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# Glyphosate-based herbicides toxicity on life history parameters of zoophytophagous *Podisus nigrispinus* (Heteroptera: Pentatomidae)

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ABSTRACT

The increase of agricultural areas with glyphosate-resistant (GR) crops, and use of this herbicide in Brazil, makes necessary to assess its impacts on non-target organisms. The objective was to evaluate the development, reproduction and life table parameters of *Podisus nigrispinus* (Heteroptera: Pentatomidae) reared on GR-soybean plants treated with glyphosate formulations (Zapp-Qi, Roundup-Transorb-R and Roundup-Original) at the recommended field dose (720 g acid equivalent $ha^{-1}$). Glyphosate formulations had no affect on nymph and adult weight of this predator. Fourth instar stage was shortest with Zapp Qi. Egg-adult period was similar between treatments (26 days) with a survival over 90%. Zapp-Qi and Roundup-Transorb-R (potassium-salt: K-salt) reduced the egg, posture and nymph number per female, and the longevity and oviposition periods of this predator. *Podisus nigrispinus* net reproductive rate was highest in GR-soybean plants treated with Roundup-Original (isopropylamine-salt: IPA-salt). However, the duration of one generation, intrinsic and finite increase rates, and time to duplicate the population, were similar between treatments. Glyphosate toxicity on *P. nigrispinus* depends of the glyphosate salt type. IPA-salt was least harmless to this predator. Formulations based on K-salt altered its reproductive parameters, however, the development and population dynamic were not affect. Therefore, these glyphosate formulations are compatible with the predator *P. nigrispinus* with GR-soybean crop.

## 1. Introduction

Pesticides are the main method of controlling insects, diseases and weeds but they may cause environmental impacts, making necessary to search environmentally friendly and cheaper methods for pest control (Silva-Filho et al., 2014). Biological insect control is an important tool of the Integrated Pest Management (IPM) with low environmental impact (Kuar-Gill and Garg, 2014; Alcántara-de la Cruz et al., 2017). Parasitoids, entomopathogens and predators use is becoming a common practice to control agricultural pests (Lenteren et al., 2006; El-Wakeil et al., 2013).

The stink bug predator, *Podisus nigrispinus* Dallas (Heteroptera: Pentatomidae) naturally occurs in soybean crop (*Glicine max* L.) controlling pests (Castro et al., 2013), and it is used for the biological control of agriculture and forest pests (Zanuncio et al., 2016). This insect and other predators feed on plants to supplement their diet obtaining water, what favors their metabolism and predation (Grosman et al., 2005). *Podisus nigrisponus* may change feeding habits in periods of prey scarcity (Holtz et al., 2009).

The expansion of transgenic glyphosate-resistant (GR) crops, such as soybean, has been increasing the use of glyphosate [(N-phosphonomethy) glycine] (Kleter et al., 2011), a systemic non-selective herbicide globally used for over 40 years in weed management (Alcántara-de la Cruz et al., 2016b; Duke, 2017). Glyphosate is not a chemically pure active ingredient, and its formulations may be based on potassium salt (K-salt), ammonium salt ($NH_4$-salt) or isopopylamine salt (IPA-salt). This herbicide has low adverse effects on wildlife when properly used (Giesy et al., 2000). In Brazil, GR-soybean occupies 20.6 million ha corresponding to 86% of the total area of this crop (Hungria et al., 2014), making the use of glyphosate inevitable, often repeatedly and

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unduly. Under these circumstances, the glyphosate impact on the environment and non-target organisms continues raising concerns (Capinera, 2005).

Biological control can be combined with selective pesticides. The International Organization for the Biological Control (IOBC) has reports about pesticide effects on non-target organisms (Stark et al., 2007), some of them related to herbicide effects on amphibians (Jones et al., 2010), microorganisms (Zaller et al., 2014) or insects (Desneux et al., 2007; Schneider et al., 2009; Evans et al., 2010; Albajes et al., 2011; Szénási et al., 2014). However, conventional toxicological studies may under or overestimate the results, therefore assessment of the pesticide impacts on non-target organisms must integrate ecological parameters (Stark et al., 2007). Life tables indicate population increases, decreases or risks in different scenarios (Zanuncio et al., 2004, 2006).

*Podisus nigrispinus* exposition to glyphosate treated plants could affect its innate predation. The objective of this work was to evaluate the reproduction and development parameters of *P. nigrispinus* (non-target insect) reared on GR-soybean plants treated with glyphosate formulations through life table parameters.

## 2. Material and methods

### 2.1. Biological material

Experiments were conducted in a greenhouse at the Fitotecnia Department of the Univesidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais, Brazil. Five GR-soybean seeds (cultivar CD-219RR) were sown in pots (3 L) with substrate (soil: organic matter) fertilized with ammonium sulphate (equivalent to 50 kg N $ha^{-1}$). Two plants with 3–4 true leaves were kept after the germination.

*Podisus nigrispus* individuals were obtained from the Laboratory of Biological Control of Insects (LCBI/BIOAGRO) of UFV. Egg masses of *P. nigrispinus* were maintained in 9 cm Petri dishes in a controlled condition room with 25 ± 2 °C, 75 ± 5% relative humidity, and a photoperiod of 12 h until transferred to the greenhouse.

### 2.2. Treatments evaluated during the experiment

Three glyphosate formulations were tested: Zapp Qi (62% w/v K-salt; Syngenta Proteção de Cultivos Ltda, Brazil, Roundup Transorb R (58.8% w/v K-salt; Monsanto do Brasil Ltda, Brazil), and Roundup Original (48% w/v IPA-salt; Monsanto do Brasil Ltda, Brazil). Mention of trade names in this publication is solely for the purpose of providing specific information and does not imply their recommendation.

### 2.3. Nymph development

GR-soybean plants were immersed during five seconds in glyphosate solutions, with 720 g acid equivalent (ae) $ha^{-1}$ in a volume of 200 L $ha^{-1}$, following guidelines of the International Organization for Biological Control. Control plants were immersed in common water. *Podisus nigrispinus* development reared without plant and without herbicide also was evaluated in laboratory conditions.

Second instar nymphs were transferred to greenhouse. *Podisus nigrispinus* nymphs were placed on a trifoliolated soybean leaf (Zanuncio et al., 2004), in groups of ten individuals (experimental unit) inside of organza bags (20 × 30 cm), two hours after herbicide application. *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) pupae were offered *ad libitum* inside the bags to fed *P. nigrispinus* nymphs. Herbicide can reach the herbivorous insects predated by *P. nigrispinus* in field conditions and, for this reason, 50% of *T. molitor* pupae offered the first time were also immersed in the corresponding glyphosate solution. The organza bags were changed between leaves weekly.

The experiment was arranged in a completely randomized design with eight replications. The survival, weight and duration of each stage of *P. nigrispinus* were daily evaluated. After each molt, nymphs and the newly emerged adults were weighed on an analytical balance ( ± 0.1 mg). The Kaplan-Meyer model was used to determine the survival curves of *P. nigrispinus* nymphs.

### 2.4. Life table

*Podisus nigrispinus* adults with three days old were placed on treated soybean leaves (Zapp Qi, Roundup Transorb R, Roundup Original and water as control), inside organza bags with *T. molitor* pupae supplied *ad libitum*, as described before. Fifty per cent of *T. molitor* pupae offered the first time were immersed in the corresponding glyphosate solution.

Pre-oviposition, oviposition and post-oviposition periods besides the numbers of eggs per female and egg mass, incubation period and female longevity of fifteen *P. nigrispinus* pairs per treatment were daily evaluated, in a completely randomized design. The data were used to construct a *P. nigrispinus* life table. Gross reproductive rate ($G = \Sigma_{x=0}^{y} mx$); net reproductive rate [$Ro = \Sigma_{x=0}^{y} (lx)(mx)$]; the time necessary for the *P. nigrispinus* population to double in size ($DG = [\Sigma_{x=0}^{y} (lx)(mx)]/Ro$); intrinsic increase rate ($rm = \ln(Ro)/DG$); finite increase rate ($\lambda = antilog[(rm)(0.4343)]$); and time required to duplicate the population ($TD = \ln(2)/rm$) were estimated (Krebs, 2009), where: $mx$ = specific fertility (females number produced per surviving female in the age range $x$), $lx$ = survival rate (survival rate from age zero to the beginning of age $x$); and $x$= nymph stage.

### 2.5. Statistical analysis

Development and reproduction data of *P. nigrispinus* were submitted to ANOVA. The Tukey HSD test at 5% probability was used to separate means. Statistical analysis was performed with Statistix software (version 9.0; Analytical Software, USA). The life table parameters were calculated and analyzed with the SAS statistical program (SAS Institute Inc, USA) according to the Jackknife technique (Maia et al., 2000).

## 3. Results

### 3.1. Nymph stage

The glyphosate formulations did not affect *P. nigrispinus* weight of fourth instar and newly emerged adults. Insects reared without plant/herbicide had lowest weight, showing the importance of the plants to this predator (Table 1).

The duration of the fourth instar *P. nigrispinis* nymphs was shorter on plants treated with Zapp Qi and Roundup Transorb R, herbicides based on potassium-salt (K-salt) of glyphosate. However, these variations did not affect the total duration from egg to adult for this predator (Table 2).

The survival rate of *P. nigrispinus* nymphs was 89% in the control (reared on GR-soybean plants immersed in water), 94% in plants treated with Zapp Qi, and those individuals raised on plants treated

**Table 1**
Weight (mg) of fourth and fifth instar nymph adult males and females *Podisus nigrispinus* (Heteroptera: Pentatomidae) fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insects of the control were reared on plants immersed in water and without plant/herbicide.

| Treatments | Fourth[ns] | Fifth | Male | Female |
|---|---|---|---|---|
| Zapp Qi | 12.3 ± 0.5 | 34.7 ± 1.3 a | 50.5 ± 1.0 a | 72.2 ± 1.6 ab |
| Roundup Transorb R | 12.6 ± 0.5 | 35.9 ± 1.6 a | 48.2 ± 1.0 a | 70.2 ± 2.2 ab |
| Roundup Original | 11.1 ± 0.4 | 36.0 ± 1.5 a | 49.5 ± 1.0 a | 73.5 ± 1.4 a |
| Water immersion | 11.3 ± 0.5 | 35.0 ± 1.5 a | 48.5 ± 0.9 a | 70.3 ± 1.7 ab |
| Without plant/ herbicide | 11.3 ± 0.6 | 31.0 ± 1.2 c | 45.1 ± 1.0 b | 68.2 ± 1.2 b |

Means with the same letter per column do not differ at 5% probability by Tukey test. [ns] not significant at 5% probability. ± Standard error of the mean (n = 8).

**Table 2**
Duration (days) of second, third, fourth and fifth instar and form egg to adult of *Podisus nigrispinus* (Heteroptera: Pentatomidae) fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insect of control were reared on plants immersed in water and without plant/herbicide.

| Treatments | Second[ns] | Third[ns] | Fourth | Fifth[ns] | Egg-adult |
|---|---|---|---|---|---|
| Zapp Qi | 4.6 ± 0.6 | 3.7 ± 0.1 | 4.2 ± 0.1 b | 6.2 ± 0.1 | 25.7 ± 0.3 |
| Roundup Transorb R | 4.7 ± 0.1 | 3.9 ± 0.1 | 4.2 ± 0.1 b | 6.1 ± 0.1 | 26.2 ± 0.3 |
| Roundup Original | 4.6 ± 0.1 | 3.7 ± 0.1 | 4.6 ± 0.1 a | 6.2 ± 0.1 | 25.9 ± 0.2 |
| Water immersion | 4.9 ± 0.0 | 3.7 ± 0.1 | 4.5 ± 0.1 ab | 6.1 ± 0.1 | 26.2 ± 0.2 |
| Without plant/herbicide | 4.7 ± 0.1 | 3.7 ± 0.1 | 4.4 ± 0.1 ab | 6.1 ± 0.1 | 25.9 ± 0.4 |

Means with the same letter per column do not differ at 5% probability by the Tukey test. [ns] non-significant at 5% probability. ± standard error of the mean (n = 8).

with Roundup Transorb R and Roundup Original, or without plant/herbicide presented 96% survival. The high survival rate over 90% indicated compatibility of glyphosate formulations with this predator.

### 3.2. Adult stage

Egg and nymph numbers per posture, egg viability, and pre- and post-oviposition and incubation periods of *P. nigrispinus* eggs did not differ between treatments. The egg and nymphs number per female was higher in individuals reared on GR-soybean plants treated with Roundup Original, than those individual of the K-salt treatments. Female longevity ranged from 53.9 to 87.8 days between treatments. The longer longevity of *P. nigrispinus* females was with IPA-salt (87.8 days), resulting in the longest oviposition period (77.3 days) and postures number (28.8 times) compared to the others glyphosate treatments (Table 3).

Survival rate of *P. nigrispinus* ranged from 110 to 120 days in all treatments, except for those individuals reared on GR-soybean plants treated with IPA-salt, presenting a survival period of up to 129 days. High peaks of eggs and nymphs number per female per day of *P. nigrispinus* was observed at the beginning of its reproductive cycle, and low peaks at the end (Fig. 1). Patterns of eggs and nymphs number were similar between treatments, and the peaks coincided with those of high temperature during the period evaluated (Fig. 2).

### 3.3. Life table

Net reproductive rate (*Ro*) of *P. nigrispinus* differed between treatments. The females of this predator with GR-soybean plants treated with IPA-salt showed highest *Ro*. However, the period to duplicate the population (*TD*), the finite ($\lambda$) and intrinsic (*rm*) increase rates, and the duration of one generation (*DG*) of *P. nigrispinus* did not differ between treatments (Table 4).

Gross reproductive rate (*G*) of *P. nigrispinus* differed between treatments. The highest *G* was found with GR-soybean plants treated with IPA-salt. The highest fecundity (*mx*) of this insect was observed at 60 days old, and decreased until death with survival (*lx*) drop (Fig. 3).

## 4. Discussion

Nymph stage duration is important for mass rearing natural enemies for biological control of insects. Species with longer nymph period have higher rearing costs (Coudron et al., 2002). Similar weight gains of *P. nigrispinus* nymphs fed with soybean leaves treated with glyphosate and control is a major finding, because heavier females tend to be more productive (Zanuncio et al., 1996, 2002). This demonstrates the compatibility of *P. nigrispinus* with this herbicide. In addition, nymphs fed only with *T. molitor* (without plant/herbicide) presented the lowest weight gain, evidencing the important role of plants in the diet of this predator to complete satisfactory development, due to *P. nigrispinus* has zoophytophagous habit (Holtz et al., 2009). In the same way, the development of this predator is affected when fed only with plants (Grosman et al., 2005).

Low *P. nigrispinus* mortality in all treatments indicates harmless glyphosate formulations to this predator. Mortality is not the only parameter used to evaluate pesticide risks (Stark et al., 2007), because surviving individuals may be sterile or their mobility could be reduced (Castro et al., 2013). *Podisus nigrispinus* nymph survival over 89% is high, and the addition of plants in its diet increases this parameter in predatory stinkbugs (Oliveira et al., 2004).

*Podisus nigrispinus* longevity is biologically important, since those with longer longevity may be better adapted to environmental conditions (Evangelista et al., 2003). The lower longevity and shorter ovipositon period of females treated with formulations of K-salt, show that these herbicides were more harmful to this predator. On the other hand, the higher longevity and oviposition observed in females reared GR-soybean plants treated with IPA-salt, even, than in the control (water immersion), demonstrated that the glyphosate toxicity on *P. nigrispinus* depends of the salt type. The longevity reduction by glyphosate formulations based on K-salt, may be related to an insufficiency of some dietary component or element that is only found in plants, due to glyphosate causes biochemical alterations in plants that are even resistant (Zobiole et al., 2010, 2012). Glyphosate reduces photosynthesis activity, carbon metabolism, mineral nutrition, oxidative events and mainly blocks the shikimic acid pathway disturbing plant-microorganism interactions (Gherekhloo et al., 2017). Formulations based on K-salt could have caused higher disturbances in the shikimic acid

**Table 3**
Reproductive parameters of *Podisus nigrispinus* (Heteroptera: Pentatomidae) fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insect of control were reared on plants immersed in water and without plant/herbicide.

| Parameters | Treatments | | | | |
|---|---|---|---|---|---|
| | Zapp Qi | Roundup Transorb R | Roundup Original | Water immersion | Without plant/herbicide |
| Eggs number per female | 496 ± 92 b | 523 ± 102 b | 798 ± 63 a | 609 ± 73 ab | 634 ± 70 ab |
| Eggs number per posture[ns] | 28.5 ± 4.0 | 29.9 ± 2.5 | 27.8 ± 0.8 | 29.3 ± 1.5 | 25.1 ± 1.4 |
| Nymphs number per posture[ns] | 25.9 ± 3.9 | 25.0 ± 3.0 | 23.8 ± 0.8 | 23.6 ± 2.0 | 22.5 ± 1.2 |
| Nymphs number per female | 453 ± 83 b | 429 ± 101 b | 685 ± 56 a | 502 ± 70 ab | 569 ± 64 ab |
| Egg viability (%)[ns] | 85.4 ± 4.8 | 81.4 ± 6.7 | 83.0 ± 2.6 | 77.1 ± 5.4 | 86.3 ± 1.7 |
| Pre-oviposition period (days) [ns] | 5.9 ± 0.3 | 5.9 ± 0.5 | 5.1 ± 0.6 | 6.3 ± 0.7 a | 5.5 ± 0.2 |
| Post-oviposition period (days) [ns] | 3.7 ± 1.0 | 7.2 ± 2.7 | 5.8 ± 1.3 | 7.5 ± 2.1 | 4.1 ± 0.8 |
| Egg incubation period (days) [ns] | 6.8 ± 0.2 | 6.8 ± 0.3 | 7.4 ± 0.2 | 7.2 ± 0.3 | 7.1 ± 0.3 |
| Female longevity (days) | 53.9 ± 9.2 b | 56.3 ± 10.8 b | 87.8 ± 7.4 a | 71.7 ± 7.6 ab | 67.8 ± 7.9 ab |
| Oviposition period (days) | 44.4 ± 9.1 b | 43.2 ± 10.3 b | 77.3 ± 7.4 a | 57.9 ± 7.0 ab | 58.2 ± 7.5 ab |
| Postures number per female | 17.9 ± 3.2 c | 19.9 ± 4.0 bc | 28.8 ± 2.2 a | 20.6 ± 2.5 bc | 26.4 ± 2.9 ab |

Means with the same letter per line do not different at 5% probability by Tukey test. [ns] non-significant at 5% probability. ± standard error of the mean (n = 15).

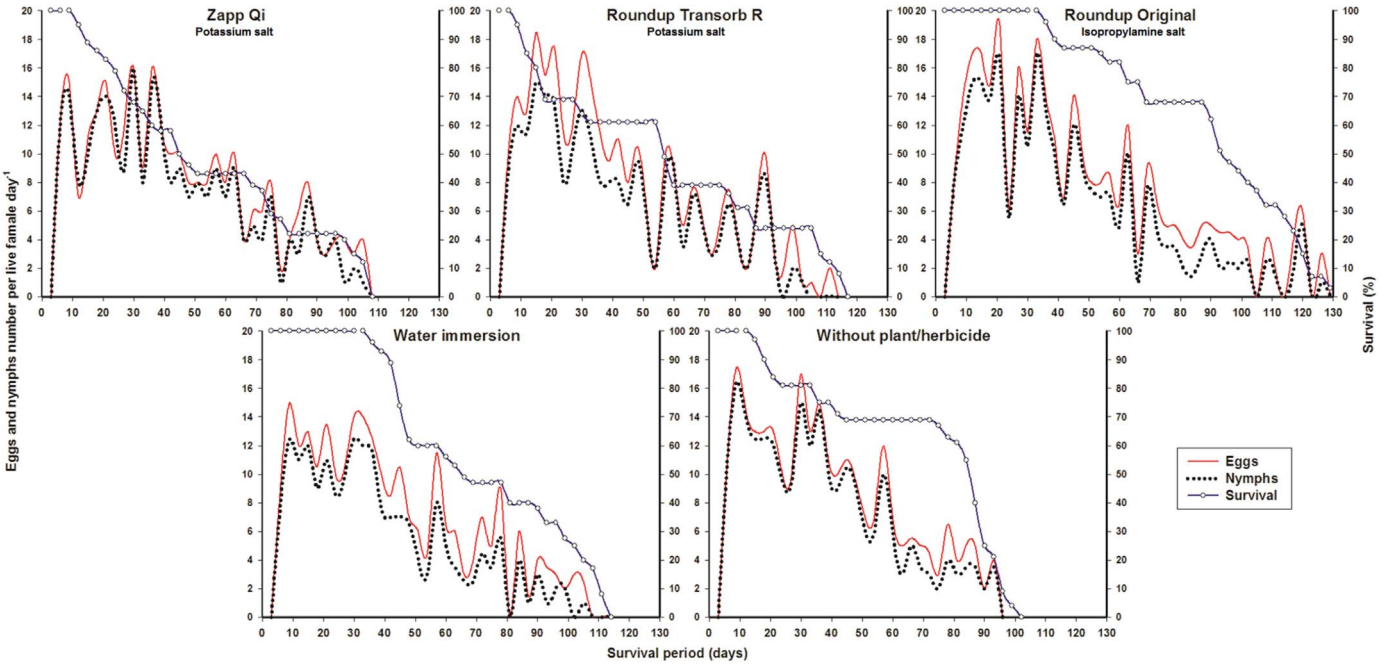


**Fig. 1.** Survival percentage and daily egg production per *Podisus nigrispinus* (Heteroptera: Pentatomidae) female fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insect of control were reared on plants immersed in water and without plant/herbicide.

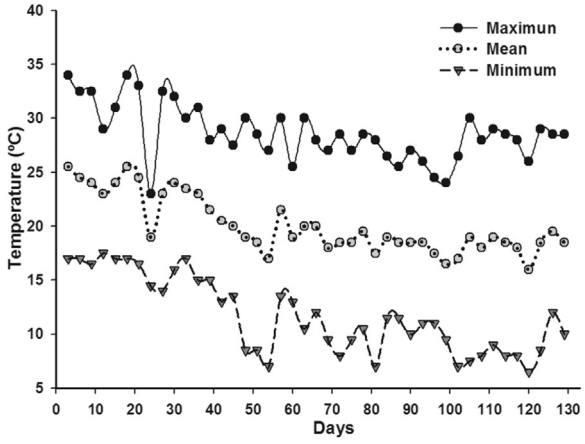


**Fig. 2.** Temperature regime in Viçosa, Minas Gerais state, Brazil during the reproductive stage (March to July 2013) of *Podisus nigrispinus* (Heteroptera: Pentatomidae) in greenhouse.

**Table 4**
Life table parameters of *Podisus nigrispinus* (Heteroptera: Pentatomidae) fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insect of control were reared on plants immersed in water and without plant/herbicide.

| Treatments | *Ro* | *TD* $^{ns}$ | $\lambda$ $^{ns}$ | *rm* $^{ns}$ | *DG* $^{ns}$ |
|---|---|---|---|---|---|
| Zapp Qi | 200 ± 37 b | 6.3 ± 0.2 | 1.1 ± 0 | 0.1 ± 0 | 48.4 ± 2.5 |
| Roundup Transorb R | 149 ± 29 a | 6.6 ± 0.3 | 1.1 ± 0 | 0.1 ± 0 | 47.5 ± 2.9 |
| Roundup Original | 289 ± 23 a | 6.4 ± 0.1 | 1.1 ± 0 | 0.1 ± 0 | 52.0 ± 1.6 |
| Water immersion | 173 ± 21 b | 6.5 ± 0.2 | 1.1 ± 0 | 0.1 ± 0 | 48.7 ± 2.1 |
| Without plant/herbicide | 216 ± 24 ab | 6.3 ± 0.1 | 1.1 ± 0 | 0.1 ± 0 | 48.8 ± 1.6 |

Means obtained by Jackknife technique with the same letter per column do not differ at 5% probability by Student´s *t*-test. $^{ns}$ non-significant at 5% probability. ± standard error of the mean (n = 15). *Ro* = net reproductive rate; *TD* = time required to duplicate the population; $\lambda$ = finite increase rate; *rm* = intrinsic increase rate; and *DG* = duration of one generation.

pathway of the GR-soybean plants, than those formulations based on IPA-salt. This essential metabolic pathway synthesizes phenylalanine, tyrosine and tryptophan (Alcántara-de la Cruz et al., 2016a), aromatic amino acids that could be indispensable for *P. nigrispinus*. Chemical analysis of GR-soybean plants, treated with different glyphosate formulations revealed reduction of N, Ca, Fe and Cu contents, and increase of Mg. The largest micronutrients reduction was caused by the K-salt formulation (Zapp Qi) (Santos et al., 2007), suggesting that these elements are also essential in the diet of *P. nigrispinus*.

The similar percentages of accumulated daily posture of *P. nigrispinus* between treatments, indicated that glyphosate formulations did not affected the egg posture. Some predators, such as *Supputius cincticeps* (Heteroptera: Pentatomidae), compensated longevity for fecundity (reduction of the second to maintain the first), contributing to the establishment and survival of this predator with prey shortage (Mourão et al., 2003). In this case, it was observed that *P. nigrispinus* did not compensate the fecundity for longevity, laying eggs continuously. In addition, the peaks number of eggs and nymphs per live female per day of *P. nigrispinus* depended of temperature, showed decreasing offspring production and increased longevity at lower temperatures. The maximum fecundity potential of *P. nigrispinus* is at 28–30 °C (Medeiros et al., 2003). At the beginning in this experiment, similar temperature regimes were observed during the adult stage of this predator, explaining its high eggs and nymphs production in all treatments.

Life table is a useful method to assessing pesticide toxicity because ecological and toxicological parameters are combined, resulting in better predictions of toxic effects at a population level (Stark et al., 2007). The highest net reproductive rate (*Ro*) and longevity in GR-soybean plants treated with IPA-salt allowed a higher offspring during the reproductive life of this predator. Similar results with high *Ro* and offspring per generation of *P. nigrispinus* was found with this predator reared with plant and prey has been documented (Oliveira et al., 2002; Evangelista et al., 2003).

*Podisus nigrispinus* delays offspring production in the same time and presents higher longevity, but its intrinsic increase ratio (*rm*) being smaller. This was observed for *P. nigrispinus* females in *Ageratum conyzoides* plants that, although presented higher *Ro* and lower *rm* than those in *Bidens pilosa*, where it presented longer longevity and offspring

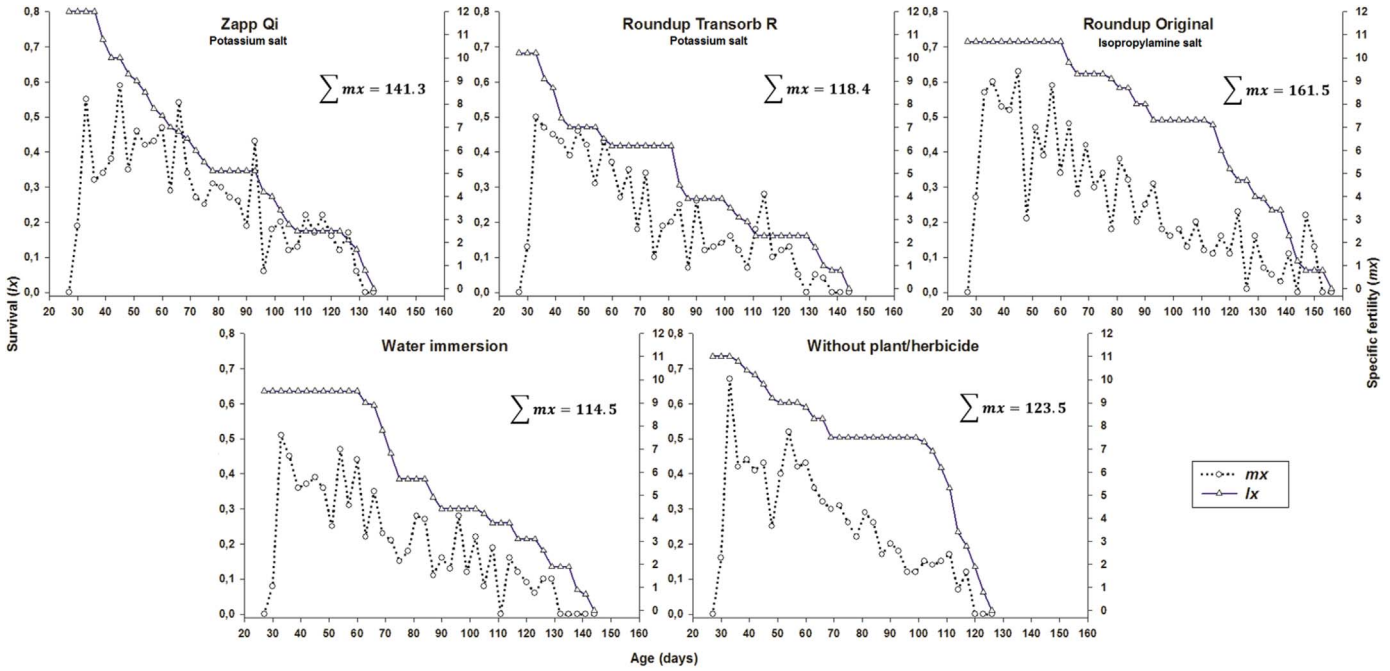


**Fig. 3.** Survival (*lx*) rate and specific fertility (*mx*) of the predator *Podisus nigrispinus* (Heteroptera: Pentatomidae) fed *Tenebrio molitor* (Coleoptera: Tenebrionidae) pupae, reared on glyphosate-resistant soybean (cultivar CD-219RR) plants immersed in glyphosate solutions. Insect of control were reared on plants immersed in water and without plant/herbicide.

production (Evangelista et al., 2003). *Brontocoris tabidus* reared on eucalyptus leaves in the field presented a longevity increase, allowing to improve its reproductive parameters (Zanuncio et al., 2006).

The higher *Ro* of *P. nigrispinus* was in GR-soybean plants treated with IPA-salt. However, the intrinsic increase rate (*rm*) was similar between treatments. This parameter is more feasible for toxicological studies, because is a statistic parameter based on survival (*lx*), fecundity (*mx*) and duration of one generation (*DG*), and its estimate is a specific environment (Stark et al., 2007). This showed that glyphosate formulations did not affect the reproductive capacity of *P. nigrispinus* in GR-soybean plants. *Podisus nigrispinus* presented similar behavior of these parameters when exposed to chlorantraniliprole (Castro et al., 2015), and already when exposed to deltamethrin they were affected (Oliveira et al., 2002). *Supputius cincticeps* also presented lower values of the duration of one generation (*DG*), *Ro* and *rm* when exposed to sublethal doses of permethrin (Castro et al., 2015).

A clear pattern of positive or negatives impacts of glyphosate cannot be demonstrated, because these tend to vary among species (Albajes et al., 2009; Kaur-Gill and Garg, 2014; Szénási et al., 2014). In this case, the formulation based on IPA-salt presented the longest longevity period of *P. nigrispinus* improving its reproductive parameters with the longest oviposition period and the highest postures number.

## 5. Conclusion

Glyphosate toxicity on *Podisus nigrispinus* depends of the glyphosate salt type. Isopropylamine-salt was the least harmless to *P. nigrispinus*, and although formulations based on potassium-salt affected its reproductive parameters, life history parameters, i.e., duration of one generation (*DG*), intrinsic (*rm*) and finite (λ) increase rates, and time to double its population (*TD*) were no affect, guaranteeing a population dynamic enough to maintain colonization of this predator in the agroecosystem. Therefore, herbicides based on potassium- and isopropylamine-salt of glyphosate are compatible with this predator in Integrated Pest Management programs in soybean crop.

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