Effect of Two Host Plants, *Helianthus annuus* L. and *Sinapis arvensis* L., on Life Table Parameters of *Nysius cymoides* (Spinola) (Hemiptera: Lygaeidae) under Laboratory Conditions

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Abstract

Mollashahi M., Sahragard A., Mohaghegh J., Hosseini R., Sabouri H. (2016): **Effect of two host plants,** *Helianthus annuus* L. **and** *Sinapis arvensis* L., **on life table parameters of** *Nysius cymoides* (Spinola) (Hemiptera: Lygaeidae) **under laboratory conditions**. Plant Protect. Sci., 52: 209–216.

The false chinch bug, *Nysius cymoides* (Spinola) is a pest of sunflower attacking sunflower fields from their weedy and cultivated hosts. The effect of sunflower and wild mustard (wild host) on the life table parameters of *N. cymoides* was studied under laboratory conditions (24 ± 1°C, 65 ± 5% RH, a $16 : 8$ h (L : D) photoperiod). Data were analysed based on the age-stage, two-sex life table theory. Developmental time (sum of incubation and nymphal periods) on wild mustard was longer than on sunflower with significant difference ($P < 0.05$). The adult longevity was significantly shorter on wild mustard than on sunflower. The adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), mean fecundity and adult longevity reared on sunflower and wild mustard showed significant differences ($P < 0.05$). The highest fecundity (58.72 eggs) and the longest female longevity (68.09 days) were on sunflower and lowest fecundity (5.67 eggs) was on wild mustard. The intrinsic rate of increase (r) on sunflower was higher than that on wild mustard, as it was 0.0437 ± 0.0039 on sunflower and 0.00033 ± 0.00599 per day on wild mustard and net reproductive rate (R_0) on sunflower and wild mustard was 12.94 ± 2.77 and 1.075 ± 0.34 (offspring), respectively. The mean generation time (T) was 58.01 ± 1.59 and 56.76 ± 2.43 days, on sunflower and wild mustard, respectively. The life expectancy (e_{xj}), survival rate (s_{xj}), and cumulative reproductive rate (R_x) on sunflower were higher than wild mustard. The results showed that sunflower was more suitable host than wild mustard to *N. cymoides.*

Keywords: false chinch bug; two-sex life table; wild mustard; sunflower

In Iran the false chinch bug, *Nysius cymoides* does occur in most provinces (Guilan, Mazandaran, Golestan, Ardebil, Zanjan, Tehran, Khuozestan, Semnan, North Khorasan, Qazvin) and the humid northen regions are the most suitable (Pericart 1999; Linnavuori 2007; Solhjouy-Fard *et al.* 2013).

The species *N. cymoides* (Spinola) (Lygaeidae) is very polyphagous with a great host range – alfalfa (Yasunaga 1990; Wheeler 2001; Mirab-balou *et al.* 2008), cabbage, cauliflower, wild mustard, grapevines (Rivnay 1962), cotton (Behdad 2002), clover (Rivnay 1962; Wipfli *et al.* 1990), canola and sunflower (Heidary Alizadeh *et al.* 2009; Sarafrazi *et al.* 2009), almond, jojoba (Parenzan 1985), and apple (Ghauri 1977).

Agricultural landscapes regularly consist of crop fields interspersed with uncultivated habitats, thus providing abundant food resources for generalist phytophagous insects (Kennedy & Storer 2000; Du Plessis *et al.* 2015). Change in the phenology of certain host or food plants results in a constantly changing mosaic of habitats across the agrolandscape

(Kennedy & Storer 2000; Du Plessis *et al.* 2015). In this process, some areas may be transformed into temporary habitats. Insects breeding in temporary habitats, especially on annual plants, need to migrate regularly from unfavorable habitats, to exploit those where conditions are better for survival, development, and reproduction (Cammell & Knight 1992; Du Plessis *et al.* 2015).

Most polyphagous plant feeding insects do not only exploit suitable host plants and habitats, but change their hosts to locate new, more suitable hosts (Kennedy & Storer 2000; Du plessis *et al.* 2015). Using a wide range of hosts increases food availability and allows mixtures of different types of food, which may improve nutrient balance. This variation in host plants may affect the performance of insects (Awmack & Leather 2002; Du plessis *et al.* 2015).

The wild mustard (*Sinapis arvensis* L.) is a dominant weed in the rapeseed (Abtali *et al.* 2009; Haghighi *et al.* 2010) and sunflower fields (Ashrafi *et al.* 2010), and can cause major yield losses. A strongly persistent seed bank, competitive growth habit, and high fecundity all contribute to its nature as a weed and ensure that it will be a continuing problem (Warwick *et al.* 2000).

In Italy, the *N. cymoides* appeared to have built up large populations in the plantation on the weed *Portulaca oleracea* L. and then had migrated to jojoba (Parenzan 1985). Rivnay (1962) reported that in one year, *N. cymoides* nymphs had developed in the wild mustard fields and, when the short-lived mustard plants died back, the nymphs migrated to adjoining vineyards, destroying them.

The sunflower (*Helianthus annuus* L.) is one of the most important oil crops and is grown on more than 22 mil. ha and with a crop yield of 26 mil. t worldwide (Skoric *et al.* 2007). Flowering and pod stage in sunflower is after canola and wild mustard (Khajehpour 2011). Therefore, *N. cymoides* on canola or wild mustard migrate to sunflower and other host plants.

The *N. cymoides* is extremely mobile, annually migrates from cultivated crops and non-cultivated habitats to canola and aggregate on them causing significant damage during early flower and pod stages (Mohaghegh 2008). Seeds of host plant species are an essential source of nutrients for *N. natalensis* reproduction, whereas the vegetative plant parts are unsuitable (Du Plessis *et al.* 2012).

An age-stage, two-sex life table model incorporating variable development rates and both sexes (male and female) were developed by Chi and Liu (1985) and Chi (1988). Since development rates often differ between the sexes and among individuals (Istock 1981), and ignoring the sex of individuals can also result in errors (Chi 1988). The intrinsic rate of increase is the most suitable biological parameters to measure the suitability of host plants variations and determine plant resistance level to an insect herbivore (Southwood & Henderson 2000).

So far, there is no information about life table parameters of *N. cymoides* on sunflower and wild mustard. The objective of this study was to determine the suitability of sunflower and wild mustard seeds for development and adult life of *N. cymoides* using life tables.

MATERIAL AND METHODS

Insect rearing. The initial population was originally collected from canola fields of Gonbad e Qabus (37°15'40.02''N and 55°11'14.19''E), Iran, in late July 2014. The bugs were reared on sunflower and wild mustard separately for three generations to adapt with new host plants in growth chambers at 24 ± 1°C, 65 ± 5% RH, and 16:8 h (L:D).

Age-stage, two-sex life table. Hunder eggs of *N. cymides* laid on cotton balls within 24 h of the experiment by laboratory reared females were used to begin experiment on sunflower and wild mustard. The newly hatched nymphs were placed individually in Petri dishes (6 cm diameter × 1.5 cm height) with a hole (2 cm) covered with a fine mesh net for ventilation. The newly emerged nymphs were fed by fresh seed germinated of sunflower and wild mustard. The eggs and nymphs were checked daily and their developmental times were recorded. The developmental times and the mortality is calculated from the survival of the whole cohort. Upon emergence, the adult females with males were paired and transferred to the ovipositing container (30 cm diameter × 5 cm height). The adults were fed by fresh seed germinated of sunflower and wild mustard. The number of eggs produced and adult longevity were also recorded daily. Monitoring continued until the death of the last individual in the cohort.

The life history raw data were analysed according to the age-stage, two-sex life table theory (Chi & Liu 1985; Chi 1988) and life table parameters were calculated accordingly by using the TWOSEX-MS Chart programme (Chi 2015). The TWOSEX-MS Chart is

Table 1. Means and standard errors of biological parameters and adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), female longevity, and mean fecundity of *Nysius cymoides* on sunflower and wild mustard.

Host	Nymphal instar					
	egg	N1	N2	N3	N4	N5
Sunflower	8.31 ± 0.14^a	6.62 ± 0.11^a	5.73 ± 0.11^a	5.12 ± 0.13^a	4.86 ± 0.11^a	5.35 ± 0.12^a
Wild mustard	8.67 ± 0.14^a	7.16 ± 0.11^b	6.09 ± 0.12^a	5.54 ± 0.13^a	5.30 ± 0.17^b	5.97 ± 0.19^b

Host	development time	APOP	TPOP	fecundity	adult	
					female	male
Sunflower	37.18 ± 0.74^a	5.76 ± 0.21^a	43.12 ± 1.17^a	58.72 ± 6.01^a	68.09 ± 2.74^a	70.84 ± 2.74^a
Wild mustard	39.88 ± 0.88^b	11.84 ± 0.37^b	52.00 ± 731.38^b	5.67 ± 1.39^b	59.27 ± 1.67^b	57.36 ± 1.93^b

APOP – adult pre-oviposition period; TPOP – total pre-oviposition period; means followed by the same letters in each column are not significantly different ($P > 0.05$).

available at http://140.120.197.173/Ecology/prod02.htm (Chung Hsing University) and http://nhsbig.inhs.uiuc.edu/wes/chi.html (Illinois Natural History Survey).

The means and standard errors of the demographic indexes were assessment by using the Bootstrap procedure (Huang & Chi 2013). In this process, a sample of *n* individuals was randomly selected from the cohort with displacement and compute the $r_{i\text{-boot}}$ for this sample as follows:

$$\sum_{x=0}^{\omega} e^{-r_{i-\text{boot}}(x+1)}\, l_x m_x = 1$$

where: subscript *i*-boot indicates the *i* bootstrap; l_x and m_x are estimate from the *n* individuals selected randomly with replacement

Generally, the data on the same individual are repeatedly selected. In this study, we used 10 000 bootstrap replicates ($m = 10\,000$).

The finite rate of increase (λ), net reproductive rate (R_0) and mean generation time (T) were estimates with same methods.

The two-sex life table bootstrap-values of the *N. cymoides* on sunflower and wild mustard were compared using the *t*-test procedure (TWOSEX-MS Chart programme; Chi 2015).

RESULTS

Biological parameters. Results showed no significant differences in the incubation period of *N. cymoides* reared on sunflower and wild mustard ($P > 0.05$). The nymphal periods were significantly different between two hosts (except for third nymphal stages). Developmental time of the immature stages (sum of incubation and nymphal periods) on wild mustard were longer than on sunflower and this period was significantly different between two host plants ($P < 0.05$). The adult longevity of *N. cymoides* was significantly shorter on wild mustard than sunflower (Table 1).

There were significant differences among adult pre-reproductive period (APOP), total pre-reproductive period (TPOP), female longevity and fecundity on sunflower and wild mustard (Table 1). The results showed the highest fecundity and the longest female longevity were on sunflower and lowest fecundity was on wild mustard (Table 1).

Population growth parameters. Results showed significant differences between the host plants for net reproductive rate (R_0), intrinsic rate of increase (r) (bootstrap estimate of r), finite rate of increase

Table 2. Two-sex life table parameters (mean ± SE) of *Nysius cymoides* on sunflower and wild mustard

Host	R_0 (offspring/individual)		r (day^{-1})		λ		T (day)	
	original	bootstrap	original	bootstrap	original	bootstrap	original	bootstrap
Sunflower	12.93	12.94 ± 2.77^a	0.0441	0.0437 ± 0.0039^a	1.045	1.044 ± 0.004^a	58.01	58.01 ± 1.59^a
Wild mustard	1.08	1.075 ± 0.34^b	0.0013	0.00033 ± 0.00599^b	1.001	1.0003 ± 0.0059^b	56.55	56.76 ± 2.43^a

R_0 – net reproductive rate; λ – finite rate of increase; T – mean generation time; means followed by the same letters in each column are not significantly different ($P > 0.05$)
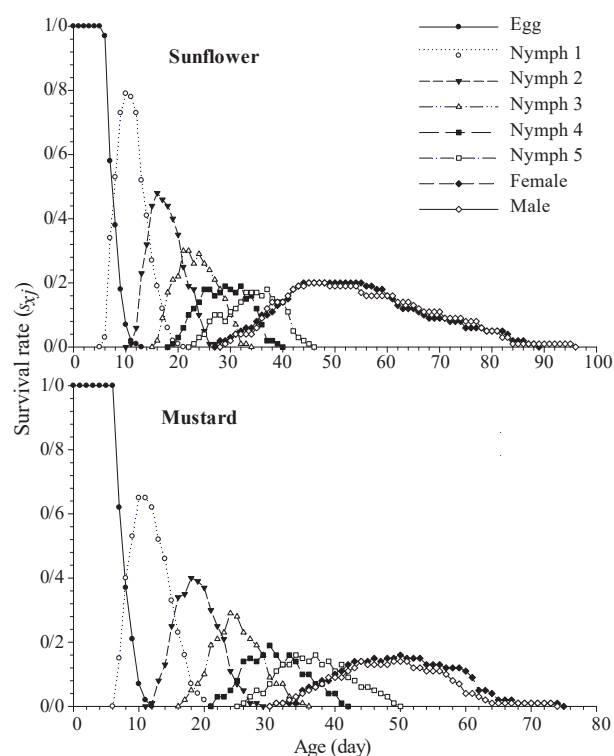
Figure 1. Survival rate to each age-stage interval (s_{xj}) of *Nysius cymoides* on sunflower and wild mustard

Figure 2. Age-specific survival rate (l_x), fecundity (f_{x7}), fecundity of the total population (m_x), maternity ($l_x m_x$) and cumulative reproductive rate (R_x) of *Nysius cymoides* on sunflower and wild mustard

(λ), mean generation time (T) and doubling time (DT) at the 5% probability level and indicated that the host plants had a significant impact on biological performance of *N. cymoides* (Table 2), In this study, r value obtained on sunflower (0.0437 ± 0.0039 per day) was higher than wild mustard (0.00033 ± 0.00599 per day) and R_0 value on sunflower (12.94 ± 2.77) was higher than that on wild mustard. This results showed that sunflower was a more suitable host for the development and reproduction of *N. cymoides* than wild mustard.

The age-stage specific survival rates (s_{xj}) of *N. cymoides* (Figure 1) show the probability that a new born will survive to age x and develop to stage j. These curves also show the survivorship and stage differentiation as well as the variable developmental rate. The survival rates of *N. cymoides* on wild mustard were lower than sunflower and this was due to the higher mortalities of immature stages that occurred on wild mustard.

There were prominent overlaps in survival curves of different life stages. Adult male had higher survival rate than female on two host plants and the maximum lifespan (98 days) was observed on sunflower (Figure 1). The survivorship (l_x) curves of *N. cymoides* on
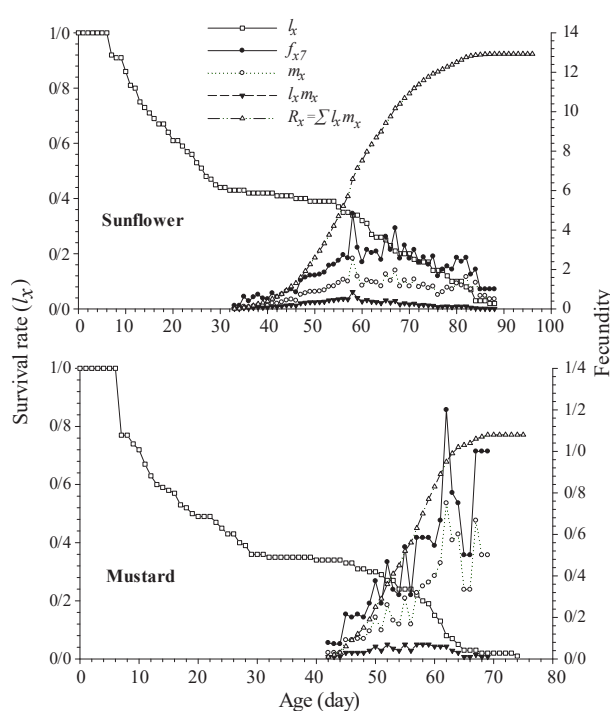
sunflower and wild mustard are shown in Figure 2. The result showed that those insects had been reared on sunflower and wild mustard had high ability to survive and the trend of mortality were not same on two host plants (Figure 1).

The female age-specific fecundity (f_{x7}), the age-specific fecundity of total population (m_x), the age-specific maternity ($l_x m_x$), and the cumulative reproductive rate of *N. cymoides* are plotted in Figure 2.

The mean number of offspring produced by *N. cymoides* individuals of the age x and stage j per day is shown with the age-stage specific fecundity in Figure 2. The trend of cumulative reproductive rate on sunflower was higher than another host (Figure 2).

The age-stage-specific life expectancy (e_{xj}) of *N. cymoides* reveals the expected life span of an individual of age x and stage j can live after age x are shown in (Figure 3). The life expectancy trends on two host plants were close to each other. The highest life expectancy obtained on sunflower (Figure 3).

The reproductive value (v_{xj}) represents the contribution of individuals of age x and stage j to the next population (Figure 4). The highest reproductive value happened at ages of 48–50 days when reared on sunflower. This implies that, in comparison to
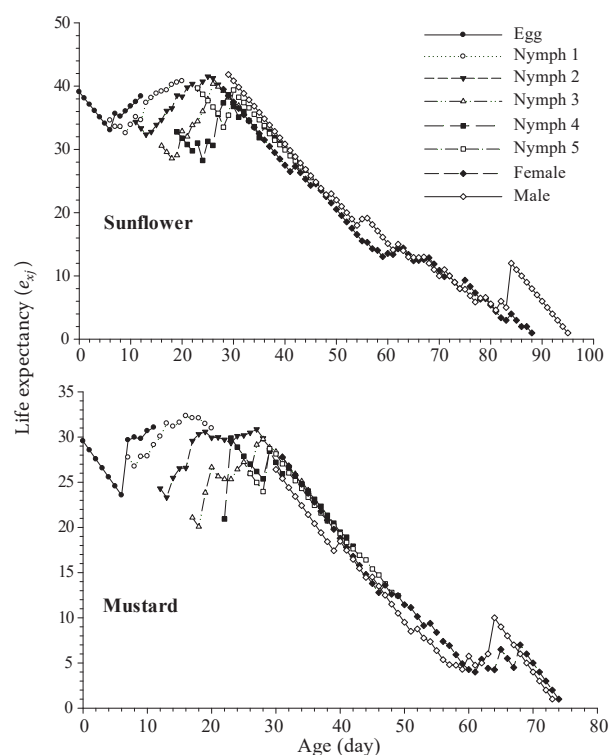
Figure 3. Age-stage life expectancy (e_{xj}) of *Nysius cymoides* on sunflower and wild mustard

Figure 4. Age-stage reproductive value (v_{xj}) of *Nysius cymoides* on sunflower and (wild mustard

other ages, female individuals of ages 48 and 50 days contribute much more to the future population when reared on sunflower and wild mustard, respectively.

DISCUSSION

Host plants of *N. cymoides* are generally abundant before sunflower crops are planted, upon which *N. cymoides* can build up its population. Similar trend of population increase in *Nysius natalensis* was reported by feeding on numerous host plants (Du Plessis *et al.* 2007).

Du Plessis *et al.* (2015) reported that wild host plants, namely, *Amaranthus hybridus* L. (Amaranthaceae), *Portulaca oleracea* L. (Portulacaceae), *Chenopodium album* L. (Chenopodiaceae), *Conyza albida* Spreng. (Asteraceae), are usually abundant in patches of varying size that constitute one or more species. Seeds of all these wild hosts and sunflower are suitable for feeding, development, and survival of *N. natalensis* that agree with our results.

To achieve the potential advantages of polyphagy via food mixing, host switching is necessary, requiring mobility and some orientation capabilities to secure the timely finding of a new food source (Mody *et al.*
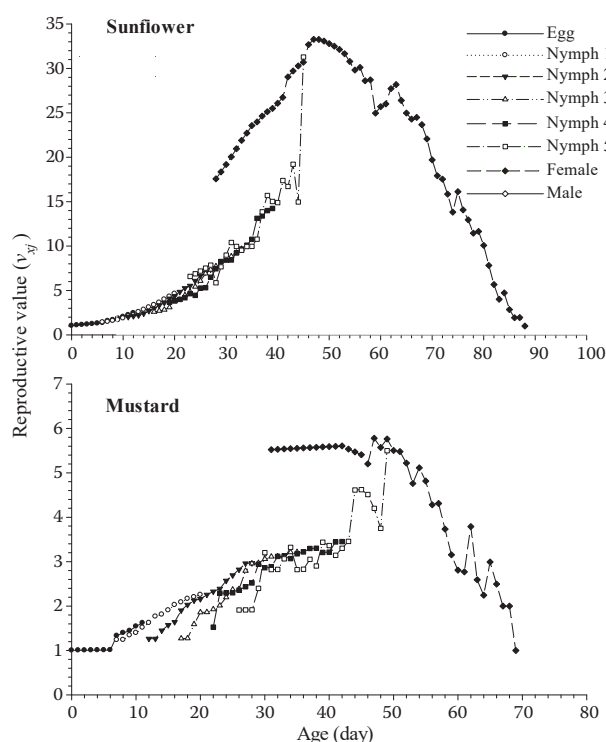
2007; Du Plessis *et al.* 2015). Regular intraspecific host plant change may provide specialist herbivores with an optimised diet that positively affects herbivore performance. When herbivores are mobile and can easily select the best plants within a limited plant range, intraspecific host variation should lead to an aggregated herbivore distribution and marked preferences for certain plant individuals (Mody *et al.* 2007; Du Plessis *et al.* 2015). Both *N. cymoides* adults and nymphs are mobile and within-generation movement between host plant species occurs (Rivnay 1962; M. Mollashahi, unpublished).

Quality and availability of host plant may play a role in pest population dynamics by influencing immature as well as adult efficiency (Golizadeh *et al.* 2009). No studies have investigated the influence of host plants on the developmental periods and life table parameters of *N. cymoides*. In the present study, there were significant differences in developmental times and adult longevity on sunflower and wild mustard. The immature period on wild mustard was longer than sunflower that was similar to other research results (Vattanakul & Rose 1982; Mohaghegh 2008). Although this period in *Nysius inconspicuus* Distant at 30°C on sunflower was much shorter than our results (Kakakhel & Amjad 1997), this differ-

ence could be related to temperature, species, and host plant. Our result showed that sunflower and wild mustard influenced development time, adult longevity, APOP, TPOP, and fecundity of *N. cymoides* significantly.

Slower developmental time of a herbivore on a particular host plant means a longer life span, usually a lower reproductive ability, slower population growth, and increased exposure to natural enemies. A faster developmental time on a particular host plant may allow a shorter life cycle and more rapid population growth and may also reduce generation time (Goodarzi *et al.* 2015). According to our results, shorter developmental time on sunflower (37.18 days) than on wild mustard makes it the more suitable host plant for *N. cymoides*.

Intrinsic rate of increase "*r*" is the most useful demographic parameter for contrasting the compatibility of populations across various weather and food resource conditions (such as cardenolids, glucosinolate, waxes, plant volatiles, leaf morphology or all of these factors) (Smith 1991; Soufbaf *et al.* 2010a, b, 2012; Goodarzi *et al.* 2015). Comparison of the intrinsic rate of increase often provides considerable insight in evaluating host plant suitability to herbivorous arthropods in integrated pest management programs (Fathipour & Sedaratian 2013; Rezaie *et al.* 2013; Ahmad & Shafiq Ansari 2014; Goodarzi *et al.* 2015). The value of *r* determines whether a population increases exponentially ($r > 0$), stable in size ($r = 0$), or declines to extinction ($r < 0$). Our results showed that sunflower and wild mustard affected *r* value of *N. cymoides.*

Mohaghegh (2008) obtained the *r* value (0.0717 per day), R_0 (32.86), and generation time (48.69 days) for *N. cymoides* feeding on Option canola cultivar and life table parameters on *N. wekiuicola* while feeding daily on *Drosophila melanogaster* such as the net reproductive rate was 15.4 (female offspring per female), the gross reproductive rate was 38.15 (offspring), the mean generation time was 39.7 days, intrinsic rate of increase (*r*) was 0.069 per day, and finally, the doubling time of the population assuming overlapping generations was 10.1 days (Eiben 2012) that differ with our results. This difference may be due to host and geographical area. In conclusion, the high *r* value on sunflower indicated that *N. cymoides* had a greater reproductive potential and it was maybe more appropriate host plant than wild mustard.

Although wild mustard species seems less suitable for development than sunflower, *N. cymoides* was still able to develop solely on this host plant. however, *N. natalensis* was also able to reproduce solely on *Amaranthus hybridus* L. therefore be regarded as a suitable wild host plant for oviposition over sunflower (Du Plessis *et al.* 2012, 2015).

Nysius cymoides is hosted by a variety of plant species many of which occur as weeds in crop fields (Rivnay 1962). Damage inflicted to sunflower by *N. cymoides* usually occurs when canola (*Brassica napus* L.) are harvested and wild host (such as wild mustard) are destroyed, therefore they move from weeds in summer to sunflower during seed fill (M. Mollashahi unpublished). Host switching by *N. cymoides* from its natural host plants to sunflower is therefore beneficial to the species. Its reproductive phase during summer therefore provides the pest with a good host plant species during the period just prior to winter. It explains their injuriousness to sunflower where they will feed on the seed and get moisture from plant sap when senescence of weed species occurs prior to winter. "Host plant switching by *N. natalensis* from its wild host plants to sunflower likely happens as a result of senescence of wild host plants prior to winter" (Du Plessis *et al.* 2015). Displacement of *N. vinitor* in Australia was also described by Kehat and Wyndham (1973) as a direct or indirect response to adverse conditions, among which food and water are of significant importance.

Sunflower pest, *N. cymoides* may well survive on an abundant weed species such as wild mustard. The informations of how host plants quality influence the life table parameters of *N. cymoides* can help to realise the population dynamics and select for the appropriate measures in control and management of this pest.

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