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Research Article

The simultaneous application effects of nitrogen, phosphorus and silicon on life table parameters of *Aphis gossypii* (Hemiptera: Aphididae) on cucumber

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Abstract: *Aphis gossypii* Glover is one of the major pests of cucumber in Iran. The effects of different concentrations of nitrogen (N_1 = 0, N_2 = 30, N_3 = 60, N_4 = 90 and N_5 = 120 kg/ha), phosphorus (P_1 = 0, P_2 = 15 and P_3 = 22.5 kg/ha) and silicon (Si_1 = 0, Si_2 = 100 and Si_3 = 200 kg/ha) on life table parameters of apterous morph of *A. gossypii* were studied. This study was conducted as factorial experiment based on RCD with nine replications in a growth chamber at temperature of 25 ± 3 °C, 60 ± 5% relative humidity (RH) and a photoperiod of 16: 8 h (light: dark). The experiments were carried out using clip-cages that were fixed on leaves of cucumber growing in pots. According to the results, total fecundity of *A. gossypii* significantly was different among treatments and it was the highest on $N_1P_2Si_2$ (64.33 offspring) and the lowest on $N_3P_2Si_1$ (22.67 offspring). The lowest and the highest values of R_0 were observed on $N_3P_2Si_1$and $N_4P_2Si_2$, respectively. The shortest mean generation time (*T*) was found on $N_4P_1Si_3$ and the longest was on $N_5P_3Si_1$. Furthermore, the lowest and the highest values of *r* were obtained on $N_5P_3Si_2$ (0.27 day^{-1}) and $N_5P_1Si_1$ (0.41 day^{-1}). Our results showed that in simultaneous application, the phosphorus had a more impact on life history and performance of cotton aphid.

Keywords: Cucumber, *Aphis gossypii*, Fertilizer, Life table parameters, Integrated pest management

Introduction

Cucumber is planted in both field and greenhouse conditions worldwide (Jafari *et al.*, 2012).One of the most important pests of cucumber in field and greenhouse conditions in Iran and in other cucumber growing areas is *Aphis gossypii* Glover (Aphididae) (Jafari *et al.*, 2013). *Aphis gossypii* has long been regarded as a cosmopolitan, highly polyphagous species, widely distributed in tropical, subtropical and temperate regions (Satar *et al.*, 2005). Since cucumber is eaten raw and also the time interval between two harvests is short, therefore the control of its pests with minimum application of synthetic pesticides is very important (Jafari *et al.*, 2013).

Nowadays, application of fertilizers to increase yield of different crops is becoming a more common practice. Therefore, understanding the relationship between fertilizers application and the incidence of insect pests is essential. Some studies showed that population growth rate and developmental time of phytophagous insects were influenced by plant nutrient levels as well as nutrient ratios

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(Busch and Phelan, 1999; Jansson and Ekbom, 2002; Mohiseni and Dashadi, 2016).

A cheap and available practice to increase the yield in agro ecosystems is nitrogen manipulation. Nitrogen profoundly influences the growth and fecundity of herbivorous insects (Douglas, 2006). Often nitrogenous compounds are scarce in plant tissues, particularly in phloem sap (Mattson, 1980). Therefore, sucking insects such as aphids show strong response to change in nitrogen level in host plants (Van Emden, 1966). Many researches demonstrated positive responses of aphids to a change in concentration of nitrogen (Letourneau *et al*., 1996; Gary *et al*., 2005; Zarghami *et al*., 2010; Butler *et al*., 2012; Mohiseni and Dashadi, 2016).

Phosphorus is an another essential element for plants that is necessary for energy transfer and its deficiency can affect various processes, such as protein synthesis and active ion uptake and therefore lead to retarded plant growth (Mengel and Kirkby, 2001). Moreover, silicon is one of the beneficial nutrients that influences defenses of plants against insects. The absorbed silicon is deposited in the epidermal cells as amorphous silica, making the leaf tissue more rigid and more difficult for insects to feed on (Basagli *et al*., 2003; Moraes *et al*., 2004). In addition, silicon elicits the production of defense metabolites, such as peroxidases, polyphenol oxidases (Cherif *et al*., 1992; Gomes *et al*., 2005), lignin, and tannins (Gomes *et al*., 2008). The object of this research was to study the effects of different concentration of N, P and Si on cotton aphid life table parameters of *A. gossypii* under controlled conditions on cucumber.

Materials and Methods

Preparing the colony of *Aphis gossypii*

Aphids were collected from cucumber fields in the Kamalvand region in the vicinity of Khorramabad, Lorestan Province, Western Iran, during summer 2014. For providing the colonies of *A. gossypii*, the collected aphids were reared and multiplied on cucumber (cv. Negin) in greenhouse. After two generations of rearing under laboratory conditions, the apterous morphs of *A. gossypii* were used for experiments.

Plant culture, fertilization and examination

Cucumber plants (*Cucumis sativus* L.) (cv. Negin) were sown in plastic pots (14 cm height × 20 cm diameter) in a substrate composed of soil and vermicompost (1: 2). No fertilizer was added to the soil used for direct seeding. Pots of sown cucumber were individually watered and maintained in a climate-controlled room at 25 ± 2 °C, 50 ± 10% RH and a 16: 8 h (L: D) photoperiod . To provide a continuous supply of the host plants for rearing the insect, cucumber seeds were planted every two or three weeks. No insecticides were applied on the plants. A primary soil analysis test was carried out to determine the level of each element in the soil. To accomplish the experiments, a small plastic cage (clip-cage) was placed on one leaf of each cucumber per pot. Cages were large enough so that food and space were not limiting factors. All potted plants were kept at 25 ± 3 °C, 60 ± 5% RH and a 16:8 h (L: D) photoperiod in a climate-controlled room. Micro complete fertilizer micronutrients were added to all treatments once every 15 days up to the end of the experiment. This study was carried out as factorial experiment based on RCD with nine replications. Potted plants received phosphorous, as triple super phosphate, at three treatment levels (0, 15, and 22.5 $kg.ha^{-1}$ of recommended dose) that was added in pots before planting, nitrogen, as Urea, CO $(NH_2)_2$, at five treatment levels (0, 30, 60, 90, and 120 $kg.ha^{-1}$of recommended dose) that was added to pots in three portions (at seedling planting time i.e., four or five leaf stage; one week later and two weeks later) and silicon (in the form of sodium silicate) was used at the three treatment levels (0, 100 and 200$kg.ha^{-1}$of recommended dose) that was suspended in water then added to pot. Also three treatments with different substrate fertilizer were used as control, including vermicompost and soil (ratio 1: 1), pit and vermiculite (ratio 1: 1) and compost and soil (ratio 1: 1). A newly emerged nymph (less than 6 h old) was carefully transferred individually to in a clip-cage on cucumber leaf. Each clip-cage (including one aphid) on a separate plant was considered a replicate. Individual nymphs were observed every 12 h under a stereo-microscope for recording the molting time and survivorship until the last individual from each treatment moulted to the adult stage. Adult aphids were observed daily and newly born offspring were counted and removed until the last individual from each treatment died. These experiments allowed us to determine the reproductive parameters, adult longevity and life span of each aphid.

Data analysis

All data were checked for normality before statistical analysis by Kolmogorov-Smirnov test (SPSS Inc. 2007, ver.16). The life table parameters including net reproductive rate (R_0), intrinsic rate of increase (r), finite rate of increase (λ), doubling time (DT) and the mean generation time (T) were determined according to the Birch (1948) and Carey (1993) equations. Statistical differences in demographic parameters were tested using Jackknife procedure to estimate the variance for demographic parameters (Meyer *et al*., 1986). This procedure is mostly used to estimate variance and bias of estimators. It is based on repeated recalculation of the required estimator, missing out each sample in turn (Maia *et al.*, 2000) and it is used to quantify uncertainty associated with parameter estimates, as an alternative to over-complicated analytical procedures (Maia *et al.*, 2000). The influence of N, P and Si on developmental periods of *A. gossypii* was analyzed using one-way analysis of variance (ANOVA). When a significant difference was detected, the means of developmental time were compared using Tukey's test ($P < 0.05$).

Results and Discussion

Reproductive parameters, adult longevity and life span

The influence of different concentrations of NPSi on reproductive parameters, adult longevity, life span and total fecundity of *A. gossypii* is presented in Table 1. The effect of tested treatments on pre-reproductive (F = 1.09; df = 47; P = 0.3237) and post-reproductive (F = 1.16; df = 47; P = 0.2312) periods was not significant. However, pre-reproductive period was ranged from 0.45 day on pit- vermiculite to 1.50 days on $N_1P_3Si_3$. The shortest and the longest post-reproductive periods were observed on $N_2P_1Si_3$ (0.77 day) and $N_2P_1Si_1$ (3.67 days), respectively. The influence of treatments on reproduction (F = 1.92; df = 47; P < 0.0006), adult longevity (F = 1.43; df = 47; P = 0.0400) and life span (F = 2.14; df = 47; P < 0.0001) was significant. The shortest reproductive period was 4.71 days that was found on $N_3P_2Si_1$ and longest one was 13.50 days on $N_2P_3Si_3$. The adult longevity ranged from 6.28 days on $N_4P_1Si_3$ to 15.89 days on $N_2P_3Si_3$. Also the shortest and the longest lifespan periods were found on $N_4P_1Si_3$ (12.50 days) and $N_5P_3Si_1$ (20 days), respectively. As shown in Table 2, the main effects of N and Si on pre-reproductive, reproductive and post-reproductive periods, adult longevity and life span were not significant. These results agreed with those reported for *Aphis craccivora* Koch (Hosseini *et al*., 2015) and *Diuraphis noxia* (Mordvilko) (Moon *et al*., 1995). Alasvand Zarasvand *et al*. (2015) reported that the different levels of N had no effect on pre and post-reproductive periods but had significant effects on reproductive period, adult longevity and fecundity of *Schizaphis graminum* (Rondani). However, our results showed that the main effect of P on reproductive period, adult longevity and life span was significant. Similarly Jansson and Ekbom (2002) found that P had a positive effect on longevity of *Macrosiphum euphorbiae* (Thomas).

Table 1 The reproductive parameters, adult longevity and life span (± SE) of *Aphis gossypii* reared on plants grown in soil amended with different concentrations of N: P: Si, at 25 ± 3 °C, 60 ± 5% RH and 16L: 8D.

Ttreatments	Per-reproductive period (day)	Reproductive period (day)	Post reproductive period (day)	Adult longevity (day)	Lifespan (day)	Fecundity (offspring)
$N_1P_1Si_1$	0.56 ± 0.06^{a}	7.92 ± 1.68^{ab}	2.25 ± 0.64^{a}	8.75 ± 1.88^{ab}	17.00 ± 2.09^{abc}	56.25 ± 2.63^{abcd}
$N_1P_1Si_2$	0.77 ± 0.16^{a}	5.88 ± 0.74^{b}	1.44 ± 0.24^{a}	8.11 ± 0.65^{ab}	13.50 ± 0.62^{abc}	23.00 ± 3.34^{g}
$N_1P_1Si_3$	0.67 ± 0.11^{a}	8.75 ± 1.37^{ab}	1.66 ± 0.16^{a}	10.12 ± 1.61^{ab}	17.00 ± 1.59^{abc}	28.83 ± 1.72^{efg}
$N_1P_2Si_1$	0.73 ± 0.18^{a}	8.78 ± 1.09^{ab}	1.11 ± 0.20^{a}	10.62 ± 1.09^{ab}	16.89 ± 1.07^{abc}	27.71 ± 2.59^{efg}
$N_1P_2Si_2$	0.45 ± 0.04^{a}	7.64 ± 1.84^{ab}	1.33 ± 0.33^{a}	7.73 ± 1.92^{ab}	17.13 ± 1.63^{abc}	64.33 ± 4.98^{a}
$N_1P_2Si_3$	0.67 ± 0.11^{a}	8.38 ± 1.28^{ab}	3.00 ± 1.44^{a}	11.12 ± 2.37^{ab}	17.88 ± 1.98^{abc}	58.30 ± 10.1^{ab}
$N_1P_3Si_1$	0.61 ± 0.07^{a}	8.75 ± 1.24^{ab}	1.44 ± 0.60^{a}	9.83 ± 1.74^{ab}	18.33 ± 1.60^{abc}	42.60 ± 1.86^{abcdefg}
$N_1P_3Si_2$	0.77 ± 0.16^{a}	7.37 ± 0.71^{ab}	1.66 ± 0.23^{a}	9.00 ± 0.98^{ab}	16.13 ± 1.01^{abc}	28.43 ± 1.39^{efg}
$N_1P_3Si_3$	1.50 ± 0.70^{a}	10.00 ± 1.29^{ab}	1.22 ± 0.22^{a}	10.50 ± 1.68^{ab}	19.11 ± 1.07^{abc}	49.20 ± 5.59^{abcdef}
$N_2P_1Si_1$	1.22 ± 0.26^{a}	8.69 ± 1.63^{ab}	3.67 ± 1.35^{a}	12.61 ± 2.55^{ab}	20.44 ± 2.75^{abc}	39.25 ± 6.25^{abcdefg}
$N_2P_1Si_2$	0.55 ± 0.05^{a}	7.88 ± 0.72^{ab}	1.11 ± 0.26^{a}	9.55 ± 0.74^{ab}	15.22 ± 0.68^{abc}	33.14 ± 2.75^{bcdefg}
$N_2P_1Si_3$	0.56 ± 0.09^{a}	9.39 ± 1.36^{ab}	0.77 ± 0.14^{a}	10.73 ± 1.29^{ab}	16.89 ± 1.39^{abc}	41.80 ± 3.85^{abcdefg}
$N_2P_2Si_1$	0.72 ± 0.16^{a}	8.39 ± 1.18^{ab}	1.22 ± 0.32^{a}	10.33 ± 1.32^{ab}	14.87 ± 0.83^{abc}	35.00 ± 6.50^{bcdefg}
$N_2P_2Si_2$	1.27 ± 0.40^{a}	8.63 ± 1.29^{ab}	1.11 ± 0.11^{a}	10.06 ± 1.82^{ab}	18.22 ± 1.41^{abc}	35.86 ± 3.79^{bcdefg}
$N_2P_2Si_3$	1.22 ± 0.34^{a}	6.50 ± 1.73^{ab}	1.44 ± 0.37^{a}	7.72 ± 1.48^{ab}	15.25 ± 1.59^{abc}	51.00 ± 5.13^{abcde}
$N_2P_3Si_1$	1.11 ± 0.28^{a}	7.19 ± 1.12^{ab}	1.33 ± 0.23^{a}	8.83 ± 1.30^{ab}	17.78 ± 1.78^{abc}	44.20 ± 3.57^{abcdefg}
$N_2P_3Si_2$	1.22 ± 0.44^{a}	8.19 ± 1.03^{ab}	0.88 ± 0.26^{a}	9.39 ± 1.62^{ab}	18.75 ± 1.11^{abc}	34.57 ± 4.38^{bcdefg}
$N_2P_3Si_3$	0.83 ± 0.27^{a}	13.50 ± 2.26^{a}	1.55 ± 0.62^{a}	15.89 ± 2.68^{a}	21.50 ± 1.97^{ab}	43.29 ± 4.77^{abcdefg}
$N_3P_1Si_1$	0.64 ± 0.09^{a}	7.00 ± 0.79^{ab}	1.00 ± 0.21^{a}	7.64 ± 1.25^{ab}	15.57 ± 1.21^{abc}	30.00 ± 2.88^{efg}
$N_3P_1Si_2$	0.75 ± 0.09^{a}	9.07 ± 1.56^{ab}	1.37 ± 0.26^{a}	10.06 ± 1.85^{ab}	16.57 ± 1.85^{abc}	42.80 ± 1.46^{abcdefg}
$N_3P_1Si_3$	0.62 ± 0.10^{a}	8.00 ± 1.02^{ab}	1.55 ± 0.72^{a}	10.18 ± 1.62^{ab}	15.89 ± 1.55^{abc}	28.75 ± 6.61^{efg}
$N_3P_2Si_1$	0.51 ± 0.09^{a}	4.71 ± 0.92^{b}	1.14 ± 0.34^{a}	6.37 ± 1.06^{b}	12.86 ± 1.24^{c}	22.67 ± 1.67^{g}
$N_3P_2Si_2$	0.66 ± 0.08^{a}	7.56 ± 1.29^{ab}	1.77 ± 0.22^{a}	10.00 ± 1.51^{ab}	15.38 ± 1.15^{abc}	57.50 ± 4.97^{abc}
$N_3P_2Si_3$	0.77 ± 0.27^{a}	6.31 ± 0.82^{ab}	1.44 ± 0.17^{a}	7.83 ± 1.31^{ab}	15.78 ± 1.36^{abc}	32.60 ± 3.56^{bcdefg}
$N_3P_3Si_1$	0.67 ± 0.18^{a}	10.36 ± 1.90^{ab}	1.55 ± 0.62^{a}	10.29 ± 2.65^{ab}	19.13 ± 2.23^{abc}	41.25 ± 4.09^{abcdefg}
$N_3P_3Si_2$	1.05 ± 0.29^{a}	8.69 ± 1.50^{ab}	2.78 ± 1.41^{a}	11.56 ± 2.68^{ab}	16.12 ± 0.81^{abc}	32.60 ± 6.67^{bcdefg}
$N_3P_3Si_3$	0.72 ± 0.08^{a}	7.75 ± 1.47^{ab}	1.88 ± 0.48^{a}	9.50 ± 1.82^{ab}	17.89 ± 1.36^{abc}	46.00 ± 5.49^{abcdefg}
$N_4P_1Si_1$	0.72 ± 0.08^{a}	6.75 ± 1.24^{ab}	2.44 ± 0.85^{a}	9.17 ± 1.06^{ab}	14.75 ± 1.37^{abc}	35.00 ± 4.89^{bcdefg}
$N_4P_1Si_2$	0.88 ± 0.19^{a}	7.68 ± 0.75^{ab}	1.00 ± 0.18^{a}	9.57 ± 0.70^{ab}	14.75 ± 0.70^{abc}	37.60 ± 2.01^{bcdefg}
$N_4P_1Si_3$	0.72 ± 0.08^{a}	5.25 ± 1.07^{b}	0.88 ± 0.26^{a}	6.28 ± 1.13^{b}	12.50 ± 0.88^{c}	28.67 ± 1.20^{efg}
$N_4P_2Si_1$	0.57 ± 0.11^{a}	5.18 ± 0.98^{b}	1.33 ± 0.16^{a}	7.20 ± 1.17^{ab}	13.71 ± 1.08^{abc}	23.40 ± 2.66^{fg}
$N_4P_2Si_2$	0.77 ± 0.27^{a}	11.00 ± 1.47^{ab}	1.44 ± 0.44^{a}	12.38 ± 1.41^{ab}	18.75 ± 1.33^{abc}	41.83 ± 5.02^{abcdefg}
$N_4P_2si_3$	1.16 ± 0.22^{a}	8.50 ± 1.39^{ab}	1.66 ± 0.37^{a}	11.50 ± 1.30^{ab}	17.63 ± 1.21^{abc}	39.20 ± 3.93^{abcdefg}
$N_4P_3Si_1$	0.94 ± 0.15^{a}	11.17 ± 1.45^{ab}	1.22 ± 0.49^{a}	13.33 ± 1.85^{ab}	19.22 ± 1.89^{abc}	37.33 ± 2.65^{bcdefg}
$N_4P_3Si_2$	0.80 ± 0.29^{a}	6.44 ± 1.16^{ab}	2.44 ± 0.95^{a}	8.74 ± 1.03^{ab}	17.00 ± 1.25^{abc}	32.83 ± 2.94^{bcdefg}
$N_4P_3Si_3$	0.83 ± 0.16^{a}	7.88 ± 1.51^{ab}	1.11 ± 0.26^{a}	8.86 ± 1.16^{ab}	18.33 ± 1.69^{abc}	30.75 ± 4.80^{defg}
$N_5P_1Si_1$	0.83 ± 0.27^{a}	6.61 ± 0.79^{ab}	1.11 ± 0.20^{a}	7.50 ± 0.46^{ab}	13.62 ± 0.70^{abc}	29.57 ± 2.88^{efg}
$N_5P_1Si_2$	0.77 ± 0.16^{a}	6.18 ± 0.85^{ab}	1.66 ± 0.44^{a}	8.62 ± 0.92^{ab}	14.75 ± 1.18^{abc}	26.80 ± 1.32^{efg}
$N_5P_1Si_3$	1.05 ± 0.25^{a}	6.72 ± 0.92^{ab}	1.00 ± 0.16^{a}	8.77 ± 0.84^{ab}	14.66 ± 0.88^{abc}	26.33 ± 4.23^{efg}
$N_5P_2Si_1$	0.61 ± 0.07^{a}	6.75 ± 1.33^{ab}	1.67 ± 0.36^{a}	8.89 ± 1.52^{ab}	15.44 ± 1.61^{abc}	32.00 ± 6.56^{cdefg}
$N_5P_2Si_2$	0.67 ± 0.18^{a}	7.00 ± 1.25^{ab}	1.33 ± 0.16^{a}	8.76 ± 1.53^{ab}	15.33 ± 1.28^{abc}	31.60 ± 5.37^{cdefg}
$N_5P_2Si_3$	0.55 ± 0.05^{a}	9.05 ± 0.90^{ab}	1.24 ± 0.26^{a}	10.85 ± 0.86^{ab}	16.44 ± 0.95^{abc}	36.00 ± 3.44^{bcdefg}
$N_5P_3Si_1$	1.01 ± 0.35^{a}	11.50 ± 1.30^{ab}	1.71 ± 0.28^{a}	14.10 ± 1.58^{ab}	22.00 ± 1.95^{a}	49.40 ± 2.60^{abcde}
$N_5P_3Si_2$	0.78 ± 0.10^{a}	8.00 ± 1.71^{ab}	1.71 ± 0.18^{a}	9.08 ± 2.12^{ab}	16.86 ± 2.06^{abc}	34.50 ± 9.26^{bcdefg}
$N_5P_3Si_3$	0.94 ± 0.21^{a}	11.28 ± 2.15^{ab}	1.90 ± 0.53^{a}	12.51 ± 2.03^{ab}	20.44 ± 2.39^{abc}	42.80 ± 6.76^{abcdefg}
Compost & soil	1.00 ± 0.29^{a}	5.62 ± 0.94^{b}	1.62 ± 0.26^{a}	8.25 ± 0.99^{ab}	14.37 ± 0.90^{abc}	36.75 ± 5.04^{bcdefg}
Vermicompost & soil	0.55 ± 0.05^{a}	6.93 ± 0.88^{ab}	1.11 ± 0.11^{a}	8.50 ± 0.86^{ab}	14.37 ± 0.99^{abc}	31.40 ± 5.01^{defg}
Pit & vermiculite	0.45 ± 0.05^{a}	8.00 ± 0.68^{ab}	1.88 ± 0.39^{a}	10.33 ± 0.83^{ab}	16.00 ± 0.84^{abc}	33.00 ± 4.32^{bcdefg}

Means with the same superscript letters in each column are not significantly different (Tukey's test, $P < 0.05$). Refer to the materials and methods for information on fertilizer values.

Table 2 Mean squares of the reproductive parameters, adult longevity and life span of *Aphis gossypii* reared on plants grown in soil amended with different concentrations of N: P: Si, at 25 ± 3 °C, 60 ± 5% RH and 16L: 8D.

Source	Df	Pre -reproductive (day)	Reproductive (day)	Post- reproductive (day)	Adult longevity (day)	Lifespan (day)	Fecundity (offspring)
N	4	0.77^{ns}	11.23^{ns}	0.73^{ns}	19.05^{ns}	27.11^{ns}	517.91**
P	2	1.16^{ns}	106.17**	0.69^{ns}	89.09*	316.50**	683.75**
Si	2	0.27^{ns}	14.10^{ns}	0.50^{ns}	14.19^{ns}	21.39^{ns}	114.00^{ns}
N × P	8	0.36^{ns}	19.04^{ns}	2.40^{ns}	23.46^{ns}	33.40^{ns}	242.37*
N × Si	8	0.30^{ns}	18.88^{ns}	3.58^{ns}	27.73^{ns}	11.02^{ns}	335.11**
P × Si	4	0.27^{ns}	37.34*	7.38*	23.96^{ns}	65.12**	1584.84**
N × P*Si	16	0.56^{ns}	23.41*	2.82^{ns}	38.79*	20.24^{ns}	335.33**
Error		348	313	348	334	325	181
CV		13.485	14.793	20.610	16.685	16.710	8.040

**: Significant at 1%;*: Significant at 5%; ^{ns}: Non-significant.

According to our results, the fecundity of *A. gossypii* was significantly affected by tested treatments (F = 4.02; df = 47; P < 0.0001). The total fecundity ranged from 22.67 offspring/female on $N_3P_2Si_1$ to 64.33 offspring/female on $N_1P_2Si_2$ (Table 1). As shown in Table 2, N and P had significant effects on fecundity of *A. gossypii*, but the effect of Si was not significant. The highest reproductive period, adult-longevity, life span and fecundity of *A. gossypii* were obtained at level of P_3 (22.5 kg.ha^{-1}) and the lowest values of these parameters were obtained at level of P_1 (0 kg.ha^{-1}) (Table 3). According to Dixon (1987) fecundity and growth rate of phytophagous insects are affected by the nutritional value of the host plant. Our study indicates that the fecundity of *A. gossypii* decreased with increasing the nitrogen amount. Unlike our findings, Nevo and Coll (2001) showed that increasing the N level significantly raised the fecundity of *A. gossypii*. Furthermore, Aqueel and Leather (2011) showed a positive effect of N fertilizer on fecundity of *Sitobion avenae* (F.) and *Rhopalosiphum padi* (L.) on wheat. Hosseini *et al*. (2015) reported that highest fecundity of *A. craccivora* was acquired on the plants fertilized with 100% recommended N level and the lowest produced number was on the plants that were not fertilized. Also, Hosseini *et al*. (2014) found similar result to mentioned studies for mustard aphid *Lipaphis erysimi* Kalt. It seems that in our study the simultaneous application of three fertilizers lead to these results. In agreement to our results, Khattak *et al*. (1998) found that N fertilizer alone increased the population of *Brevicoryne brassicae* L. on canola, but the application of N and P reduced the pest population. The present study showed that the fecundity of cotton aphid increased with increasing the level of P. Skinner and Cohen (1994) found similar result for *Bemisia tabaci* (Gennadius). In addition, Jansson and Ekbom (2002) found that P had a positive effect on number of produced offspring of apterous aphid of *M.euphorbiae*.

Table 3 The main effects of phosphorus on the reproduction parameters of *Aphis gossypii* at 25 ± 3 °C, 60 ± 5% RH and 16L: 8D.

Treatment	Mean reproductive Period (day)	Mean adult longevity (day)	Mean life span (day)	Mean fecundity (offspring)
P_1	7.43^{b}	9.20^{b}	15.57^{b}	33.44^{b}
P_2	7.71^{b}	9.46^{ab}	16.16^{b}	37.87^{a}
P_3	9.25^{a}	10.77^{a}	18.56^{a}	38.97^{a}

Means with the same superscript letters in each column are not significantly different (Tukey's test, P < 0.05). Refer to the materials and methods for information on fertilizer values.

Demographic parameters

Population growth parameters of *A. gossypii* on cucumber when reared on different levels of NPSi are given in Table 4. The net reproductive rate (R_0) was significantly affected by tested treatments (F = 2.35; df = 47; P < 0.001), which was highest on $N_4P_2Si_2$ (47.70 offspring) and lowest on $N_3P_2Si_1$ (15.19 offspring). Intrinsic rate of natural increase (r) was significantly influenced by tested treatments (F = 2.45; df = 47; P < 0.001) and ranged from 0.27

day^{-1} on $N_5P_3Si_2$ to $0.41 day^{-1}$ on $N_5P_1Si_1$. As shown in Table 5, N and Si did not have significant effect on *r* of *A. gossypii*. Opposite results in comparison to our results about the effects of N were reported for *S. graminum* (Alasvand Zarasvand *et al*., 2015), *Peregrinus maidis* (Ashmead) (Delphacidae) (Wang *et al*., 2006), *A. gossypii* (Nevo and Coll, 2001) and *R. padi* (Khan and Port, 2008).

Table 4 Population growth parameters (± SE) of *Aphis gossypii* reared on plants grown in soils amended with different concentrations of N: P: Si, at temperature of 25 ± 3°C, 60 ± 5% RH and 16L: 8D.

Treatments	R_0[1]	r[2]	T[4]	DT[5]	λ[3]
$N_1P_1Si_1$	41.68 ± 6.32^{ab}	0.34 ± 0.01^{abc}	9.04 ± 0.59^{bcdefgh}	1.78 ± 0.13^{bcd}	1.42 ± 0.05^{abc}
$N_1P_1Si_2$	19.25 ± 2.63^{bc}	0.34 ± 0.02^{abc}	8.20 ± 0.36^{efgh}	1.97 ± 0.15^{bcd}	1.41 ± 0.02^{abc}
$N_1P_1Si_3$	27.57 ± 1.93^{abc}	0.37 ± 0.01^{abc}	9.33 ± 0.62^{bcdefgh}	1.95 ± 0.12^{bcd}	1.42 ± 0.03^{abc}
$N_1P_2Si_1$	25.88 ± 3.22^{abc}	0.33 ± 0.01^{abc}	9.62 ± 0.43^{bcdefgh}	1.97 ± 0.09^{bcd}	1.40 ± 0.02^{abc}
$N_1P_2Si_2$	19.43 ± 6.65^{bc}	0.34 ± 0.02^{abc}	9.94 ± 0.34^{bcdefgh}	2.09 ± 0.11^{abcd}	1.41 ± 0.03^{abc}
$N_1P_2Si_3$	31.45 ± 5.99^{abc}	0.36 ± 0.02^{abc}	10.83 ± 0.36^{abcdef}	1.88 ± 0.16^{bcd}	1.43 ± 0.04^{abc}
$N_1P_3Si_1$	39.00 ± 4.93^{abc}	0.32 ± 0.01^{abc}	10.94 ± 0.61^{abcde}	2.12 ± 0.09^{abcd}	1.40 ± 0.02^{abc}
$N_1P_3Si_2$	30.63 ± 2.51^{abc}	0.33 ± 0.01^{abc}	9.27 ± 0.48^{bcdefgh}	1.83 ± 0.07^{abcd}	1.43 ± 0.02^{abc}
$N_1P_3Si_3$	37.59 ± 5.36^{abc}	0.32 ± 0.01^{abc}	10.13 ± 0.57^{bcdefgh}	2.22 ± 0.06^{abcd}	1.40 ± 0.03^{abc}
$N_2P_1Si_1$	32.93 ± 6.37^{abc}	0.31 ± 0.01^{abc}	$10.43 \pm 0.43^{abcdefgh}$	2.20 ± 0.06^{abcd}	1.38 ± 0.02^{abc}
$N_2P_1Si_2$	25.57 ± 2.50^{abc}	0.39 ± 0.01^{ab}	8.24 ± 0.19^{efgh}	1.74 ± 0.08^{d}	1.48 ± 0.02^{a}
$N_2P_1Si_3$	28.81 ± 4.51^{abc}	0.35 ± 0.02^{abc}	9.23 ± 0.54^{bcdefgh}	2.05 ± 0.12^{abcd}	1.42 ± 0.03^{abc}
$N_2P_2Si_1$	28.86 ± 5.40^{abc}	0.38 ± 0.02^{abc}	8.65 ± 0.19^{cdefgh}	1.87 ± 0.09^{bcd}	1.44 ± 0.02^{abc}
$N_2P_2Si_2$	31.00 ± 3.66^{abc}	0.28 ± 0.01^{bc}	10.82 ± 0.52^{abcdef}	2.40 ± 0.09^{abcd}	1.34 ± 0.02^{bc}
$N_2P_2Si_3$	15.79 ± 4.62^{bc}	0.28 ± 0.01^{bc}	$10.21 \pm 0.51^{abcdefgh}$	2.45 ± 0.12^{abcd}	1.32 ± 0.01^{c}
$N_2P_3Si_1$	32.93 ± 4.68^{abc}	0.30 ± 0.01^{abc}	9.53 ± 0.73^{bcdefgh}	2.42 ± 0.19^{abcd}	1.35 ± 0.02^{abc}
$N_2P_3Si_2$	22.99 ± 2.45^{abc}	0.31 ± 0.01^{abc}	10.80 ± 0.43^{abcdefg}	2.22 ± 0.13^{abcd}	1.36 ± 0.02^{abc}
$N_2P_3Si_3$	35.60 ± 3.65^{abc}	0.33 ± 0.02^{abc}	11.30 ± 0.55^{abc}	2.18 ± 0.11^{abcd}	1.37 ± 0.02^{abc}
$N_3P_1Si_1$	20.39 ± 2.39^{bc}	0.35 ± 0.02^{abc}	8.538 ± 0.33^{defgh}	2.19 ± 0.17^{abcd}	1.39 ± 0.02^{abc}
$N_3P_1Si_2$	32.55 ± 3.69^{abc}	0.35 ± 0.01^{abc}	9.14 ± 0.27^{bcdefgh}	2.11 ± 0.31^{abcd}	1.43 ± 0.02^{abc}
$N_3P_1Si_3$	17.14 ± 2.42^{bc}	0.35 ± 0.02^{abc}	8.423 ± 0.33^{defgh}	2.05 ± 0.07^{abcd}	1.39 ± 0.02^{abc}
$N_3P_2Si_1$	15.19 ± 1.12^{c}	0.28 ± 0.03^{bc}	8.51 ± 0.43^{defgh}	2.68 ± 0.17^{a}	1.32 ± 0.04^{c}
$N_3P_2Si_2$	40.00 ± 8.72^{abc}	0.32 ± 0.01^{abc}	9.13 ± 0.21^{bcdefgh}	2.10 ± 0.08^{abcd}	1.38 ± 0.02^{abc}
$N_3P_2Si_3$	25.33 ± 3.29^{abc}	0.35 ± 0.02^{abc}	8.18 ± 0.31^{efgh}	1.93 ± 0.15^{bcd}	1.42 ± 0.03^{abc}
$N_3P_3Si_1$	28.63 ± 5.61^{abc}	0.28 ± 0.01^{bc}	11.41 ± 0.55^{ab}	2.42 ± 0.08^{abcd}	1.32 ± 0.01^{bc}
$N_3P_3Si_2$	29.01 ± 5.93^{abc}	0.31 ± 0.01^{abc}	9.39 ± 0.14^{bcdefgh}	2.16 ± 0.08^{abcd}	1.39 ± 0.02^{abc}
$N_3P_3Si_3$	34.00 ± 6.47^{abc}	0.34 ± 0.02^{abc}	9.39 ± 0.40^{bcdefgh}	2.18 ± 0.10^{abcd}	1.41 ± 0.03^{abc}
$N_4P_1Si_1$	28.19 ± 4.26^{abc}	0.33 ± 0.01^{abc}	8.92 ± 0.62^{bcdefgh}	2.08 ± 0.10^{abcd}	1.39 ± 0.02^{abc}
$N_4P_1Si_2$	30.41 ± 3.39^{abc}	0.37 ± 0.02^{abc}	8.61 ± 0.29^{cdefgh}	1.84 ± 0.11^{bcd}	1.45 ± 0.03^{abc}
$N_4P_1Si_3$	17.94 ± 2.78^{bc}	0.36 ± 0.01^{abc}	7.95 ± 0.34^{h}	1.97 ± 0.08^{bcd}	1.41 ± 0.02^{abc}
$N_4P_2Si_1$	18.25 ± 2.07^{bc}	0.32 ± 0.01^{abc}	8.65 ± 0.37^{bcdefgh}	2.10 ± 0.11^{abcd}	1.38 ± 0.02^{abc}
$N_4P_2Si_2$	47.70 ± 4.71^{a}	0.34 ± 0.02^{abc}	10.83 ± 0.78^{abcdef}	2.02 ± 0.14^{abcd}	1.40 ± 0.03^{abc}
$N_4P_2si_3$	30.25 ± 4.97^{abc}	0.33 ± 0.01^{abc}	9.94 ± 0.27^{bcdefgh}	2.21 ± 0.11^{abcd}	1.36 ± 0.02^{abc}
$N_4P_3Si_1$	34.33 ± 4.47^{abc}	0.34 ± 0.02^{abc}	$10.47 \pm 0.71^{abcdefgh}$	1.98 ± 0.08^{abcd}	1.41 ± 0.01^{abc}
$N_4P_3Si_2$	29.22 ± 2.61^{abc}	0.31 ± 0.02^{abc}	$10.32 \pm 0.78^{abcdefgh}$	2.40 ± 0.19^{abcd}	1.33 ± 0.03^{bc}
$N_4P_3Si_3$	18.00 ± 3.03^{bc}	0.29 ± 0.01^{bc}	$10.51 \pm 0.34^{abcdefgh}$	2.46 ± 0.08^{abc}	1.32 ± 0.01^{c}
$N_5P_1Si_1$	25.67 ± 3.40^{abc}	0.41 ± 0.02^{a}	8.04 ± 0.47^{gh}	1.83 ± 0.13^{bcd}	1.45 ± 0.03^{abc}
$N_5P_1Si_2$	28.00 ± 3.48^{abc}	0.33 ± 0.00^{abc}	8.91 ± 0.63^{bcdefgh}	2.12 ± 0.06^{abcd}	1.38 ± 0.01^{abc}
$N_5P_1Si_3$	27.46 ± 5.04^{abc}	0.34 ± 0.02^{abc}	8.33 ± 0.50^{defgh}	1.98 ± 0.10^{abcd}	1.46 ± 0.03^{abc}
$N_5P_2Si_1$	23.14 ± 3.97^{abc}	0.35 ± 0.02^{abc}	9.21 ± 0.40^{bcdefgh}	2.03 ± 0.09^{abcd}	1.42 ± 0.02^{abc}
$N_5P_2Si_2$	28.12 ± 4.78^{abc}	0.34 ± 0.02^{abc}	8.28 ± 0.30^{defgh}	2.19 ± 0.06^{abcd}	1.43 ± 0.04^{abc}
$N_5P_2Si_3$	27.86 ± 3.40^{abc}	0.38 ± 0.01^{abc}	9.00 ± 0.36^{bcdefgh}	1.90 ± 0.03^{bcd}	1.46 ± 0.02^{ab}
$N_5P_3Si_1$	36.99 ± 3.74^{abc}	0.28 ± 0.01^{bc}	12.91 ± 0.87^{a}	2.46 ± 0.12^{abc}	1.32 ± 0.02^{c}
$N_5P_3Si_2$	23.71 ± 6.44^{abc}	0.27 ± 0.01^{c}	$10.20 \pm 0.35^{abcdefgh}$	2.49 ± 0.10^{ab}	1.33 ± 0.02^{bc}
$N_5P_3Si_3$	35.57 ± 6.62^{abc}	0.30 ± 0.01^{abc}	11.03 ± 0.62^{abcd}	2.44 ± 0.10^{abcd}	1.32 ± 0.01^{c}
Compost & soil	29.01 ± 5.07^{abc}	0.33 ± 0.02^{abc}	8.17 ± 0.45^{fgh}	2.05 ± 0.13^{abcd}	1.39 ± 0.04^{abc}
Vermicompost & soil	21.50 ± 2.69^{abc}	0.35 ± 0.02^{abc}	8.79 ± 0.43^{bcdefgh}	2.00 ± 0.13^{abcd}	1.39 ± 0.02^{abc}
Pit & vermiculite	24.41 ± 4.07^{abc}	0.39 ± 0.02^{abc}	8.19 ± 0.20^{efgh}	1.76 ± 0.09^{cd}	1.49 ± 0.04^{a}

Means with the same superscript letters in each column are not significantly different (Tukey's test, $P < 0.05$). Refer to the materials and methods for information on fertilizer values. [1]. Net reproductive rate, [2]. Intrinsic rate of increase, [3]. Mean generation time, [4]. Doubling time, [5]. Finite rate of increase.

Table 5 Mean squares of the demographic parameters of *Aphis gossypii* reared on plants grown in soils amended with different concentrations of N: P: Si, at 25 ± 3 °C, 60 ± 5% RH and 16L: 8D.

Source	df	R_0[1]	r[2]	T[3]	DT[4]	λ[5]
N	4	82.612^{ns}	0.002^{ns}	5.254*	0.490**	0.011^{ns}
P	2	565.053*	0.050**	85.415**	1.962**	0.081**
Si	2	89.095^{ns}	0.001^{ns}	0.930^{ns}	0.024^{ns}	0.002^{ns}
N × P	8	196.453^{ns}	0.005^{ns}	6.560**	0.174^{ns}	0.016**
N × Si	8	647.647**	0.004^{ns}	4.371*	0.269*	0.008^{ns}
P × Si	4	762.469**	0.001^{ns}	8.828**	0.065^{ns}	0.001^{ns}
N × P × Si	16	208.009^{ns}	0.007**	4.679**	0.281**	0.010*
Error		253	278	283	261	284
CV		40.731	16.22181	13.742	15.234	5.721

**: Significant at 1%;*: Significant at 5%; ns: Non-significant.[1] -Net reproductive rate, [2]-Intrinsic rate of increase, [3]-Mean generation time, [4]-Doubling time, [5]-Finite rate of increase.

However, Jansson and Smilowitz (1986) observed that the higher levels of N decreased the *r* value of *Myzus persicae* Sulzer on potatoes.

In another study Khan and Port (2008) indicated that the *r* of *R. padi* was more on higher levels of N. Hosseini *et al*. (2015) reported the positive effects of N fertilizer levels on intrinsic rate of increase of *A. craccivora*. The finite rate of increase (*λ)* (F = 2.14; df = 47; P < 0.001) when reared on pit: vermiculite was higher (1.49 day^{-1}), whereas was the lower on $N_5P_3Si_1$ (1.32 day^{-1}). The mean generation time (T) (F = 5.25; df = 47; P < 0.001) on $N_5P_3Si_1$ and $N_4P_1Si_3$ were highest and lowest, respectively. The doubling time (DT) was influenced by tested treatments (F = 3.14; df = 47; P < 0.001) and was highest on $N_3P_2Si_1$ and lowest on $N_2P_1Si_2$ (Table 4).

The results of the present study confirmed that Si had no significant effect on demographic parameters of *A. gossypii*. Nitrogen fertilizer levels significantly influenced T and DT. Moreover, the effect of P on R_0, r, T, DT and λ was significant. In addition, the interactions of the N and P on T and DT were significant. Also the interaction effects of the N and Si on R_0, T and DT, and P and Si on R_0 and T were significant. Although, several studies have shown that silicon application affected survival, reproduction, and host plant preferences of sucking insects (Carvalho *et al*., 1999; Basagli *et al*., 2003; Correa *et al*., 2005; Gomes *et al*., 2008), in our study there was no significant difference in the case of silicon application on life table parameters of *A. gossypii*. Finally, according to our finding, treatment $N_5P_3Si_2$ (120, 22.5 and 100 kg/ha) was recommended as best treatment for A. *gossypii* management. However, further studies should be conducted for exact determination of fertilizer effects on demographic parameters of *A. gossypii*, because there are many unknown aspects in such studies. In the current study, the content of these fertilizers in plant was not measured. In fact, fertilizer contents of the soil is not necessarily an indication of their content in the plant, because fertilizers can be present in the soil but in an unavailable form to the plant. Therefore, more study would be necessary to clarify the effects of these fertilizers and their interactions on insect community.

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اثرات کاربرد هم‌زمان غلظت‌های مختلف نیتروژن، فسفر و سیلیکون بر پارامترهای جدول زندگی شته جالیز *Aphis gossypii* (Hemiptera: Aphididae) روی خیار

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چکیده: شته جالیز یکی از آفات مهم خیار در ایران می‌باشد. اثرات کاربرد هم‌زمان غلظت‌های مختلف کودهای نیتروژن (در ۵ سطح $N_1 = 0$، $N_2 = 30$، $N_3 = 60$، $N_4 = 90$ و $N_5 = 120$ کیلوگرم در هکتار)، فسفر (در سه سطح $P_1 = 0$، $P_2 = 15$ و $P_3 = 22.5$ کیلوگرم در هکتار) و سیلیکون (در سه سطح $Si_1 = 0$، $Si_2 = 100$ و $Si_3 = 200$ کیلوگرم در هکتار) بر پارامترهای جدول زندگی شکل بی‌بال شته جالیز *Aphis gossypii* Glover مطالعه شد. این مطالعه به‌صورت طرح فاکتوریل با نه تکرار در اتاقک پرورش در دمای ۳ ± ۲۵درجه سلسیوس، رطوبت نسبی ۵ ± ۶۰ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی انجام شد. آزمایش‌ها با استفاده از قفس‌هایی که بر روی برگ‌های خیار (Clip cage) در گلدان قرار می‌گرفت انجام شدند. براساس نتایج مشخص شد زادآوری شته‌ها تحت تأثیر تیمارها قرار گرفت و دارای بیش‌ترین مقدار در تیمار $N_3P_2Si_2$ و کم‌ترین میزان در تیمار $N_3P_2Si_1$ بود. بیش‌ترین و کم‌ترین میزان نرخ خالص تولیدمثل ($\underline{R_0}$) به‌ترتیب در تیمارهای $N_4P_2Si_2$ و $N_3P_2Si_1$ مشاهده شدند. کوتاه‌ترین و طولانی‌ترین میزان متوسط یک نسل(T) به‌ترتیب در تیمارهای $N_4P_1Si_3$ و $N_5P_3Si_1$ یافت شد. هم‌چنین کم‌ترین و بیش‌ترین مقادیر نرخ ذاتی افزایش جمعیت (r) در تیمارهای $N_5P_3Si_2$ (۰/۲۷ بر روز) و $N_5P_1Si_1$ (۰/۴۱ بر روز) مشاهده شد. نتایج نشان داد که در کاربرد هم‌زمان این سه عنصر فسفر بیش‌ترین تأثیر را بر فاکتورهای زیستی شته جالیز دارد.

واژگان کلیدی: خیار، شته جالیز، کود، پارامترهای جدول زندگی و مدیریت تلفیقی آفات