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Influence of processed *Halyomorpha halys* bugs on the aroma and taste of 'Chardonnay' and 'Merlot' musts and wines

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Summary

Native to East Asia, the invasive brown marmorated stink bug (*Halyomorpha halys*) was accidentally introduced into Switzerland around 2004 and is now spreading all over Europe. This pentatomid is highly polyphagous and attacks vegetables, field and tree crops as well as soft fruits. Moreover, all development stages of *H. halys* are found in vineyards, suggesting that grapevine is also a host plant for this insect. Nonetheless, its actual effects on European wine production is unclear. As such, we studied the impact of processed *H. halys* on the aroma and taste of grape musts and wines. We artificially contaminated 'Chardonnay' and 'Merlot' grapes with up to ten *H. halys* nymphs and adults per kg grapes directly before the vintage was crushed. In the freshly pressed must, the addition of 1 living bug·kg^{-1} grapes did not affect the olfactory sensation of the 'Chardonnay' juice. However, the aroma and taste of 'Chardonnay' juices and 'Merlot' musts contaminated with 3 to 10 *H. halys* individuals·kg^{-1} grapes could be distinguished from the uncontaminated controls and were perceived as 'vegetal' and 'woody'. Yet after bottling, the different wines with 0 to 10 *H. halys* individuals·kg^{-1} grapes could no longer be differentiated from each other in 2-out-of-5 discrimination tests. Amongst 17 rated organoleptic descriptors to characterise the sensory profile of the four 'Chardonnay' wines, only two showed significant differences; the 'colour intensity' increased and wines' 'harmony/finesse' decreased with the number of added bugs. For the three 'Merlot' wines, none of the 21 organoleptic descriptors of the sensory profiles differed significantly. In addition, winegrowers did not dislike *H. halys* contaminated 'Chardonnay' and 'Merlot' wines compared to their uncontaminated controls one year after bottling. It therefore seems that the molecules responsible for the off-flavours in contaminated musts volatilise to a large part during the fermentation process. Our results consequently indicate that a contamination of the vintage with *H. halys* has the potential to alter the quality of grape juices and musts but that there is little risk for influencing the taste of processed wines. Nonetheless, we recommend monitoring the development of *H. halys* in vineyards in order to anticipate quantitative and qualitative problems at harvest.

K e y w o r d s : *Vitis vinifera*; Pentatomidae; Hemiptera; wine making; sensory analyses; organoleptic tests.

Introduction

The brown marmorated stink bug, *Halyomorpha halys* (Stål) (Hemiptera, Pentatomidae), is an invasive insect pest accidentally introduced to North America, South America and Europe from East Asia (Leskey and Nielsen 2018). This pentatomid is highly polyphagous and it has been reported to feed on at least 106 plant species from 45 families in its native range (Lee *et al.* 2013) and more than 170 species in North America (Leskey and Nielsen 2018). Considered as an arboreal species, *H. halys* also attacks field crops, vegetables, ornamentals, pome fruits, stone fruits as well as soft fruits and causes substantial economic damage (Haye and Weber 2017; Hamilton *et al.* 2018). In apples only, ca. US$37 million were lost to this insect in the mid-Atlantic region of the USA in 2010 (Rice *et al.* 2014). Probably introduced in Europe already in 2004, *H. halys* has been officially recorded for the first time in the region of Zurich (Switzerland) in 2007 (Wermelinger *et al.* 2008). Whereas not detected in Italy before 2012, *H. halys* has quickly outnumbered all other bug species and has caused severe yield losses in the fruit orchards of the Emilia Romagna region since 2014 (Maistrello *et al.* 2017).

Halyomorpha halys is reported to be an occasional pest in Asian vineyards (Ohira 2003) and all development stages were found on North American grapevines (Basnet *et al.* 2015). Thus, grapevine has to be considered as a reproductive host plant for this stink bug (Basnet *et al.* 2015). In vineyards, *H. halys* has the potential to either (i) cause direct injury to grapes and thereby reduce yield, (ii) favour the development of grey mould and other late season rot diseases, or (iii) impact the taste of grapes, musts and/or wines (Fiola 2011). Smith *et al.* (2014) showed that the presence of *H. halys* nymphs and adults during and after the period of fruit set increased the number of pierced and damaged berries, but pest densities had to be extreme and sustained over a prolonged period of time until they affected yield (e.g. 5 adults per grape cluster for more than 2 weeks). There was little evidence that feeding punctures increased the incidence of fungal diseases at harvest (Smith *et al.* 2014). However, the extent to which the presence of *H. halys* in grape clusters impacts the taste of fresh berries,

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grape juices and wines remains unclear. Although its presence on table grapes might affect the visual appearance and weight of clusters (Smith *et al.* 2014, Kehrli *et al.* 2019), a direct alteration of their taste has, to our knowledge, so far not been documented. Similarly to ladybeetles (Pickering *et al.* 2005, Galvan *et al.* 2007, Linder *et al.* 2009) and earwigs (Kehrli *et al.* 2012), the presence of *H. halys* in processed grapes has been shown to impart a perceptible taint in the pressed juice through the release of volatile defence compounds as a stress response (Fiola 2011, Harris *et al.* 2015). Stress compounds of this stink bug include the odourless tridecane and *trans*-2-decenal. *Trans*-2-decenal is considered to be the main component of the *H. halys* bug taint due to its strong 'green', 'coriander'-like aroma (Fiola 2011, Mohekar *et al.* 2017a). Whereas this bug taint did not alter the taste of fermented 'Vidal blanc' and 'Cabernet Sauvignon' wines according to a study by Fiola (2011), another study by Tomasino *et al.* (2013) reported that 'Pinot noir' wines produced from *H. halys* contaminated grapes were significantly different from the control. Follow-up studies by Mohekar *et al.* (2017b) highlighted that the stress compounds tridecane and *trans*-2-decenal are predominantly released during pressing and that their concentration strongly drops during the fermentation of wines.

This study aimed at examining the effect of processed *H. halys* on the sensory quality of juices, musts and wines. In order to assess the risk for two common and internationally representative grape cultivars, we artificially contaminated white 'Chardonnay' and red 'Merlot' grapes with *H. halys* nymphs and adults at levels that could reasonably be expected in vineyards and that are comparable to Mohekar *et al.* (2017b). Compared to most previous studies, the aroma and taste of the proceeded juices, musts and wines were directly assessed by trained tasters. Thus, the organoleptic properties of grape juices and musts were analysed in extended free sorting tasks and the finished wines were analysed by conventional 2-out-of-5 discrimination tests to establish if there were differences between treatments and controls. Additionally, we also characterised aroma and taste of finished 'Chardonnay' and 'Merlot' wines with sensory profiles, and wines were tasted and rated by professional winegrowers and winemakers one year after their bottling.

Material and Methods

Halyomorpha halys contaminated wines: 'Chardonnay' and 'Merlot' grapes were artificially contaminated with different densities of brown marmorated stink bugs directly before grapes were crushed. Nymphs and adults of *H. halys* originated from our permanent laboratory culture at Agroscope where insects were reared on fresh beans as well as peanuts and sunflower seeds within transparent plastic boxes (26 x 17 x 10 cm) in a climate chamber at 23 ± 1 °C, 70 ± 10 % r.h. and L16:D8 photoperiod.

White 'Chardonnay' grapes harvested on 20 September 2017 were contaminated with four different densities of *H. halys* (0 [= "uncontaminated control"], 1, 5 and 10 individuals·kg^{-1} grapes; referred as "bug·kg^{-1}"), whereupon about half of the applied number of individuals consisted of adults and the other half consisted of last nymphal instars. The respective number of living bugs was added every time to 50 kg grapes directly before grapes were crushed. The crushed grapes were thereafter pressed in a horizontal pneumatic bladder press (maximum pressure: 2 bars). After pressing, the juices of the four different treatments were sulphited with 50 mg·L^{-1}. They were cleared with 1g·hL^{-1} Littozym® Kler P enzyme and settled after 48 h. Thereafter, they were inoculated with the *Saccharomyces cerevisiae* yeast CY3079® at 20 g·hL^{-1}. Following the alcoholic fermentation, the four wines were inoculated with *Oenococcus oeni*. After the completion of the malolactic fermentation, the wines were racked and subsequently stabilised chemically by the addition of 50 mg·L^{-1} SO_2 and physically at 1 °C for 4 weeks. In February 2018, the four wines were filtered and bottled.

On 28 September 2017, red 'Merlot' grapes were contaminated with three different densities of living *H. halys* nymphs and adults (0 [= "uncontaminated control"], 3 and 10 individuals·kg^{-1} grapes; referred as "bug·kg^{-1}"). Each time 36 kg grapes were crushed together with the respective number of living bugs; once again with about the same number of adults and last nymphal instars. After sulphitation at 50 mg·L^{-1} and inoculation with the *S. cerevisiae* yeast Zymaflor®FX10 at 20 g·hL^{-1}, crushed grapes underwent seven days of skin fermentation in three different vats. They were thereafter pressed in a pneumatic tank press (maximum pressure: 2 bars) and the malolactic fermentation was induced by the inoculation with *O. oeni*. Subsequently, the three wines were racked and stabilised chemically by the addition of 50 mg·L^{-1} SO_2 and physically at 1 °C for 4 weeks. Filtered wines were bottled in February 2018.

Chemical properties of juices and wines: One day after pressing, the basic chemical properties of the four 'Chardonnay' juices such as sugar content, pH, acidity, nitrogen (see Tab. 1 for details) were analysed with FTIR (WineScan™, Foss). In April 2018, ethanol, pH, acidity and SO_2 (see Tab. 2 for details) were measured for all 'Chardonnay' and 'Merlot' wines with FTIR (WineScan™, Foss).

Organoleptic properties of juices, musts and wines: Four to five days after pressing, the organoleptic properties of 'Chardonnay' juices and 'Merlot' musts were analysed in extended free sorting tasks. Each 'Chardonnay' juice and 'Merlot' must was served in two black INAO glasses and the 11 to 15 nonprofessional, but well trained wine experts of the Changins panel had to match and characterise the different pairs in order to verify if wines can be distinguished from each other by its organoleptic properties. Thus, for the four 'Chardonnay' juices panellists had to group the eight glasses in four pairs of two. They first did this according to their olfactory and then to their gustatory perception. Likewise, the six glasses of 'Merlot' musts had to be grouped in three pairs of two according to their odour and taste. Data were recorded using Fizz software (Biosystemes®, Couternon, France) and analysed by non-metric multidimensional scaling (MDS).

Table 1

Chemical composition of 'Chardonnay' juices processed with living nymphs and adults of *H. halys* on 21 September 2017, one day after harvest and contamination (data for 'Merlot' musts not analysed)

	Sugar content (Brix)	pH	Total acidity ($g \cdot L^{-1}$)	Tartric acidity ($g \cdot L^{-1}$)	Malic cidity ($g \cdot L^{-1}$)	YAN[1] ($mgN \cdot L^{-1}$)
Chardonnay processed with						
0 bugs·kg^{-1} grapes (= uncontaminated control)	23.0	3.36	8.5	5.4	5.2	156
1 bug·kg^{-1} grapes	22.8	3.37	8.6	5.7	5.2	157
5 bugs·kg^{-1} grapes	22.9	3.36	8.7	5.6	5.3	176
10 bugs·kg^{-1} grapes	23.0	3.36	8.7	5.8	5.2	155

[1]Yeast assimilable nitrogen

Table 2

Chemical composition of ‘Chardonnay’ and ‘Merlot’ wines processed with living nymphs and adults of *H. halys* in April 2018

	Ethanol (% vol.)	pH	Total acidity ($g \cdot L^{-1}$)	Volatile acidity ($g \cdot L^{-1}$)	Free SO_2 ($mg \cdot L^{-1}$)	Total SO_2 ($mg \cdot L^{-1}$)
Chardonnay processed with						
0 bugs·kg^{-1} grapes (= uncontaminated control)	13.6	3.33	7.1	0.4	21	90
1 bug·kg^{-1} grapes	13.4	3.35	7.5	0.4	23	99
5 bugs·kg^{-1} grapes	13.5	3.30	7.5	0.4	18	88
10 bugs·kg^{-1} grapes	13.5	3.31	7.5	0.4	24	87
Merlot processed with						
0 bugs·kg^{-1} grapes (= uncontaminated control)	14.5	3.69	5.6	0.5	33	61
3 bugs·kg^{-1} grapes	14.6	3.71	5.8	0.5	31	63
10 bugs·kg^{-1} grapes	14.6	3.64	5.6	0.4	32	60

Three months after bottling, 'Chardonnay' and 'Merlot' wines were tasted in black INAO glasses in 2-out-of-5 discrimination tests (ISO 6658) by 11 to 15 judges of the Changins panel in order to examine if wines could be distinguished organoleptically among themselves.

Data were recorded using Fizz software and analysed by simple binomial tests (Smith 1981). Additionally, 9 to 12 well trained tasters working in the field of grape and wine production at Agroscope (= Agroscope panel) established the sensory profiles of the four 'Chardonnay' and three 'Merlot' wines. During these blind tastings, this descriptive analysis panel rated standardised and defined sensory descriptors for coded samples on a continuous linear scale ranging from 1 (bad/weak) to 7 (excellent/high). In two previous sessions, the panellists were trained and calibrated for the 17 and 21 defined descriptors (see Fig. 3) to characterise white and red wines, respectively. Data were also recorded using Fizz software and thereafter analysed with 1-way ANCOVAs. The various sensory descriptors were treated as dependent variables, judges served as a factor and *H. halys* density was included in the models as a quantitative covariate.

One year after bottling, three of the four 'Chardonnay' and all three 'Merlot' wines were finally blind tasted by three different groups of professional but untrained winegrowers and winemakers (for further information see Tab. 4). Participants were asked in three independent sessions to rank the three wines of the same cultivar presented in coded, transparent glasses according to their personal preferences. Thereafter the sum of ranks for each tasted wine was calculated and statistically compared with the other two using the method of Basker (1988).

Results

The addition of living *H. halys* nymphs and adults affected neither the start nor the duration of the fermentation of the four white 'Chardonnay' juices and the three red 'Merlot' musts. Similarly, the chemical properties of the four 'Chardonnay' juices, such as sugar content, pH, total acidity, tartric acidity, malic acidity and yeast assimilable nitrogen, were not considerably affected by the contamination of the grapes with *H. halys* (Tab. 1). Nevertheless, the 15 judges of the Changins panel were able to differentiate the odour of the juices of the uncontaminated control and of the 1 bug·kg^{-1} 'Chardonnay' grapes from the two higher *H. halys* concentrations in the extended free sorting task (Fig. 1a). Panellists characterised the juices of the two lower densities as having a stronger 'grape' note, whereas they perceived the two higher dosages as more 'vegetal', 'earthy' and 'woody'. 'Chardonnay' juices were similarly grouped when judges characterised the gustatory perception of the four juices (Fig. 1b). The uncontaminated control and the 1 bug·kg^{-1} grapes juices were perceived as 'sweeter' and having a 'fuller' mouthfeel, whereas the two higher *H. halys* densities were described as more 'herbal'. Alike, the odour of the three 'Merlot' musts could be clearly discriminated by the 11 Changins panellists in the free sorting task (Fig. 2a). The odour of the two uncontaminated 'Merlot' control musts was characterised as 'fruity'; the 3 bugs·kg^{-1}grapes musts were described as 'spicy' and 'vegetal'; while the 10 bugs·kg^{-1} grapes musts were noted as 'earthy'. However, the Changins panel failed to clearly distinguish between the three 'Merlot' musts (Fig. 2b) on the basis of taste. Whereas the two musts with 3 bugs·kg^{-1}

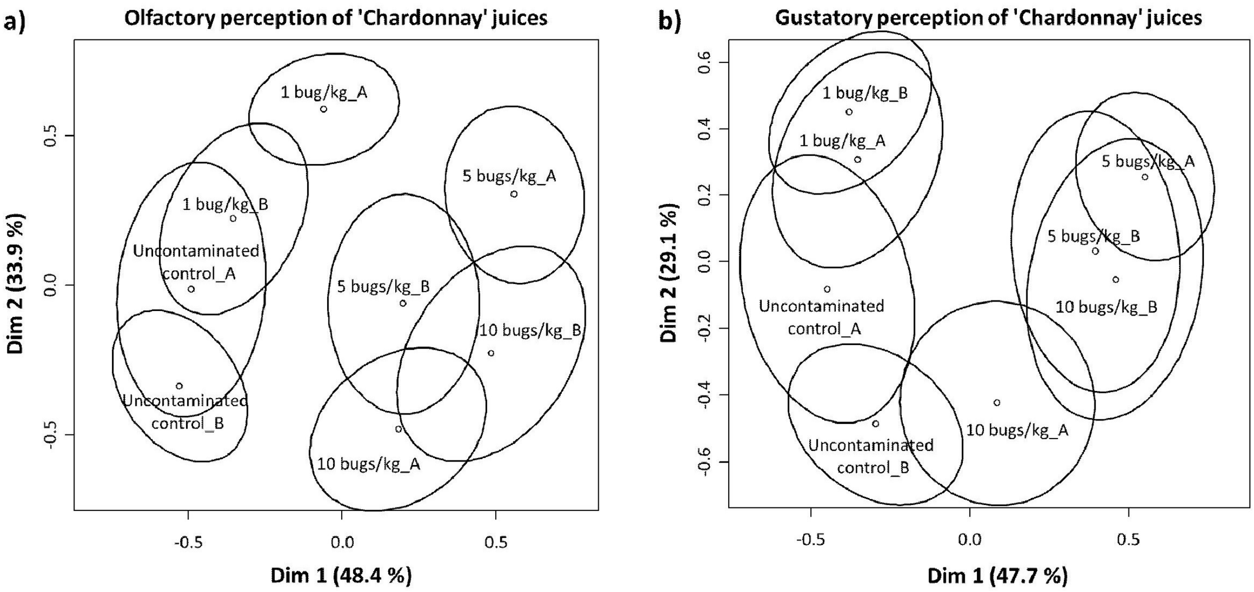

Fig. 1: First two axes of the multi-dimensional scaling plot for the free sorting task for **a**) olfactory and **b**) gustatory properties of the four 'Chardonnay' juices processed with living nymphs and adults of *H. halys*. The two duplicates of each juice are represented by the letters **A** and **B** and ellipses represent the 95 % confidence interval of each juice.

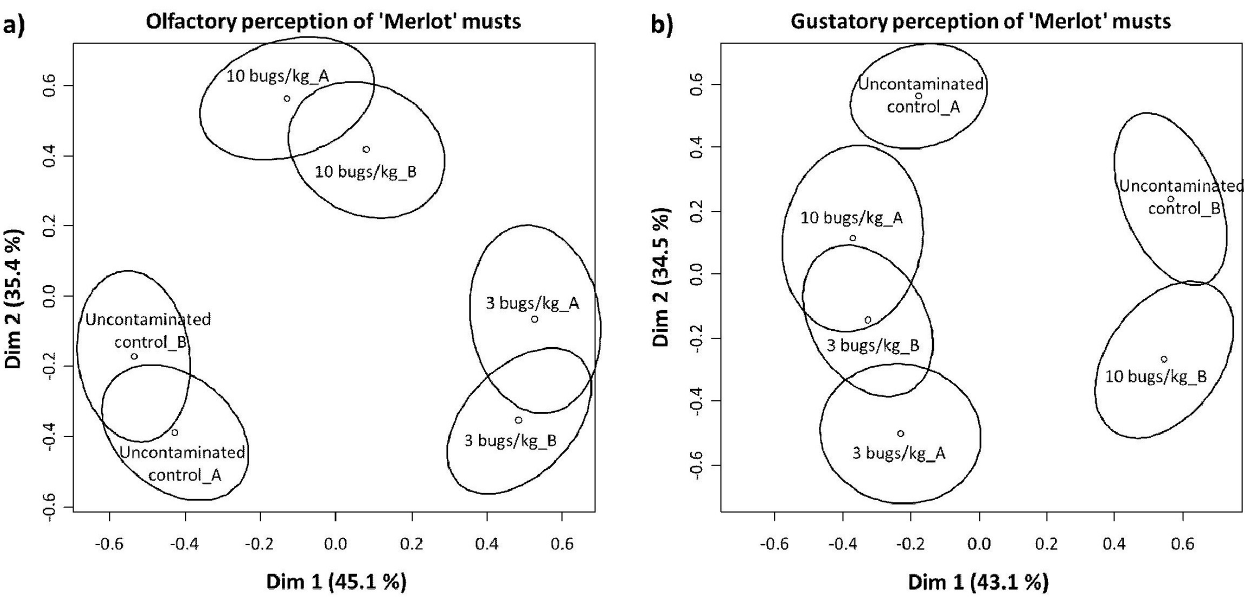

Fig. 2: First two axes of the multi-dimensional scaling plot for the free sorting task for **a**) olfactory and **b**) gustatory properties of the three 'Merlot' musts processed with living nymphs and adults of *H. halys*. The two duplicates of each must are represented by the letters **A** and **B** and ellipses represent the 95 % confidence interval of each must.

grapes could be grouped due to their sweeter taste, the panel confused the flavour of the uncontaminated controls and the 10 bugs·kg^{-1} grapes indicating that there was no gustatory difference between these two musts.

After bottling, the basic chemical properties of the four 'Chardonnay' and three 'Merlot' wines (e.g. ethanol, pH, total acidity, volatile acidity as well as free and total SO_2) were similar within the wines of the same cultivar (Tab. 2). Two months later, the judges of the Changins panel failed to discriminate the four 'Chardonnay' and three 'Merlot' wines among them in the 2-out-of-5 tests (Tab. 3). Thus, the uncontaminated 'Chardonnay' control could not be differentiated from the three contaminated 'Chardonnay' wines and the latter three could not be distinguished from each other. Likewise, the uncontaminated 'Merlot' control tasted similar to the two contaminated 'Merlot' wines and the latter two could not be discriminated among them (Tab. 3). Around the same period, the Agroscope panel established sensory profiles of all four 'Chardonnay' and all three 'Merlot' wines. Although there were highly significant differences in the rating of the organoleptic descriptors among judges, the sensory profiles of the four 'Chardonnay' and the three 'Merlot' wines were similar within the same cultivar (Fig. 3). For 'Chardonnay' wines, only two out of the 17 organoleptic descriptors were judged as differing significantly (Fig. 3a). First, 'colour intensity'

Table 3

Organoleptic comparisons of 'Chardonnay' and 'Merlot' wines processed with living nymphs and adults of *H. halys* in the 2-out-of-5 tests in June 2018

	Number of judges	Number of correct responses	*P*
Chardonnay			
Uncontaminated control vs 1 bug·kg^{-1}	15	2	0.45
Uncontaminated control vs 5 bugs·kg^{-1}	15	0	1.00
Uncontaminated control vs 10 bugs·kg^{-1}	15	1	0.80
1 bug·kg^{-1} vs 5 bugs·kg^{-1}	13	1	0.75
1 bug·kg^{-1} vs 10 bugs·kg^{-1}	13	2	0.38
5 bugs·kg^{-1} vs 10 bugs·kg^{-1}	13	0	1.00
Merlot			
Uncontaminated control vs 3 bugs·kg^{-1}	11	1	0.69
Uncontaminated control vs 10 bugs·kg^{-1}	11	2	0.30
3 bugs·kg^{-1} vs 10 bugs·kg^{-1}	11	0	1.00

significantly increased with the number of added *H. halys* from a mark of 4.12 to 4.25 ($F_{1,35}$ = 8.58, P = 0.006) and second, 'Chardonnay' wines that were more contaminated with *H. halys* were perceived as significantly less 'harmonious' and 'fine' with a mark of 4.00 for the uncontaminated control decreasing to 3.61 for the wine with 10 bugs·kg^{-1} grapes ($F_{1,35}$ = 4.49, P = 0.04). Additionally, bug contamination also tended to taste less 'acid' ($F_{1,35}$ = 3.35, P = 0.08) and to decrease 'floral' notes ($F_{1,34}$ = 3.33, P = 0.08) in these white wines (Fig. 3a). The three 'Merlot' wines could not be distinguished from each other by a single one of the 21 rated sensory descriptors (Fig. 3b).

One year after their bottling, three different groups of winemakers expressed their personal preferences for a selection of the processed wines. They did not dislike any of the *H. halys* contaminated wines compared to the uncontaminated controls (Tab. 4). On the contrary, the 10 bugs·kg^{-1} 'Chardonnay' grapes wine achieved a significantly better preference rating than its uncontaminated counterpart in two out of the three tasting sessions, while the 5 bugs·kg^{-1} 'Chardonnay' grapes situated somewhere in between. When the three 'Merlot' wines were tasted in Ticino (Switzerland), participants significantly preferred the wine contaminated with three individuals of *H. halys* per kg grapes to the highest dosage of 10 bugs·kg^{-1} grapes and the uncontaminated control wine was rated in between the two (Tab. 4).

Discussion

Our artificial contamination of grapes with *H. halys* shows that high densities of living bugs have the potential to affect the quality of fresh grape juices and musts, but that they barely alter the organoleptic properties of processed wines. These results complement the current knowledge on the impact of *H. halys* on the aroma and taste of wines and are in line with previous studies by Fiola (2011) and Mohekar *et al.* (2017b). The contamination of the vintage with up to 10 bugs before grapes' crushing did not affect the fermentation or the chemical properties of processed juices. However, tasters were able to differentiate the odour and aroma of intermediate to heavily infested juices and musts from the uncontaminated controls. At higher *H. halys* densities, contaminated 'Chardonnay' juices and 'Merlot' musts were perceived as more 'vegetal', 'herbal', 'earthy' and 'woody'. This is in accordance with the findings of Fiola (2011) who also noted a perceptible bug taint in pressed juices due to the stress response of the bugs during the processing of grapes. The perceived off-flavours originate probably from *H. halys*' alarm pheromone *trans*-2-decenal (Harris *et al.* 2015), which is an aromatic compound of strong, undesirable 'green', 'coriander' and 'musty'-like odour (Mohekar *et al.* 2017a). *Trans*-2-dece-

Table 4

Ranking of 'Chardonnay' and 'Merlot' wines by three different groups of professional winegrowers and winemakers in spring 2019. The lower the sum of ranks the higher the appreciation of the wine. The sum of ranks for each tasted wine in a series was calculated according to the method of Basker (1988) and wines with different letters were significantly different (P < 0.05)

	Number of tasters	Sum of ranks	Grouping (P < 0.05)
Chardonnay by Geneva			
Uncontaminated control	28	74	B
5 bugs·kg^{-1}	28	46	A
10 bugs·kg^{-1}	28	48	A
Chardonnay by Vaud			
Uncontaminated control	33	70	A
5 bugs·kg^{-1}	33	66	A
10 bugs·kg^{-1}	33	62	A
Chardonnay by Ticino			
Uncontaminated control	19	48	B
5 bugs·kg^{-1}	19	34	AB
10 bugs·kg^{-1}	19	32	A
Merlot by Ticino			
Uncontaminated control	19	40	AB
3 bugs·kg^{-1}	19	28	A
10 bugs·kg^{-1}	19	46	B

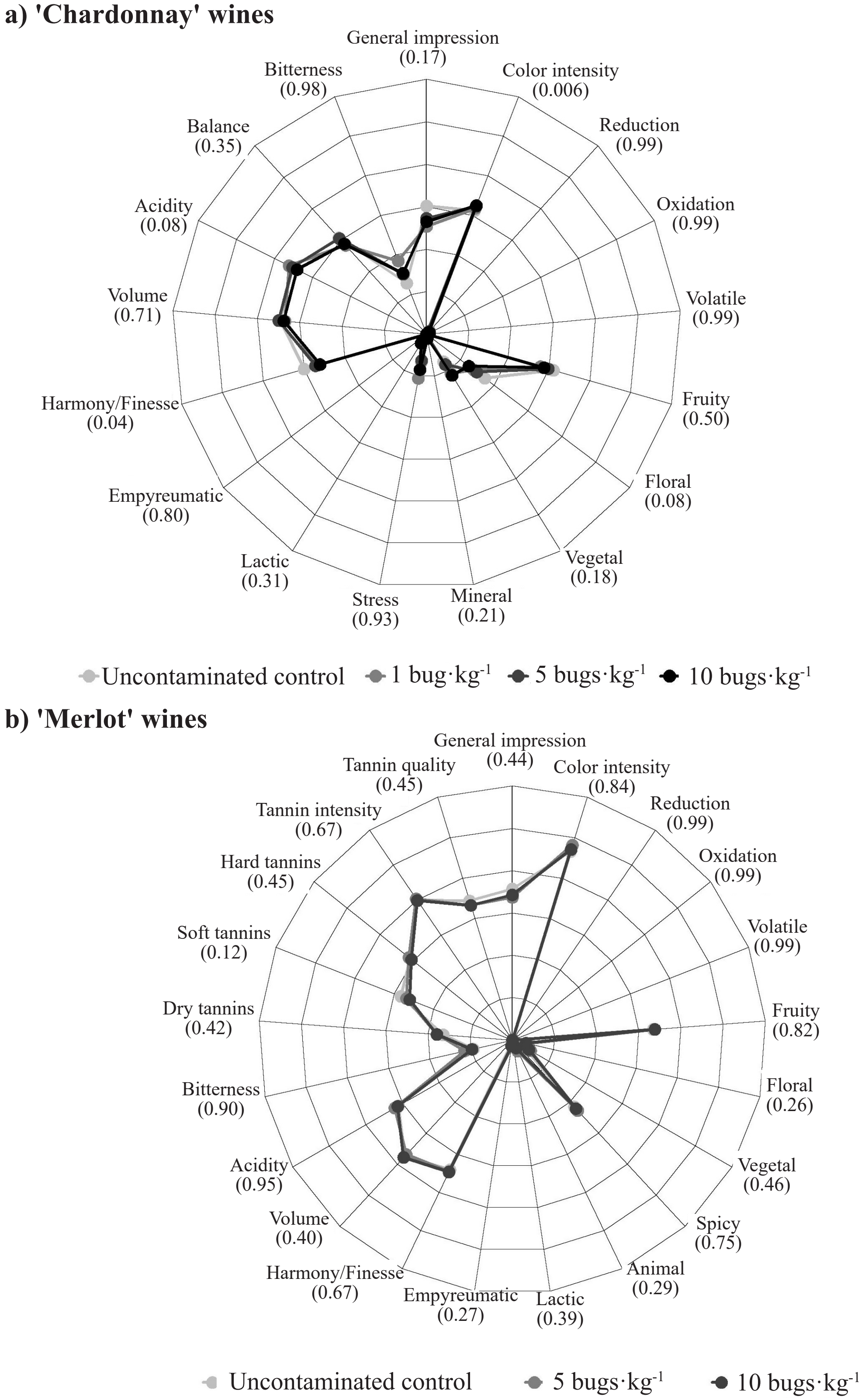

Fig. 3: Spider plots on the organoleptic properties of **a**) 'Chardonnay' and **b**) 'Merlot' wines processed with different levels of living nymphs and adults of *H. halys* (*P*-values in parentheses).

nal can be detected in 'Pinot noir' wines at an already very low dose of 1.9 to 4.9 $\mu g \cdot L^{-1}$ and it is rejected by consumers at a threshold of maximal 15.5 $\mu g \cdot L^{-1}$ (TOMASINO *et al.* 2013, MOHEKAR *et al.* 2017a). Products tainted at levels below the rejection threshold are considered as acceptable and marketable to consumers (MOHEKAR *et al.* 2017a). As MOHEKAR *et al.* (2017b) were able to show pressing is the most critical processing step for the release of *trans*-2-decenal by stressed bugs during vinification. Yet, *trans*-2-decenal is almost completely broken-down in the course of the alcoholic fermentation (MOHEKAR *et al.* 2017b). Thus, the risk of *H. halys* contamination affecting white wines is considered to be low since pressing occurs prior to fermentation (Mohekar *et al.* 2017b). In red wines however, the concentration of *trans*-2-decenal peaks twice. First, when grapes containing living bugs are destemmed and crushed. The subsequent alcoholic fermentation greatly reduces this first maximal peak. Second, *trans*-2-decenal concentration increases again when fermented grapes are pressed. Unfortunately, the following malolactic fermentation does not necessarily enable the volatilisation of all the *trans*-2-decenal, and its concentration can remain above the perception level of sensitive consumers (Mohekar *et al.* 2017a and b). In this study, we did not measure the concentration of *trans*-2-decenal. We were first of all interested to study the sensory impact of processed *H. halys* individuals on the aroma and taste of juices, musts and wines, since the perceived off-flavours might originate from a larger range of compounds than the mentioned alarm pheromones. Our judges failed to distinguish the three 'Merlot' wines in the 2-out-of-5 discriminations tests. Similarly, they could not differentiate the four 'Chardonnay' wines from each other, which concurs with the finding of Fiola (2011). Our sensory profiles indicated slight differences among white 'Chardonnay' wines. Although stronger contaminated wines did not smell more 'vegetal' (*i.e.* descriptor considering 'coriander'-like or 'greener' notes), 'colour intensity' increased with the number of added *H. halys,* whilst the 'harmony' and 'finesse' of wines decreased. We are unaware of how the addition of *H. halys* could change 'colour intensity' and 'harmony/finesse', since these phenomena could only be observed for the white 'Chardonnay' but not for the red 'Merlot' wines. Moreover, the marked differences in 'Chardonnay' were low (*i.e.* 0.13 and 0.39 for 'colour intensity' and 'harmony/finesse', respectively) and of minor importance, as the general impression of the four white wines was not affected. Similarly, we could not identify any differences for our tested red cultivar, since none of the 21 tested sensory descriptors significantly differed among the three 'Merlot' wines. In general, our findings confirm that the "vegetal", "green", "coriander"-like off-flavour of *trans*-2-decenal released by stressed bugs mostly volatilises and vanishes during the process of vinification (Mohekar *et al.* 2017b).

The effect of post-fermentation processes on reducing off-flavours in *H. halys* contaminated wines were evaluated by Mohekar *et al.* (2018). While post-fermentative fining treatments did not prove to be effective, French oak masked the expression of bug taints and reverse osmosis slightly decreased *trans*-2-decenal concentration in wines. However, the practice of aging wines in bottles for an extended period of time was recommended as the best strategy for reducing off-flavours related to *H. halys* (Mohekar *et al.* 2018). Here, we were also able to observe that bottle aging had a positive effect on *H. halys* contaminated wines. Professional winegrowers and winemakers never disliked contaminated 'Chardonnay' and 'Merlot' wines compared to the uncontaminated controls one year after their bottling. On the contrary, the 10 bugs·kg^{-1} 'Chardonnay' wine was preferred to the uncontaminated control in two out of three occasions, and participants also favoured most the 'Merlot' wine contaminated with 3 bugs·kg^{-1}. Thus, our observations indicate that *H. halys* contaminated wines are not necessarily disliked after aging.

In conclusion, our results indicate that a contamination of the vintage with *H. halys* has the potential to alter the quality of grape juices and musts, but that there is little risk for influencing the taste of processed wines. Thus, we believe that the development of viticultural control strategies against this invasive bug does not seem necessary in Europe. Overall, there is little risk for a contamination of the vintage with *H. halys* since bugs are highly mobile (Leskey and Nielsen 2018) and probably flee when grapes are gathered. Moreover, harvesters can still shake infested grape clusters, and winegrowers could finally sort heavily contaminated grapes on a sorting table. Even so, winegrowers, and in particular table grape and grape juice producers, should monitor the evolution of *H. halys* populations in their vineyards in order to anticipate potential quantitative and qualitative problems at the harvest stage.

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Corrigendum

On page 49 (Vitis **60**, 1/2020) of the manuscript:

Influence of processed *Halyomorpha halys* bugs on the aroma and taste of 'Chardonnay' and 'Merlot' musts and wines

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an error on page 49, right column, line 20 has occurred. The sentence:

"Even so, winegrowers, and in particular table grape juice producers, should monitor the evolution of *H. halys* populations in their vineyards in order to anticipate potential quantitative and qualitative problems at the harvest stage."

has to be replaced by:

"Even so, winegrowers, and in particular table grape and grape juice producers, should monitor the evolution of *H. halys* populations in their vineyards in order to anticipate potential quantitative and qualitative problems at the harvest stage."

The editors apologise for this error.