Sugar Tech (Nov-Dec 2017) 19(6):623–631
DOI 10.1007/s12355-017-0532-8

RESEARCH ARTICLE

Insecticides from Different Classes Impact on *Neomaskellia andropogonis* Population Under Sugarcane Field Conditions

Pegah Koohzad-Mohammadi[1] · Masumeh Ziaee[1] · Amin Nikpay[2]

Received: 30 April 2017 / Accepted: 1 June 2017 / Published online: 19 June 2017

Abstract Sugarcane whitefly is one of the important pest of sugarcane. Chemical and biological controls are used in an integrated program to prevent sugarcane whitefly infestations. Several insecticides from various groups have been registered to control whiteflies. In this study, efficacy of deltamethrin 2.5% EC, dinotefuran 20% SG and spiromesifen 240 SC was evaluated against sugarcane whitefly, *Neomaskellia andropogonis* Corbett (Homoptera: Aleyrodidae) under field conditions. The population of whitefly at different life stages was recorded at 3, 7, 15 and 30 days after spraying the insecticides. According to the findings, cumulative reduction in whitefly population was recorded by application of insecticides even after 30-day post-treatment. Application of insecticides significantly increased the mortality level of whitely at different life stages compared to the control. However, higher level of mortality was observed for dinotefuran (more than 65% mortality in all stages) and deltamethrin (75% egg, 48% nymph, 70% pupae and 87% adult mortality), 30 days after spraying insecticides on IRC99-02 variety of sugarcane. Our results revealed that all tested insecticides were toxic against *N. andropogonis* and can effectively control different life stages of sugarcane whitefly.

Keywords Chemical control · Insecticides · Life stages · Whitefly

✉ Masumeh Ziaee
m.ziaee@scu.ac.ir

[1] Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran

[2] Department of Plant Protection, Sugarcane & By-products Development Company, Salman-Farsi Unit, Ahvaz, Iran

Introduction

Sugarcane (*Saccharum* species hybrids) is a tropical and perennial graminaceous crop and cultivated in many countries for production of sugar and ethanol as energy cane (James 2004). This plant is a highly important and strategic cash crop in Iran and has prominent impact on both economic and social issues. Sugarcane is mainly cultivated in south west of Iran in Khuzestan province, on more than one hundred thousand hectares under full irrigated systems (Sadeghzadeh-Hemayati et al. 2011). As a monoculture system, sugarcane is sensitive to a wide range of biotic stresses including insect herbivores and pathogens which cause economic damage in both field and factory conditions. Under Iranian sugarcane agro-ecosystems, several insect pests including stalk borers (Askarianzadeh et al. 2008; Nikpay and Goebel 2016; Nikpay et al. 2015), leaf feeders (Nikpay 2016), root feeders, mites and whitefly (Nikpay and Goebel 2016) are associated with sugarcane. The sugarcane whitefly, *Neomaskellia andropogonis* Corbett (Homoptera: Aleyrodidae), was identified in 2006 (Askarianzadeh and Manzari 2006), and this species is one of the new emerging pests and damage of this pest seems expanding continuously in recent years (Nikpay and Goebel 2016). Damage of this pest in commercial varieties has increased in last decade (Minaei-Moghadam et al. 2010; Nikpay 2017), and *N. andropogonis* can infest different species of grass weeds including barnyardgrass (*Echinocloa colona* L.), cogongrass (*Imperata cylindrica* L.), bearded sprangletop (*Diplachne fusca* L.), Bermudagrass (*Cynodon dactylon* L.), Dallasgrass (*Paspalum dilatatum* L.) (Nikpay and Sharafizadeh 2017) as well. Under sugarcane fields in Iran, *N. andropogonis* is a multi-generation insect and its activity initiates in late August, and abundance in population is generally happened from late

Fig. 1 Sugarcane leaves with sooty mold growing on honeydew excreted by *Neomaskellia andropogonis* nymphs

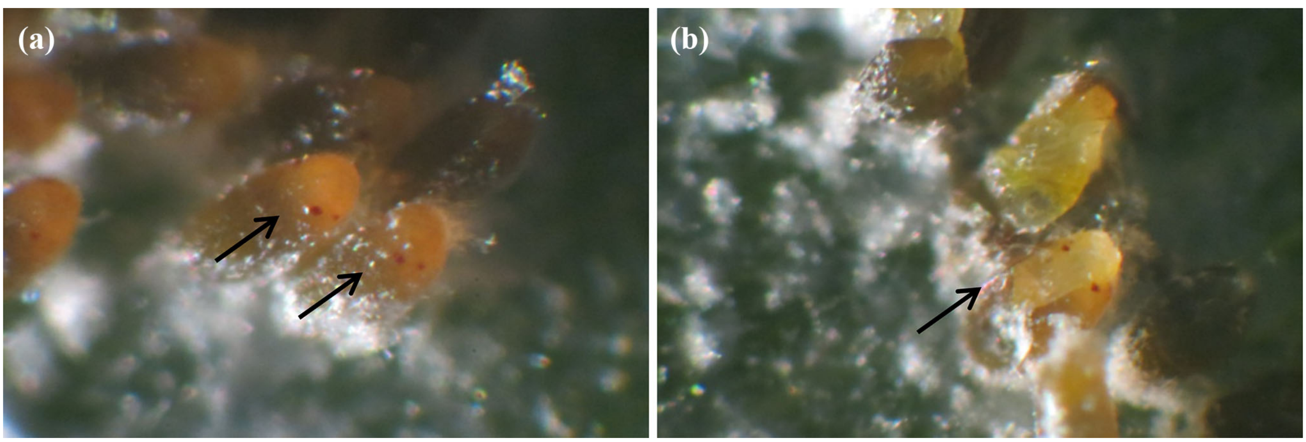

Fig. 2 Eggs of *Neomaskellia andropogonis* with eye marks (**a**) and nymph eclosion (**b**)

September until late October (Minaei-Moghadam et al. 2010). The adults are tiny, pale yellow with wings which covered with white powder. Pupa are elliptical, and cuticle is yellow to brown with irregularly dented in margins. First instar larva is mobile, but the third instar is fixed in leaves (Askarianzadeh and Manzari 2006). Sugarcane whitefly nymphs suck the plant sap from the undersurface of leaves; and finally, the honey dew excreted by this insect serves as a medium for sooty mold and other fungi (Fig. 1) resulting in interference of photosynthesis as well as reduction of purity and sugar content mainly in early-maturing varieties (Askarianzadeh 2011).

In addition to Iran, the genus *Neomaskellia* exists in several countries including India (Mann and Singh 2003) and Pakistan (Inayatullah 1984) which infest commercial varieties of sugarcane. For managing sugarcane whiteflies, different strategies encompassing biological control with predators and parasitoids (Rajak and Varma 2001; Srikanth et al. 2016), cultural practices (Jena and Nayak 1994) and application of chemical insecticides (Vijayaraghavan and Regupathy 2006) are applied.

We have been unable to find any references reporting research using application of insecticides on *N. andropogonis* in Iran and other countries on sugarcane varieties. The goal of the present study was to compare different insecticide treatments on population density of different life stages of *N. andropogonis* under field conditions.

Materials and Methods

Formulations

The insecticidal formulations that were applied in the present study were deltamethrin 2.5% EC, pyrethroid insecticide (Bayer CropScience, Germany), dinotefuran

Fig. 3 Round exit holes indicating emergence of *parasitic* wasps and T-shaped openings for *Neomaskellia andropogonis* adults emergence from whitefly pupae

20% SG, neonicotinoid insecticide (Mitsui Chemicals Agro Inc., Japan) and spiromesifen 240 SC, tetronic acid insecticide (Bayer CropScience, Germany).

Plant Materials and Cultivation

Two sugarcane varieties: CP69-1062 (Canal Point USA) and IRC99-02 (cross made in Cuba and selected in Iran) were cultivated at Salman Farsi Agro-industry-Ahwaz (48°35′E, 31°8′S), using standard tillage, following by ridging at 1.8-m furrow spacing. Before planting of sugarcane varieties, phosphorous fertilizer (Super phosphate triple/300 kg per hectare) was mixed with a pneumatic fertilizer machine based on standard procedure of sugarcane nutrient treatments in Iran. Each sugarcane variety was planted as billets (50–70 cm and free from stalk borers infestation), and following planting of seed cane sets, all furrows were treated with Atrazine and Sencor herbicides (2 + 2 kg per hectare) based on local recommendations as

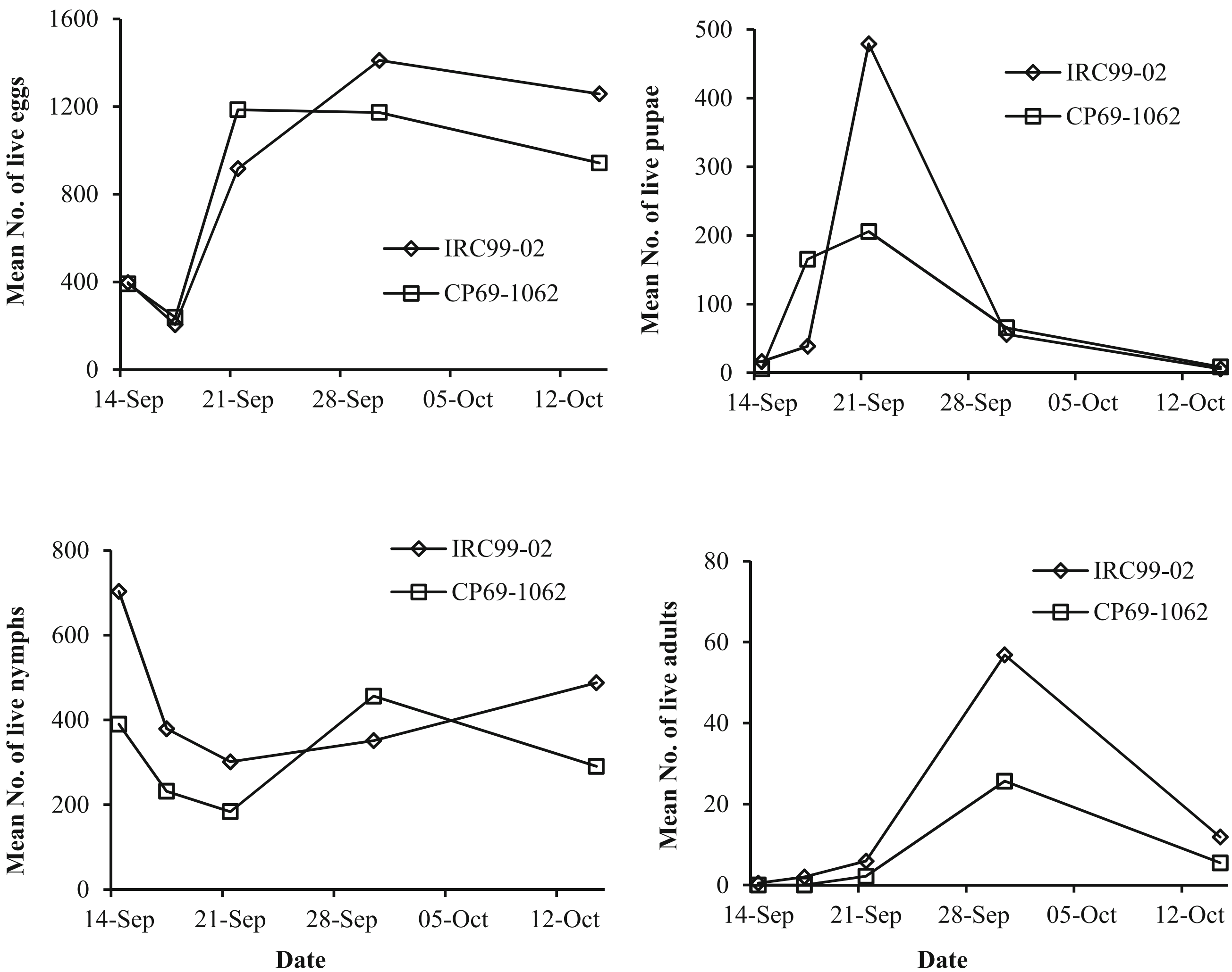

Fig. 4 Mean number of *Neomaskellia andropogonis* different life stages on IRC99-02 and CP69-1062 varieties of sugarcane

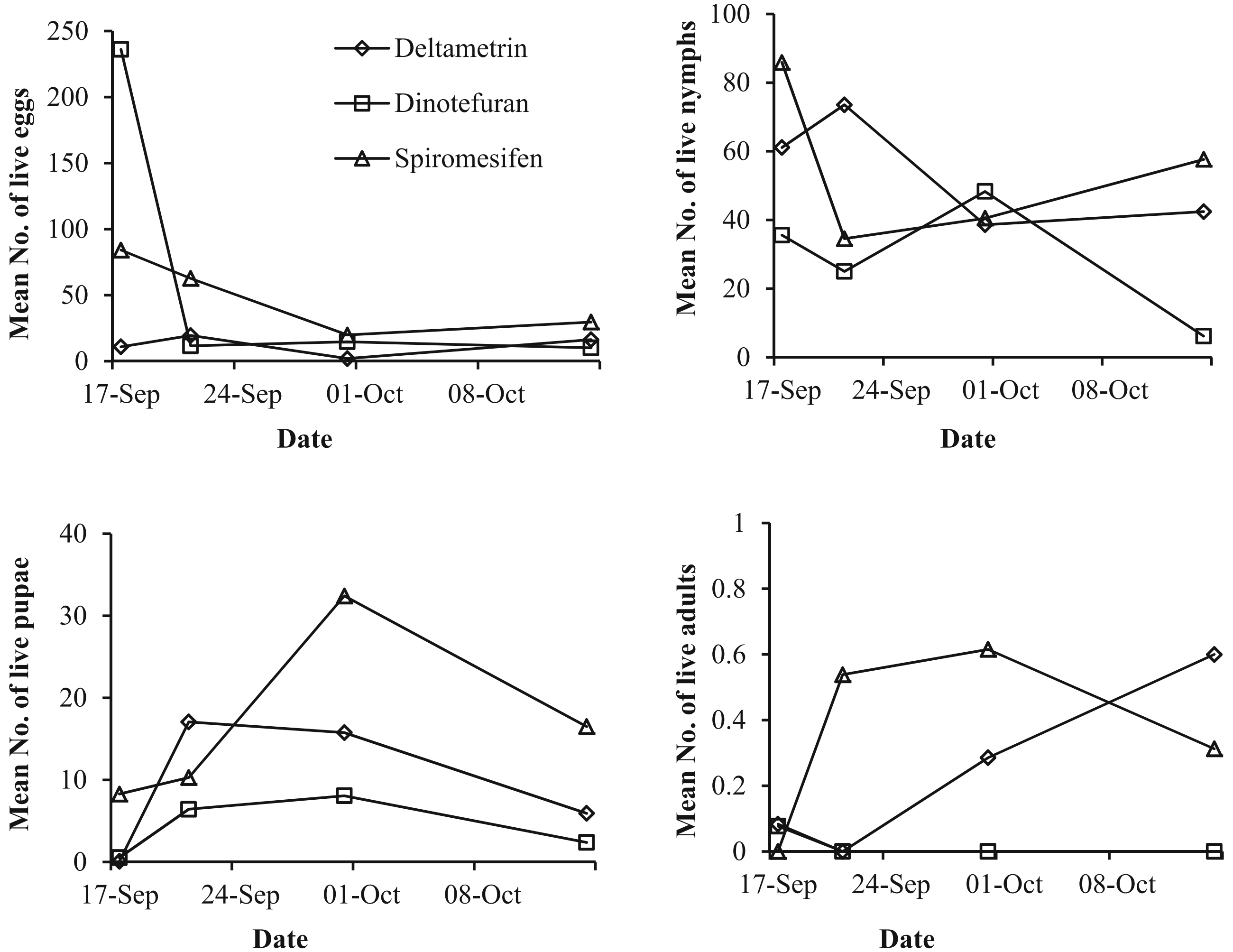

Fig. 5 Mean number of *Neomaskellia andropogonis* different life stages after spraying deltamethrin, dinotefuran and spiromesifen insecticides on IRC99-02 variety of sugarcane

early postemergence application for suppressing of annual weeds. During the crop growth, all weeds in experimental plots were removed manually by hand.

Experiments

A completely randomized block design was used for the experiments. Each experimental plot (block) consists of four rows, 15-m long and 1.8 m inter-row spaces and 135-m^2 in different areas of field. Each plot was separated by a 12-m buffer of standing cane to inhibit *N. andropogonis* dispersion between plots. The formulations were tested at the label doses on field conditions. Thus, deltamethrin was sprayed at 1 lit/ha, dinotefuran at 0.75 kg/ha and spiromesifen at 0.4 lit/ha. All insecticides were sprayed as foliar applications by a 15-liter volume knapsack sprayer (Hardi International, England). The untreated part of the field was considered as a control. Sampling was carried out one day before spraying insecticides on 14 September 2016 and 3, 7, 15 and 30 days after spraying. For each sampling date, 12 leaves of sugarcane (about 15 cm each) were randomly collected from treated and untreated (control) rows. The leaves were put inside mesh covered semi-transparent plastic bags. Specification labels were installed on each bag, and the bags were transferred to the laboratory. In the laboratory, number of live and dead stages of whitefly including egg, nymph, pupae and adult were counted by binocular (SMZ800 Nikon, Tokyo, Japan). The pupae parasitoids including *Encarsia inaron* Walker (Hym.: Aphelinidae) and *Eretmocerus delhiensis* Mani (Hym.: Aphelinidae) started their activity on mid-October. Therefore, the number of parasitized pupae was also counted at the last sampling date. Eggs, nymphs and pupal stages of whitefly were considered dead when they lost

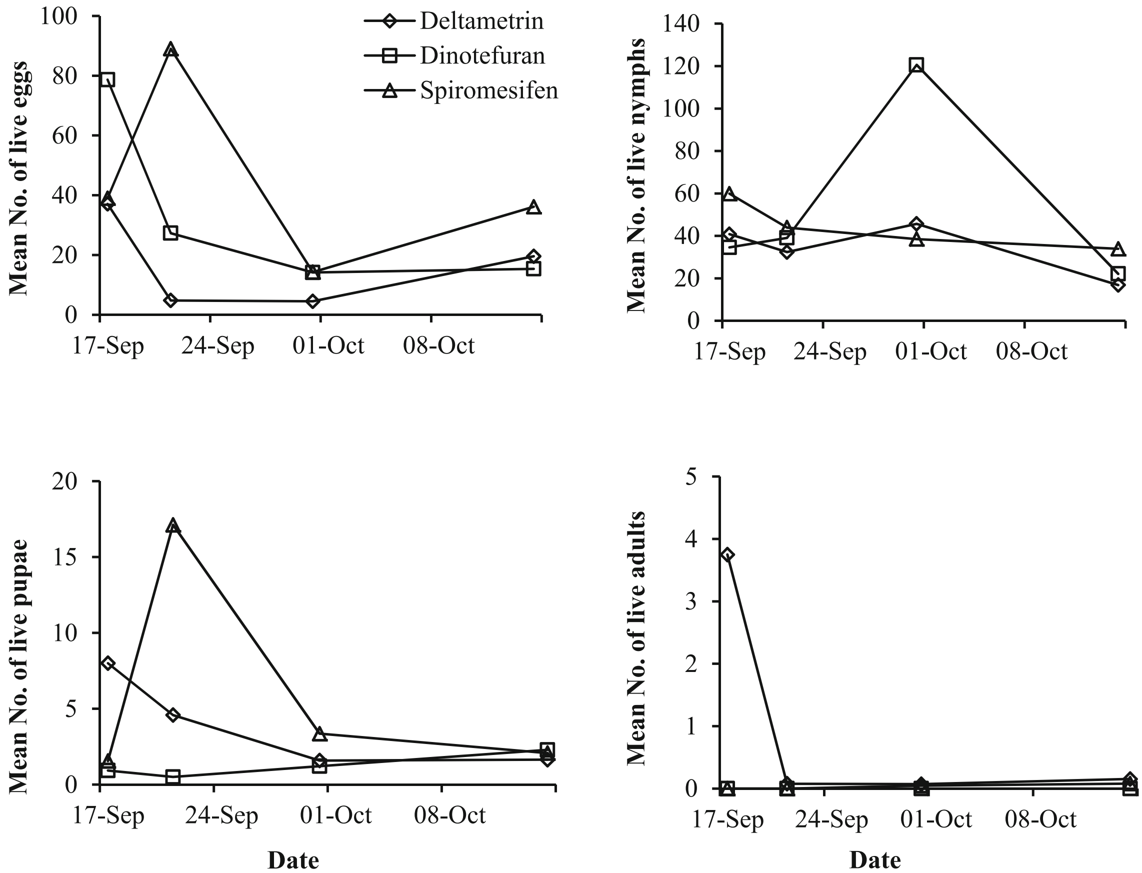

Fig. 6 Mean number of *Neomaskellia andropogonis* different life stages after spraying deltamethrin, dinotefuran and spiromesifen insecticides on CP69-1062 variety of sugarcane

their turgidity and smooth cuticle structure as described by (Qian et al. 2012). Also, eye marks is appeared on live eggs one or two day before eclosion which was also considered as a symptom of eggs viability. Whitefly eggs have a distinct longitudinal eclosion line that splits open when hatching to emerge nymph (Walker et al. 2009) (Fig. 2). Whitefly adults emerge from the pupa through a T-shaped opening, while *parasitic* wasps emerge from the round exit hole in the parasitized pupae (Fig. 3).

Data Analysis

All data were analyzed for normality and homogeneity of variance (Bartlett's test), and appropriate transformation to square root of arcsine was applied. The mortality experiment was carried out in a factorial structure (first factor: insecticides; second factor: time) with a completely randomized block design. The mortality data were analyzed using analysis of variance (ANOVA). Tukey–Kramer honestly significant difference (HSD) test was used for means separations between treatments at 0.05 significance levels. Untransformed means and standard errors are shown in the figures. All analyses were performed by SPSS software version 16 (SPSS 2007).

Results

The population of *N. andropogonis* was high in the untreated varieties of sugarcane. The mean number of eggs per leaf increased from 21 September and reached to more than 1000 eggs in both varieties. The high number of whitefly pupae was observed in 21 September and was 479 for IRC99-02 and 205 pupae in the case of CP69-1062 variety of sugarcane. Adult stage of *N. andropogonis* has the lowest population on sugarcane varieties, so that the largest number of whitefly adults was in 30 September and was 56.8 and 25.6 for IRC99-02 and CP69-1062, respectively (Fig. 4).

The population of whitefly eggs reached to less than 20 eggs, 7 days (21 September) after spraying deltamethrin and dinotefuran on IRC99-02 variety of sugarcane.

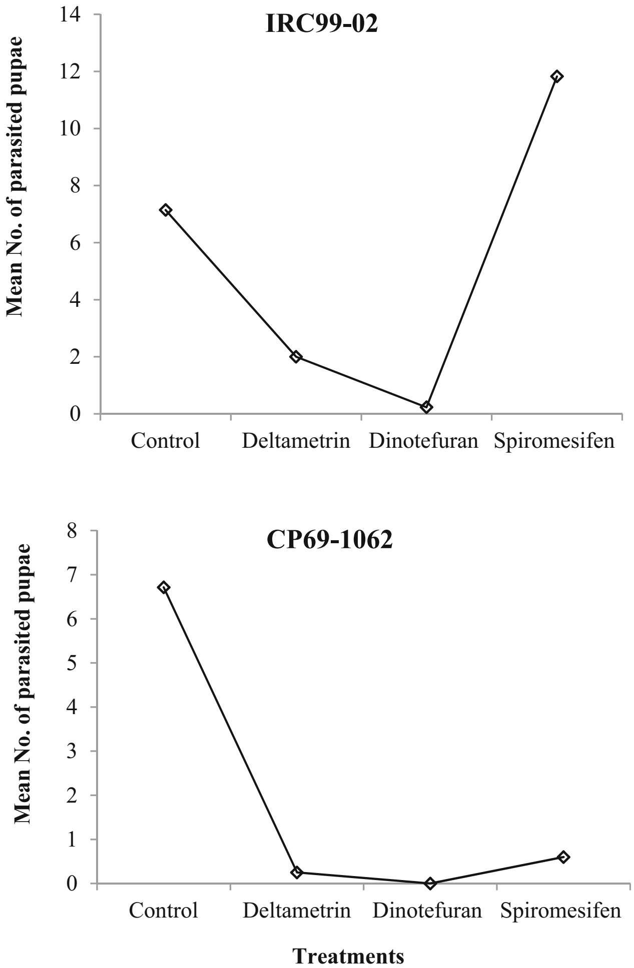

Fig. 7 Mean number of parasitized pupae of *Neomaskellia andropogonis* by parasitoid wasps 30 days after spraying on IRC99-02 and CP69-1062 variety of sugarcane

However, 63 eggs per leaf were observed in spiromesifen-treated leaves on 21 September. For whitefly nymph, the population was also reduced and the low number of nymph was recorded in dinotefuran-treated leaves which was six nymphs per leaf on 14 October. All three insecticides reduced the number of live pupae per leaf, and population was less than 30 pupae in all sampling intervals. For dinotefuran, no adult was recorded 3 days after spraying and for two other insecticides, the mean number of *N. andropogonis* adult was less than one adult per leaf on IRC99-02 variety (Fig. 5).

Different population stages of *N. andropogonis* were reduced when exposed to deltamethrin, dinotefuran and spiromesifen on CP69-1062 variety of sugarcane. In all treated insecticides, the mean number of whitefly eggs per leaf was less than 15 eggs on 30 September (15 days after spraying insecticides) and remained stable until 14 October. Nevertheless, the number of live eggs increased to 36 eggs per leaf on 14 October in the case of spiromesifen. The mean number of nymphs, pupae and adult stages of sugarcane whitefly was reduced on treated leaves of CP69-1062 variety which may be in accordance with the decrease in number of live eggs per leaf (Fig. 6).

The mean number of parasitized pupae in control was seven pupae per sugarcane leaf of both varieties, while no parasitized pupae were found in dinotefuran. For spiromesifen, the number of parasitized pupae increased specially on IRC99-02 variety of sugarcane (Fig. 7).

The main effects (insecticides: $F_{3,108} = 141.0$; time: $F_{2,108} = 17.4$) were significant ($P < 0.000$) for egg, nymph (insecticides: $F_{3,132} = 46.2$; time: $F_{2,132} = 4.3$), pupae (insecticides: $F_{3,98} = 67.3$) and whitefly adult (insecticides: $F_{3,57} = 142.4$) on IRC99-02 variety of sugarcane. There were not significant differences between time intervals for pupae ($F_{2,98} = 0.90$) and adult ($F_{2,57} = 1.4$). Associated interactions (insecticides × time) were significant for egg ($F_{6,108} = 14.8$). However, for nymph ($F_{6,132} = 2.0$), pupae ($F_{6,98} = 0.89$) and adult ($F_{6,57} = 1.24$), interactions between insecticides and time intervals were not significant. High level of egg mortality was observed in deltamethrin- and dinotefuran-treated leaves. However, the mortality was less than 50% in spiromesifen. The mortality of nymph, pupae and adult was significantly increased compared to the control (Fig. 8).

For CP69-1062 variety, the main effects (insecticides: $F_{3,112} = 35.5$; time: $F_{2,112} = 34.2$) were significant ($P < 0.000$) for egg, nymph (insecticides: $F_{3,130} = 96.8$), pupae (insecticides: $F_{3,100} = 106.1$; time: $F_{2,100} = 12.3$) and adult (insecticides: $F_{3,57} = 250.3$; time: $F_{2,57} = 3.4$). There was an exception for whitefly nymph ($F_{2,130} = 0.35$) that no significant differences were recorded between time intervals. Associated interactions (insecticides × time) were significant for egg ($F_{6,112} = 5.4$), pupae ($F_{6,100} = 9.0$) and adult ($F_{6,57} = 6.1$). However, for nymph ($F_{6,130} = 2.0$), interactions between insecticides and time intervals were not significant. The mortality of *N. andropogonis* different life stages was reduced significantly compared to the control (Fig. 9).

Discussion

The first study on seasonal population density of *N. andropogonis* under field conditions in Iran was conducted by Minaei-Moghadam et al. (2010) in two consecutive years. The peak population density of whitefly adult stage was recorded on mid-October 2006 (35 adults per leaf) and early November 2007 (21 adults per leaf) on variety CP691062. According to our findings, high population level of *N. andropogonis* adult was observed on late September 2016 and it was 57 adults per leaf for IRC99-02 and 26 adults per leaf in the case of CP69-1062. Different

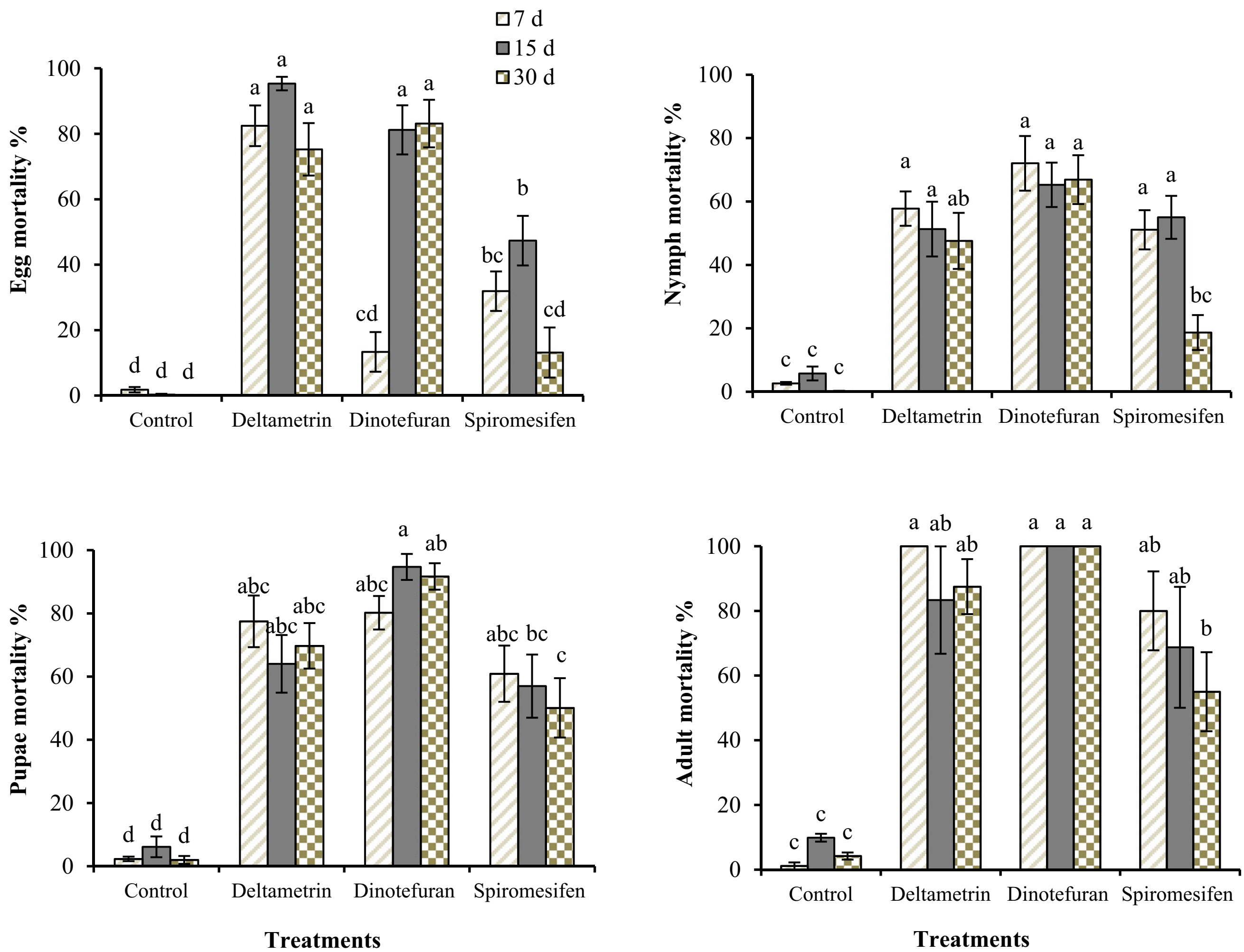

Fig. 8 Mean mortality % (±SE) of *Neomaskellia andropogonis* different life stages after spraying deltamethrin, dinotefuran and spiromesifen insecticides on IRC99-02 variety of sugarcane under field conditions. Means followed by the same letter are not significantly different using Turkey's test at $P < 0.05$

factors in the sugarcane agro-ecosystem could influence the abundance of sugarcane whitefly (Charernsom and Suasa-ard 1989). Among factors which affected whitefly population, mean temperature and relative humidity have greater effects on fluctuation of population (Ahmed et al. 2004; Minaei-Moghadam et al. 2010). Balikai et al. (1998) found that drought in summer season followed by dryness in monsoon have deep impact on resurgence on sugarcane whitefly. They concluded that this may be the main reason of whitefly populations' seasonal trends from year to year.

Sugarcane whitefly prefers to attack mature cane in and therefore, it is active during last six months of growth of the crop (Charernsom and Suasa-ard 1989). The peak population of sugarcane whitefly was recorded in first fortnight of August–September and in early October 2006 and 2007 in three sugarcane fields in Medak district of Andhra Pradesh, India. The whitefly population has a positive correlation with relative humidity and increased with an increase in relative humidity (Vemuri et al. 2014). In Iran, whitefly appears from late August to mid-November and on that time; the planted canes are becoming mature and store sucrose on their stalks (Minaei-Moghadam et al. 2010).

Our study revealed that application of insecticides against sugarcane whitefly can reduce the population compared to the control on IRC99-02 and CP69-1062 varieties of sugarcane.

Vijayaraghavan and Regupathy (2006) reported that neonicotinoid insecticides are highly toxic against sugarcane whitefly *Aleurolobus barodensis* Maskell and among three tested neonicotinoids, thiamethoxam followed by dimethoate was more effective. In the other research, Bhavani and Rao (2013) declared that removal of the infested leaves followed by spraying imidacloprid

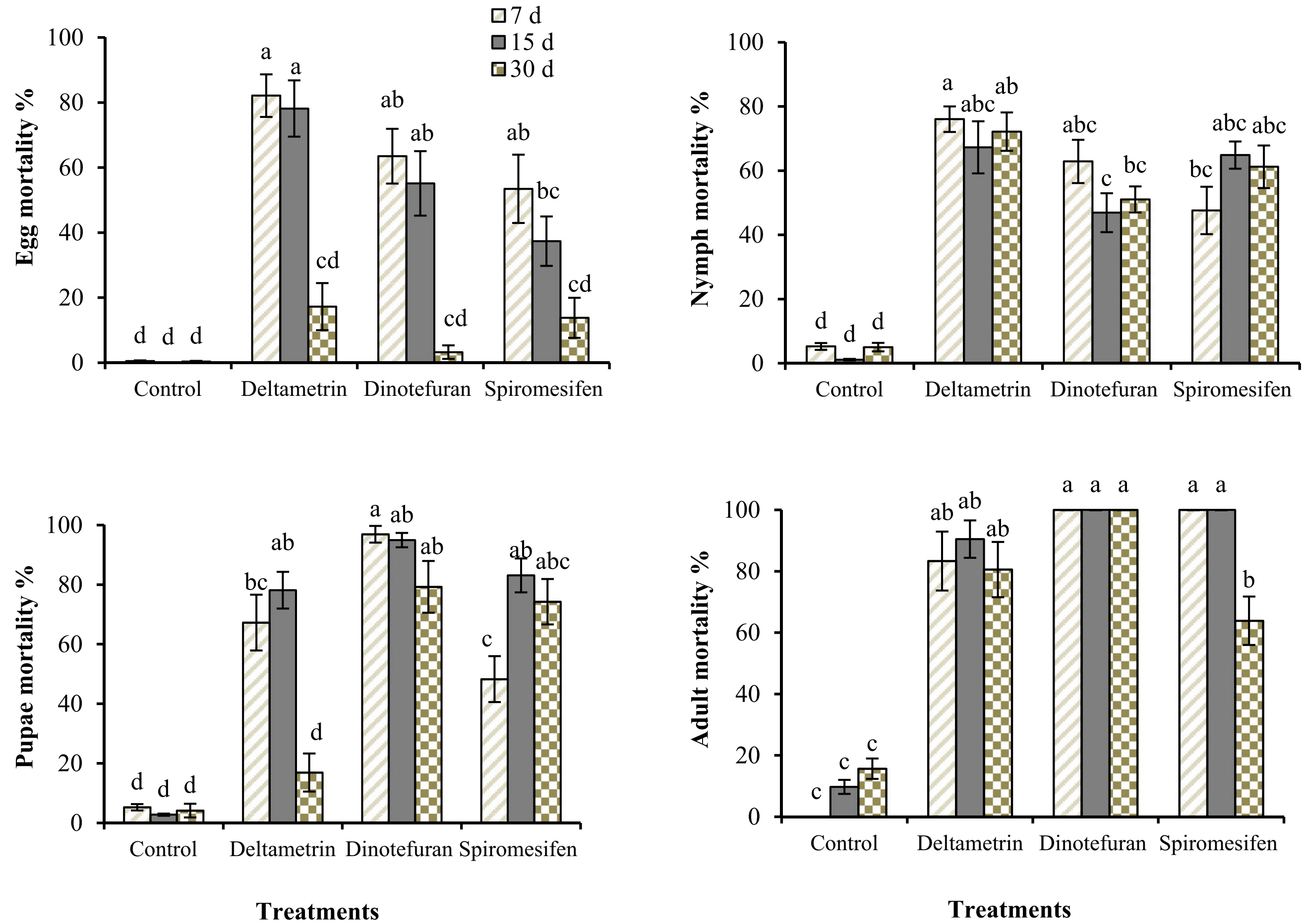

Fig. 9 Mean mortality % (±SE) of *Neomaskellia andropogonis* different life stages after spraying deltamethrin, dinotefuran and spiromesifen insecticides on CP69-1062 variety of sugarcane under field conditions. Means followed by the same letter are not significantly different using Turkey's test at $P < 0.05$

significantly reduced population density of sugarcane whitefly *A. barodensis* compared to untreated control and caused 96.6% mortality. After that, other treatments including removal infested leaves + azadirachtin and removal infested leaves + dimethoate were recorded to be effective for controlling whitefly population at Andhra Pradesh, India. In our study, dinotefuran, a neonicotinoid insecticide, was more effective against sugarcane whitefly followed by deltamethrin.

To sum up, it can be concluded that application of insecticides may significantly decrease population of *N. andropogonis* in comparison with control. However, among different type of insecticides dinotefuran caused maximum mortality in the period of insecticide application. All insecticides greatly reduced parasitized pupae, but spiromesifen seems safer than two other tested insecticides which more eclosion of parasitoid wasps observed in. However, more studies with other insecticides alone or in combination with biological control agents or cultural practices can be applied as integrated whitefly management program in the future.

Acknowledgements The authors are appreciated from Shahid Chamran University for financial and logistic support of this project.

Compliance with Ethical Standards

Conflict of interest There is no conflict of interest among the authors.

References

Ahmed, A., A. Suhail, Z. Abdin, S. Iftikhar, and K. Zahoor. 2004. Biodiversity of insects associated with sugarcane crop in Faisalabad. *Pakistan Entomologist* 26: 65–69.

Askarianzadeh, A. 2011. Evaluation of quality damage of sugarcane whitefly, *Neomaskellia andropogonis* (Hom., Aleyrodidae) on sugarcane in Khuzestan province. *Plant Protection (Scientific Journal of Agriculture)* 34: 59–67.

Askarianzadeh, A., and S. Manzari. 2006. *Neomaskellia andropogonis* (Hemiptera: Aleyrodidae), a new genus and species record for Iran. *Journal of Entomological Society of Iran* 26: 13–14.

Askarianzadeh, A., S. Moharramipour, K. Kamali, and Y. Fathipour. 2008. Evaluation of damage caused by stalk borers, *Sesamia* spp. (Lepidoptera: Noctuidae), on sugarcane quality in Iran. *Entomological Research* 38: 263–267.

Balikai, R., S. Lingappa, A. Biradar, and R. Teggelli. 1998. Incidence of sugarcane whitefly in Karnataka. *Karnataka Journal of Agricultural Sciences* 11: 820–821.

Bhavani, B., and C.V.N. Rao. 2013. Management of sugarcane white fly (*Aleurolobus barodensis M*ask.) in north coastal districts of Andhra Pradesh, India. *International Journal of Social Science & Interdisciplinary Research* 2: 112–115.

Charernsom, K., and W. Suasa-ard, 1989. Sugarcane whitefly, *Aleurolobus barodensis* Maskell, and its parasites in Thailand. *Proceedings XX Congress of the International Society of Sugar Cane Technologists*: 769-802.

Inayatullah, C. 1984. Sugar-cane aleurodids, *Aleurolobus barodensis* (Maskell) and *Neomaskellia andropogonis* Corbett (Hom.: Aleyrodidae), and their natural enemies in Pakistan. *Insect Science and Its Application* 5: 279–282.

James, G. 2004. Sugarcane. 2nd edn, 216. London: Blackwell Publishing.

Jena, B., and N. Nayak. 1994. Whitefly management in sugarcane. *Indian Sugar* 43: 849–850.

Mann, R., and K. Singh. 2003. Screening of sugarcane genotype for their reaction against sugarcane whitefly (*Aleurolobus barodensis* Mask.). *Indian Sugar Journal* 23: 110–111.

Minaei-Moghadam, M., P. Shishebor, E. Soleyman-Nejadian, and A. Askarianzadeh. 2010. Seasonal population changes of *Neomaskellia andropogonis* Corbett (Hom.: Aleyrodidae) in south Khuzestan. *Plant Protection (Scientific Journal of Agriculture)* 32: 15–24.

Nikpay, A., 2016. Effects of burning trashes on leaf feeders Mythimna spp. (Lepidoptera: Noctuidae) damage in sugarcane fields. In 38th Conference of the Australian Society of *Sugar Cane Technologists*, ed. Bruce, R.C., Makay, 135. Queensland, Australia.

Nikpay, A. 2017. Damage assessment of sugarcane whitefly *Neomaskellia andropogonis* Corbett and population dynamics on seven commercial varieties in Southwest of Iran. *Sugar Tech* 19: 198–205.

Nikpay, A., and F.R. Goebel. 2016. Major sugarcane pests and their management in Iran. *Proceedings of the International Society of Sugar Cane Technologists* 29: 103–108.

Nikpay, A., and P. Sharafizadeh. 2017. First report of wild hosts of sugarcane whitefly *Neomaskellia andropogonis* Corbett (Homoptera: Aleyrodidae) associated with sugarcane agro-ecosystems in Iran. *Sugar Journal* 3: 18–23.

Nikpay, A., E. Soleyman-Nejadian, S. Goldasteh, and H. Farazmand. 2015. Response of sugarcane and sugarcane stalk borers *Sesamia* spp. (Lepidoptera: Noctuidae) to calcium silicate fertilization. *Neotropical Entomology* 44: 498–503.

Qian, M.-H., Q.-B. Hu, S.-X. Ren, N.S. Mandour, B.-L. Qiu, and P.A. Stansly. 2012. Delayed development of the whitefly (*Bemisia tabaci*) and increased parasitism by *Encarsia bimaculata* in response to sublethal doses of piperonyl butoxide. *Insect Science* 19: 403–411.

Rajak, D., and A. Varma. 2001. Natural enemy complex of insect-pest of sugarcane in the southern zone of Andhra Pradesh. *Indian Journal of Sugarcane Technology* 6: 114–116.

Sadeghzadeh-Hemayati, S., H. Hamdi, D. Fathollah-Taleghani, and H. Amili, 2011. Strategic framework for sugarcane research. Psychology and Arts, Tehran-Iran.

SPSS. 2007. *SPSS 16 for Windows user's guide release*. Chicago: Spss Inc.

Srikanth, J., S. Easwaramoorthy, and S. Jalali. 2016. A 100 years of biological control of sugarcane pests in India: review and perspective. *CAB Reviews* 11: 1–32.

Vemuri, S., K. Suresh, and M.V. Kumar. 2014. Whitefly (*Aleurolobus Barodensis* Mask.) population fluctuations in diverse conditions of sugarcane crop in Medak district of Andhra Pradesh, India. *ZENITH International Journal of Multidisciplinary Research* 4: 217–221.

Vijayaraghavan, C., and A. Regupathy. 2006. Bioefficacy of thiamethoxam (Actara 25WG) against sugarcane whitefly *Aleurolobus barodensis* Maskell. *International Journal of Agricultural Sciences* 2: 299–304.

Walker, G.P., T.M. Perring, and T.P. Freeman. 2009. Life history, functional anatomy, feeding and mating behavior. In *Bemisia: Bionomics and management of a global pest*, ed. P.A. Stansly, and S.E. Naranjo, 109–160. London: Springer.