Biology, abundance and control strategy of *Pentatoma rufipes* L. (Hemiptera, Pentatomidae) in organic pome fruit orchards in Germany

H. Alkarrat[1], J Kienzle[2] and C.P.W Zebitz[1]

Abstract

Pentatoma rufipes *L. (Hemiptera, Pentatomidae) is commonly found in Europe. In Southern Germany, the species was well known to cause damage in organic pear orchards. However, until now it was not noticed to cause damage in apple. In a monitoring over three years the occurrence of* P. rufipes *in 13 organic apple orchards in the Lake Constance area was monitoring and the infestations rate was compared with the occurrence of fruit damage. In 2019, fruit damage on apple was observed. Discoloured spots and discoloured depressions showed on apple fruits in the orchards where a high number of* P. rufipes *nymphs was found in spring in beating trap samples. Since in 2018 no damage was recorded even in orchards with high infestation, it has to be observed if this damage was due to the particular weather conditions in 2019 or if this will be the regular case in the future.*

The combination of Neudosan NEU®, a product based on potassium soap, and Trifolio-S-forte® showed first interesting results or the direct control.

Keywords: *Pentatoma rufipes*, biology, fruit damage, NEUDOSAN®

Introduction

Pentatoma rufipes L. (Hemiptera, Pentatomidae) is commonly found in most regions of Europe. The forest bug is a polyphagous species and feeds by using piercing mouthparts into leaves, flowers, buds and fruits. It belongs to the stink bugs and recently is causing important economic losses to a wide range of plants species such as pear, peaches and apricot. In Southern Germany, the species was well known to cause damage in organic pear orchards in Germany (Koenig, 2014) and all over Europe (Kehrli, P., Pasquier, D. 2012**;** Peusens, G., Beliën, T. 2012). However, until now it was not noticed to cause damage in apple. Since in Southern Germany it was more and more observed also in apple orchards, during three consecutive years (2017-2019) a monitoring was achieved to assess potential damage on apple fruits caused by this forest bugs species.

To better understand the biology of this pest, phenology of *P. rufipes* was studied in an apple orchard from spring to fall in 2019. In the previous years, the occurrence of the nymphs in autumn was monitored.

Furthermore, the efficacy of different insecticides suitable for organic fruit growing was tests in field and laboratory trials.

Material and Methods

Biology of *P. rufipes*: in 2019 monitoring was achieved in an organic apple orchard at Lake of Constance from march to October. Sampling was conducted by beating trap samples (100 trees per sample,1 branch/tree) at regular timings during the season. In the autumn of 2017 and 2018 and 2019 in the autumn beating trap samples have been done in weekly intervals to determine the occurrence of the nymphs. Dropping insects were collected in a tray, counted and identified (life stage L1, L2, L3, L4, L5 and adult).

[1] University of Hohenheim, Institute of Phytomedicine, Department of Applied Entomology, D-70593 Stuttgart, hamdow.alkarrat@uni-hohenheim.de

[2] Apfelbluetenweg 28, D-71394 Kernen

Monitoring of fruit damage: The study was conducted over 3 years (2017–2019) in 13 organic apple orchards in the Lake of Constance province, where *P. rufipes* has been observed. To determine fruit damage in June before thinning and in August before harvest, in each orchard 500 fruits were randomly taken and externally inspected. Three types of damage were distinguished: Type I: protuberances as often attributed to damage by Miridae, and discoloured spots and discoloured depressions. In this case, the level of damage was considered: Type II showed 1-5 spots, Type III: more than 5 spots on the fruits.

Field trials: Field trials were executed at different times during the season pre blossom and post-harvest in orchards with high infestation to test and compare the efficacy of several organic products.

Trial 1: Before blossom in 2019: The plots (8 rows * 25 trees, 2 plots per treatment) were arranged in a randomized complete block design in an apple orchard. Three treatments (Neudosan® 2 %, Trifolio-S- forte® 1 % and mixture of Neudosan® 2% and Trifolio-S- forte® 1 %) were applied. The application was done by the farmer with a modulation of the sprayer for 800 l water/ha. Each row was sprayed two times, on time in opposite direction. Beating trap samples (40 branches/replicate = 80 branches/treatment) were taken immediately before the spraying and after one, seven and fourteen days to determine the effect of these products on the occurrence of the 2nd instar nymphs of *P. rufipes*.

Trial 2: After harvest in 2019: The second experiment was conducted in two apple orchards in October 2019 to determine the effect of the mixture of Neudosan® 1% and Trifolio-S- forte® 1% on the bug in comparison with the effect of Spruzit® NEU 4,6 l/ha. Even in this trial in the Neudosan plot each row was sprayed two times, one time in opposite direction with a modulation of the sprayer for 800 l/ha. Spruzit was sprayed only one time with 800 l/ha water. The trial design was a randomized block design (175 trees per plot, 2 plots per treatment). Beating trap samples were taken directly before and 24 h after spraying.

Laboratory tests

Trial A: The efficacy of Neudosan 2%, Trifolio-S- forte® 1% and the mixture of both was tested. Five 2nd instar nymphs of *P. rufipes* were placed in a Petri-dish (9 cm diam.) containing a piece of an organic apple fruit. For each treatment, five Petri-dishes, with 5 nymphs each were treated with a hand held sprayer with the test solution (0.5 ml per dish). The number of dead *P. rufipes* nymphs was assessed after 2 h, 5h, 2, 3, 4, 8, and 12 days.

Trial B: The previous experiment was repeated by using different ratios of the mixture of Neudosan® and Trifolio-S- forte® as follows: **1-** Neudosan 2%+ Trifolio-S- forte® 1%, **2-** Neudosan® 1%+ Trifolio-S- forte® 1%, **3-** Neudosan® 0.5 %+ Trifolio-S- forte® 1% to determine the effectiveness of the best mixture ratio of these products. The number of dead nymphs was counted after 24, 48 and 72 hours. In all Experiments, the efficacy of each insecticide was calculated in relation to an untreated control and calculated as corrected mortality (%) according to Schneider- Orelli.

Results

Biology: Our data confirm that the forest bug *P. rufipes* is an univoltine insect and they show that it stays in the apple orchards during the entire year (fig 1). Three different morphological appearances can be distinguished: egg, 5 nymphal stages and adult. In 2019, mid-September the eggs hatched and the first young nymphs were found. Until winter they developed into the second instar. In spring, with the first warm days, the second nymphal stage (N2) become active again. In 2019, the nymphs completed their development by piercing into buds, flowers and fruits, and first adults emerged in 2019 at the end of June. However, in this year with a very long cold period in May, nymphs were still abundant in June and were found in the last instar even in July. During our surveys in 2017 and 2018, it was observed that in autumn the first nymphal instar emerged only at the end of October, but in 2019 first nymphs were found already at mid of September (Fig. 1). Thus, 2019 cannot be considered a typical year. Thus, it was tested to shift the application in autumn against the first instar nymphs considered the most sensitive, but this proved difficult since it seemed that the nymphs develop in few days to the second instar.

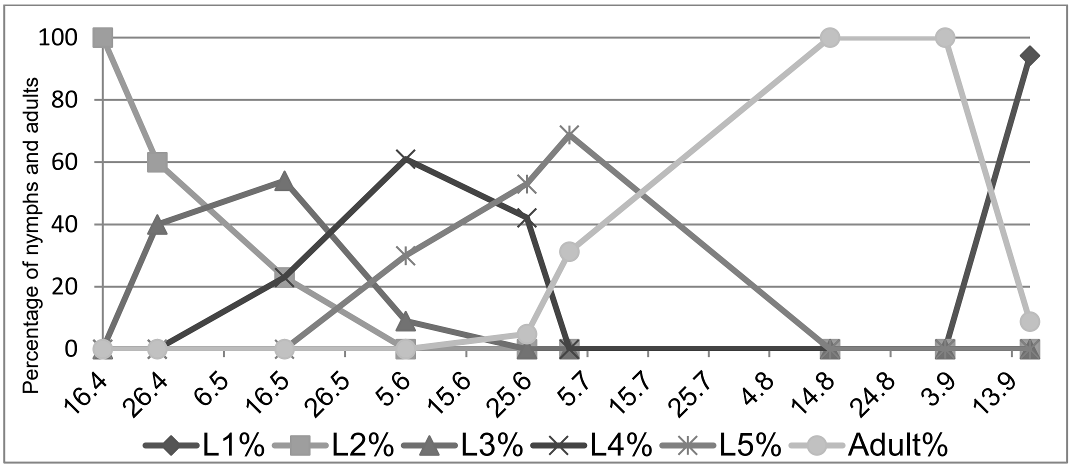

Figure 1 Biology of *P. rufipes* in the year 2019 under field conditions.

Fruit damage: In 2017 due to the frost damage, a monitoring was not possible. In 2018, no fruit damage, which could be attributed to bugs has been observed. In 2019, fruit damage has been observed on cv. Topaz, which could be attributed to bugs (table 1, Fig. 2). On cv. Braeburn, however, there was no fruit damage even if the bug population was 26 nymphs- In practice, in 2019 even higher damage than in the orchards included in the monitoring has been observed, which could be correlated to the occurrence of this bug. The early varieties Santana and Elstar were mainly concerned.

Table 1. Monitoring of the occurrence of *P. rufipes* nymphs in spring and apple fruit damage in 2019

orchard	Variety	Nymphs in beating trap 2.4.19	05.06.19				02.09.19			
			damage type I (%)	damage type II (%)	damage type III (%)	**Total damage type II and III**	damage type I (%)	damage type II (%)	damage type III (%)	**Total damage Type II and III**
1a	Topaz	0	1,6	0,4	0,2	**0,6**	1,2	0,4	0	**0,4**
1b	Topaz	75	4,6	1,6	2,2	**3,8**	3,6	1,4	1,4	**2,8**
2	Galant	0	1,4	0,4	0	**0,4**	1,8	0,2	0	**0,2**
3	Topaz	2	4,2	1	0	**1**	3	0,8	0,2	**1**
4	Santana	0	1,8	0	0	**0**	2	0	0	**0**
5a	Topaz	5	1	1,6	0	**1,6**	0,6	0,8	0	**0,8**
5b	Topaz	0	0,4	0,6	0,2	**0,8**	2	0	0,2	**0,2**
6	Topaz	26	5,8	4,2	1,2	**5,4**	6,6	3,2	0,4	**3,6**
7	Santana	8	10,8	1,8	0,4	**2,2**	12,2	3,4	0,4	**3,8**
8	Braeburn	26	1,2	0,4	0	**0,4**	2,2	0	0,2	**0,2**
9a	Topaz	5	1,2	0	0,2	**0,2**	5,8	1,4	0,6	**2**
9b	Topaz	4	0,2	0,6	0,2	**0,8**	4	0,2	0	**0,2**
10	Topaz	0	0	0,4	0	**0,4**	0,4	0	0	**0**
11	Topaz	0	1,4	0	0	**0**	1	0,2	0	**0,2**
12	Jonagold	2	0,4	0	0	**0**	1,8	0,2	0,4	**0,6**
13	Jonagold	4	0,4	0	0	**0**	3,6	0,8	0	**0,8**

Field tests: In test 1, the mixture of Neudosan® Neu 2% and Trifolio S-forte® 1% resulted in the highest efficacy (~70 % efficacy by Henderson and Tilton) compared with the efficacy of a singular application of the previous products (Fig.2).

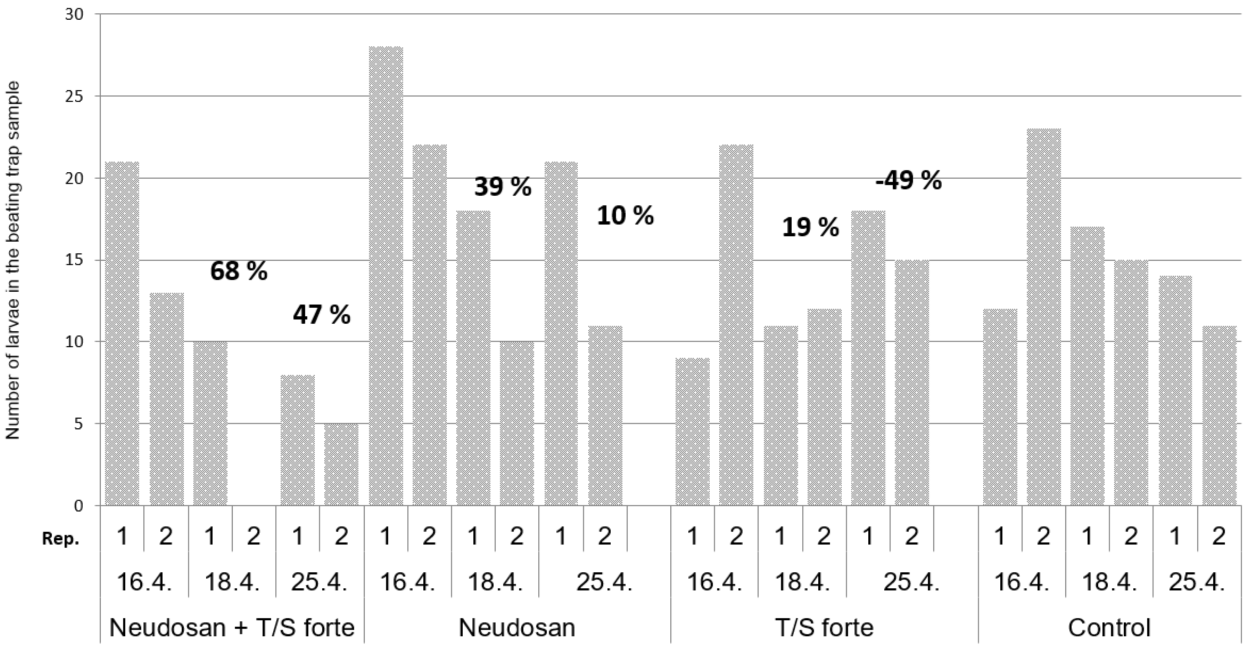

Figure 2: Number of nymphs of *P. rufipes* found before and after the application at Apr. 16, 2019 of Neudosan® 2 %, Trifolio S-forte® 1% and the mixture of both in each replicate in test 1. The efficacy (Henderson & Tilton) is indicated above the bars.

Test 2: The postharvest application of Spruzit® NEU and mixture of Neudosan® Neu 1% and Trifolio S-forte 1% reduced the number the overwintering N2 nymphs of *P. rufipes.* The efficacy of the mixture o Trifolio S- forte 1 % and Neudosan® Neu 1% was not as good as the effect of this mixture with Neudosan® 2 % in trial 1. In replication 2, it was nevertheless comparably low as the effect of Spruzit® NEU (Fig. 3).

Laboratory tests

Test A: The data indicate that both Neudosan® Neu 2% and Trifolio S-forte 1% reduced the number of bugs. Neudosan® Neu gave the highest reduction, and the mixture of these two products had efficacy, but it acted slower (Fig. 3).

After five days, more than 70 % of treated nymphs were killed by the application of Neudosan® Neu 2%, whereas Trifolio S-forte® 1% and the mixture killed ca. 50 % of the nymphs (Fig. 4).

Test B: The mixing ratio Neudosan® Neu 2% and Trifolio S-forte 1% was the best and in this test it killed 60 % exposed nymphs within 3 days, exerting the highest efficacy (Fig. 5). Less than 50% of treated nymphs were killed in the first two days when they treated with all mixtures.

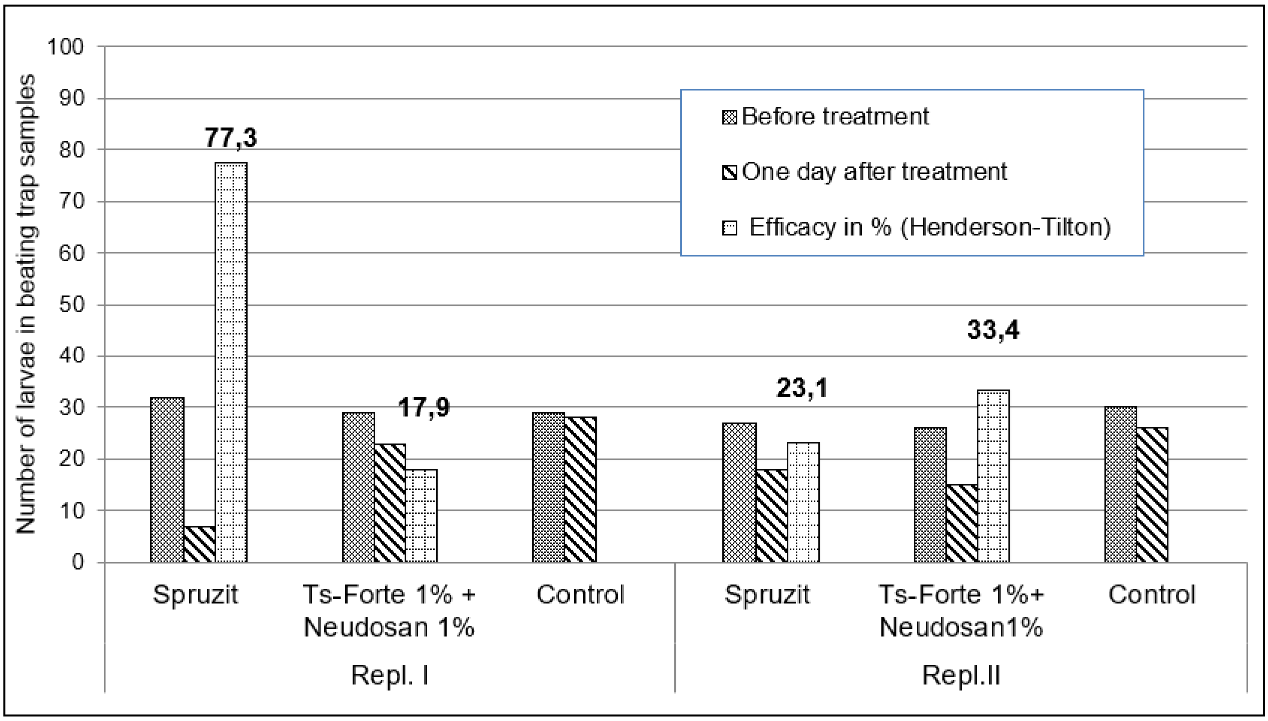

Fig. 3. Number of nymphs of *P. rufipes* found before and after the application at 16.4.2019 of Spruzit 4,6 l/ha and the mixture of Neudosan® 1 % and Trifolio S-forte® 1%. The efficacy (Henderson & Tilton) is indicated above the bars.

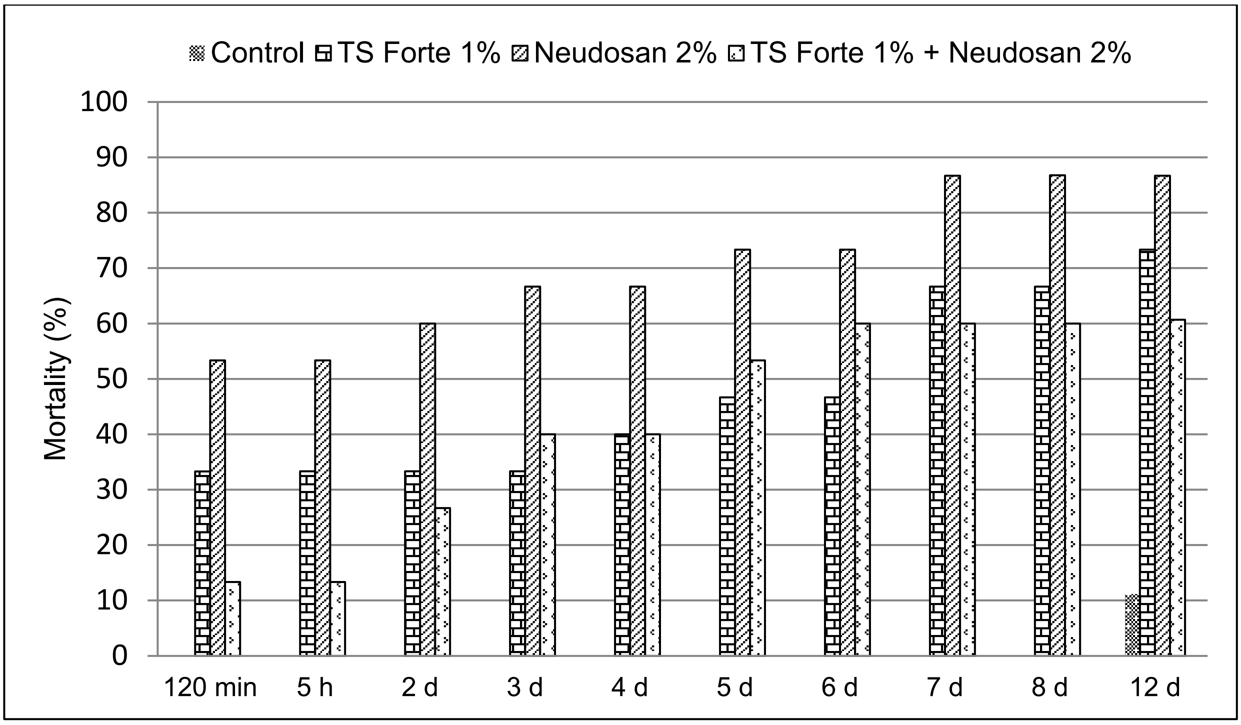

Fig. 4 Effect of the mixture of Neudosan® 2%+Trifolio S-forte® 1% and Spruzit® 2% on the second nymphal stage of *P. rufipes* in the laboratory

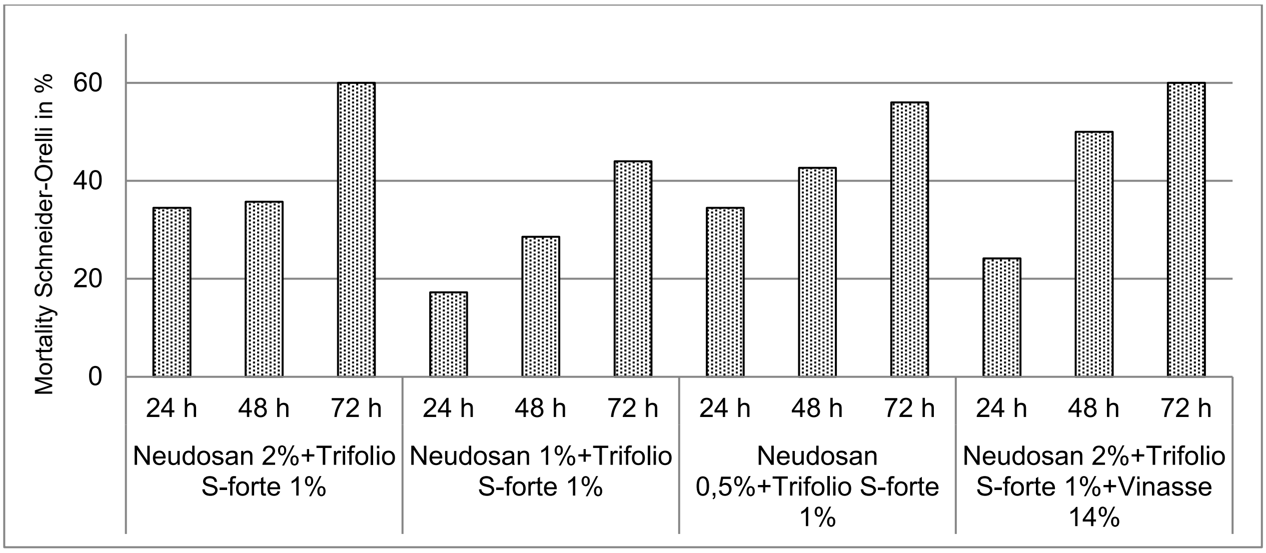

Fig. 5 Corrected mortality of second nymphal instar *P. rufipes* after 24, 48 and 72 h when exposed to different dosages of mixture Neudosan® and Trifolio S-forte®

Conclusions

P. rufipes is present in many apple orchards in the Lake Constance area. In 2019, for a first time considerable fruit damage was observed that could be attributed to this bug. This may be due to the extremely cold period in May in 2019 which resulted in the occurrence of bug nymphs during the period of development of the young fruits. Since in 2018 no damage has been recorded even in orchards with high infestation, it has to be observed if this damage was due to the particular weather conditions in 2019 or if this will be the regular case in the future. Whether the future monitoring will show if there is a need to control *P. rufipes* even in apple orchards, in each case, in pear orchards, there is strong need for control measures suitable to organic farming. Since pyrethrum products are concerned to have side effects on beneficial insects, the combination of Neudosan® Neu and Trifolio-S forte® is very attractive. In the first tests, since the rows were treated twice, the amount applied of Neudosan® per ha was higher than intended in the authorization. An attempt to reduce the concentration to 1 %, the efficacy was not convincing. The laboratory tests confirmed that 2 % is necessary. Thus, in spring, the field trials will be continued with Neudosan® 2 % mixed with Trifolio-S forte® but the apple rows will be treated only once.

Graph 1; Fruit damage Type I (left) and Type III (right) at harvest

However, even if the efficacy of this treatment will be comparable to the application of pyrethrum, other measures are needed in the strategy. Since it seems, that *Trissolcus japonicus* is able to parasitze *P. rufipes* (Alkarrat et al., 2020), in the future the release of this parasitoid might be an additional valuable tool in the control strategy of this and other bugs if approved and authorized as biocontrol agent.

The brown marmorated Stink bug (*Halyomorpha halys Stål*) is the most dangerous pest among these species, which has been described by Stål as *Pentatoma halys* from China in 1855, and now is considered a recent neozoon in Europe (Rabitsch 2008, Milonas and Partsinevelos 2014) and North America (Hoebeke and Carter 2003, Fogain and Graff 2011). Moreover, Callot and Brua, 2013 reported that populations of *H. halys* has been established in Europe.

Acknowledgements

We acknowledge financial support of BMEL/BLE (BOELN 2815OE074**)**.

References

Alkarrat, H., Kienzle, J. & Zebitz, C.P.W. (2020): Is the brown marmorated stink bug parasitoid *Trissolcus japonicus* (Ashmead) already in Germany? Proceedings ecofruit 2020, *in press*

Callot, H., & C. Brua. (2013). *Halyomorpha halys* (Stål, 1855) la Punaise diabolique, nouvelle espèce pour la faune de France (Heteroptera Pentatomidae). L'Entomologiste 69: 69-71.

Fogain, R., & S. Graff. (2011). First records of the invasive pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), in Ontario and Quebec. Journal of the Entomological Society of Ontario 142: 45-48.

Henderson, C.F. &. Tilton, E. W. (1955).Tests with acaricides against the brow wheat mite, Journal of Economic Entomology 48:157-161.

Hoebeke, E.R.& Carter, M.E. (2003). Halyomorpha halys (Stål) (Heteroptera: Pentatomidae): A polyphagous plant pest from Asia newly detected in North America. Proceedings of the Entomological Society of Washington 105: 225-237.

IKehrli P. & Pasquier D. (2012). Biology and impact of the forest bug *Pentatoma rufipes* L. (Heteroptera, Pentatomidae) in pear and apricot orchards. IOBC-WPRS Bulletin. 74: 33-37.

Koenig, V. (2014). Phänologie, Schadwirkung und Bekämpfung von *Pentatoma rufipes* L. im ökologischen Obstbau. MSc-thesis, University of Hohenheim, 78 pp.

Milonas, P. G. & Partsinevelos, G.K. (2014). First report of brown marmorated stink bug *Halyomorpha halys* Stal (Hemiptera: Pentatomidae) in Greece. Bulletin OEPP/ EPPO Bulletin, 44: 183-186.

Peusens, G. & Beliën, T. (2012). Life cycle and control of the forest bug *Pentatoma rufipes* L. in organically managed pear orchards. Communications in Agricultural and Applied Biological Sciences 77: 663-6.

Rabitsch, W. (2008). Alien true bugs of Europe (Insecta: Hemiptera: Heteroptera). Zootaxa 1827: 1-45.