

## Performance of Jujube Lace Bug, *Monosteira alticarinata*, on Jujube, *Ziziphus jujuba* under Different Levels of Nitrogen Fertilization

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### ABSTRACT

Nitrogen is one of the most critical elements for plants and herbivores because it is the main component of amino acids and nucleic acids. Understanding the relationship between nitrogen fertilization and the biology and reproductive potential of pests are critical in integrated pest management programs. This study evaluated the effects of nitrogen fertilization on the biology and life history traits of the jujube lace bug, *Monosteira alticarinata* Ghauri, feeding on jujube trees. The fertilizer treatments were administered at 0, 50, and 100% of recommended rates. The results showed that the lace bugs reared on plants receiving no nitrogen fertilization had a significantly longer total developmental time, shorter adult longevity, and lower fecundity than those reared on the other treatments. The lace bugs that fed on plants fertilized at the highest nitrogen fertilization level had the highest fecundity compared to those reared on other treatments. The net reproduction, mean generation time, gross reproductive rate, finite rate of increase and intrinsic rate of natural increase of lace bugs feeding on plants treated with the highest nitrogen dose were the highest, but doubling time was the lowest. The present data suggest that increasing nitrogen availability to the plants has the potential to increase population of the jujube lace bug and its damage to jujube trees.

**Keywords:** Life table, Nitrogen fertilizer, Nitrogen nutrition, Sap-feeding insects.

### INTRODUCTION

Nitrogen, fundamental for amino acid and protein synthesis in any biological system, constitutes around 0.5–5% of plant tissue and 10% of animal tissue, and is considered to be a frequently limiting nutrient for both plants and their consumers (Mattson, 1980). Nitrogen has been found to affect the reproduction, longevity and general fitness of some herbivores (Tran *et al.*, 2020). Sap-feeding insects show a strong response to nitrogen levels in their host plants, especially in phloem sap (Hogendorp *et al.*, 2006). The relationship between host plant nitrogen fertilization and performance of insects has been studied in

detail by researches (e.g., Shah, 2017; Tran *et al.*, 2020). Overall results indicated that some aspects of arthropod performance including development time, survivorship, longevity, and fecundity are often enhanced on plants receiving supplemental nitrogen fertilizer.

Jujube (*Ziziphus jujuba* Mill), belongs to Rhamnaceae family and is one of the most important *Ziziphus* species (Huang *et al.*, 2008). Different parts of jujube are consumed all around the world because of their health benefits, as both food and herbal medicine (Miri, 2018). It is becoming increasingly important for its wide adaptation, early bearing, and rich nutrition and multiuse (Shahin *et al.*, 2011). Jujube trees grow in the

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arid and semiarid zones of Iran, especially in South Khorasan Province (Vahedi *et al.*, 2008). Among the most injurious pests of jujube trees in the region, the jujube lace bug, *Monosteira alticarinata* Ghauri (Hem.: Tingidae) is in the second place after the jujube fly, *Carpomyia vesuviana* Costa (Dip.: Tephritidae) (Moodi, 2012). Its occurrence in Iran was reported for the first time in 2012 from Birjand, South Khorasan (Moodi, 2012). Based on the Integrated Taxonomic Information System, geographical distribution of *M. alticarinata* includes subtropical regions of Europe, Northern Asia (excluding China) and Southern Asia.

It overwinters in the adult stage and both adults and nymphs feed on underside of leaves and produce small chlorotic stippling on the upper leaf surface. Leaf undersides appear specifically black varnish spotted due to lace bug excrement. Their injury reduces photosynthesis and respiration and also causes aesthetically displeasing injured leaves. As a result, foliage becomes bronzed and leaves may drop early (Aysal and Kivan, 2008; Moodi, 2012). The accumulation of excrements on the leaves also leads to reduction of the gas exchange (Aysal and Kivan, 2008; Sánchez-Ramos *et al.*, 2017).

It is well known that increased fertilizer application to crops affect the performance of herbivores, however, the influence of varying nitrogen fertilizer levels on the performance of jujube lace bug on jujube has not been investigated. Our aims were to determine the effect of different nitrogen fertilization levels on: (a) Some physiological and biochemical characteristics of the host plant, *Z. jujuba* Mill, and (b) Demographic parameters of *M. alticarinata*.

## MATERIALS AND METHODS

### Plant Physiological and Biochemical Measurements

In early September, four plants were randomly selected from each replicate of each treatment for physiological and

biochemical testing. Chlorophyll a, chlorophyll b, total chlorophyll, carotenoid, total carbohydrate, protein, total phenolic content, organic carbon, nitrogen uptake, C/N ratio, phosphorus, potassium and sodium accumulation were measured. To measure amount of chlorophyll a, b, total and carotenoid content, the standard method proposed by Arnon (1967) was used. Nitrogen and protein in jujube leaves were determined according to the Kjeldahl method (Latimer, 2016). The total organic carbon was measured by the combustion of 1 g of oven-dried leaf samples in an electric furnace (after 5 hours at 500°C) according to McDicken (1997). Total carbohydrate content was measured based on the Anthrone method (Irigoyen *et al.*, 1992) and was expressed in milligrams per gram of fresh leaf weight. The total phenolic content of the extracts was estimated with Folin-Ciocalteu reagent (Makkar *et al.*, 1993) and was expressed in milligrams per gram of dry leaf weight. Potassium (K) and sodium (Na) in the jujube leaves were measured following Plank (1992) and Phosphorous (P) was measured by Murphy and Riley (1962) method.

### Study Organisms

The jujube seedlings used for rearing the lace bug were two-years old and homogenous, and were obtained from Alizadeh Nursery in Birjand (32° 56' N, 59° 13' E), South Khorasan Province. Fifty seedlings were planted individually in plastic pots of 26 cm in diameter and 26 cm height and filled with a mixture of sandy loam soil, peat, and vermicompost in 1:1:1 ratio, in early March 2020. The potted seedlings were divided into three groups: the first group of 30 for nitrogen fertilizer experiment, the second group of 10 for maintaining the stock colony of the lace bugs, and the third group of 10 for replacing the second group when they were severely damaged. All potted seedlings were placed in a private garden in outside conditions,

inside wooden frame cages (150×90×100 cm) covered with transparent nylon cloth with an access door in their fronts for manipulating the study organisms as well as horticultural practices during growth season. The potted seedlings were irrigated with tap water and received 100% of field capacity of the soil every week. Each fertilizer treatment had ten replicates. Applied nitrogen fertilizer was in the form of commercial urea, 46%, and fertilization treatments were 0, 50, and 100% of recommended dose (180 kg ha<sup>-1</sup>) (Ghouth, 2016). This was equivalent to application rate of 0, 1 and 2 g urea fertilizer per pot, respectively, for zero, 50, and 100% fertilization treatments. Nitrogen (as urea) was dissolved in water and applied in liquid form. This amount of the fertilizer was applied in three installments during the growing season. Two months after applying the first fertilization treatment, fresh leaves of each treatment were used for conducting the performance experiments in the laboratory.

Starting with female and male individuals of *M. alticarinata* collected in early May 2020 from the jujube trees in Birjand, a culture of the lace bug was established on the second group of potted seedlings of jujube in the semi-field conditions as described above. Adult males and females were separated based on their genitalia under the stereomicroscope in the laboratory (Kumar and Kumar, 2018).

### Experimental Set up

Laboratory experiments were conducted in three sequential steps. To have enough number of the same-aged individuals of the test insect, two arenas were prepared separately for each nitrogen fertilizer treatment. To set up an arena, fresh leaves of jujube seedlings were obtained from each nitrogen treatment and were placed upside down on a 3 mm layer of 3% agar (Merck Company, Germany) in Petri dish of 65 mm diameter×10 mm height. This procedure was repeated every four days. Then, five pairs of male and female were transferred

from the stock culture to each Petri dish. To ventilate the Petri dish, a hole with a diameter of 2 cm was made on the lid and covered with a fine fabric net. All Petri dishes were kept in a growth chamber with a temperature of 25±1°C, relative humidity of 65±2% and photoperiod of 16:8 (L:D). After 24 hours, the leaves were inspected and all the eggs laid counted under a stereomicroscope. Following Oliveira *et al.* (2019), the area around the eggs were marked with a red pen to facilitate inspections before the emergence of the nymphs. Then, the adults were removed from the arenas. The Petri dishes containing eggs were kept in the growth chamber until eggs hatched. In the next step of the laboratory experiment, the newly emerged individuals of the first-instar nymphs (< 24 hours) were transferred into new arenas. At least 30 arenas were prepared for each nitrogen treatment. Individual nymphs were examined daily and their molting and survival were recorded. After the emergence of adults, they were sexed and the sex ratio was recorded. In the third step of the experiment, the emerged adults were then randomly paired and transferred into new arenas in the same laboratory conditions as above. The number of eggs laid by each female was recorded daily until the last female died.

### Life Table Parameters

Based on the fate of a cohort of nymphs that were reared on detached leaves of each given nitrogen fertilizer treatment and by considering the sex ratio, survival rate of immature and female adult stages, daily fecundity, population growth parameters were estimated. The equations and life table construction were adopted from Birch (1948) and Carey (1993).

### Statistical Analysis

The experiments were laid out in Completely Randomized Design (CRD). The data were analyzed using a General



Linear Model (GLM) in SAS software version 9.4 (SAS Institute Inc. 2013). Differences between treatments were compared using Tukey Honestly Significant Difference (HSD) test at the 5% level. Standard error of population growth parameters was calculated using the Jackknife re-sampling method (Meyer *et al.*, 1986).

## RESULTS

### Effects of Nitrogen Fertilization on Jujube Tree

Nitrogen fertilization had significant effects on chlorophyll content of jujube leaves, but the carotenoid was not affected. The highest leaf chlorophyll a, b and total chlorophyll content was observed in 100% nitrogen fertilization treatment, but differences between 100 and 50% N and between 50% and no N treatments were not significant (Table 1). There was a significant difference in protein content among the three nitrogen treatments. The highest level was observed in 100% nitrogen treatment (31.44%), followed by 50% (26.65%), and no nitrogen treatments (22.91%).

The total carbohydrate content in control treatment, 50 and 100% nitrogen fertilization treatments were 43.6, 37.55, and 32.32 mg g<sup>-1</sup> fw, respectively, and there was no significant difference between 50 and 100% nitrogen treatments.

The uptake of phosphorus, potassium and sodium accumulation were affected significantly under nitrogen fertilization treatments. The lowest uptake of phosphorus, potassium and the highest sodium accumulation occurred in the control treatment. Nitrogen fertilizer significantly reduced the total phenolic content of leaves.

#### Biological Parameters of *M. alticarinata*

Embryonic developmental time in both females and males was significantly influenced by nitrogen fertilization levels (Table 2). The applied nitrogen fertilization levels had no significant effect on lace bug pre-oviposition ( $F_2 = 0.39$ ,  $df = 2$ ,  $P > 0.05$ ) and post-oviposition period ( $F_2 = 2.93$ ,  $df = 2$ ,  $P > 0.05$ ), but they significantly influenced the duration of the oviposition period (Table 3). Mean oviposition period was significantly ( $P < 0.0001$ ) higher for 100% nitrogen treatment compared to zero or 50% treatments. Female longevity and the duration of life span in both female and male were significantly shorter in the no nitrogen

**Table 1.** Mean ( $\pm$ SE) of some physiological and biochemical characteristics of the jujube tree subjected to different nitrogen fertilization regimes. <sup>a</sup>

| Physiological characteristic                   | Fertilizer treatments |                      |                      |
|--|-----------------------|----------------------|----------------------|
|  | 100% N                | 50% N                | No N                 |
| Chlorophyll a (mg g <sup>-1</sup> fw)          | 23.381 $\pm$ 0.368a   | 21.654 $\pm$ 1.209ab | 16.732 $\pm$ 2.098b  |
| Chlorophyll b (mg g <sup>-1</sup> fw)          | 13.005 $\pm$ 0.449a   | 12.314 $\pm$ 0.727ab | 9.906 $\pm$ 0.455b   |
| Total chlorophyll (mg g <sup>-1</sup> fw)      | 36.387 $\pm$ 0.811a   | 33.969 $\pm$ 1.827ab | 26.638 $\pm$ 2.258b  |
| Carotenoid (mg g <sup>-1</sup> fw)             | 0.617 $\pm$ 0.023a    | 0.556 $\pm$ 0.052a   | 0.549 $\pm$ 0.041a   |
| Total carbohydrate (mg g <sup>-1</sup> fw)     | 32.323 $\pm$ 2.129b   | 37.553 $\pm$ 2.037b  | 43.6 $\pm$ 2.345a    |
| Total phenolic content (mg g <sup>-1</sup> dw) | 7.144 $\pm$ 0.284b    | 8.663 $\pm$ 0.621b   | 10.915 $\pm$ 0.434a  |
| Nitrogen (%)                                   | 5.03 $\pm$ 0.16a      | 4.264 $\pm$ 0.137b   | 3.665 $\pm$ 0.044C   |
| Organic carbon (%)                             | 52.33 $\pm$ 0.333a    | 50.66 $\pm$ 0.333b   | 49.33 $\pm$ 0.333b   |
| C/N ratio (%)                                  | 10.423 $\pm$ 0.332c   | 11.908 $\pm$ 0.431b  | 13.462 $\pm$ 0.094a  |
| Protein (%)                                    | 31.443 $\pm$ 1.006a   | 26.654 $\pm$ 0.858b  | 22.908 $\pm$ 0.278c  |
| Phosphorus (P) (mg L <sup>-1</sup> )           | 92.953 $\pm$ 1.751a   | 87.993 $\pm$ 1.553a  | 67.367 $\pm$ 0.91b   |
| Potassium (K) (mg L <sup>-1</sup> )            | 220.953 $\pm$ 0.998a  | 505.290 $\pm$ 2.188b | 442.467 $\pm$ 7.274c |
| Sodium (Na) (mg L <sup>-1</sup> )              | 62.130 $\pm$ 0.644c   | 63.78 $\pm$ 1.275b   | 108.200 $\pm$ 1.327a |

<sup>a</sup> Within rows, mean followed by different letters are significantly different according to Tukey HSD test ( $P < 0.05$ ).

**Table 2.** Mean values ( $\pm$ SE) of developmental times of *M. alticarinata* reared on different nitrogen fertilization treatments. <sup>a</sup>

|        | Stage                        | 100% N (32)       | 50% N (30)         | No N (21)         |
|--------|------------------------------|-------------------|--------------------|-------------------|
| Female | Egg                          | 9.59 $\pm$ 0.31b  | 10.37 $\pm$ 0.27b  | 11.81 $\pm$ 0.37a |
|        | 1st instar nymph             | 2.72 $\pm$ 0.23a  | 2.87 $\pm$ 0.23a   | 3.14 $\pm$ 0.28a  |
|        | 2 <sup>nd</sup> instar nymph | 2.84 $\pm$ 0.23a  | 2.63 $\pm$ 0.24a   | 3.29 $\pm$ 0.27a  |
|        | 3rd instar nymph             | 2.75 $\pm$ 0.23a  | 2.70 $\pm$ 0.26a   | 2.95 $\pm$ 0.29a  |
|        | 4th instar nymph             | 2.97 $\pm$ 0.24a  | 2.83 $\pm$ 0.23a   | 3.1 $\pm$ 0.3a    |
|        | 5th instar nymph             | 4.1 $\pm$ 0.22a   | 4.17 $\pm$ 0.24a   | 4.38 $\pm$ 0.32a  |
|        | Egg-Adult                    | 24.94 $\pm$ 0.52b | 25.57 $\pm$ 0.52b  | 28.67 $\pm$ 0.71a |
|        | Life span                    | 72.13 $\pm$ 1.94a | 67.53 $\pm$ 1.68a  | 57 $\pm$ 1.14b    |
|        | Female longevity             | 47.19 $\pm$ 2.01a | 41.97 $\pm$ 1.68a  | 28.33 $\pm$ 0.99b |
| Male   |                              | (14)              | (13)               | (19)              |
|        | Egg                          | 9.71 $\pm$ 0.39b  | 10.62 $\pm$ 0.41ab | 11.42 $\pm$ 0.37a |
|        | 1st instar nymph             | 2.64 $\pm$ 0.27a  | 2.08 $\pm$ 0.21a   | 2.84 $\pm$ 0.23a  |
|        | 2nd instar nymph             | 2.36 $\pm$ 0.31a  | 2.38 $\pm$ 0.29a   | 2.74 $\pm$ 0.25a  |
|        | 3rd instar nymph             | 2.79 $\pm$ 0.37a  | 2.62 $\pm$ 0.29a   | 2.68 $\pm$ 0.24a  |
|        | 4th instar nymph             | 2.57 $\pm$ 0.36a  | 2.46 $\pm$ 0.27a   | 2.84 $\pm$ 0.23a  |
|        | 5th instar nymph             | 3.79 $\pm$ 0.37a  | 4.08 $\pm$ 0.21a   | 4.47 $\pm$ 0.25a  |
|        | Egg-Adult                    | 23.86 $\pm$ 0.1b  | 24.23 $\pm$ 0.5b   | 27 $\pm$ 0.49a    |
|        | Life span                    | 70.36 $\pm$ 3.01a | 66 $\pm$ 2.19a     | 55.58 $\pm$ 1.11b |

<sup>a</sup> Number in parentheses represents the number of replicates. The means in each row with the same letters are not significantly different according to Tukey HSD test ( $P < 0.05$ ). Note: Developmental times are in days.

treatment than the other treatments (Table 2).

The results revealed that mean total fecundity of *M. alticarinata* was significantly influenced by nitrogen fertilization levels ( $F_2 = 44.62$ ,  $df = 2$ ,  $P < 0.0001$ ) and was the highest (139.16 eggs per female) at 100% nitrogen fertilizer treatment (Table 3). The highest rate of daily fecundity was recorded for 100% nitrogen

treatment (3.61 eggs). Also, age specific fecundity was higher in 100% nitrogen fertilizer than the other treatments (Figure 1). However, as can be seen in Figure 2, the survival rates ( $l_x$ ) of the jujube lace bugs reared on different nitrogen treatments were not influenced, and they followed almost a similar pattern to type I survivorship curve (Figure 2).

**Table 3.** Mean values ( $\pm$ SE) of survival and reproductive parameters of *M. alticarinata* reared on different nitrogen fertilization regimes. <sup>a</sup>

| Parameter               | 100% N (32)        | 50% N (30)        | No N (21)         |
|-------------------------|--------------------|-------------------|-------------------|
| Pre-oviposition (days)  | 4.1 $\pm$ 0.27a    | 4.43 $\pm$ 0.29a  | 4.19 $\pm$ 0.33a  |
| Oviposition (days)      | 38.97 $\pm$ 1.87a  | 33.2 $\pm$ 1.68b  | 21 $\pm$ 1.01c    |
| Post-oviposition (days) | 4.13 $\pm$ 0.34a   | 4.33 $\pm$ 0.31a  | 3.14 $\pm$ 0.38a  |
| Total fecundity (eggs)  | 139.16 $\pm$ 7.53a | 84.67 $\pm$ 5.66b | 55.43 $\pm$ 2.83c |
| Daily fecundity (eggs)  | 3.61 $\pm$ 0.12a   | 2.59 $\pm$ 0.14b  | 2.68 $\pm$ 0.11b  |
| Survival ( $l_x$ )      | 0.68 $\pm$ 0.035a  | 0.66 $\pm$ 0.036a | 0.72 $\pm$ 0.034a |

<sup>a</sup> Number in parentheses represents the number of replicates. The means in each row with the same letters are not significantly different according to Tukey HSD test ( $P < 0.05$ ).

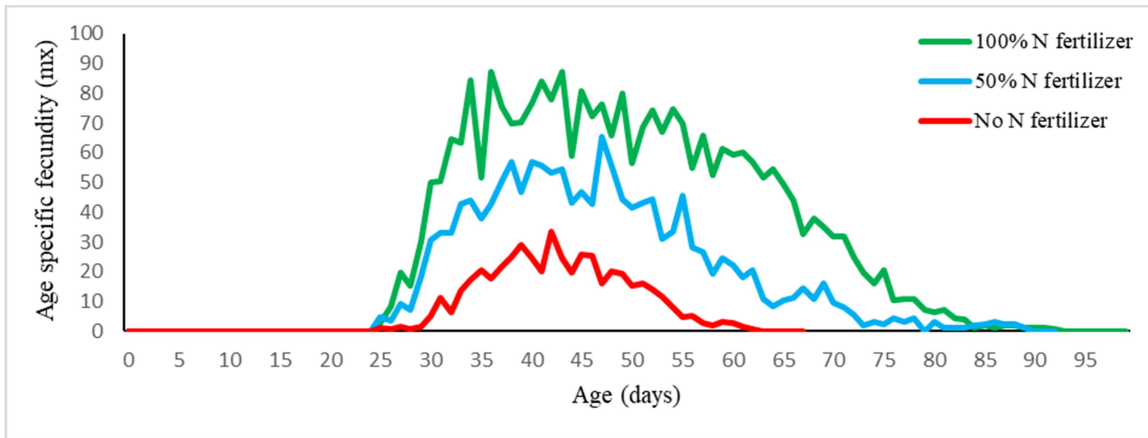


Figure 1. Age-specific fecundity ( $m_x$ ) of *M. alticarinata* at different nitrogen fertilization treatments.

### Life Table Parameters

As shown in Table 4, all life table parameters of the jujube lace bug were influenced by nitrogen fertilization. The highest net Reproductive rate ( $R_0$ ), mean generation Time (T), intrinsic rate of increase (r), finite rate of increase ( $\lambda$ ), Gross Reproductive Rate (GRR) and the lowest Doubling Time (DT) were observed in 100% nitrogen fertilizer treatment, 50% nitrogen fertilizer treatment and the control, respectively.

### DISCUSSION

The content of chlorophyll a, b and total, protein, nitrogen and phosphorous that may increase herbivore performance were higher in plants under application of nitrogen fertilizer compared with the control one (Rashid *et al.*, 2017). Application of nitrogen fertilizer increased chlorophyll content of jujube leaves. These results are consistent with many other studies that have shown a positive effect of nitrogen fertilizer application on leaf chlorophyll contents (Uysal, 2018; Li *et al.*, 2021; Peng *et al.*,

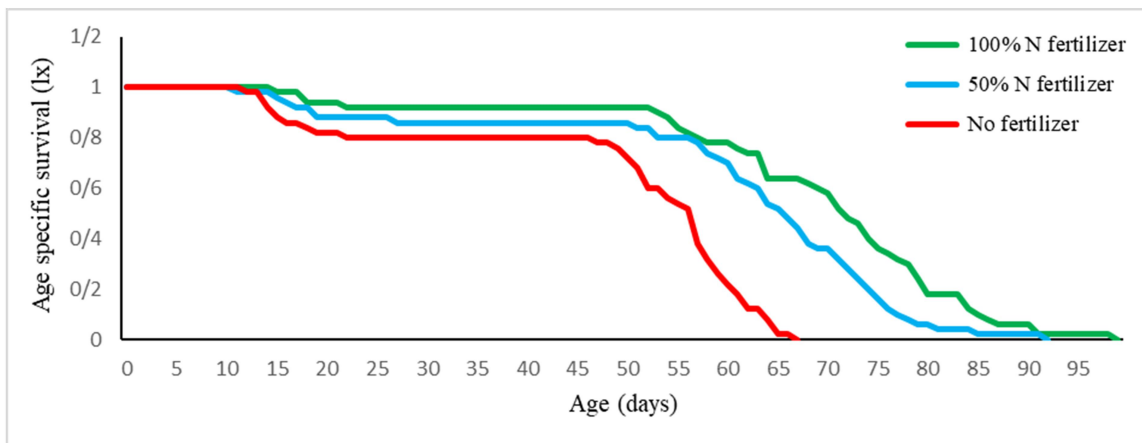


Figure 2. Age-specific survival ( $l_x$ ) of *M. alticarinata* at different nitrogen fertilization treatments.

2021; Wang *et al.*, 2021).

In this study, there was a negative relationship between increased nitrogen fertilizer and phenolic content of jujube. This finding is in agreement with the carbon/nutrient balance theory that increasing nitrogen fertilization can decrease the levels of secondary compounds in plants (e.g., phenolics, tannins and terpenes) (Muzika and Pregitzer, 1992). Phenolic compounds play an important role in the host/pest relationship, being the basis for many plant defense mechanisms (Imas, 2013). According to Gayler *et al.* (2008), phenolic content in plant tissues might be affected by environmental factors such as nitrogen fertilizers. Also, Wu *et al.* (2013) demonstrated that phenolic levels and antioxidant activity of jujube can be manipulated through fertilizer management.

Similarly to the results of others (e.g., Heidari *et al.*, 2020; Leite *et al.*, 2021) a negative correlation between carbohydrate content and the amount of applied nitrogen fertilizer was observed. This may be due to the main role of nitrogen in the stabilization of amino acids (Taiz and Ziger, 2010).

Application of nitrogen fertilizer increased phosphorus, potassium and decreased sodium in jujube leaves. Similarly, in citrus rootstocks, increased nitrogen fertilization increased leaf nitrogen and potassium concentration (Ghasemnezhad *et al.*, 2009). Nitrogen fertilization also has increased the content of nitrogen and phosphorus in *Rubia*

*tinctorum* L. (Salek *et al.*, 2017) and nitrogen, phosphorus and potassium content in marshmallow, *Althaea officinalis* L. (Mardani *et al.*, 2019) and reduced the content of sodium in both plants.

Considering the overall effects of nitrogen fertilization on physiological and biochemical traits of the jujube seedlings, the best conditions for population growth of *M. alticarinata* were observed under 100% N treatment, as evidenced by shorter generation time, higher intrinsic rate of increase, finite rate of increase, gross reproductive rate and total fecundity in comparison with other fertilizer treatments. The nitrogen levels in the diet of herbivorous insects have been reported as the most important factor affecting their performance (Awmack and Leather, 2002). Carbon-based chemicals such as phenolics have antibiotic and antimicrobial activity and, consequently, have some level of phytotoxicity, which may play a role in plant defense (Harborne, 1985). In our study, an increase on the performance of *M. alticarinata* (high fecundity, shorter developmental time, long life span, etc.) can be due to an increase in the nutrient contents such as nitrogen and protein, in case of the 100% nitrogen fertilization. Insects prefer plant tissues rich in nitrogen, since it is a limiting factor for development, and production of eggs by females (Eubanks and Styrsky, 2005). On the other hand, the reduced levels of phenolic content induced by high levels of nitrogen

**Table 4.** Life table parameters (mean±SE) of *M. alticarinata* reared on jujube under different nitrogen fertilization regimes.<sup>a</sup>

| Life table parameters                 | N Fertilizer treatments |                 |                 |
|---------------------------------------|-------------------------|-----------------|-----------------|
|                                       | 100% N (32)             | 50% N (30)      | No N (21)       |
| Net reproductive rate ( $R_0$ )       | 2487.63±474.06a         | 1349.62±264.35b | 440.62±101.321c |
| Mean generation time (T)              | 47.51±1.12a             | 44.64±0.94b     | 42.02±0.94c     |
| Intrinsic rate of increase (r)        | 0.165±0.01a             | 0.161± 0.01b    | 0.145±0.01c     |
| Finite rate of increase ( $\lambda$ ) | 1.179±0.016a            | 1.175±0.01b     | 1.156±0.01c     |
| Doubling time (DT)                    | 4.21±0.13c              | 4.29±0.14b      | 4.78±0.2a       |
| Gross reproductive rate (GRR)         | 2760.86±517.88a         | 1470.88±290.27b | 465.6±106.8c    |

<sup>a</sup> Within rows, mean followed by different letters are significantly different according to Tukey HSD test ( $P < 0.05$ ). Note:  $R_0$  ( $\frac{\text{♀♀/♀}}{\text{♀/♀}}$ /generation); T (days); r ( $\frac{\text{♀♀/♀}}{\text{♀/♀}}$ /day);  $\lambda$  ( $\text{day}^{-1}$ ); DT (days); GRR (eggs per individual/generation).



fertilization may have contributed to the improved lace bug performance too. Prudic et al. (2005) also reported that plant nutritional quality and plant defenses that directly act on herbivores are altered by nitrogen fertilization.

Similar to the results presented here, a large number of investigations have found that increasing nitrogen fertilization increased the growth and reproduction of many sap sucking insects, such as *Schizaphis graminum* (Rondani) (Alasvand Zarasvand et al., 2013); *Aphis craccivora* Koch. (Hosseini et al., 2015); *Aphis gossypii* Glover (Hosseini et al., 2010); *Sitobion avenae* (F.), *Rhopalosiphum padi* (L.), and *Melanaphis sacchari* (Zehntner) (Aphididae) (Aqueel and Leather, 2011; Lama et al., 2019); *Nilaparvata lugens* (Stål) (Delphacidae) (Rashid et al., 2017); *Sogatella furcifera* (Horváth) (Delphacidae) (Li et al., 2021); *Bemisia argentifolii* Bellows and Perring (Aleyrodidae) (Bi et al., 2001); *Planococcus citri* (Risso) and *P. ficus* (Signoret) (Hogendorp et al., 2006; Cocco et al., 2015); *Phenacoccus manihoti* (Matile-Ferrero) (Pseudococcidae) (Tran et al., 2020).

Contrary to our results, Casey and Raupp (1999) showed that supplemental nitrogen fertilization of azalea did not affect performance of *Stephanitis pyrioides* Scott. (Hemi.: Tingidae). Our finding that nitrogen fertilization resulted in significantly longer female adult longevity and oviposition periods is in agreement with the results reported for the oviposition period of adult *P. manihoti* (Tran et al., 2020) and for the longevity of adult *S. furcifera* (Li et al., 2021), *S. graminum* (Alasvand Zarasvand et al., 2013) *Peregrinus maidis* (Ashmead) (Wang et al., 2006), *A. gossypii* (Hosseini et al., 2010), and *S. avenae* and *R. padi* (Aqueel and Leather, 2011). Nevertheless, varying nitrogen levels did not significantly change the duration of either the reproductive period or adult longevity of *Diuraphis noxia* (Kurdjumov) (Moon et al., 1995). The longevity of *Brevicoryne brassicae*

(L.), *Metopolophium dirhodum* (Walker) and *A. craccivora* remained unaffected by the level of nitrogen fertilization.

## CONCLUSIONS

Increased nitrogen fertilizer has the potential to boost agricultural yields, but, simultaneously, plants become more susceptible to many herbivores (Alasvand Zarasvand et al., 2013). As shown here, increased nitrogen fertilizer resulted in an increase in performance and population of *M. alticarinata*. To prevent population outbreak and avoid the economic damage of this pest to jujube trees, an appropriate nitrogen fertilization amount should be utilized. Further research on the optimal dose of nitrogen fertilizer can reduce insecticide application, avoid ground water contamination, and reduce worker exposure to pesticide residues.

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## عملکرد زیستی سنک *Monosteira alticarinata* Ghauri تحت سطوح مختلف کود

### نیترोजن در درختان عناب

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### چکیده

نیترोजن یکی از حیاتی ترین عناصر برای گیاهان و گیاه-خواران مرتبط با آنها است زیرا جزء اصلی اسیدهای آمینه و اسیدهای نوکلئیک است. در تصمیم-گیری برای برنامه-های مدیریت تلفیقی آفات در اکوسیستم-های کشاورزی، درک رابطه-ی بین کوددهی نیترोजن، زیست-شناسی و پتانسیل تولیدمثلی آفات بسیار مهم است. این مطالعه اثرات کوددهی نیترोजن بر ویژگی‌های زیستی و تاریخچه-ی زندگی سنک عناب (*Monosteira alticarinata* Ghauri) با پرورش بر روی گیاهان گلدانی عناب ارزیابی کرد. تیمارهای کودی در سطوح ۰، ۵۰ و ۱۰۰ درصد دوز توصیه شده در منطقه اعمال شدند. نتایج نشان داد سنک-های پرورش یافته روی گیاهان عناب بدون دریافت کود نیترोजن، زمان کل رشد و نمو بسیار طولانی‌تر، طول عمر بالغ کمتر و زادآوری کمتری نسبت به



سایر تیمارها داشتند. سنک-هایی که از گیاهان عناب با بالاترین سطح کود نیتروژن تغذیه کرده بودند، بالاترین زادآوری (زادآوری کل و روزانه) را نسبت به سایر تیمارها داشتند. در اندازه-گیری پارامترهای جدول زندگی سنک عناب از روش جک-نایف برای تعیین عدم قطعیت پارامترها استفاده شد. سنک-های عناب تغذیه شده از گیاهان تیمار شده با بیشترین میزان نیتروژن بالاترین نرخ تولید مثل خالص (Ro)، میانگین زمان یک نسل (T)، نرخ تولید مثل ناخالص (GRR)، نرخ افزایش محدود ( $\lambda$ ) و نرخ ذاتی افزایش طبیعی (rm) را داشتند اما زمان دو برابر شدن نسل آن-ها (DT) پایین-ترین بود. داده های حاضر نشان می-دهد که افزایش دسترسی گیاهان به نیتروژن عامل مهمی در افزایش انبوهی جمعیت سنک و شدت خسارت آفت به درخت عناب است.