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Color Preference and Sticky Traps for Field Management of Thrips *Ceratothripoides claratris* (Shumsher) (Thysanoptera: Thripdae) in Tomato in Central Thailand

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ABSTRACT

The response of *Ceratothripoides claratris*, a newly identified pest on tomato, to colors was evaluated in a pesticide free tomato field. Traps were designed by color boards or clear polypropalene sheets coated with Beetle-Glue®. Tested colors were yellow, blue, white, light green, dark green, orange, purple, red and black. A clear polypropylene sheet covered with the insect adhesive was used as control. Blue and white cards attracted more *C. claratris* compared with other colors. Strongly UV-and blue light-reflecting colors and UV regions caught more *C. claratris* compared to the other colors. Hence intensity of blue and UV reflection appeared to be an important component of trap efficacy. A correlation existed between cumulative thrips counts and the leaf infestation level of tomato. The tomato plots without sticky traps showed higher leaf infestation by thrips.

Key Words: *Ceratothripoides claratris;* Color preference; Tomato; Thrips; Color traps

INTRODUCTION

Thrips are recognized as a great menace in agriculture. They are known to damage young and immature plants due to their piercing and sucking nature and also act as vectors for viral diseases, which is a secondary problem. Thrips species may vary from country to country. In Thailand, *Scitrothrips dorsalis*, *Thrips parvispiness*, *Thrips tabaci*, *Haplothrips floricola* and *Thrips flavus* have been recognized as most important thrips species (Bansiddhi & Poonchaisiri, 1991). Of these *T. flavus* and *H. floricola* have been emphasized for their economic importance as a major obstacle for high quality vegetable and tomato production. In 1999, *C. claratris*, a known tropical thrips species was discovered damaging foliage of tomatoes in Central Thailand. It was the first record on the *C. claratris* (Shumsher) as a tomato pest, which could cause serious damage to tomato leaves, except for *T. setosus* Moulton in Japan (Murai *et al*., 2000). However, the former was reported as a pest of cucurbits (Mound & Kibby, 1998) and melon in Thailand (Okajima *et al*., 1992). Murai *et al*. (2000) suggested that *C. claratris* can severely injure leaves and stems leading to dry out of tomato plants and hence alarmed as a potential threat to become a serious pest of Southeast Asia. Recently, Premachandra *et al*. (2004) also reported its seriousness as a pest of tomato in greater Bangkok area of Thailand based on their studies on the influence of temperature on its growth and development, which revealed the potential of rapid population build up of *C. claratris* under hot humid conditions.

Escalated public concern over extensive pesticide use and high pesticide residue levels in vegetables demanded the use of integrated pest management approaches in high pest attractive vegetable crops such as tomato. The IPM approaches in vegetable production involve monitoring of insect pests and identifying appropriate cultural, physical or biological methods during crop growth and development. Both visual and chemical stimuli play a role in locating host plants by insects (Prokopy & Owens, 1983). Plant spectral quality (particularly hue & intensity) appears to be the principle stimuli for alignment of herbivorous insects on living plants (Prokopy & Owens, 1983). Determination of color preference of crop pests may help develop pest traps using such attractive colors, thus providing opportunities for pest control by integrating specific colors into crop management methods. This helps either reduce or avoid the use of synthetic pesticides and hence helping to avoid the build up pesticide residues in the environment and food. Attractive colors incorporated into various traps have been tried for a number of decades in population monitoring or direct control of thrips throughout the world. Among the colored traps light traps (Norris *et al*., 2002), sticky traps and water traps (Lewis, 1959; Kirk, 1984) etc., have been tried for thrips management. Different color preferences of many species of thrips have been studied by numerous scientists to enhance the attractiveness and sensitivity of various traps (Lewis, 1997; Wickramarachchi, 2004). Unfortunately, there were no records on the color preference of *C. claratris* to facilitate the development of effective monitoring and direct control methods.

Yudin *et al*. (1987) mentioned that the colors used in color traps for thrips management should exhibit a high correlation between trapped thrips counts and actual populations in the field. However there were only a few studies that had attempted to relate the insect counts on color traps and infestation level of the surrounding crops (Lewis, 1997; Wickramarachchi, 2004). Furthermore, only a few publications were available on the use of attractive colors for direct control of thrips (Kawai & Kitamura, 1987; Shipp, 1995; Wickramarachchi, 2004). Hence, this study was conducted to determine the color preference of *C. claratris* and assess the utility and efficacy of color sticky trap catches in estimating *C. claratris* abundance in tomato foliage for various colors in thrips' population in the field.

MATERIALS AND METHODS

This experiment was conducted during March to May, 2004 in the Agricultural Systems Experimental Farm at the Asian Institute of Technology, Thailand. The experimental field was surrounded by corn, rice and Chinese kale plots. The land area used for the tomato cultivation was previously a fallow land. The tomato variety Luktho (produced by Tropica Seeds®) was first raised in mini pots in a nursery and later transplanted at two seedlings per hill with inter-and intra-row spacings of 50 cm and 40 cm, respectively in east-west direction with a population of 100,000 plants ha^{-1}, in raised-flat beds of 4 m x 3 m, prepared by ploughing once and harrowing twice, added with chicken manure at the rate of 5 t ha^{-1}. No pesticides were applied to the crop in nursery and field. Each plot was given Nitrogen (N), Phosphorus (P) and Potassium (K) at the rate 28 kg ha^{-1} as the basal dressing, 40.95 kg ha^{-1} of N as the first top dressing at 7 days after transplanting (DAT), N, P and K at the rate 28 kg ha^{-1} at 28 DAT as the second top dressing and at the rate of 24.3, 24.3 and 39.3 kg ha^{-1}, respectively at 41 DAT as the third top dressing. A standard meteorological station operated at the Asian Institute of Technology, 500 m away from the experimental field, provided records weather data of each day during the study period.

Nine colors (viz. white, yellow, light & dark green, red, purple, orange, black & blue) were tested as treatments together with colorless polypropylene film and a control (i.e., without any colour cards) to determine the preference or attractiveness of *C. claratris*. Specific colors were provided using special plastic color cards, called "future board" in Thailand. Each card was double-sided, horizontally divided into six equal frames of 6 cm horizontal strips and demarcated with a thin black line just sufficient to see the demarcation and convenient counting of thrips trapped on the card. Each card was fixed into a metal frame, which was fixed in the field using a bamboo stick. The colorless polyethylene transparent sheet also had the same dimensions and was erected as above. The colorless and transparent insect trapping adhesive, Beetle-Glue® (Greenplana Co., Thailand) was uniformly applied as a thin layer on both surfaces of each color card to retain the insects landing on it. Prior to applying on color cards, Beetle-Glue® was heated at 85°C for about 30 min in an oven to reduce the viscosity for easy application as a thin layer.

The cards were mounted on individual metal frames and the frames were fixed up on bamboo sticks above the crop for proper visibiity and convenient handling. Eleven treatments including the control were randomly allocated among tomato plots in each replicate of a randomized block design with three replicates. Each tomato plot received eleven cards of the same color. Color cards were introduced for six week starting from two weeks after transplanting. Each color card was given an identification number and placed at a height of 60 cm in each plot in a systemmatic and visible manner for all insects entering into the plot area from all directions.

Every week since introduction, five randomly selected color cards out of 11 cards in each plot were taken out of the frames from each plot in all three replicates, for counting thrips that stuck on glue on either side of the color card under stereoscope. At the time of sampling for insect counts, all the frames were replaced with new sets of color cards and the sampled sets were transferred to the laboratory for identification of insects. *C. claratris* was identified based on the morphological characteristics and using voucher specimens available at the Division of Entomology, Department of Agriculture, Bangkok, Thailand. Other thrips species were not identified to the species level and considered under a common category as "other thrips". Thrips counts were recorded using a dissecting microscope (x 10). No attempt was made to keep records of the sexual specificity of *C. claratris* responded to different colors.

The reflectance spectrum of the color cards, mature and immature tomato leaves and immature fruits were recorded between, 350 and 650 nm representing the range within the electromagnetic energy spectrum perceptible to insects via ocular receptors including the UV region. Measurements were taken from plants and color cards with and without glue in the field during the noon using a portable spectrometer (Spectra Co-op). The purpose of measuring reflectance using color cards with and without glue was to determine whether application of glue alters the reflectance and insect attraction. The spectral reflectance was measured as a percentage of reflectance from standards plate of barium sulphate ($BaSO_4$). In addition, digital images were taken from each color card using a digital camera (Canon Digital Camera Model SD 75) under the same light level. The colors were characterized by intensity (in terms of density of pixels for three basic colors; red, green & blue) and luminosity values by analyzing the digital images using histogram feature of the Adobe Photoshop (Version 7.0).

From each plot, five tomato plants representing every part of the plot excluding border area were randomly selected for crop infestation records. Total number of leaflets and the number of thrips infested leaflets were counted. This monitoring was done for a period of six weeks. Thrips counts were transformed to Log values and analysis of variance was performed. Treatment means were compared using Fisher's protected least significant difference test (Steel & Torrie, 1980). Correlation analysis was conducted for *C. claratris* count and crop infestation. The level of infestation recorded each week was a cumulative value without differentiation between old and new levels. Therefore, data of *C. claratris* catches were added to those of the previous weeks. Correlation analysis was performed using cumulative trap catches and level of infestation on leaves.

RESULTS

Reflectance pattern. The colors and their characteristics are shown in Table I. Reflectance measurements showed that there was a slight reduction in the relative spectral reflectance of color cards with the application of glue without altering the pattern of reflectance (Fig. 1a & b). There was a reflection of UV range (350 to 455 nm) from blue, purple and colorless polyethylene films and reflectance in the blue range (455 to 500 nm) from dark green, light green and yellow cards in addition to blue, purple and polyethylene although peak reflectance occurs in specific color cards varied (Fig. 1a & b). There was a reflectance in the green range (500 - 580 nm) from dark green and light green, also from blue, yellow and transparent polyethylene treatments. Light green had a higher reflectance in the green wave lengths than dark green color cards. Mature and immature leaves and immature green fruits of tomato gave maximum reflectance at 550 nm (Fig. 2). The pattern of spectral reflectance was similar in both mature and immature leaves. However, mature leaves showed 14% and immature ones had 7% of peak at 550 nm. Immature fruit also had its peak reflectance in the green range, but there was a higher reflectance than both mature and immature leaves from 350 to 650 range.

Color preference test thrips (> 99.9%) collected on glued color cards were winged adults. *C. claratris* (Shumsher) was the dominant thrips species and accounted for 99.99% of all thrips counted in the tomato field during the study period. Other thrips species collected on color cards were not specifically identified. The colors used in the study significantly affected catches of thrips (Table II). White, blue and purple were the most attractive colors, followed by light green, dark green and transparent than orange, red and black in the descending order. Total thrips collected on blue cards were significantly greater than on all the other color cards, except white and purple. However, during the first and fourth weeks, white color card had significantly greater thrips counts than blue and purple color cards. The number of thrips trapped by all the color cards, except black and red were very indicative of their active role in pest attraction.

There was no difference in the number of thrips between dark and light green during the study, except in the fifth week. In all five weeks the lowest thrips counts were observed with black and red (Table II). The transparent traps did not differ much from green color traps.

Table I. Color evaluation through luminosity, degree of redness, blueness and greenness from color cards used

Color	Luminosity	Red	Blue	Green
Yellow	147. 9	171.3	1.9	163.2
Blue	129.7	69.0	201.7	146.9
White	146.91	149	145.5	146.2
Light green	121.3	37.8	99.3	170.7
Dark green	132.7	54.0	103.0	173.6
Orange	132.1	194.2	52	115.6
Purple	101.5	113.5	173.2	81.7
Red	109.4	186.8	36.25	55.23
Black	64.71	80.1	49.1	59.8

Fig. 1a. Relative reflectance of wavelengths from different color cards without glue based on the $BaSO_4$ standard plate

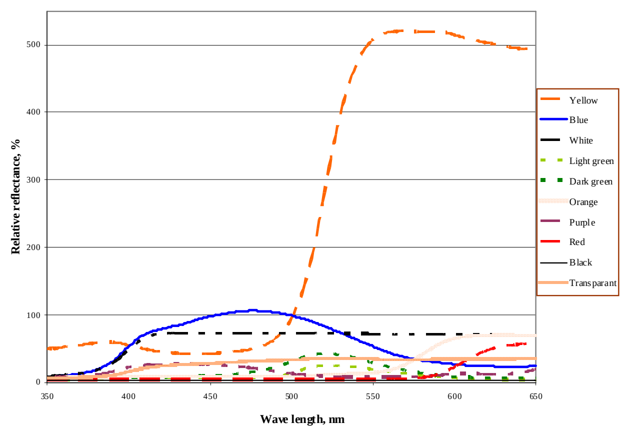
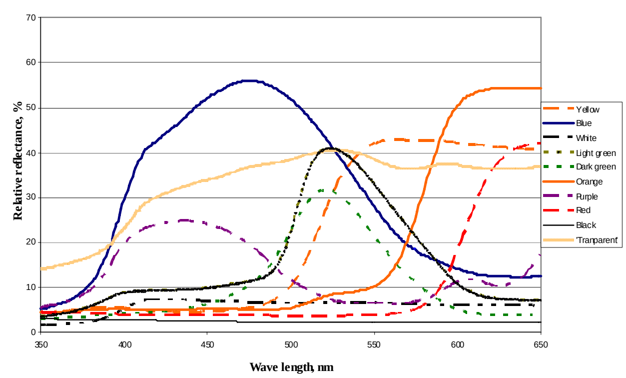


Fig. 1b. Relative reflectance of wavelengths from different glued color cards based on the $BaSO_4$ standard plate



Variation of thrips population. There was a rapid increase in the thrips counts representing rapid population build up at the end of third week of March (Fig. 3). The weather data during this period showed that a dry, humid weather prevailed and there was no precipitation over this period. Day time temperatures ranged from the 38 - 39°C with night time temperatures around 26°C. Relative humidity was

Table II. Mean number of thrips caught on different color sticky traps used in tomato

Color	Week				
	1	2	3	4	5
Yellow	$15.8 \pm 3.0^{ab*}$	15.4 ± 4.6^{ab}	61.2 ± 16.1^{ab}	257.1 ± 46.5^{abc}	633.3 ± 112.6^{ab}
Blue	33.9 ± 3.7^{c}	83.8 ± 16.7^{c}	225.2 ± 37.5^{d}	1313.4 ± 210.3^{f}	3285.3 ± 518.4^{d}
White	67.1 ± 14.0^{d}	88.6 ± 31.1^{c}	247.2 ± 51.4^{d}	867.1 ± 129.7^{e}	3542.7 ± 353.2^{d}
Light green	25.4 ± 4.8^{bc}	34 ± 5.2^{ab}	103.9 ± 13.4^{bc}	557.4 ± 83.7^{cd}	1390.3 ± 153.7^{b}
Dark green	21.3 ± 2.7^{bc}	43.9 ± 8.1^{ab}	124.4 ± 22.6^{bc}	529.2 ± 71.6^{cd}	977.9 ± 134.8^{ab}
Orange	16.4 ± 1.1^{ab}	19.8 ± 5.4^{ab}	111.4 ± 22.6^{bc}	208.1 ± 48.5^{ab}	513.2 ± 73.9^{a}
Purple	22.1 ± 3.7^{bc}	53.4 ± 16.4^{bc}	174.0 ± 27.4^{cd}	711.9 ± 142.8^{de}	2293.4 ± 443.8^{c}
Red	3.6 ± 1.2^{a}	12.1 ± 2.7^{ab}	20.4 ± 4.6^{a}	84.2 ± 21.3^{a}	244.8 ± 37.4^{a}
Black	2.8 ± 1.1^{a}	2.1 ± 0.4^{a}	49.3 ± 15.1^{ab}	24 ± 4.7^{a}	267.6 ± 64.1^{a}
Transparent	18.3 ± 3.01^{abc}	28.1 ± 4.3^{ab}	80.9 ± 12.5^{ab}	427.3 ± 64.3^{bcd}	894.7 ± 108.7^{ab}

Data were counts, analyzed after transforming to log (X+1), but presented are means of actual data;
*Means within a column followed by the same letter are not significantly different (P=0.05) according to LSD

around 70% having a maximum of 99% (data not given).

Relationship between trap catches and crop infestation. Feeding injury was mainly observed on leaves compared to stem and shoots and which was greater on lower than upper leaves. Tomato fruits were not damaged considerably by thrips. The control plots without color sticky traps showed significantly greater infestation by thrips in terms of damage when compared to plots having sticky cards during the complete study period (Table III).

In all cases the lowest level of leaf infestation and crop damage was recorded in plots having white color traps followed by blue traps. Plots with purple, yellow, light green and transparent colors showed lower levels of thrips infestations than plots, which had dark green, red, black and orange color traps. At the end of the third week of the experiments (by 3rd April) tomato cultivation showed the signs of severe thrips infestation.

The correlation between cumulative thrips count and level of infestation expressed as average percent leaflets infested with thrips per plant. Nine color cards and transparent (clear) sheet had a significant correlation between cumulative thrips catches on color cards and level of infestation in the field (Table IV).

DISCUSSION

There are numerous studies on the preference of white color by the thrips species such as *Frankliniella occidentalis* (Beavers *et al*., 1971; Yudin *et al*., 1987; Hoddle *et al*., 2002). Yudin *et al*. (1987) found that insect traps made of white color attracted a significantly greater number of thrips among the 14 other colors tested in the studies. Hoddle *et al*. (2002) also found that white cards were most attractive for *F*. *occidentalis* and *F*. *orizabensis* than blue and yellow cards. Vernon and Gillespie (1990) found that *F*. *occidentalis* alighted preferentially on traps of bright blue, violet, yellow and purple, whereas green, orange and UV reflecting white hues were not attractive. Lewis (1973) noted that white usually offers the greatest contrast to the surrounding environment for attracting thrips and hence suggested that attractive colors to be avoided as a mean to estimate populations within a unit area of vegetation,

Fig. 2. Relative reflectance of wavelengths of mature and immature leaves and immature fruits of tomato based on the $BaSO_4$ standard plate

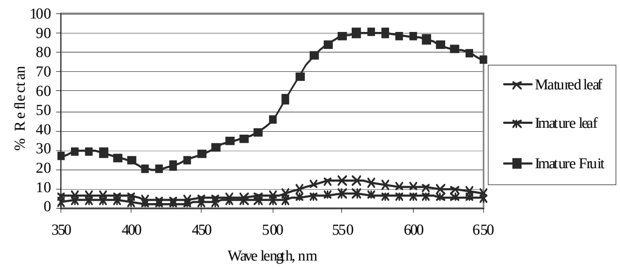
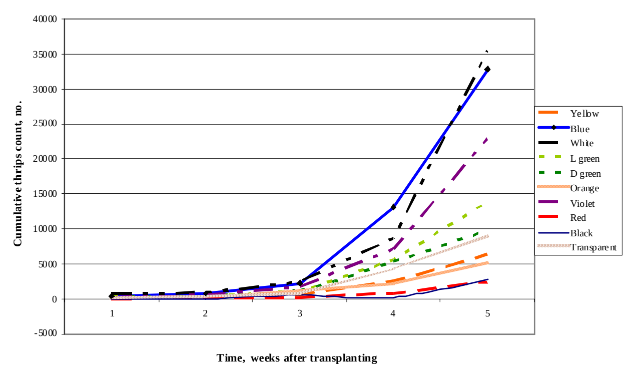


Fig. 3. Weekly cumulative thrips count on each color card



because thrips are stimulated to settle in canopies that show white color compared to natural vegetation. Vernon and Gillespie (1990) also observed that there was no difference between dark and light green in attracting thrips. A lesser difference of transparent traps from green color traps though they were supposed to use as control to determine the rates of random interception independent of trap color was also observed by Weseloh (1972) and Romeis *et al*. (1998) with clear traps in gypsy moths, some parasitoids and *Tricogamma* spp. and suggested that insects see plants through clear traps.

Blue, white, purple and transparent colors were the four colors out of ten that strongly reflect in the UV region (approximately 300 - 400 nm) (Fig. 1). Blue region was

Table III. Percentage thrips infestation in tomato leaves in five sampling dates

Color	Average tomato leaflets infested per plant %				
	March 11	March 18	March 25	April 3	April 9
Yellow	1.00 ± 0.62^{a*}	2.00 ± 0.80^{ab}	25.92 ± 3.08^{b}	66.21 ± 6.69^{cd}	82.78 ± 3.89^{cde}
Blue	0.12 ± 0.12^{a}	0.46 ± 0.36^{a}	16.17 ± 3.64^{ab}	42.24 ±10.15^{ab}	63.90 ± 3.78^{b}
White	0.05 ± 0.50^{a}	0.09 ± 0.09^{a}	13.65 ± 1.97^{a}	30.78 ± 8.98^{a}	46.70 ± 6.36^{a}
Light green	0.37 ± 0.26^{a}	0.85 ± 0.36^{a}	19.24 ± 2.33^{ab}	64.84 ± 7.63^{cd}	77.20 ± 4.33^{c}
Dark green	2.67 ± 1.02^{ab}	5.65 ± 1.18^{bcd}	32.20 ± 3.96^{cd}	84.41 ± 3.72^{de}	89.90 ± 2.17
Orange	5.91 ± 1.81^{b}	9.04 ± 2.38^{d}	56.43 ± 4.94^{e}	85.13 ± 5.04^{de}	93.16 ± 1.57^{ef}
Purple	0.27 ± 0.14^{a}	0.61 ± 0.24^{a}	19.39 ± 2.71^{ab}	59.39 ± 8.16^{bc}	80.60 ± 4.34^{cd}
Red	2.23 ± 1.44^{ab}	4.11 ± 1.70^{abc}	55.36 ± 4.42^{e}	75.44 ± 5.64^{cde}	92.60 ± 2.11^{ef}
Black	3.77 ± 1.37^{ab}	7.91 ± 1.44^{cd}	37.40 ± 5.57^{d}	79.80 ± 6.87^{cde}	86.50 ± 2.53^{cdef}
Transparent	0.59 ± 0.28^{a}	1.19 ± 0.42^{ab}	20.13 ± 2.09^{ab}	83.14 ± 2.44^{de}	87.70 ± 2.83^{cdef}
Control	32.43 ± 3.50^{c}	49.30 ± 3.53^{e}	61.80 ± 3.94^{e}	88.99 ± 2.14^{de}	95.30 ± 0.74^{f}

Data were counts, analyzed after transforming to arc sine values, but results are means of actual data;
*Means within a column followed by the same letter are not significantly different (*P>0.05*) according to LSD.

reflected by blue and transparent treatments and some by purple. These colors caught most of the thrips. High reflectance of blue and UV appears to be an important component of trap efficacy for *C. claratris*. Finding of the present study are contradictory to many studies noting that UV reflectance can affect the response of thrips to colors. If UV reflectance is very high, then anthophilous thrips (flower thrips) are repelled from the surface of attractive colors, whereas grass feeding thrips are not affected by the UV reflectance (Terry, 1997). Matteson and Terry (1992) reported that highly UV reflective white (78% reflectance at 365 nm) captured fewer *F. occidentalis* compared with low UV reflective white (14% reflectance at 365 nm). Cho *et al*. (1995) also found that UV reflective white (66% at 365 nm) showed less attraction for *Frankliniella* spp. than low UV reflecting yellow and blue (35% reflectance at 365 nm). However, all these findings on UV response of thrips were on anthophilous thrips (flower dwelling thrips). Present thrips species was mainly foliage dwelling thrips species.

Terry (1997) suggested that there are two types of photo pigments residing in two types of photoreceptors in flower thrips, of which one type is sensitive to UV and the other one sensitive to green and yellow wavelengths. However, Vernon and Gillespie (1990) suggested that flower thrips have three photoreceptors tuned to 350 to 360 nm in UV, 440 to 450 nm in blue and 540 to 570 nm in the yellow wavelength. If assumed to have the same type of photoreceptors in the present thrips species, it would help to explain their preference to blue, purple, light green and dark green, over the colors such as red, black and orange.

Table IV. Correlation between cumulative number of thrips trapped on color cards and level of infestation expressed as percentage of infested leaves

Color	Correlation coefficient
Yellow	0.86**
Blue	0.79**
White	0.90**
Light green	0.88**
Dark green	0.86**
Orange	0.82**
Purple	0.73*
Red	0.74*
Black	0. 67*
Transparent	0.86**

*, ** Significantly different at P< 0.05 and P< 0.01 respectively

The prevailing hot and humid conditions towards the end of the March 2004 may have facilitated reproductive potential and the short life cycle of *C. claratris* causing rapid population build up (Premachandra *et al*., 2004). The temperature during this period lied within the range of optimum temperature for *C. claratris* (Premachandra *et al*., 2004). Furthermore, lack of rain also facilitated this population build up as rains can wash thrips off causing a decline in population density (North & Shelton, 1986).

Significantly higher infestation in the control plots without color sticky traps indicated probable effectiveness of color sticky traps in mass trapping of thrips. The findings of significant correlation between cumulative thrips catches on color cards and level of infestation in the field support the utility of color cards in estimating the abundance of *C. claratris* in tomato leaves. As *C. claratris* preferentially attacks leaves of tomato than fruits and stem, change in thrips counts on color cards could be used as an indicator of the change in abundance of *C. claratris* in tomato foliage.

CONCLUSION

Blue and white colours were more effective in trapping the *C. claratris* followed by purple. Since colors showed high correlation between cumulative trap catches and the level of leaf infestation by thrips, they may serve as suitable tools for monitoring the field infestation of insect population. Use of white and blue colors to design a pest trap is worthwhile and these color cards can also be used for mass trapping and monitoring insect in vegetable production. Higher reflectance in blue and UV from sticky cards appeared to be an important component in trapping *C. claratris*. Use of color cards alone to maintain low infestation level is not viable as the population of thrips increases exponentially during the favorable period.

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