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Effect of trap colour, installation height and size on insect capture in grapevine (*Vitis vinifera*) ecosystem

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ABSTRACT

Effects of optimum colour, installation height and size of sticky traps were studied for monitoring insects in grapes. *Aphis* spp., *Amrasca biguttula biguttula* Ishida, *Rhipiphorothrips cruentatus* Hood, *Scirtothrips dorsalis* Hood and *Stethorus rani* Kapur were the major insect species trapped. Yellow was most effective colour for trapping all these five insect species as compared to blue. Optimum installation height was at near-ground for *Aphis* spp. and *A. biguttula biguttula* and above-canopy for *S. rani*. Optimum size of traps was found to be 11×30 square cm over 22×30 square cm sizes. When analysed for interaction effects, yellow sticky traps of 11×30 square cm installed at near-ground level provided most effective trapping for *A. biguttula biguttula* (1.47, 2.46 and 1.22 and 1.14, 2.12 and 0.95 catches per cell during 2011-12, 2012 and 2012-13 in bower and Y, respectively) and *Aphis* spp. (5.92, 0.37 and 1.42 and 4.31, 0.37 and 1.11 catches per cell during 2011-12, 2012 and 2012-13 in bower and Y, respectively). Yellow sticky traps (11×30 square cm size) installed at above-canopy were most effective in trapping *R. cruentatus* (0.03, 0.86 and 0.47 catches per cell during 2011-12, 2012 and 2012-13) in Y system, however at near-ground in bower system (0.92 and 0.727 catches per cell during 2012 and 2012-13). Yellow sticky traps installed at above-canopy were most effective in trapping *S. rani* in both bower (0.027 and 0.010 catches per cell during 2011-12 and 2012-13) and Y system (0.058 and 0.007 catches per cell during 2011-12 and 2012-13).

Key words: Colour, Grapes, Insect monitoring, Sticky trap

Grape (*Vitis vinifera* L.) has aroused considerable interest in recent years about its cultivation in India due to its prolific yield and good monetary returns (Mani *et al.* 2014). It is also important from export point of view as it has great demand in the foreign markets such as United Kingdom, Saudi Arabia and United Arab Emirates fetching valuable foreign exchange (Mani *et al*. 2014). The major part of the grape area is in peninsular states of India where winters are mild and the grapevines do not undergo dormancy and remain evergreen throughout the year.Therefore, the grapevines remain available for the pest development all the year round which leads to high pest infestations (Yadav *et al.* 2012). Among arthropod pests; thrips, *Scirtothrips dorsalis* Hood and *Rhipiphorothrips cruentatus* Hood; mealybugs, *Maconellicoccus hirsutus* (Green) and red spider mites, *Tetranychus* spp. are major pests in peninsular India. Leafhoppers were earlier considered minor pests in grapes, however, outbreak of *Amrasca biguttula biguttula* Ishida in grapes in state of Maharashtra was observed during October-November, 2011 (Sharma *et al.* 2013). Since then, *A. biguttula biguttula* remained as one of the major pests in viticulture.

Monitoring is a basic tool for decision making in pest management. The first step in managing pests is to determine the practically implementable, accurate and effective monitoring system to measure their population levels. The sticky traps are very efficient and important monitoring tools alerting growers to pests before damage is observed in crops (Bethke *et al.* 2009). The sticky traps are also very useful when other trapping methods such as pheromone or light traps are either unavailable or economically or practically not feasible.

Trap height (Atakanand Canhilal 2004, Pilkington *et al.* 2004) and colour (Clare *et al.* 2000, Roubos and Liburd 2008) can also influence the catch of insects in sticky traps. Blue traps captured more *Frankliniella occidentalis* than yellow traps in plum (Allsopp 2010), broccoli (Chen *et al*. 2004) and lettuce and onion (Natwick *et al*. 2007). Demirel and Yildirim (2008) found yellow sticky traps effective in trapping leafhoppers. Among beneficial insects, blue attracted more *Allograptao bliqua* (S.) than yellow or white traps in broccoli (Chen *et al*. 2004). However, *Chrysoperla carnea* (S.) in alfalfa showed a variable seasonal response

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to orange, red, black hues and clear traps (Blackmer *et al*. 2008). Esker *et al*. (2004) evaluated effect of installation heights (0.15, 0.30, 0.45, 0.60, and 0.90m) on sticky trap insect catch in corn field.

In grapes, yellow sticky traps were recommended by Scatoni *et al*. (2007) against *F. occidentalis* and Akbarzadeh Shoukat and Shayesteh (2006) against *Rubiothrips vitis*. Blue traps were suggested by Tsitsipis *et al*. (2003), Allsopp (2010) and Lucas and Ceron (2011) against *F. occidentalis*. Mani *et al*. (2008) recommended installation of yellow or blue sticky traps for monitoring thrips. Sufficient information is not available on optimum colour, size and height of sticky traps for installation in vineyard ecosystems for monitoring various insect species in peninsular India. Therefore, the present study was carried out to find out optimum installation height, colour and size of sticky traps for insect catch to develop insect monitoring method using sticky traps in grapevine ecosystem.

Further, two training systems, viz. bower and extended Y, are commonly followed in Indian viticulture. In the bower system the vines are trained at the height of about 6.5 feet with horizontal canopy. However, in case of the extended Y system, the cordons are trained horizontally with vertical shoot positioning which helps in harvesting of maximum sunlight required for effective fruit bud differentiation. As these different training systems affect the canopy architecture, they may also affect the optimum height of the traps. Thus, the study was carried out in both of these training systems separately.

MATERIALS AND METHODS

Commercially available sticky traps of yellow and blue colours were used. To define colours of sticky traps RGB (red, green, blue) values of the coloured traps were measured by method described by Rodriguez-Saona *et al*. (2012). Digital images of the coloured sticky traps were taken with a Sony Cybershot DSC-TX9 digital camera at 4000 × 2248 pixel resolution and 24-bit colour during 1130 to 1230 hours from the vineyard. Internet software described by Byers (2006) was used to analyse the RGB attributes of pixels.

The experiments were conducted in table grape, *Vitis vinifera* on Thompson Seedless variety on Dog Ridge rootstock for two years from 2011-13 in 12-14 years old vineyards with bower and Y training systems. The location of the vineyards was at ICAR-National Research Centre for Grapes, Pune, India.

Effect of colour, size and height of sticky traps was assessed during two fruiting seasonsduring 2011-12 and 2012-13 and one vegetative season during 2012 for catch of insects. A 2×3×2 levels for colour (main factor) × height (sub factor) × size (sub-sub factor) factorial design with five replicates was used in both the training systems separately. Traps set at different heights were placed in plant row and separated by a distance of at least 15 m for the same colour. The traps for different sizes were placed in a single plot for colour with minimum distance of one meter. To create height variations, traps for a given colour and size were tied to a thin bamboo stick at different positions, viz., above canopy level, inside canopy and near ground (30 cm above ground surface) with the help of plastic threads. The positions, at which the traps were set, were determined relative to the ground surface for near ground level; and to the height of the canopy of the vines for inside canopy and above canopy levels.

The traps were replaced from 1000 to 1200 hours at every 10 day intervals. The traps were removed and brought to the laboratory for visual observations on both of the adhesive sides of the traps. The visual observations were taken on total number of thrips and leafhoppers per trap under stereo-zoom-microscope. We also counted the number of other insects trapped such as aphids, coccinellid predators, parasitic wasps, etc. Insect predators were identified to the order level and, when possible, to family and species. The sticky substance was dissolved with acetone to remove the insects for identification whenever necessary.

To bring uniformity in insect counts per unit area in traps of 11×30 cm^2 size with 22×30 cm^2 size, the insect numbers for equivalent unit area of 2.50 × 2.50 cm^2 were calculated for data analysis and this area was considered as one cell. A three-factor analysis of variance (2×3×2 for colour × height × size) was performed on the data to determine the optimum colour, height and size of sticky traps and the best interaction. When significant, the means were separated by least significant difference. All the statistical analyses were carried out using statistical software SAS Institute 9.3 (SAS Institute 2012).

RESULTS AND DISCUSSION

Aphid, *Aphis* spp.; leafhopper, *Amrasca biguttula biguttula*; chilli thrips, *Scirtothrips dorsalis*; grapevine thrips, *Rhipiphorothrips cruentatus* Hood and coccinellid beetle, *Stethorus rani* were the major insect species trapped in decreasing order during fruiting season 2011-12. During 2012 vegetative season, it was *A. biguttula biguttula*, *R. cruentatus, Aphis* spp. and *S. dorsalis* and *S. rani* in decreasing order. During 2012-13 fruiting season, the decreasing order of catch of insects was *Aphis* spp, *A. biguttula biguttula, R. cruentatus, S. dorsalis* and *S. rani.* However, higher numbers of *S. dorsalis* during 2011-12 fruiting season can be attributed to the fact that the population of *R. cruentatus* was found lower during the season (NRCG 2012). Therefore, the conclusion that which insect species showed more attraction towards sticky traps cannot be drawn on the basis of present data. The differences in number of different insect species per cell only indicate their population levels in the vineyards.

Individual effects of colour, height and size of sticky traps

When analysed separately, colour, height and size significantly affected capture of insects. In all three seasons, yellow was the most effective trap in descending order to *Aphis* spp, *A. biguttula biguttula, R. cruentatus, S. dorsalis* and *S. rani* as compared to blue traps in both bower and

Y training systems.Trap colour affecting the spectral reflectance pattern has a significant effect on the trap catch of diurnal insects (Childers and Brecht 1996). The yellow sticky traps were found attractive to leafhoppers by Lessio and Alma (2004), Raja and Arivudainambi (2004). Yellow sticky traps also attracted beneficial mite predator, *S. rani*. Wallis and Shaw (2008) also reported yellow sticky traps as the best monitoring tool for acarophagous predator, *Stethorus bifidus* in apple orchards. Dowell and Cherry (1981) also reported yellow colour as the more attractive colour trapping major coccinellids under field conditions. The present observation can be used in terms of utilizing yellow sticky trap for monitoring this beneficial insect fauna occurring in the vineyards.

Near ground height traps captured both *Aphis* spp. and *A. biguttula biguttula* most effectively in both bower and Y training system during all three seasons (Table 1). Above canopy height captured *R. cruentatus* more effectively followed by inside canopy in bower during 2011-12, and in Y training system during all three seasons. During vegetative season 2012 in bower inside canopy and near ground traps captured statistically higher numbers of *R. cruentatus* than above canopy. During 2012-13, near ground traps were significantly more effective. During 2011-12 fruiting season, near ground height captured *S. dorsalis* more effectively followed by above canopy and inside canopy in both bower and Y training systems. During vegetative season 2012 in both bower and Y training system and during fruiting season 2013 in bower training system, above canopy height traps captured statistically higher number of *S. dorsalis* as compared to inside canopy and near ground levels, however, near ground level was found more efficient in Y training system during fruiting season 2013. Above canopy height was most effective in capturing *S. rani* and other coccinellid predators during all three seasons in both training systems.

In the present study, significantly higher trap catch of *Aphis* spp. and *A. biguttula biguttula* were observed near ground level irrespective of the training systems. This might be due to the higher activity of the insects in the lower part of the canopy due to different background colours or other stimuli (Saxena and Saxena 1975). Roditakis *et al.* (2001) and Pearsall (2002) reported in various crops that sticky trap catch of insects decreased with increase in trap height. On the contrary, in present study beneficial predator, *S. rani* was mostly caught in significantly more numbers on the traps erected above canopy level. *S. rani* was reported to be an efficient predator of red spider mites, *Tetranychus urticae* in grapes (Amala and Yadav 2013). The results of the present study can be used to monitor the peak time of activity of predator, *S. rani* in the vineyards so as to restrict application of insecticides to conserve this natural enemy pool in the vineyards. *S. dorsalis* and *R. cruentatus* catches varied largely on traps placed at different heights, thus not showing any distinct pattern.

11×30 cm^2 size traps were most effective in trapping insects per cell in majority of observations during all three seasons except for *Aphis* spp. during 2011-12 in bower

Table 1 Summary of insect attraction to interaction effects of colour, height and size of sticky traps

Trap color	Trap height	Trap size (cm 2)	*A. biguttula biguttula*						*S. dorsalis*						*R. cruentatus*						*Aphis* spp.						*S. rani*				
			2011-12		2012		2012-13		2011-12		2012		2012-13		2011-12		2012		2012-13		2011-12		2012		2012-13		2011-12		2012	2012-13	
			B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	B	Y	Y	B	Y
Yellow	Above canopy	22×30	-	-	o	o	-	-	-	-	+	o	-	-	o	o	-	-	-	-	-	-	o	o	-	-	+	+	o	o	+
		11×30	-	-	-	+	-	-	-	O	+	+	+	o	+	+	-	+	-	+	-	-	o	o	-	-	+	+	o	+	+
	Inside canopy	22×30	-	-	-	-	-	-	-	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o	+
		11×30	-	-	-	-	-	-	-	-	+	o	o	-	-	o	o	+	o	o	-	-	o	-	-	-	o	o	o	o	+
	Near Ground	22×30	o	o	+	+	o	o	o	o	o	-	-	-	-	-	-	o	o		+	o	+	+	o	o	-	o	o	-	o
		11×30	+	+	+	+	+	+	+	+	o	-	-	+	-	-	+	o	+	o	o	+	+	+	+	+	o	o	o	o	o
Blue	Above canopy	22×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	-	o
		11×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o	-	+
	Inside canopy	22×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	-	o
		11×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o	-	+
	Near Ground	22×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	-	-
		11×30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	+	o	+

B = Bower training system, Y = Y training system, + Most superior treatments, o Second most superior treatments, - Inferior treatments.

and 2012 in bower and Y system, *A. biguttula biguttula* during 2012 in bower, *S. dorsalis* during 2012-13 in Y system. Therefore, the 22×30 cm^2 size traps can be cut into half to make smaller size of 11×30 cm^2 can be used to cover larger area for monitoring purpose thus providing cost-effectiveness.

Interaction effects of colour, height and size of sticky traps

During fruiting season 2011-12 in bower, yellow+near ground+11×30 cm^2 interaction was most effective in trapping *A. biguttula biguttula* and *S. dorsalis* and yellow+near ground+22×30 cm^2 interaction was most effective for *Aphis* spp. (Table 2). Yellow+above canopy+11×30 cm^2 interaction was most effective for *R. cruentatus* and *S. rani*. This interaction was at par with yellow+above canopy+22×30 cm^2 for *S. rani*. In Y training system during the same season, yellow+near ground+11×30 cm^2 interaction was most effective in trapping *A. biguttula biguttula*, *S. dorsalis and Aphis* spp. Yellow+above canopy+11×30 cm^2 interaction was most effective for *R. cruentatus* and *S. rani*. This interaction was at par with yellow+above canopy+22×30 cm^2 for *S. rani*.

During vegetative season 2012, yellow+near ground+11×30 cm^2 and yellow+near ground+22×30 cm^2 interactions were most effective in trapping *A. biguttula biguttula* and *Aphis* spp. in both bower and Y systems (Table 3). Yellow+above canopy+11×30 cm^2 interaction was most effective for *S. dorsalis* in both training systems. This interaction was at par with yellow+inside canopy+11×30 cm^2 for bower. Yellow+near ground+11×30 cm^2 interaction was most effective for *R. cruentatus* in bower. However, yellow+above canopy+11×30 cm^2 and yellow+inside canopy+11×30 cm^2 interactions were most effective and at par with each other in Y system.

During fruiting season 2012-13, yellow+near ground+11×30 cm^2 interaction was most effective in trapping *A. biguttula biguttula* and *Aphis* spp. in both training systems (Table 4). Yellow+above canopy+11×30 cm^2 interaction was most effective for *S. dorsalis* in Y system and *R. cruentatus* in bower. Yellow+near ground+11×30 cm^2 interaction was most effective for *S. dorsalis* in bower and *R. cruentatus* in Y system. Yellow+above canopy+11×30 and 22×30 cm^2 and yellow+inside canopy+11×30 and 22×30 cm^2 were most effective and at par with each other in trapping *S. rani* in Y system. However, yellow+above canopy+11×30 cm^2 interaction was most effective for *S. rani* in bower system.

Yellow+near ground+11×30 cm^2 was most effective interaction for *A. biguttula biguttula* and *Aphis* spp. in both training systems. *R. cruentatus* and *S. rani* preferred yellow+above canopy+11×30 cm^2. *S. dorsalis* showed equal preference towards yellow+nearground+11×30 cm^2 and yellow+above canopy+11×30 cm^2.

Single-lens eyes are able to focus on objects at different distances. However, insect compound eyes have the same angular resolution at far and close distances, therefore, the insects are unable to resolve spatial details of distant objects, though they can use vision at extremely close distances (Hempel de Ibarra *et al*. 2015). It was also emphasized that insects could not distinguish small objects or small-scaled variations of shapes and patterns over long distances, e.g. swallowtail butterfly, *Papilio xuthus* (Takeuchi *et al*. 2006). In the present experiment, the smaller sticky trap size of 11×30 cm^2 was physiological sufficient for *A. bigutulla bigutulla* and *Aphis* spp. to detect for yellow+near ground+11×30 cm^2 interaction, and mostly for *S. dorsalis*, *R. cruentatus* and *S. rani* to detect for yellow+above

Table 2 Mean number of insect catches during fruiting season 2011-12

Trap color	Trap height	Trap size (cm^2)	Mean number of insect catches per cell									
			A. biguttula		*S. dorsalis*		*R. cruentatus*		*Aphis* spp.		*S. rani*	
			Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y
Yellow	Above canopy	22×30	0.51 c	0.264 cd	0.143 c	0.071 c	0.077 b	0.025 bc	1.58 c	0.74 d	0.025 a	0.031 ab
		11×30	0.40 de	0.298 c	0.145 c	0.108 b	0.105 a	0.036 a	1.53 c	0.67 d	0.027 a	0.058 a
	Inside canopy	22×30	0.39 e	0.235 d	0.083 e	0.055 d	0.044 c	0.011 e	1.39 d	0.73 d	0.008 cd	0.012 b
		11×30	0.46 cd	0.226 d	0.108 d	0.078 c	0.045 c	0.029 b	1.24 e	0.82 cd	0.014 b	0.023 b
	Near Ground	22×30	1.31 b	0.829 b	0.168 b	0.116 b	0.029 cde	0.011 e	6.55 a	4.01 b	0.005 cd	0.013 b
		11×30	1.47 a	1.141 a	0.199 a	0.130 a	0.041 cd	0.018 d	5.92 b	4.31 a	0.009 bcd	0.019 b
Blue	Above canopy	22×30	0.06 fg	0.078 e	0.036 fg	0.034 f	0.003 g	0.005 ef	0.26 g	0.81 cd	0.008 cd	0.007 b
		11×30	0.09 fg	0.097 e	0.033 fg	0.052 d	0.020 efg	0.022 cd	0.26 g	0.81 cd	0.010 bcd	0.018 b
	Inside canopy	22×30	0.06 g	0.061 e	0.029 g	0.037 ef	0.011 fg	0.004 f	0.22 g	0.66 d	0.005 cd	0.003 b
		11×30	0.09 fg	0.074 e	0.045 f	0.047 de	0.025 def	0.007 ef	0.30 g	0.73 d	0.011 bc	0.011 b
	Near Ground	22×30	0.08 fg	0.078 e	0.038 fg	0.039 ef	0.019 efg	0.006 ef	0.44 f	0.75 cd	0.004 d	0.003 b
		11×30	0.11 f	0.098 e	0.072 e	0.050 d	0.012 efg	0.002 f	0.44 f	0.93 c	0.009 bcd	0.010 b
		F-value	439.99	203.71	123.97	70.12	18.44	17.93	1631.15	311.35	8.82	1.82
		df (model, error)	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44
		Pr>F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0618

Table 3 Mean number of insect catches during vegetative season 2012

Trap color	Trap height	Trap size (cm²)	Mean number of insect catches per cell									
			A. biguttula		*S. dorsalis*		*R. cruentatus*		*Aphis* spp.		*S. rani*	
			Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y
Yellow	Above canopy	22×30	1.796 b	1.55 b	0.122 ab	0.12 b	0.56 d	0.626 c	0.264 b	0.32 b	0	0.000 b
		11×30	1.499 c	1.93 a	0.127 a	0.14 a	0.71 c	0.864 a	0.255 b	0.33 b	0	0.000 b
	Inside canopy	22×30	0.910 d	0.29 c	0.100 c	0.10 c	0.66 c	0.601 c	0.202 c	0.24 c	0	0.000 b
		11×30	1.381 c	0.34 c	0.126 a	0.13 b	0.85 b	0.866 a	0.237 b	0.25 c	0	0.000 b
	Near Ground	22×30	2.416 a	1.90 a	0.104 c	0.08 d	0.65 c	0.767 b	0.391 a	0.39 a	0	0.000 b
		11×30	2.468 a	2.12 a	0.112 bc	0.06 e	0.92 a	0.790 b	0.379 a	0.37 a	0	0.000 b
Blue	Above canopy	22×30	0.386 e	0.14 c	0.027 de	0.03 gh	0.03 e	0.039 d	0.090 de	0.09 e	0	0.000 b
		11×30	0.315 e	0.14 c	0.038 d	0.05 f	0.05 e	0.051 d	0.103 d	0.10 de	0	0.000 b
	Inside canopy	22×30	0.191 e	0.08 c	0.023 e	0.02 h	0.03 e	0.035 d	0.073 e	0.08 e	0	0.000 b
		11×30	0.195 e	0.10 c	0.034 de	0.04 g	0.04 e	0.063 d	0.090 de	0.11d	0	0.000 b
	Near Ground	22×30	0.188 e	0.17 c	0.022 e	0.02 h	0.03 e	0.028 d	0.081 de	0.09 e	0	0.000 b
		11×30	0.182 e	0.15 c	0.033 de	0.03 gh	0.04 e	0.050 d	0.104 d	0.09 de	0	0.004 a
		F-value	104.61	60.35	77.73	83.51	212.67	184.45	105.85	133.32		31.25
		df (model, error)	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44
		Pr>F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001

Table 4 Mean number of insect catches during fruiting season 2012-13

Trap color	Trap height	Trap size (cm²)	Mean number of insect catches per cell									
			A. biguttula		*S. dorsalis*		*R. cruentatus*		*A. craccivora*		*S. rani*	
			Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y
Yellow	Above canopy	22×30	0.477 e	0.366 e	0.139 c	0.102 c	0.282 e	0.355 c	0.61 de	0.62 d	0.0066 bc	0.0058 abcde
		11×30	0.551 d	0.436 d	0.193 a	0.128 b	0.426 c	0.474 a	0.68 c	0.75 c	0.0104 a	0.0078 a
	Inside canopy	22×30	0.484 e	0.401 de	0.106 e	0.071 e	0.386 d	0.342 c	0.54 f	0.41 f	0.0072 bc	0.0066 abcd
		11×30	0.628 c	0.562 c	0.158 b	0.091 cd	0.533 b	0.425 b	0.64 cd	0.55 e	0.0080 b	0.0076 ab
	Near Ground	22×30	0.891 b	0.800 b	0.087 f	0.075 de	0.559 b	0.347 c	1.12 b	0.95 b	0.0042 de	0.0047 cde
		11×30	1.228 a	0.955 a	0.122 d	0.327 a	0.727 a	0.424 b	1.42 a	1.11 a	0.0081 b	0.0051 bcde
Blue	Above canopy	22×30	0.037 f	0.048 f	0.020 gh	0.025 fgh	0.020 f	0.016 d	0.28 hi	0.33 g	0.0033 e	0.0037 ef
		11×30	0.057 f	0.045 f	0.027 g	0.029 fg	0.033 f	0.022 d	0.34 h	0.43 f	0.0059 cd	0.0072 abc
	Inside canopy	22×30	0.042 f	0.042 f	0.009 h	0.010 h	0.020 f	0.018 d	0.23 i	0.23 h	0.0032 e	0.0042 def
		11×30	0.053 f	0.059 f	0.016 gh	0.015 gh	0.027 f	0.030 d	0.29 h	0.35 g	0.0038 e	0.0076 ab
	Near Ground	22×30	0.062 f	0.062 f	0.012 h	0.011 gh	0.025 f	0.029 d	0.45 g	0.42 f	0.0026 e	0.0020 f
		11×30	0.061 f	0.064 f	0.027 g	0.034 f	0.032 f	0.036 d	0.57 ef	0.54 e	0.0081 b	0.0053 abcde
		F-value	632.16	416.69	195.16	138.51	336.37	557.90	211.13	258.92	11.20	3.06
		df (model, error)	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44	15,44
		Pr>F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0020

canopy+11x30 cm^2 interaction. Higher capture of *A. bigutulla bigutulla* on sticky traps at near ground height in both bower and Y training systems present indications of movement away from canopy towards ground during day time possibly due to higher temperatures which needs further investigations.

The analyses of RGB will allow comparisons of the trap colours with data during future studies which may utilize similar measurements (Table 5). Further, the batches of plastic traps from commercial sources can also be checked in future for consistency with earlier used traps so that the attractive properties can be standardized and reliable (Rodriguez-Saona *et al*. 2012).

On the basis of these observations, it can be concluded that the sticky traps can be used in grapevine ecosystems for the monitoring of *Aphis* spp., *A. biguttula biguttula, R. cruentatus, S. dorsalis* and *S. rani* when installed using most effective colour, at right installation height and optimum size. The future area of research calls for standardization of sticky trap based economic threshold levels (ETL) for

Table 5 Mean (±standard deviation) red (R), green (G), blue (B), trichromatic percentages (% R, G, B) and H:S:L values (Hue: Saturation: Luminosity) from areas of digital photos of sticky traps taken under vineyard conditions in Bower and Y training system

Trap colour	Trap level	R ± SD		R%a		G ± SD		G%		B ± SD		B%		H:S:L	
		Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y	Bower	Y
Yellow	Near ground	153 ± 4	165 ± 4	50.00	49.69	141 ± 4	148 ± 4	46.07	44.57	12 ± 3	19 ± 4	3.92	5.72	0.15:0.85:032	0.15:0.79:0.36
	Inside canopy	164 ± 3	158 ± 3	48.95	49.68	157 ± 4	141 ± 3	46.86	44.33	14 ± 5	19 ± 4	4.17	5.97	0.15:0.84:034	0.15:0.78:0.35
	Above canopy	164 ± 3	164 ± 3	46.72	48.95	152 ± 3	147 ± 3	43.30	43.88	35 ± 9	24 ± 4	9.97	7.16	0.15:0.64:039	0.15:0.74:0.37
Blue	Near ground	19 ± 6	17 ± 3	4.65	4.27	148 ± 8	145 ± 2	36.27	36.43	241 ± 7	236 ± 2	59.06	59.29	0.90:0.77:0.51	0.90:0.86:0.50
	Inside canopy	13 ± 4	20 ± 3	3.77	5.18	121 ± 6	138 ± 3	35.17	35.75	210 ± 5	228 ± 3	61.04	59.06	0.91:0.88:0.44	0.90:0.84:0.49
	Above canopy	15 ± 4	18 ± 3	4.34	4.81	121 ± 7	134 ± 3	35.07	35.82	209 ± 8	222 ± 2	60.57	59.35	0.91:0.87:0.44	0.90:0.85:0.47

[a]Represents the percent red {R/(R + G+ B) × 100}, similarly %G and %B was also determined.

decision making in grapes.

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