frugiperda* fed on wheat and barley had lower fecundity than insects fed on maize and faba beans[45]. Furthermore, a positive correlation was observed between pupal weight and fecundity in *S.*

frugiperda, as also found in *Mythimna separata* (Lepidoptera: Noctuidae) and *Spodoptera littoralis* (Lepidoptera: Noctuidae)[46,47].

The age–stage, two-sex life table effectively evaluates the fitness of insect populations and can be used to predict the characteristics of pest populations[23,48]. Life table parameters such as R_0, r, λ, and T are important indicators of the effects of host plants on insect population performance[49], and these variables differ according to the host plant[6,50,51]. In this study, we found that r was lowest for *S. frugiperda* fed on sweet potato (0.083 day^{-1}), followed by soybean (0.147 day^{-1}) and maize (0.183 day^{-1}). The trend for λ was similar to that for r. Based on life table theory, $r > 0$ and $\lambda > 1$ indicate that the host plant is suitable for the growth and development of insects[52], as clearly supported by our results. R_0 is an equally vital index of population growth[51]. Our results indicated that R_0 was significantly higher for *S. frugiperda* fed on maize (332.058) than for insects fed on soybean (145.592) and sweet potato (47.892), suggesting that the three plant species were vulnerable to *S. frugiperda* damage.

Our results demonstrated that maize was more suitable for the growth, survival, and reproduction of *S. frugiperda* than soybean and sweet potato. However, when *S. frugiperda* larvae become excessively dense or their preferred hosts are scarce or undernourished in the field, the pests may move to other host plants, such as soybean and sweet potato[2,53]. In China, the maize–soybean/sweet potato intercropping system is widely adopted, allowing *S. frugiperda* larvae to transfer from maize to soybean or sweet potato, thereby damaging all of these crops. Therefore, it is necessary to strongly monitor the population dynamics of *S. frugiperda* in the field. Certainly, we know well that monitoring alone is insufficient to address the potential threat posed by this pest. Based on our study's results and the current understanding of *S. frugiperda*'s biology and ecology, we propose the following integrated pest management (IPM) strategies to complement regular monitoring. First, utilize or breed crop varieties that exhibit resistance to *S. frugiperda*. Second, implement crop rotation and diversification practices to disrupt the pest's life cycle and reduce its population density. Third, enhance the use of natural enemies, such as parasitoids, predators, and pathogens, which can help keep *S. frugiperda* populations in check. Fourth, when necessary, apply selective pesticides with caution to reduce the damage of this pest. Finally, continue research into the pest's behavior, host range, and management options, including the development of novel control methods and the improvement of existing ones.

Conclusion

This study investigated the effects of three host plants—maize, soybean, and sweet potato—on the growth, survival, and reproduction of *S. frugiperda*. *S. frugiperda* was able to survive and complete its entire life cycle on all three plants, although the performance of insect populations varied significantly among the hosts. Based on the results obtained from the experiments, we concluded that *S. frugiperda* is likely to cause harm to alternative plants, such as soybean and sweet potato, in the field.

Data availability

The data presented in this study are availability on request from the corresponding author.

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References

1. Sparks, A. N. A review of the biology of the fall armyworm. *Fla. Entomol.* **62**, 82–87 (1979).
2. Tay, W. T., Meagher, R. L. Jr, Czepak, C. & Groot, A. T. *Spodoptera frugiperda*: ecology, evolution, and management options of an invasive species. *Annu. Rev. Entomol.* **68**, 299–317 (2023).
3. Montezano, D. G. et al. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *Afr. Entomol.* **26**, 286–300 (2018).
4. Chen, Y. et al. Performance of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on six host plants: potential risks to mid-high latitude crops in China. *J. Agr Sci.* **12**, 16–27 (2020).
5. Wan, J. et al. Biology, invasion and management of the agricultural invader: fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *J. Integr. Agr*. **20**, 646–663 (2021).
6. Wu, L. H. et al. Fitness of fall armyworm, *Spodoptera frugiperda* to three solanaceous vegetables. *J. Integr. Agr*. **20**, 755–763 (2021).
7. Nandhini, D., Deshmukh, S. S., Satish, K. M., Kalleshwaraswamy, C. M. & Sannathimmappa, H. G. Host plant feeding and ovipositional preferences of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) under laboratory conditions. *J. Entomol. Sci.* **59**, 133–141 (2024).
8. Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A. & Tamò, M. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS One*. **11**, e0165632 (2016).
9. Wyckhuys, K. A. G. et al. Global scientific progress and shortfalls in biological control of the fall armyworm *Spodoptera frugiperda*. *Biol. Control*. **191**, 105460 (2024).
10. Jiang, Y. Y. et al. Observation on law of diffusion damage of *Spodoptera frugiperda* in China in 2019. *Plant. Prot.* **45**, 10–19 (2019).
11. Chen, W. H., Itza, B., Kafle, L. & Chang, T. Y. Life table study of fall armyworm (*Spodoptera frugiperda*) (Lepidoptera: Noctuidae) on three host plants under laboratory conditions. *Insects* **14**, 329 (2023).
12. Wang, Z., Zhu, H., Huang, J., Jin, D. C. & Yang, H. Feeding preference and fitness of *Spodoptera frugiperda* on rice and its relationship with biochemical substance contents of leaves. *China Plant. Prot.* **49**, 21–28 (2023). (in Chinese).
13. Tao, W. C. et al. Effects of the host plants of the maize-based intercropping systems on the growth, development and preference of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Insects* **15**, 26 (2024).
14. Pashley, D. P. Host-associated genetic differentiation in fall armyworm (Lepidoptera: Noctuidae): a sibling species complex? *Ann. Entomol. Soc. Am.* **79**, 898–904 (1986).
15. Dumas, P. et al. *Spodoptera frugiperda* (Lepidoptera: Noctuidae) host-plant varitwos: Two host strains or two distinct species? *Genetica* **143**, 305–316 (2015).
16. Juarez, M. L. et al. Population structure of *Spodoptera frugiperda* maize and rice host forms in South America: are they host strains? *Entomol. Exp. Appl.* **152**, 182–199 (2014).

17. Zhang, L. et al. Molecular characterization analysis of fall armyworm populations in China. *China Plant. Prot.* **45**, 20–27 (2019). (in Chinese).
18. Wetzel, W. C., Kharouba, H. M., Robinson, M., Holyoak, M. & Karban, R. Variability in plant nutrients reduces insect herbivore performance. *Nature* **539**, 425–427 (2016).
19. Wang, W. W. et al. The population growth of *Spodoptera frugiperda* on six cash crop species and implications for its occurrence and damage potential in China. *Insects* **11**, 639 (2020).
20. Punithivali, M., Sharma, A. & Rajkumar, B. M. Seasonality of the common cutworm, *Spodoptera litura* in a soybean ecosystem. *Phytoparasitica* **42**, 213–222 (2014).
21. Ivas, A. & Muresanu, F. Researches on the monitoring of the most frequent pests from maize and soybean crops in the conditions at ARDS Turda. *Agriculture* **70**, 265–272 (2013).
22. Chi, H. & Liu, H. Two new methods for the study of insect population ecology. *Bull. Inst. Zool. Acad. Sin*. **24**, 225–240 (1985).
23. Chi, H. Life-table analysis incorporating both sexes and variable development rates among individuals. *Environ. Entomol.* **17**, 26–34 (1988).
24. Chi, H. et al. TWOSEX-MSChart: the key tool for life table research and education. *Entomol. Gen*. **42**, 845–849 (2022).
25. Chi, H. TWOSEX-MSChart: a computer program for the age-stage, two-sex life table analysis. (2023). http://140.120.197.174/Ecology/download/TWOSEX-MSChart.rar
26. Awmack, C. S. & Leather, S. R. Host plant quality and fecundity in herbivorous insects. *Annu. Rev. Entomol.* **47**, 817–844 (2002).
27. Moreau, J., Benrey, B. & Thiéry, D. Grape variety affects larval performance and also female reproductive performance of the European grapevine moth *lobesia botrana* (Lepidoptera: Tortricidae). *B Entomol. Res.* **96**, 205–212 (2006).
28. Guo, J. F. et al. Comparison of larval performance and oviposition preference of *Spodoptera frugiperda* among three host plants: potential risks to potato and tobacco crops. *Insect Sci.* **28**, 602–610 (2021).
29. Zhang, Q. Y. et al. Oviposition preference and age-stage, two-sex life table analysis of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on different maize varieties. *Insects* **14**, 413 (2023).
30. Dias, A. S. et al. Bioecology of *Spodoptera frugiperda* (Smith, 1757) in different cover crops. *Biosci. J.* **32**, 337–345 (2016).
31. da Silva, D. M. et al. Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. *Sci. Agr*. **74**, 18–31 (2017).
32. Peruca, R. D. et al. Impacts of soybean-induced defenses on *Spodoptera frugiperda* (Lepidoptera: Noctuidae) development. *Arthropod-Plant Inte*. **12**, 257–266 (2018).
33. Isman, M. Insect antifeedants. *Pestic Outlook*. **13**, 152–157 (2002).
34. Schoonhoven, L. M., van Loon, J. J. A. & Dicke, M. *Insect-plant Biology* (Oxford University Press, 2005).
35. Eduardo, M. S. et al. Pupal emergence pattern in cactophilic *Drosophila* and the effect of host plants. *Insect Sci.* **25**, 1108–1118 (2018).
36. He, L. M. et al. Larval diet affects development and reproduction of east Asian strain of the fall armyworm, *Spodoptera frugiperda*. *J. Integr. Agr*. **20**, 736–744 (2021).
37. Slansky, J. & Scriber, J. Food consumption and utilization in Comprehensive Insect Physiology, Biochemistry, and Pharmacology (ed Kerkut, G. A.) (1985). & Gilbert, L. I.) 87–163 (Pergamon.
38. Giongo, A. M. M. V., Freitas, J. D., Freitas, S. D. L. & Silva, M. F. G. F. Growth and nutritional physiology of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on Meliaceae fractions. *Rev. Colomb Entomol.* **41**, 33–40 (2015).
39. Wu, K. J. & Li, M. H. Nutritional ecology of the cotton bollworm, *Heliothis armigera* (Hübner): life tables of the population on the artificial diets with different protein levels. *Acta Entomol. Sin*. **36**, 21–28 (1993). (in Chinese).
40. Soto, E. M. et al. Pupal emergence pattern in cactophilic *Drosophila* and the effect of host plants. *Insect Sci.* **25**, 1108–1118 (2018).
41. Jabraeil, R., Bahram, N. & Seyed, A. H. Comparative performance of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on various host plants. *J. Pest Sci.* **87**, 29–37 (2014).
42. Blair, W. C. et al. Does host plant quality constrain the performance of the Parthenium beetle *Zygogramma Bicolorata*? *Biol. Control*. **139**, 104078 (2019).
43. Gong, Z. J. et al. Life table study of *Spodoptera frugiperda* at different wheat stages and the effect of larval population density on wheat yield. *Pest Manag Sci.* **79**, 4057–4065 (2023).
44. Xu, L. N. et al. Effects of maize-soybean intercropping on the growth, development and reproduction of fall armyworm *Spodoptera frugiperda*. *J. Plant. Prot.* **50**, 642–650 (2023). (in Chinese).
45. Gebretsadik, K. G. et al. Population growth of fall armyworm, *Spodoptera frugiperda* fed on cereal and pulse host plants cultivated in Yunnan Province, China. *Plants* **12**, 950 (2023).
46. Huang, Q. et al. A comparative study on growth, development and reproduction of *Mythimna Separata* in four host plants. *China Plant. Prot.* **38**, 5–10 (2018). (in Chinese).
47. Hemmati, S. A., Shishehbor, P. & Stelinski, L. L. Life table parameters and digestive enzyme activity of *Spodoptera Littoralis* (Boisd) (Lepidoptera: Noctuidae) on selected legume cultivars. *Insects* **13**, 661 (2022).
48. Shi, M. Z., Fu, J. W., Li, J. Y., Chi, H. & You, M. S. Projection of insect population dynamics with age-stage, two-sex life table and its application in pest management. *Acta Entomol. Sin*. **66**, 255–266 (2023). (in Chinese).
49. Atlihan, R., Kasap, İ., Özgökçe, M. S., Polat-Akköprü, E. & Chi, H. Population growth of *Dysaphis pyri* (Hemiptera: Aphididae) on different pear cultivars with discussion on curve fitting in life table studies. *J. Econ. Entomol.* **110**, 1890–1898 (2017).
50. Alami, S., Naseri, B., Golizadeh, A. & Razmjou, J. Age-stage, two-sex life table of the tomato looper, *Chrysodeixis chalcites* (Lepidoptera: Noctuidae), on different bean cultivars. *Arthropod-Plant Inte*. **8**, 475–484 (2014).
51. Ahmed, M. A. et al. Oviposition preference and two-sex life table of *Plutella xylostella* and its association with defensive enzymes in three Brassicaceae crops. *Crop Prot.* **151**, 105816 (2022).
52. Chi, H., Fu, J. W. & You, M. S. Age-stage, two-sex life table and its application in population ecology and integrated pest management. *Acta Entomol. Sin*. **62**, 255–262 (2019). (in Chinese).
53. Bai, Y. W., Li, X. S., La, B. P. C. & Sun, L. J. Risk warning of fall armyworm invading soybean in China. *J. Plant. Prot.* **47**, 729–734 (2020). (in Chinese).

Author contributions

Z.W. and D.C.J. conceived and designed the experiments. Z.W., H.Z., J.T.H., and X.L. performed the experiments. Z.W. and D.C.J. analyzed the data and wrote the paper. All authors have read and approved the manuscript for publication.

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Declarations

Competing interests
The authors declare no competing interests.
Tables.

Additional information
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