J. Agric. Sci. Technol. (2023) Vol. 25(4): 1001-1012

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

S. A. Notghi Moghadam[1], H. Sadeghi-Namaghi[1*], and S. Moodi[2]

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

[1] Department of Plant Protection, Faculty of Agriculture, Ferdowsi University of Mashhad, Razavi Khorasan, Islamic Republic of Iran.

[2] Department of Plant Protection, Faculty of Agriculture, Birjand University, Birjand, South Khorasan, Islamic Republic of Iran.

* Corresponding author's email: sadeghin@um.ac.ir

[DOI: 10.22034/jast.25.4.17]

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,

[DOI: 10.22034/jast.25.4.17]

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^{-1}) (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

[DOI: 10.22034/jast.25.4.17]

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^{-1} 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 (±SE) of some physiological and biochemical characteristics of the jujube tree subjected to different nitrogen fertilization regimes. [a]

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

[a] Within rows, mean followed by different letters are significantly different according to Tukey HSD test (P< 0.05).

[DOI: 10.22034/jast.25.4.17]

Table 2. Mean values (±SE) of developmental times of *M. alticarinata* reared on different nitrogen fertilization treatments. [a]

	Stage	100% N (32)	50% N (30)	No N (21)
Female	Egg	9.59±0.31b	10.37±0.27b	11.81±0.37a
	1st instar nymph	2.72±0.23a	2.87±0.23a	3.14±0.28a
	2nd instar nymph	2.84±0.23a	2.63±0.24a	3.29±0.27a
	3rd instar nymph	2.75±0.23a	2.70±0.26a	2.95±0.29a
	4th instar nymph	2.97±0.24a	2.83±0.23a	3.1±0.3a
	5th instar nymph	4.1±0.22a	4.17±0.24a	4.38±0.32a
	Egg-Adult	24.94±0.52b	25.57±0.52b	28.67±0.71a
	Life span	72.13±1.94a	67.53±1.68a	57±1.14b
	Female longevity	47.19±2.01a	41.97±1.68a	28.33±0.99b
Male		(14)	(13)	(19)
	Egg	9.71±0.39b	10.62± 041ab	11.42± 0.37a
	1st instar nymph	2.64±0.27a	2.08±0.21a	2.84±0.23a
	2nd instar nymph	2.36±0.31a	2.38±0.29a	2.74±0.25a
	3rd instar nymph	2.79±0.37a	2.62±0.29a	2.68±0.24a
	4th instar nymph	2.57±0.36a	2.46±0.27a	2.84±0.23a
	5tth instar nymph	3.79±0.37a	4.08±0.21a	4.47±0.25a
	Egg-Adult	23.86±0.1b	24.23±0.5b	27±0.49a
	Life span	70.36±3.01a	66±2.19a	55.58±1.11b

[a] 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 (±SE) of survival and reproductive parameters of *M. alticarinata* reared on different nitrogen fertilization regimes. [a]

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

[a] 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).

[DOI: 10.22034/jast.25.4.17]

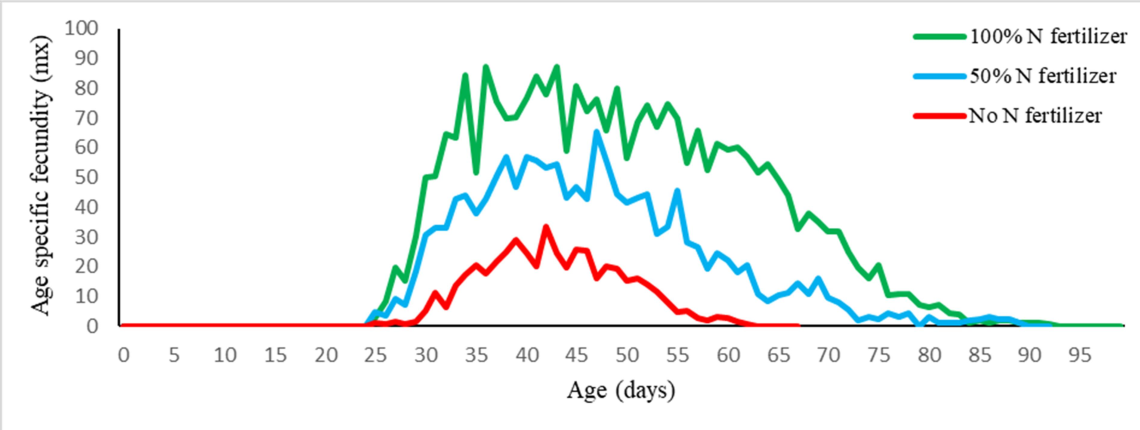

Figure 1. Age-specific fecundity (m_x) of *M. alticarinata* at different nitrogen fertilization treatments.

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 (λ), 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*.,

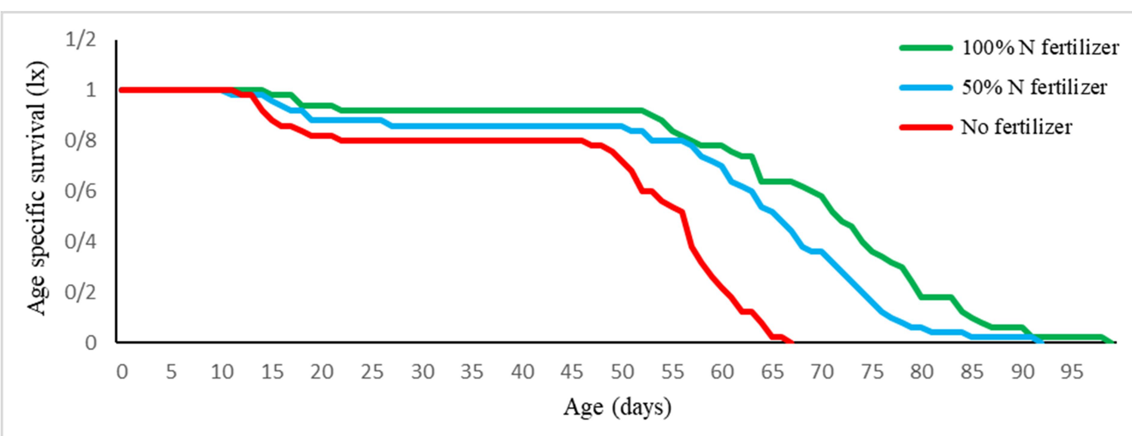

Figure 2. Age-specific survival (l_x) of *M. alticarinata* at different nitrogen fertilization treatments.

[DOI: 10.22034/jast.25.4.17]

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 afficinalis* 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.[a]

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 (λ)	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

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

[DOI: 10.22034/jast.25.4.17]

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); *Planocuccus 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.

ACNOWLEDGEMENTS

Authors would like to thank the authorities of Ferdowsi University of Mashhad and Birjand University for supporting this research. This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors. All authors agree on the content of the paper and have no conflict of interest to disclose.

REFERENCES

1. Alasvand Zarasvand, A., Allahyari, H. and Fattah-Hosseini, S. 2013. Effect of Nitrogen Fertilization on Biology, Life Table Parameters and Population Abundance of Greenbug; *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae). *Arch. Phytopathol. Pflanzenschutz*., **46 (8)**: 882–889.
2. Aqueel, M. A. and Leather, S. R. 2011. Effect of Nitrogen Fertilizer on the Growth and Survival of *Rhopalosiphum padi* (L.) and *Sitobion avenae* (F.) (Homoptera: Aphididae)

[DOI: 10.22034/jast.25.4.17]

on Different Wheat Cultivars. *J. Crop Prot*., **30 (2)**: 216-221.
3. Arnon, A. N. 1967. Method of Extraction of Chlorophyll in the Plants. *Agron. J*., **23**: 112-121.
4. Awmack, C. S. and Leather, S. R. 2002. Host Plant Quality and Fecundity in Herbivorous Insect. *Annu. Rev. Entomol*., **47 (1)**: 817-844.
5. Aysal, A. and Kivan, M. 2008. Development and Population Growth of *Stephanitis pyri* (F.) (Heteroptera: Tingidae) at Five Temperatures. *J. Pest Sci*., **81 (3)**: 135-141.
6. Bi, J. L., Ballmet, G. R., Hendrix. D. L., Henneberry, T. J. and Toscano, N. C. 2001. Effect of Cotton Nitrogen Fertilization on *Bemisia argentifolii* Population and Honeydew Population. *Entomol. Exp. Appl*., **99 (1)**: 25-36.
7. Birch, L. C. 1948. The Intrinsic Rate of Natural Increase of an Insect Population. *J. Anim. Ecol*., **17(1)**: 15-26.
8. Carey, J. R. 1993. Applied Demography for Biologists with Special Emphasis on Insects. Oxford University Press, New York, 206 PP.
9. Casey, C. A. and Raupp, M. J. 1999. Supplemental Nitrogen Fertilization of Containerized Azalea Does Not Affect Performance of Azalea Lace Bug (Heteroptera: Tingidae). *Environ. Entomol*., **28(6)**: 998-1003.
10. Cocco, A., Marras, P. M., Muscas, E., Mura, A., Lentini, A. 2015. Variation of Life-History Parameters of *Planococcus ficus* (Hemiptera: Pseudococcidae) in Response to Grapevine Nitrogen Fertilization. *J. Appl. Entomol*., **139(7)**: 519-528.
11. Eubanks, M. D. and Styrsky, J. D. 2005. Effects of Plant Feeding on the Performance of Omnivorous Predators. In: "*Insect Natural Enemies: Practical Approach to Their Study and Evolution*", (Eds.): Jervis, M. A. and Kidd, N. A. C. Chapman & Hall, London, PP. 148-177.
12. Gayler, S., Grams, T. E. E., Heller, W., Treutter, D. and Priesack, E. A. 2008. Dynamical Model of Environmental Effects on Allocation to Carbon-Based Secondary Compounds in Juvenile Trees. *Ann. Bot*., **101(8)**: 1089–1098.
13. Ghasemnezhad, M,. Zamani, Z., Savaghebi, G. R. and Ebrahimi, Y. 2009. Effects of Nitrogen Source and Rate on Vegetative Growth and Leaf Mineral Nutrient Content of Three Citrus Rootstocks. *J. Pajouhesh Sazandegi*., **21(4)**: 170-174. (in Persian)
14. Ghouth, K. 2016. Jujube (Botany and Horticulture). Fekr-e-Bekr Publications, Tehran. 216 PP. (in Persian)
15. Harborne, J. 1985. Phenolics and Plants Defense. In: "*The Biochemistry of Plant Phenolics*", (Eds.): Van Sumere, C. F. and Lea, P. J. Oxford University Press, Oxford, 483 PP.
16. Heidari, N., Shekari, F., Golchin, A. and Sehati, N. 2020. Interaction of Nitrogen Stress and Salicylic Acid on Physiologic and Photosynthetic Characteristics of Borage (*Borago officinials* L.). *J. Plant Proc. Func*., **8(34)**: 37-50.
17. Hogendorp, B. K., Cloyd, R. C. and Swiader, J. M. 2006. Effect of Nitrogen Fertility on Reproduction and Development of Citrus Mealybug, *Planocuccus citri* Risso (Homoptera: Pseudococcidae), Feeding on Two Colors of Coleus, *Solenostemon scutellarioides* L. *Codd. Environ. Entomol*., **35(2)**: 201-211.
18. Hosseini, A., Hosseini, M., Goldani, M., Karimi, J. and Madadi, H. 2015. Effect of Nitrogen Fertilizer on Biological Parameters of the *Aphis craccivora* (Hemiptera: Aphidiae) and Associated Productivity Losses in Common Globe Amaranth. *J. Agr. Sci. Tech*., **17(6)**: 1517-1528.
19. Hosseini, M., Ashouri, A., Enkegaard, A., Goldansaz, S. H., Nassiri Mahalati, M. and Hosseininave, V. 2010. Performance and Population Growth Rate of the Cotton Aphid, and Associated Yield Losses in Cucumber, under Different Nitrogen Fertilization regimes. *Int. J. Pest Manag*., **56(2)**: 127–135.
20. Huang, Y. L., Yen, G. C., Sheu, F. and Chau, C. F. 2008. Effects of Water-Soluble Carbohydrate Concentrate from Chinese Jujube on Different Intestinal and Fecal Indices. *J. Agric. Food Chem*., **56(5)**: 1734-1739.
21. Imas, P. 2013. *Potassium: the Quality Element in Crop Production.* International Potash Institute, Switzerland, 36 PP.
22. Irigoyen, J. J., Emerich, D. W. and Sanchez-Diaz, M. 1992. Water Stress Induced Changes in Concentrations of Proline and Total Soluble Sugars in Nodulated Alfalfa (*Medicago sativa*) Plants. *Physiol. Plant*., **84(1)**: 55-60.
23. Kumar, N. and Kumar, A. 2018. Study the Biology of Lace Bug, *Cochlochila Bullita* (Stål) (Hemiptera: Tingidae) under Ambient

[DOI: 10.22034/jast.25.4.17]

Laboratory Conditions. *J. Pharmacogn. Phytochem*., SP1: 1755-1760.
24. Lama, L., Wilson, B. E., Davis, J. A. and Reagan, T. E. 2019. Influence of Sorghum Cultivar, Phenological Stage and Fertilization on Development and Reproduction of *Melanaphis sacchari* (Hemiptera: Aphididae). *Fla. Entomol*., **102(1)**: 194-201.
25. Latimer, G. W. 2016. *Official Methods of Analysis of AOAC International.* 19th Edition, AOAC International: Gaithersburg, MD, USA.
26. Leite, R. G., Cardoso, A. S., Fonseca, N. V. B., Silva, M. L. C., Tedeschi, L. O., Delevatti, L. M., Ruggieri, A. C. and Reis, R. A. 2021. Effects of Nitrogen Fertilization on Protein and Carbohydrate Fractions of *Marandu palisadegrass*. *Sci. Rep*., **11**: 14786.
27. Li, Z., Xu, B., Du, T., Ma, Y., Tian, X., Wang, F. and Wang, W. 2021. Excessive Nitrogen Fertilization Favors the Colonization, Survival, and Development of *Sogatella furcifera* via Bottom-Up Effects. *Plants*, **10(5)**: 875.
28. Makkar, H. P. S., Blummel, M., Borowy, N. K. and Becker, K. 1993. Gravimetric Determination of Tannins and Their Correlations with Chemical and Protein Precipitation Methods. *J. Sci. Food. Agric*., **61**: 161–165.
29. Mardani, H., Razmjoo, J. and Ghafari, H. 2019. Interactive Effect of Salinity and Urea Fertilizer on Some Physiological Characteristics Quality and Quantity Yield of Marsh Mallow (*Althaea afficinalis*). *J. Plant Proc. Func*., **8(32)**: 223-243. (in Persian)
30. Mattson, W. J. 1980. Herbivory in Relation to Plant Nitrogen Content. *Ann. Rev. Ecol. Syst*., **11**: 119-161.
31. Mcdicken, K. G.1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development. 87 pp.
32. Meyer, J. S., Ingersoll, C. G., McDonald, L. L. and Boyce, M. S. 1986. Estimating uncertainty in population growth rates: Jackknife vs. Bootstrap techniques. *Ecology*, **67 (5)**: 1156 –1166.
33. Miri, S. M. 2018. Cultivation, Chemical Compositions and Health Benefits of Jujube (Ziziphus jujuba Mill.). The First National Congress and the International Exhibition of Medicinal Plants and Iranian Medicines Effective on Diabetes, Mashhad, Iran, 12 PP.
34. Moodi, S. 2012. Studies on Biological Parameters of *Monosteira alticarinata* Ghauri (Hemiptera: Tingidae) as a Jujube Trees Pest under Laboratory Conditions. *Proceedings of Twentieth Iranian Plant Protection Congress,* 685 PP.
35. Moon, C. E., Lewis, B. E., Murray, L. and Sanderson, S. M. 1995. Russian Wheat Aphid (Homoptera: Aphididae) Development, Reproduction, and Longevity on Hydroponically Grown Wheat with Varying Nitrogen Levels. *Environ. Entomol*., **24(2)**: 367–371.
36. Murphy, J. and Riley, H. P. 1962. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Anal. Chim. Acta*., **27**: 31-36.
37. Muzika, R. M. and Pregitzer, K. S. 1992. Effect of Nitrogen Fertilization on Leaf Phenolic Production of Grand Fir Seedlings. *Trees - Struct. Funct*., **6**: 241–244.
38. Oliveira, S. R., Silva, C. A. D., Carvalho, T. S. and Costa, L. A. A. 2019. Biology of *Corythucha gossypii* Fabricius, 1794 (Hemiptera: Tingidae) in *Ricinus communis* at Different Temperatures and Thermal Requirements. *Braz. J. Biol*., **79(2)**: 278-285.
39. Peng, J., Feng, Y., Wang, X., Li, J., Xu, G., Phonenasay, S., Luo, Q., Han, Z. and Lu, W. 2021. Effects of Nitrogen Application Rate on the Photosynthetic Pigment, Leaf Fluorescence Characteristics, and Yield of Indica Hybrid Rice and Their Interrelations. *Sci. Rep*., **11**: 1-10.
40. Plank, C. O. 1992. *Plant analysis refrence producers for the southern region of the United States*. The University of Georgia, Southern Cooperative Bulletin Series 368, 68 PP.
41. Prudic, K. L., Oliver, J. C. and Bowers, M. D. 2005. Soil Nutrient Effects on Oviposition Preference, Larval Performance and Chemical Defense of a Specialist Insect Herbivore. *Oecolgia*, **143(4)**: 578-587.
42. Rashid, M. M., Ahmed, N., Jahan, M., Islam, K. S., Nansen, C., Willers, J. L. and Ali, M. P. 2017. Higher Fertilizer Inputs Increase Fitness Traits of Brown Planthopper in Rice. *Sci. Rep*., **7**: 4719.
43. Salek, M., Saadatmand, S., Khavari-Nejad, R. A. and Zeinali, H. 2017. Effects of Different Levels of and Superphosphate Fertilizers on Mineral Elements Accumulation in *Rubia tinctorum* L. *Iran J. Med. Aromat. Plants.*, **33(2)**: 219-232. (in Persian)

[DOI: 10.22034/jast.25.4.17]

44. Sánchez-Ramos, I., Pascual, S., Fernández, C. E. and González- Núñez, M. 2017. Reproduction, Longevity and Life Table Parameters of *Monosteira unicostata* (Hemiptera: Tingidae) at Constant Temperatures. *Span. J. Agric. Res*., **15(4)**: e1012.
45. SAS Institute. 2013. SAS users guide: statistics. SAS Institute, Cary, NC.
46. Shah, T. H. 2017. Plant Nutrients and Insects Development. *Int. J. Entomol. Res*., **2(6)**: 54-57.
47. Shahin, M. A., Yehia, T. A., Hussien, E. A. and El-amary, E. I. 2011. Effect of Different Soil Water Levels on Growth of Three Jujube *Ziziphus jujuba* Mill. Genotypes. *J. Ornam. Hortic. Plants*, **3(3)**: 270-275.
48. Taiz, L. and Zeiger, E. 2010. *Plant Physiology.* 5th Edition, Sinauer Associates Inc., Sunderland, 782 PP.
49. Tran, D. H., Nguyen, T. G., Hoang, T. N., Hoang, H. T., Le, K. P., Nguyen, H. L., Hoang, H. L. and Tran, T. X. P. 2020. Effects of Nitrogen Fertilization on the Biology of the Cassava Pink Mealybug *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae). *Int. J. Entomol. Res*., **5(4)**: 162-166.
50. Uysal, E. 2018. Effects of Nitrogen Fertilization on the Chlorophyll Content of Apple. *Meyve bilim*., **5(1)**: 12-17.
51. Vahedi, F., Fathi Najafi, M. and Bozari, K. 2008. Evaluation of Inhibitory Effect and Apoptosis Induction of *Zyzyphus Jujube* on Tumor Cell Lines, an *in Vitro* preliminary Study. *Cytotechnology*, **56(2)**: 105-111.
52. Wang, J. J., Tsai, J. H. and Broschat, T. K. 2006. Effect of Nitrogen Fertilization of Corn on the Development, Survivorship, Fecundity and Body Weight of *Peregrinus maidis* (Hom,. Delphacidae). *J. Appl. Entomol*., **130(1)**: 20-25.
53. Wang, N., Fu, F., Wang H., Wang, P., He, S., Shao, H., Ni, Z. and Zhang, X. 2021. Effects of Irrigation and Nitrogen on Chlorophyll Content, Dry Matter and Nitrogen Accumulation in Sugar Beet (*Beta vulgaris* L.). *Sci. Rep*., **11**: 16651.
54. Wu, C. S., Gao, Q. H., Kjelgren, R. K., Guo, X. D. and Wang, M. 2013. Yields, Phenolic Profiles and Antioxidant Activities of *Ziziphus jujuba* Mill. in Response to Different Fertilization Treatments. *Molecules*, **18(10)**: 12029-12040.

عملکرد زیستی سنک *Monosteira alticarinata* Ghauri تحت سطوح مختلف کود نیتروژن در درختان عناب

س. آ. نطقی مقدم، ح. صادقی نامقی، و س. مودی

چکیده

نیتروژن 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 نیتروژن، زیست¬شناسی و پتانسیل تولیدمثلی آفات بسیار مهم است. این مطالعه اثرات کوددهی نیتروژن بر ویژگی‌های زیستی و تاریخچه¬ی زندگی سنک عناب (Monosteira alticarinata Ghauri)را 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 نیتروژن، زمان کل رشد و نمو بسیار طولانی‌تر، طول عمر بالغ کمتر و زادآوری کمتری نسبت به

[DOI: 10.22034/jast.25.4.17]

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 (λ) 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.

[DOI: 10.22034/jast.25.4.17]