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Colored Bottle Traps With And Without Methyl Eugenol For Monitoring *Bactrocera spp.* In Tarakan Chili Fields

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ABSTRACT

Fruit flies (*Bactrocera spp.*) are economically important pests of chili and other horticultural crops. This study compared captures in recycled plastic-bottle traps containing yellow, green, or white paper inserts at three selected chili-growing sites in North Tarakan, North Kalimantan, Indonesia. Trapping comprised an unbaited stage followed by a stage with methyl eugenol (Petrogenol); observations were indexed from Day 1 to Day 5. Cumulative fruit-fly catches across the three sites were 18, 2, and 0 in unbaited yellow, green, and white traps, respectively, and 213, 18, and 32 in the corresponding baited traps. *Bactrocera dorsalis* and *Bactrocera umbrosa* were recorded. Baited yellow traps captured 193 *B. dorsalis* and 20 *B. umbrosa*. Yellow traps had the highest observed catches in both stages. Because the stages were sequential, differences between stages cannot isolate the effect of methyl eugenol or establish a color-by-lure interaction. The short observation period and unresolved sampling-effort details further restrict inference. Yellow bottle traps with methyl eugenol warrant further evaluation for monitoring responsive Bactrocera species in these fields; the study does not establish reduced fruit damage, population suppression, or increased yield.

INTRODUCTION

Chili pepper (*Capsicum frutescens* L.) is an important horticultural commodity because of its food uses and economic value. Regional agricultural statistics provide context for horticultural production in North Kalimantan [1]. Maintaining marketable fruit quality requires attention to pests that damage developing and ripening fruit. Tephritid fruit flies are particularly relevant because their larvae feed internally, causing deterioration, reduced market quality, and postharvest losses [2]. Monitoring adults can provide information about their occurrence around a crop, but an adult caught near chili is not itself evidence that the insect developed in chili fruit. This distinction matters when interpreting traps placed in mixed horticultural landscapes. A useful monitoring study should therefore define its sampling outcome clearly and distinguish captures from direct assessments of infestation, crop protection, or production.

The oriental fruit fly, *Bactrocera dorsalis*, has a broad host range and is considered a major threat to fruit and vegetable production in tropical and subtropical regions [3,4]. Its management requires consideration of both the insect and the agricultural landscape. Fruit fly abundance and species occurrence can vary with host availability, fruiting season, and environmental conditions [5,6]. Consequently, captures at a particular location and time describe only part of a changing ecological setting. Adjacent fruit crops, vegetables, and settlements may also influence the resources and conditions encountered by adults. Regular monitoring is therefore relevant to management decisions, while interpretation must remain specific to the target species, capture method, observation period, and field context. A short sampling period cannot establish long-term seasonal patterns or island-wide species prevalence.

Conventional fruit fly management includes insecticides, sanitation, fruit protection, and lure-based trapping. Integrated approaches are preferred because repeated or indiscriminate pesticide use may expose non-target organisms and increase production costs [2,3]. Traps can support surveillance by providing a defined sampling point for adult insects. Their performance, however, depends on design, color, placement, target species, and local conditions. Experiments on chili have demonstrated that trap color and height influence adult captures [7]. These findings make standardization important when comparing trap treatments: a difference in capture can reflect the characteristics of the device as well as the number and activity of insects encountering it. Monitoring performance must therefore be evaluated separately from suppression, which requires additional evidence about field populations or crop outcomes.

Insects respond to both visual and olfactory signals. Yellow surfaces attract several groups of diurnal insects [8], and methyl-eugenol-baited colored traps have produced higher captures in yellow traps than in other colors in previous experiments [9]. Methyl eugenol is an established male lure for several Bactrocera species, although responses depend on physiological state and the conditions under which attraction is assessed [10,11,12,13]. Recycled transparent bottles fitted with colored inserts offer a simple device for examining capture patterns, but bottle construction, insert placement, and chemical baiting represent distinct components. Comparing colors within a common trapping stage can

describe their relative performance under that stage's conditions. Comparing successive unbaited and baited stages is more limited because lure presence changes together with time, preventing the independent attribution of differences to the lure.

In Tarakan, chili is grown in landscapes containing other fruit crops, vegetables, and settlements. Local evidence about the relative capture performance of yellow, green, and white bottle traps remains limited. A field comparison can help identify a candidate device for further monitoring trials while documenting the insects caught and the short-term variability of captures. This study therefore aimed to (i) compare fruit fly catches among three bottle-trap colors within an unbaited stage and within a subsequent methyl-eugenol-baited stage and (ii) describe recorded species composition and five-day capture patterns at three selected chili-growing sites. The contribution is a site-specific comparison of adult captures using readily available materials. The study did not measure fruit infestation, population suppression, marketable yield, or economic returns; conclusions concern monitoring performance rather than verified crop protection.

MATERIALS AND METHODS

Research site and time

This study was conducted at three chili-growing sites in North Tarakan District, North Kalimantan Province, Indonesia: Juata 1 (Yellow Bridge), Juata 2 (White Bridge), and Juata 3 (Maya River).

Sampling sites were selected purposively based on cultivated area, chili planting intensity, and recommendations from local farmers. The three sites represented selected field settings with different surrounding vegetation and management practices. Purposive selection limits generalization beyond these sites.

Sampling activities were carried out during the fruiting stage of chili plants, when developing and ripening fruits were present. At each selected location, traps were used to record adult fruit fly captures. Trap catches were compared descriptively among sites and treatments; they were not treated as direct estimates of field population density or crop infestation.

Materials tools and research design

Fruit fly traps were installed in the three selected chili-growing sites. The traps were constructed using recycled transparent plastic mineral-water bottles containing white, yellow, or green paper as visual inserts. Thus, "trap color" refers to the colored insert rather than a uniformly painted bottle surface.

The trapping experiment comprised two sequential stages. In the first stage, traps contained colored paper without added methyl eugenol. In the second stage, methyl eugenol (Petrogenol) was incorporated into the colored traps. Soapy water was added to the bottom of the traps to retain captured insects and stabilize the bottles. Because lure presence changed between stages, between-stage differences may reflect temporal variation as well as lure-related effects; this design does not isolate an independent lure effect.

Research procedures

Data on fruit fly pest management practices were collected through direct interviews with six chili farmers, with two respondents from each of the three study sites. A structured questionnaire covered cultivation practices, farmers' experiences of fruit fly occurrence, pest monitoring, insecticide use, and other management strategies. Responses were summarized descriptively as counts and percentages of the six respondents. Pest occurrence and management practices were self-reported rather than independently measured infestation outcomes.

Fruit fly captures were recorded by sampling site, trap treatment, and observation day. Observations were indexed from Day 1 to Day 5. Captured insects were assigned taxonomic names, and fruit-fly counts were distinguished from non-target insect counts. Cumulative counts summarize captures across the three sites for each treatment.

Daily capture patterns were used to describe short-term variation within each trapping stage. Fruit-fly counts were kept separate from non-target insect counts, and cumulative treatment totals were obtained by adding the counts across the three sites. Aggregate counts were not converted to standardized capture rates because the numbers of functioning traps and their exposure intervals were not established. Species names indicate the recorded assignments; diagnostic and voucher limitations restrict interpretation of species-level records.

Supporting meteorological information included temperature and relative humidity from the nearest station of the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG). These observations were considered contextual information rather than site-level explanatory covariates. The meteorological period could not be aligned with the trapping observations, so weather values were not used to explain treatment differences.

Observed parameters and data analysis

The observed outcomes were daily captures, cumulative fruit-fly counts by treatment and site, recorded species composition, and farmer questionnaire responses. Respondent percentages were calculated as the number selecting a response divided by six, multiplied by 100. Counts and percentages were presented together because of the small survey sample. No estimate of crop infestation, damage reduction, yield response, or cost-effectiveness was derived from these observations.

Farmer questionnaire responses and cumulative captures were summarized descriptively. Analyses of variance (ANOVA), followed by Duncan's multiple range test (DMRT), were performed using MS Excel and JMP version 4.0 to compare colors within each trapping stage at $\alpha = 0.05$. Descriptive totals provide the principal evidence because independent replicate numbers, model degrees of freedom, repeated-measure structure, and distributional diagnostics were not established. The numerical ANOVA and DMRT outputs are presented with these inferential limitations. No combined test of lure presence or a color-by-lure interaction was established.

RESULTS

Study sites and farmer practices

The three selected sites differed in their surrounding agricultural setting (Table 1). Juata 1 (Yellow Bridge) contained fruit crops and vegetables, including bitter gourd, papaya, and chili. Juata 2 (White Bridge) was associated mainly with papaya cultivation and nearby residential settlement. Juata 3 (Maya River) contained papaya and leafy vegetables, including mustard greens, water spinach, and spinach. Meteorological context comprised temperatures of 28.74–29.25 °C and a mean relative humidity of 78.89%; these values were not analyzed as treatment-specific measurements.

Table 1. Agricultural land use and surrounding characteristics of the study sites.

Study site	Main land use	Surrounding characteristics
Juata 1 (Yellow Bridge)	Fruit crops and vegetables	Agricultural area with bitter gourd, papaya, chili, and other vegetables.
Juata 2 (White Bridge)	Fruit crops	Papaya cultivation and nearby residential settlements.
Juata 3 (Maya River)	Fruit crops and vegetables	Papaya and leafy vegetables, including mustard greens, water spinach, and spinach.

The survey comprised six farmers, with two respondents at each site. Respondents were aged 34–52 years (mean 39 years) and cultivated areas of 300–1,800 m² (mean 925 m²). All six farmers (6/6; 100%) cultivated bird's eye chili on relatively flat land, used commercially obtained planting materials, applied organic fertilizers, and practiced manual irrigation. River water was used by two farmers (2/6; 33.3%) and pond water by four (4/6; 66.7%). Planting distances were 60 × 70 cm for two farmers and 60 × 60 cm for four farmers.

All respondents (6/6; 100%) reported aphids and fruit flies as major insect pests and used synthetic insecticides as their primary pest control method. Sedges were reported by six respondents (6/6; 100%) and *Ageratum conyzoides* by five (5/6; 83.3%). Five farmers (5/6; 83.3%) used manual cutting for weed management, and all six marketed harvested chili directly. These observations summarize the participating farmers rather than a population-wide survey.

Composition and distribution of captures

Two fruit fly species were recorded: *B. dorsalis* and *B. umbrosa* (Table 2). Non-target entries included *Apis mellifera*, *Harmonia axyridis*, Heteroptera, and a harlequin lady beetle of unresolved identification. The harlequin entry remained separate from *H. axyridis* because the relationship between these records was not established. The numeric entries in Table 2 totaled 112 insects at Juata 1, 93 at Juata 2, and 87 at Juata 3; these totals include non-target captures.

In baited yellow traps, *B. dorsalis* counts were 80 at Juata 1, 59 at Juata 2, and 54 at Juata 3, giving 193 individuals. *Bactrocera umbrosa* counts in the same treatment were 7, 5, and 8, respectively, giving another 20 individuals. Thus, the cumulative fruit-fly catch in baited yellow traps was 213. This total is distinct from the *B. dorsalis*-only count and from the all-insect totals in the table.

Table 2. Cumulative insect captures by trap treatment and study site.

Trap treatment	Species / morphospecies	Juata 1	Juata 2	Juata 3
Green	*Bactrocera dorsalis*	0	2	0
Yellow	*Apis mellifera*	1	0	1
	Bactrocera dorsalis	2	6	8
	Bactrocera umbrosa	0	0	2
	Harmonia axyridis	2	0	0
	Heteroptera	1	0	0
	Harlequin lady beetle (unresolved)	1	0	0
White	-	0	0	0
Green + attractant	*Bactrocera dorsalis*	2	7	6
	Bactrocera umbrosa	1	1	1
Yellow + attractant	*Bactrocera dorsalis*	80	59	54
	Bactrocera umbrosa	7	5	8
	Harmonia axyridis	1		
White + attractant	*Bactrocera dorsalis*	11	11	7
	Bactrocera umbrosa	2	1	0
	Harmonia axyridis	1	1	0
	Total	112	93	87

Note: Counts are cumulative individuals across the sampling observations and include non-target insects. A dash denotes an unassigned taxon; numeric zeros denote recorded zero counts. Blank cells remain unspecified and are not automatically interpreted as zeros. Column totals of the displayed numeric entries are 112, 93, and 87 for Juata 1, Juata 2, and Juata 3, respectively. The harlequin lady beetle entry remains separate pending identification checks. Equal sampling effort among treatments has not been confirmed.

Color differences within trapping stages

Cumulative unbaited fruit-fly catches were 18 in yellow traps, 2 in green traps, and 0 in white traps. The corresponding mean values were 0.24, 0.03, and 0.00 (Figure 1a). ANOVA yielded $F = 5.37$ and $p = 0.005$; DMRT assigned yellow to a different group from green and white. These numerical outputs are retained with the sampling-unit and model limitations described in Materials and Methods.

Cumulative baited fruit-fly catches were 213 in yellow traps, 32 in white traps, and 18 in green traps. The corresponding mean values were 2.84, 0.43, and 0.23 (Figure 1b). ANOVA yielded $F = 81.62$ and $p < 0.001$, with DMRT separating yellow from the other colors. Yellow had the highest observed cumulative catch in each stage. Means remain unstandardized because their sampling denominator and any transformation were not established.

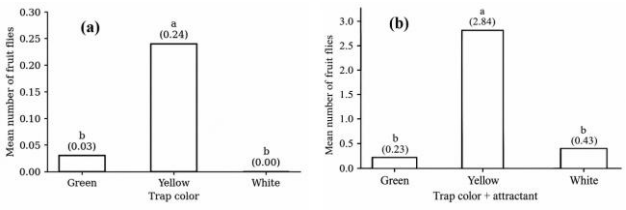


Figure 1. Mean fruit fly captures in green, yellow, and white bottle traps: (a) without attractant and (b) with methyl eugenol. The sampling denominator and any transformation of the mean values were not established. Letters indicate the within-stage DMRT groupings at $\alpha = 0.05$ and do not compare stages. Sample sizes and uncertainty estimates were not established; no error bars are shown. The plotted values and groupings should therefore be interpreted provisionally.

Five day capture patterns

The daily trajectories differed between stages (Figure 2). Unbaited yellow-trap counts fluctuated across Days 1–5 and were highest on Day 5. Green and white unbaited traps

generally recorded few or no fruit flies. In the baited stage, yellow-trap counts peaked on Day 2 before declining; catches in the other colors remained lower. These trajectories represent daily trap captures rather than cumulative running totals or independently measured changes in the field population.

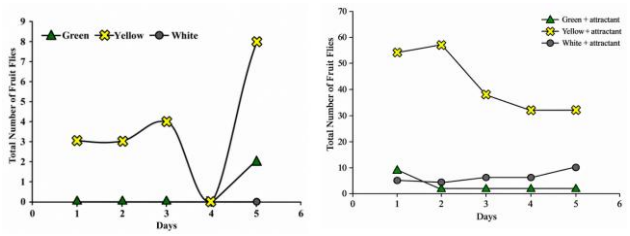


Figure 2. Daily fruit fly capture trajectories for colored bottle traps: (a) without attractant and (b) with methyl eugenol, indexed from Day 1 to Day 5. The vertical axes display total numbers of fruit flies rather than cumulative running totals. Panels use different vertical scales. Treatment-specific sampling effort was not established.

DISCUSSION

Interpretation of trap color and lure responses

Yellow traps ranked highest within both trapping stages, consistent with earlier findings on visual responses and colored trapping devices [7,8,9]. This agreement supports yellow as a candidate visual component for further local trials. It does not establish that the same ranking will hold under every crop stage, light environment, or trap configuration. The device used transparent bottles and colored paper inserts, whereas other studies used sticky surfaces or different trap structures. The amount, orientation, and exposure of a colored surface can differ between designs. Consequently, the meaningful comparison is the ranking under the tested conditions, rather than an assumption that all devices described as yellow are functionally equivalent.

Visual attraction depends on insect photoreceptor sensitivities and the spectral properties of the trap and its surroundings [18]. The present study did not measure reflectance or spectral sensitivity and therefore cannot identify the visual mechanism underlying the observed ranking. Green traps exceeded white traps in the unbaited stage, whereas white traps exceeded green traps in the baited stage. Consequently, a general preference for green over white is not supported.

Baited yellow traps had the largest observed catches, but the sequential design does not isolate the effect of methyl eugenol. Lure presence changed together with time, so changes in adult activity, host availability, or other field conditions could contribute to the difference. A simultaneous factorial comparison would be needed to estimate separate effects of color and lure and to test their interaction. The present results therefore identify a combination for additional evaluation rather than demonstrate synergy. Evidence that methyl eugenol attracts responsive males [10,11,12,13] explains its relevance to trap design, but does not remove the temporal confounding in this experiment.

Lure choice can influence the species detected in fruit fly surveys. In Depok and Bogor, methyl eugenol and cue-lure attracted different assemblages, with *B. dorsalis* and *B. umbrosa* responding to methyl eugenol [19]. This supports interpreting baited catches as a sample of lure-responsive flies. Attraction distance, olfactory detection limits, and the spatial reach of Petrogenol were not measured in the present study; no numerical attraction radius can be inferred.

Species composition and non target captures

Fruit flies were captured at all three study sites, but this does not identify the host plants from which the adults originated. Surveys of horticultural landscapes have documented associations between fruit flies and multiple host plants [6]. Confirming local host use requires examination or rearing of insects from sampled fruits rather than trap captures alone.

The recorded species composition reflects both local occurrence and the selectivity of the trapping method. It does not establish that *B. dorsalis* and *B. umbrosa* are the most prevalent fruit fly species throughout Tarakan Island. Earlier observations in West Lombok used historical names including *B. papayae* and *B. philippinensis* [15]. These names are currently treated as synonyms of *B. dorsalis* [22] and should not be interpreted as separate species confirmed by the present study. The absence of documented diagnostic criteria and voucher verification limits confidence in species-specific interpretation.

Non-target captures occurred in both trapping stages (Table 2). Unequal or unverified sampling effort and unresolved non-target identifications prevent a firm comparison of selectivity. Locally constructed traps and attractants have been described as components of fruit fly management [16], but the present study measured adult captures rather than population suppression. In a separate study of *Ceratitis capitata*, yellow, white, green, and red traps captured 12.16, 11.75, 9.68, and 9.06 males per trap per week, respectively [17]. That experiment involved a different target species and lure system, so its numeric capture rates cannot be directly compared with the present counts.

Temporal variability and practical implications

Trap catch can vary with trap type, observation period, lure performance, placement, and environmental conditions [11]. The decline in baited yellow-trap catches after Day 2 could reflect several of these factors, but no cause can be assigned without contemporaneous measurements. Work on methyl eugenol dispensers has examined changes in lure amount, release rate, and field captures during weathering [20]. Those findings identify a possible process for future investigation rather than a demonstrated explanation for the five-day pattern observed here.

Yellow recycled-bottle traps with methyl eugenol are a candidate monitoring option for responsive Bactrocera species in the selected chili-growing sites. Their construction uses readily available materials, but local costs, durability, and cost-effectiveness were not measured. Deployment should complement field sanitation, removal of infested fruit, and routine crop scouting within integrated pest management [2,3,4,16]. Research in peach orchards has also examined locally fabricated traps and lure combinations [21], although differences in crop, target species, exposure, and study design limit direct transfer of performance estimates.

The questionnaire findings provide a local management context for monitoring: all six participating farmers reported fruit flies and used synthetic insecticides. However, a small purposive survey cannot quantify pesticide use across North Tarakan or determine whether a trapping intervention would change farmers' decisions. Demonstrating practical value requires observations linking trap deployment to a defined management response, together with measurements of labor, costs, crop infestation, and marketable production. These outcomes should be assessed directly rather than inferred from the number of adults captured.

Study limitations and future research

Interpretation is limited by purposive selection of three sites, a short observation window indexed over five days, and sequential unbaited and baited stages. Independent replicate numbers, exposure intervals, trap placement, lure dose, taxonomic verification, and the denominator of mean catches were not established, limiting reproducibility and interpretation of ANOVA and DMRT. Daily observations from the same trap cannot automatically be treated as independent replicates. No fruit infestation, marketable yield, or economic cost outcomes were measured. Future trials should use simultaneous randomized treatments, verified trap-level exposure, longer monitoring, documented species identification, and direct measurements of crop damage. Count-data models should account for repeated observations and assess dispersion before inferential conclusions are drawn.

CONCLUSION

Bactrocera dorsalis and *Bactrocera umbrosa* were recorded at three selected chili-growing sites in North Tarakan. Yellow traps had the highest cumulative fruit-fly catches within both stages: 18 without attractant and 213 with methyl eugenol, including 193 *B. dorsalis* in the baited stage. These findings identify yellow bottle traps with methyl eugenol as a candidate for further monitoring trials under comparable field conditions. Sequential deployment, short observation, purposive site selection, and unresolved sampling-effort and analytical details limit causal and statistical inference. The study does not establish an independent lure effect, color-by-lure synergy, reduced crop infestation, field population suppression, improved yield, or economic benefit. Further trials should evaluate simultaneous randomized treatments, document trap exposure and species identification, and measure crop damage alongside adult captures.

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