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碩士論文

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塵蛛垃圾型隱帶之獵物捕食與防禦掠食者功能之探討

A test of prey attraction and predator defense functions of detritus decorations built by *Cyclosa* spider

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Contents

Abstract

In some orb-weaving spiders, in addition to regular components of web, they also construct extra structures on webs called decorations. In many spiders, decorations are made entirely of silk, but in some species such as those in the genus *Cyclosa*, carcasses, debris, leaf, and even egg sacs are also used. So far there is no direct test of the functions of detritus decorations built by *Cyclosa* spiders. In this study, I first tested the prey-attraction function by manipulating the presence of detritus decorations in *Cyclosa confusa*, then examined this treatment's effect on spiders' foraging performance. Results from field studies conducted in Orchid Island showed that the insect interception rate of the experimental group (decoration removed) was not significantly different from that of the control group (decoration remained). This result suggests that detritus decoration did not serve as prey attractant and their presence may even reduce the foraging success of *Cyclosa* spiders. In this study, I also tested the predator-defense function by manipulating presence of decoration then observing the predator's response. In addition, how visual signals of detritus decorations were perceived by predators were examined by calculating the colour contrasts of the decorations and spiders against various backgrounds. The videotaped observations made in the study sites revealed that paper wasp repeatedly directed their attacks on decorations in most of the recorded attacks, rather than on the spiders. The colour contrasts of spiders and decorations against various types of vegetation backgrounds differed, which indicats that the visibility of decorations varied when viewed in front of different vegetations. The colour contrast of *C. confusa* against the decoration did not exceed the threshold value, indicating that the hymenopteran predators could not distinguish the spider from the decorations. All the results suggest that decorations seemed to be able to prevent paper wasps from

accurately attacking the spiders, thus might enhance the survival of spiders. Various groups of yeasts were found on webs, decorations, spiders, and plants in the study sites. Totally 74 yeast strains were separated and 37 morphospecies were identified. Twenty-eight yeast strains were analyzed with biolog and eight species were identified. Ribosomal DNA ITS regions were amplified and digested by endonucleases *Hinf*I, *Hae*III, and *Hha*I and 74 yeast strains could be separated into 31 groups. The distribution of most of yeast species did not show specificity. However, a widely distributed species, *Aureobasidium pullulans,* showed a specificity with *C. mulmeinensis* by occurring only in the bodies, webs, decorations of such spiders and the plants (pineapple and screwpine) on which the webs were built. Whether this specificity simply resulted from chance events or involved certain ecological interactions awaits further study.

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摘要

隱帶(decoration)為結網性蜘蛛網上特殊的附屬結構；有些種類的隱帶完全由絲組成，有些種類的隱帶則是除了絲外尚有其他組成。塵蛛屬（*Cyclosa* sp.）之隱帶是由獵物屍體、碎屑、落葉或卵囊等構成，而這些類型的隱帶功能為何尚未有直接之探討，因此本研究的目標之一為探討塵蛛隱帶之功能。在蘭嶼進行之野外實驗結果顯示，實驗組（移除隱帶組）的捕蟲率與控制組（有隱帶組）的捕蟲率在二月、四月及八月並無顯著差異。在八月進行之錄影記錄顯示，隱帶之存在似乎會誤導胡蜂之攻擊，而使得蜘蛛有脫逃的機會。此外，我們亦從胡蜂視覺角度下，計算塵蛛與隱帶在不同背景下之顏色對比。隱帶在某些植物之葉及樹皮前的顏色對比顯著高於臨界值，但在其他種類則低於臨界值，但隱帶與蜘蛛間的顏色比並未達臨界值，顯示胡蜂在顏色上並無法區分隱帶與塵蛛。綜合這些實驗結果顯示熱帶塵蛛之隱帶並無增加捕食率之功能，但具有隱蔽作用。本實驗的第二個目的在檢測塵蛛酵母菌之多樣性。在過去之研究多著眼於臨床上或是與工業生產相關之酵母菌，自然棲地之酵母菌多樣性並未受到太大注意。塵蛛會將昆蟲屍體長期留置於網上，此種行為模式提供了適合酵母菌生長繁殖的微環境。本研究藉分離熱帶塵蛛及二角塵蛛網上、隱帶上、身上及塵蛛結網之植物（鳳梨、林投及檳榔）上的酵母菌來探討塵蛛酵母菌之多樣性。由蘭嶼不同植物（鳳梨、檳榔及林投）上所採集之二角塵蛛及熱帶塵蛛其網、隱帶、蜘蛛個體和所依附的植物體上皆發現有酵母菌的存在。從所採得之樣本中，共分離出 74 株菌株，由菌落之外部形態初步可鑑定出 37 個形態種，而利用 biolog 可鑑定出 8 種酵母菌；全部菌株之 rDNA ITS 區域經增幅後以三種限制內切酶 *Hinf*I、*Hae*III 及 *Hha*I 進行酵母菌分群，共可分成 31 群。進一步分析不同酵母菌和生長環境之間的關係，發現 31 群酵母菌中，其分佈大部分並未有特別的模式，唯獨 *Aureobasidium pullulans* 只出現在二角塵蛛的個體、網、隱帶及所依附的鳳梨及林投上；顯示

A. pullulans 的生長與二角塵蜘似乎具專一性。此種專一性係屬巧合或具有特殊之生態意義，仍待進一步探討。

INTRODUCTION

Many diurnal orb-weaving spiders incorporate various objects in their webs called decorations after they have constructed an orb (Herberstein et al. 2000a). Those spiders decorating their webs are mostly members of the family Araneidae, Uloboridae, and Tetragnathidae (Eberhard 1990). Not only the shape of decorations is variable, the material used by various spiders is also quite different. Most spiders use silk to construct decorations and there are several types: cross, linear, drop-like, round, and spiral (Eberbard 1990; Herberstein et al. 2000a). Some other species, such as *Cyclosa* spp., construct their decorations using debris, such as the body of insects, leaves, sticks, spider ecdysis, and egg sacs (Comstock 1913).

Most orb-weaving spiders usually drop prey carcasses from their webs after every meal. If the spiders do not remove the prey carcasses, it is usually because they do not finish consuming the prey yet thus they want to preserve it on web temporarily. In Australia, some *Nephila* species put the prey carcasses on the web for several weeks called “rubbish band” (Main 1976). Although *Nephila* species arrange the prey remains in a linear form on the web, this probably functions as storage (Herbertstein et al. 2000a). Few spiders, such as *Cyclosa* spp. and *Arachnura* spp. build more or less permanent detritus decorations in a linear form (Neet, 1990; Rod 1996; Rovner, 1976). In addition to prey remains, some other species of *Cyclosa* also use silk or egg

sacs to build decorations (Comstock 1913). It is unlikely that *Cyclosa* spiders such as *C. confusa* use their carcasses decorations as a food cache because the carcasses they incorporated were digested already.

In the past, several functional hypotheses for decorations have been proposed and most of them centered on silk decorations. These hypotheses include: 1. disguise itself or to make the spider look bigger (Schoener & Spiller 1992; Blackledge 1998b); 2. warn large flying animals to avoid web destruction (Eisner & Nowicki 1983; Blackledge 1998a; Tolbert 1975); 3. serve as a shelter or hideout (Hingston 1927; Blackledge & Wenzel 2001); 4. increase web stability (Robinson & Robinson 1970); 5. regulate spider body temperature (Humpreys 1992); 6. attract prey by reflecting UV light (Craig & Bernard 1990; Tso 1996; Tso 1998a; Tso 1998b; Herberstein et al. 2000b; Craig et al. 2001); 7. reflect physiological condition under stress (Nentwig & Rogg 1988) or 8. serve as a display of female fecundity (McClintock & Dodson 1999). Among these hypotheses, only the hypotheses of prey attraction and predator defense have received relatively more evidence (Herberstein et al. 2000a).

Most of the previously mentioned studies focused on silk decorations built by *Argiope* spiders, only a few examine detritus decorations built by *Cyclosa* spiders. Neet (1990) and McClintock & Dodson (1999) studied the circular and linear decoration made by *C. insulana*. Neet (1990) found that most *C. insulana* build their

webs without circular decoration in calm weather and proposed that the type of decorations was determined by weather condition. However, no direct experimental test was provided to support this hypothesis. McClintock & Dodson (1999) observed the mating behaviours of *C. insulana* and proposed that linear decoration may represent female fecundity. However, this study was mostly descriptive, with no empirical evaluation of the hypothesis. Tso (1998a) compared the prey interception rate between decorated and undecorated webs. Although the prey interception rate was higher for decorated web, the decoration of *C. conica* was made of silk, not detritus. The functions of detritus decoration remain to be tested experimentally.

Previous studies showed that prey carcasses were used by certain spiders as prey attractant. Tietjen et al (1987) found that the social spider *Mallos gregalis* uses scent emitted from consumed prey to attract prey. *Mallos gregalis* catch and consume large prey communally and they do not remove the prey carcasses. The yeasts growing on the prey carcasses produce an odor which was attractive to flies (Tietjen et al. 1987). Since *Cyclosa* spiders always leave their prey carcasses on the webs for a long time, such behaviour may also provide a suitable microhabitat for yeasts. Therefore, we doubt that the detritus decoration built by *Cyclosa* may also be inhabited by yeasts thus function as prey attractant.

Most *Cyclosa* spiders rest in the center of their decoration. When they rebuild

their webs, the detritus decoration is usually retained (Neet 1990; I. C. Chou personal observation). The body colour of *Cyclosa* spider is similar to the decoration and the spider is always huddled within the decorations. Because it is not easy for humans to distinguish the spider from the decoration, arachonologists have long suggested that the detritus decoration build by *Cyclosa* spiders function for hiding and concealing. However, human visual system is quite different from those of insects, the major predators and prey of *Cyclosa* spiders (Chittka, 2001). Hence, it is not clear whether insect can visually distinguish *Cyclosa* spider from the detritus decoration. Therefore, a behaviour test of predators' responses to decoration and inspections of visual signals of the spiders and decorations to the predator's eye are needed.

In this study we tested the prey-attraction and predator defense hypotheses by both field manipulation and laboratory study. First, we test whether the decoration built by *C. confusa* function to increase prey interception rate. Secondly, we examine whether detritus decoration of *Cyclosa* spiders serve as a concealing device. We manipulated presence of detritus decoration of *C. confusa* then compared the prey interception rate. Video recording was used to track the behavioural responses of predators to spider with and without decorations in the field. We also calculated the colour contrasts of spiders and decorations against different backgrounds in the colour space of Hymenoptera to determine whether predators can visually distinguish the

decoration and *Cyclosa* spiders. Another goal of this study is to investigate the diversity of yeasts associated with *Cyclosa* spiders. In the past, yeast diversity of natural habitats have received little attention, and most of the previous studies focused on yeasts associated with clinics or food industry. *Cyclosa* spiders always leave their prey carcass on the webs for a long time, such behaviour provides a suitable microhabitat for yeasts. In this part of study, we investigated *Cyclosa*-associated yeast diversity by collecting yeasts from the webs, decorations, the bodies of *C. confusa* and *C. mulmeinensis* and the plants (pineapple, screwpine, and betel palm) on which *Cyclosa* spiders build their webs.

MATERIALS AND METHODS

Study Site

Field behavioural studies were conducted in February, March 2002, and August 2002 at the Yung-Hsing Farm in Orchid Island (22º03’ N, 121º32’ E), Taitung County, in southern Taiwan. Orchid Island is a tropical island, with an average annual rainfall of 2600 mm per year, an average annual temperature of 22.4 ºC (Chen et al. 1982), and a clearly separated dry season and monsoon (Wang 1984). Breadfruits (*Artocarpus xanthocarpus & A. altilis*), betel palms (*Areca catechu*), and figi longan (*Pometia pinnata*) are the dominant vegetations in the study site. A stable population of *Cyclosa confusa* spider population could be found in the study site throughout the year.

Comparison of Prey Interception Rates

Web sites of *Cyclosa confusa* were marked by fastening adhesive tape on vegetation near by with identification numbers. As most orb weavers with decorations are diurnal (Herberstein et al. 2000), observations were conducted during daytime. The spiders were randomly assigned into two groups. In the experimental group we removed all decorations and in the control group the webs were left intact. Each day

before 0900 h, we used forceps to remove new decorations incorporated by spiders of experimental groups and the removed prey remains were preserved in 70% ethanol. Horizontal and vertical web diameters, spider body length, and decoration length on all webs were measured. Each marked web was visited every hour from 0900 to 1800 hour to monitor web damage pattern and number and taxonomic order of prey captured. In each field trip, the study was conducted for eight days. The monitoring was not conducted during heavy rainy or strong windy days. Half digested insects which were difficult to determine were marked as unidentified. In the August 2002 study, in addition to hourly monitoring we also retrieved prey interception data from video taped recordings. The details of video recording were given in the next text section. Our prey interception data set was characterized by low probability of prey capture and large sample size, which fitted the Poisson distribution (Person Chi-square< 0.05) (Steel et al. 1997). Therefore, we used the Poisson regression to examine the relationship between capture probability and various variables. Categorical variables included decoration, weather, and web area. We designated decoration (presence or absence) and weather (rain or sun) as zero or one. The web areas were assigned as continuous variables, except those of video taped data. Those web areas were designated as categorical variable for the small sample size. We ranked web area of the video-taped data into nine categories: <100, 100-200, 200-300,

300-400, 400-500, 500-600, 600-700, 700-800, and >800 cm^2. The Possion model was:

$$\log \mu_N = \log N(X_i) + X_i \beta$$

Where μ is expected value, X is variable of decoration, weather, or web area, β is probability, and N is total number of individuals.

In addition, to compare the species composition of prey caught by *Cyclosa confusa* with those available in the study site, we established a Malasie trap for four days in August 2001. Malasie traps generally intercept the insects living in the middle and lower strata exhibiting the escape behaviour of flying upward (Borror & Long 1954). We collected the insects and preserved them in 70 % ethanol then identified them to taxonomic orders in the laboratory. A Chi-square test of homogeneity was used to compare the composition of prey caught by *C. confusa* and those in the study site.

Recording of Predation Events

To identify the predators of *Cyclosa confusa* and the behavioural interactions between the predators and prey, we set up four video recorders in the study site. The recordings were conducted from 8 to 17 August 2002 (except 14 August due to bad weather) each day from 1000-1800. Two recorders were placed in front of the spiders of the control groups and the other two the experimental groups. Prey encounter time,

predator attack time, behaviour of predators and responses of *C. confusa* were recorded while reviewing the videotapes back in the laboratory. Attack behaviours were classified into three categories: attacking spider directly, attacking the web, and attacking the decoration. We tested for a difference in frequencies among three behaviours with a Chi-square test of homogeneity.

Reflectance Spectral Measurements

Thirteen *C. confusa* spiders were collected from the study site and their decorations were collected by plastic frames. We also collected leaves and barks of the four dominant plant species: betel palm *Areca catechu*, Indian almond *Terminalia catapa*, figi longan *Pometia pinnata*, and breadfruit *Artocarpus altilis*. We only collected the fresh leaves of the herbaceous giant elephant's ear *Alocasia odora*. The reflectance spectra of the spiders, decorations, and different background types were measured with a spectrometer (S2000, Ocean Optics, Inc., Dunedin. Florida, U.S.A.) in the laboratory. For each measurement, the illumination leg of a reflection probe (with six illumination fibers) was attached to a light source (450-W, Xenon arc lamp) and the read leg (with one read fiber) to the spectrometer. The probe end was placed vertically 5 mm above the sample. We measured the dorsum and ventrum of each *C. confusa*. Four measurements of reflectance spectra were made on each decoration and

the means were used in the subsequent calculations of colour contrasts. Those of barks and leaves were obtained in the similar way but six measurements were made from each object. The fraction of the light reflected by the surface are the surface-reflectance function. Colour signals could be generated when the surface reflectance function was multiplied by the illumination function of the habitat. The illumination function of the forest understory in the tropical Orchid Island was obtained from Lin (2003). To determine photoreceptor excitations for each measured spectra, we used spectral sensitivity functions of standard photoreceptors for Hymenoptera . The relative amount of light absorbed by each photoreceptor type is:

$$P = R\int_{300}^{700} Is(\lambda)S(\lambda)D(\lambda)d\lambda \qquad (1)$$

where $Is(\lambda)$ is the spectral reflectance function of the spider colourations or web decorations; $S(\lambda)$ is the spectral sensitivity function of the receptor in question and $D(\lambda)$ is the illuminating daylight spectrum (Chittka 1996). The sensitivity factor R in equation (1) is determined by the equation

$$R = 1/\int_{300}^{700} I_B(\lambda)S(\lambda)D(\lambda)d\lambda \qquad (2)$$

$I_B(\lambda)$ is the spectral reflection function of the background to which the receptors are adapted. We assume the receptors to be adapted to a background reflection function averaged from the reflections of various fresh leaves, fallen leaves and barks (Chittka & Menzel 1992). With this model, it is assumed that the photoreceptors display half their maximal response when stimulated by the light reflected from the adaptation background (Naka & Rushton 1966).

The quantum catch in the photoreceptors *P* [equation (1)] is the input to the photoreceptors, not input to the insect brain. On a neural level, the brain performs "calculations" with graded potentials generated by receptor cells. These signals are not linearly related to the logarithm of the quantum flux that forms the input to the receptor. When the maximum excitation E_{max} of the photoreceptors is set to one, the nonlinear phototransduction process is well described by

$$E = P / (P+1) \qquad (3)$$

Where *P* is the stimulus strength [eqn (1)], in units such that for P=1, E=0.5. The three excitation values in the bee's UV, blue and green receptors can be depicted in a three-dimensional receptor excitation space or in the colour hexagon (Chittka 1996).

With the three receptor excitation values plotted at angles of 120°, the *x* and *y* coordinates in the colour plane are given by:

$$x = \sin 60^{\circ} \ (E_G - E_{UV}) \quad (4)$$

$$y = E_B - 0.5\ (E_{UV} + E_G) \quad (5)$$

Where Eu, E_B and E_G are the inputs from the three photoreceptors.

Euclidean distances ΔSt between stimuli are calculated as

$$\Delta St = \sqrt{(\Delta x)^2 + (\Delta y)^2} \quad (6)$$

The Euclidean distance (ΔSt) is the colour contrast in the colour space of organisms under consideration.

Since the visual systems of Hymenoptera were quite similar among 40 species studied so far (Peitsch et al. 1992), we chose the spectral sensitivity functions of *Apis mellifera* to determine the photoreceptor excitement for each measured spectra. To analyze the colour contrasts of spiders and decorations against different backgrounds types, one-tailed t-tests were used to compare calculated values with the discrimination threshold value of 0.05 (Théry & Casas 2002). Previous studies showed that hymenopterans used achromatic vision when searching objects far ahead and chromatic vision when they approaching the object (Giurfa & Lehrer 2001; Heiling et al. 2003). In this study the colour contrasts were calculated under these two

conditions to examine how predators view spiders and decorations under different chromatic systems.

Collect and Culture of Yeasts

In Orchid Island, two species of *Cyclosa* spiders could be found on screwpine *Pandanus odoratissimus*, pineapple *Ananas comosos*, and betel palm *Areca catechu* vegetations. While *C. confusa* were abundant in betel palm vegetation, *C. mulmenensis* were abundant in screwpine and pineapple vegetations. To obtain yeast samples, the plant leaves, spiders, decorations, and silk were collected. Three leaves were sampled from each plant, and then each leave was cut into three replicates. Three *C. confusa* with decoration and three individuals without decoration were also collected. Plant leaves were first put in the plastic bag and then broke the leaves without hand touching. Decorations, spiders and webs were collected with sterile toothpicks. Samples and toothpicks (the part touched by hand were removed) were put into the 500 μl sterile yeast medium broths. Web samples were collected after removing the spider and decoration then waving the toothpick back and forth. The yeast medium broths were carried back to the laboratory and incubated at room temperature for two days. Then 100 μl yeast medium broth was removed and streaked into an acid yeast extract-malt medium composed of chloramphenicol

(30mg/ml) and hydrochloric acid to prevent bacterium growth. After 2-3 days we chose a single colony from different sources and streaked into a new acid yeast medium. The mediums were incubated at 26 ℃ for two days, and then we selected different yeasts to grow on new yeast mediums at 26 ℃ for two days to confirm the purity of the colony. In order to sustain yeast strains and protect the yeast from contamination, we mixed 0.7 ml of the yeast medium broth with 0.3 ml glycerol and preserved at –80 ℃.

Identification of Yeasts

Yeast identifications were carried out by biochemical evaluation using biolog, polymorphism chain reaction- restriction fragment length polymorphism (PCR-RFLP), and direct sequencing of D1 and D2 domains of ribosomal DNA. Traditional taxonomy takes time and sometimes the results may lead to the wrong identification. Anamorphic and teleomorphic species made the traditional taxonomy even more complicated. Recently molecular biology techniques were progressed very fast and many alternative identification methods were studied (Guillamón et al. 1998). Biolog metabolic reactions help us understand the nutritional characters of yeast, but sometimes the intraspecific variation of the utilization of carbon and nitrogen might lead to synonyms, so alternative ways to identification correctly is very important (Fell et al. 2000). PCR-RFLP and sequencing are both reliable and rapid

identifications, and they were applied extensively to industry and food yeast identification. (Esteve-Zarzoso et al. 1999; Fell et al. 2000; Jasalavich et al. 2000; Masneuf et al. 1996; Vilgalys & Hester 1990). Between 18S rRNA and 28S rRNA genes include two internal spaces ITSI and ITSII and ribosomal 5.8S gene. The 5.8S gene is a highly conserved region and the ITS regions have very high copy number and thus are useful to identify close species since ITS region exhibit high interspecific differences (James et al. 1996).

Biochemical Evaluation

Biolog MicroStation (Biolog's MicroLogTM 3.0, Biolog, USA) identification system provided a standardized micromethod using 94 biochemical tests to identify a broad range of yeasts. Biolog's MicroLog 3 software was used to identify the yeast from its metabolic pattern in the YT MicroPlate. As the metabolic properties and biochemistry reactions varied with each yeast, we could identify yeasts based on reaction colour and turbidity. The metabolic pattern was then interpreted by Biolog's MicroLog3 computer program. Biolog is not only used for clinical, but also for medical, food, and spoilage yeast identification (Praphailong et al. 1997). Selected yeast strains were cultured on yeast medium for two days. A sterile toothpick was used to pick some colonies into 15 ml sterile water and the concentration was adjusted to among 0.08-0.1 M. At this concentration, the numbers of yeasts were about 10^6

cells/ml. We used 8-channel repeating pipetter to take 100 μl cell suspension into each well, then the panels were incubated at 26 ℃. The yeast strains were identified by Biolog's MicroLog™ 3.0 database after 24 hours, 48 hours, and 72 hours. Within 24 hours, the similarity of identification should be greater than 0.75. From 48 hours and 72 hours, the similarity of identification should be greater than 0.50. If the results of identification after 24 hours, 48 hours, and 72 hours were the same then we accepted the identification result.

PCR-RFLP

DNA extraction was conducted according to the methodology described by Chung (2001). Seventy-four yeast strains were cultured, then pure colonies were placed into 500 μl CTAB buffer to break the cell membrane, and then heated for 30 min at 94 ℃ and 10 min at 65 ℃. Then 500 μl dichromathane/IAA (24:1) was added to precipitate protein and carbohydrate. After shaking slightly for 20 times, the solution was centrifuged (14,000 rpm, 2 min). The suspension was added 300 μl isopropanol to precipitate DNA. After being shaken slightly 20 times the solution was centrifuged again (14,000 rpm, 2 min) then the suspension was removed and 500 μl wash buffer was added to the precipitation. After mixing for 1 min, the mixture was centrifuged (14,000 rpm, 2 min). The suspension was removed again and the DNA was air-dried. After drying, 40 μl distilled H_2O was added to the DNA pellet and the

DNA was incubated at 37 ℃ for 30 min and was then preserved at –20 ℃.

The internal transcribed spacer (ITS) region was amplified by polymerase chain reaction from DNA isolated from pure cultures of yeast. The universal primes ITS1 (5' –TCC GTA GGT GAA CCT GCG G-3') and ITS4 (5' –TCC TCC GCT TCA TTG ATA TGC- 3') and used for amplification (White *et al.*, 1990). The reaction mixture (25 μl in total volume) contained 2.5 μl DNA, 17.55 μl H_2O, 2.5 μl buffer, 1. 5 μl $MgCl_2$ (150 mM), 0.25 μl dNTPs (5 mM), 0.25 μl primer ITS4, 0.25 μl Primer ITS4, and 0.2 μl Taq polymerase (4 units, MBI Fermentas, Lithuania). Amplification was carried out as followed: denaturation at 94 ℃ for 2 min the first cycle, 1 min the following 40 cycles, annealing at 58 ℃ for 20 sec, and extension at 72 ℃ for 3 sec, with a final extension at 72 ℃ for 5 sec. A 5 μl sample from each reaction was assayed by electrophoresis on a 1.2 % agarose gel (Agarose, Techcomp, Hong Kong), stained with ethidium bromide and photographed. A 100-bp DNA ladder marker (Promaga USA) served as the size standard.

Seventy-four yeast strains were examined using restriction patterns generated from the region spanning the internal transcribed spacers (ITSI and ITSII) and the 5.8S rRNA gene (White et al. 1990). Polymerase chain reaction product was digested with the restriction endonucleases *Hinf*I, *Hae*III, and *Hha*I (New England Biolabs, UK). One μl buffer and 1 μl restriction endonuclease were added to 8 μl of PCR

product and the reaction was conducted for 16 hours at 37 ℃. Restriction fragments were electrophoresed on 1.5 % Seakem LE agarose (BMA, Rockland, ME, USA) stained with ethidium bromide and photographed (Ultra Violet Product imagestore 7500, UVP, USA). A 50-bp DNA ladder marker (Promaga USA) served as the size standard. The photo were modified and then read by Photo-CaptMw version 99.03 (Vilber Lourmat, France) to get various fragment size. Then calculated each reading cutting fragment size to evaluate the theoretical values to avoid underestimating the overlapped cutting bands.

Amplification and Sequencing of LSU DNA D1/D2 Region

The D1 and D2 domains of ribosomal DNA were amplified using primer F63 (5'-GCA TAT CAA TAA GCG GAG GAA AAG-3') and LR3 (5'- GGT CCG TGT TTC AAG AACG-3') (Fell et al., 2000). Polymerase chain reactions were performed following the same protocol of amplifying ITS region. Amplified products were separated and eluted using Gel/ PCR DNA Fragment Extraction Kit (Geneaid). Sequencing was performed on an ABI 377 automated sequence (Applied Biosystems, Forster city, CA.). The sequences were aligned with MegAlign version 4.00 (Dnastar Inc.) and visually corrected. All sequences were compared through the basic local alignment search tool (BLAST) of GeneBank (Altschul et al. 1990).

RESULTS

Field Census of Prey Interception and Availability

The marked spiders of control (Figure 1a) and experimental (Figure 1b) groups were 99 and 75 spiders respectively during eight days in February 2002 field trip; 87 and 69 in April 2002 and 15 and 23 in August 2002. Insects of the order Coleoptera, Hymenoptera, and Diptera were the major components of carcasses of *C. confusa* found in August 2001. The insects in the study site were, however, mainly members of the orders Diptera, Collembola, Hymenoptera (Formicidae), and Homoptera orders. The order Coleoptera, Homoptera, and Diptera were again the major prey of *C. confusa* in the 2002 census. Prey composition in web decorations and insect composition of the study site in the Yung-Hsing Farm from August 2001 to April 2002 are given in Table 1.

From February to April 2002, the population of *C. confusa* was stable. In February, the sample size of experimental groups and control groups were 145 and 129 webs respectively. From March 2002, the sample size of experimental and control groups were 186 and 181 webs respectively. In August 2002, the population had decreased, and the sample size of experimental and control groups were 34 and 81 webs respectively. Comparison of the prey interception rates of experimental and control

groups estimated from the traditional hourly monitoring showed no significant difference. Poisson regression indicated that prey interception rates estimated from hourly monitoring did not vary significantly between two groups in February, April and August 2002 (Table 2). Since the estimate of web area of three study periods showed a positive value, it meant that the larger the web area, the higher prey interception rate. Especially in April 2002, the web is a significant variable affecting the prey interception rate (Table 2b). The weather in February also affected the prey interception rate significantly (Table 2a), but in April the weather did not affect the prey interception rate. The prey interception data estimated from video recording conducted in August 2002 showed a significant difference between two groups (Table 3). The prey interception rate of the experimental group was 1.41 ($e^{0.347}$) times higher than control groups.

Recording of Predation Events

Totally the recordings were done for 72 hours during nine days, the valid data of experimental and control groups were 24 and 25 recoding tapes respectively. Each recording period was conducted for full four hours except being interrupted by sudden rain. During the nine days of observation by video recording, paper wasp *Vaspa affinis* was the only predator that attacked *C. confusa*. *Vaspa affinis* repeatedly attacked the control group daily from August 8-12, and on August 15 and 17 the wasp just passed

by. The attack behaviours of *V. affinis* were classified into three types: attack directly on spider, attack directly on decoration, and attack directly on web. Every attack event was defined as each time the wasp bumped into the objects, such as web, spider and decoration. Totally we recorded 20 attack events. *Vespa affinis* seemed to attack the spider of experimental group directly. After the first attack by *V. affinis* on one *C. confusa* in the experimental group, the spider disappeared. Result of Chi-square test showed a significant difference among recorded numbers of the three attack targets of control group ($X^2 = 7.6$, $P < 0.05$, d.f. =2). Most of the attacks of *V. affinis* were directed at the web decorations or webs (Figure 3). *Cyclosa confusa* jumped away very quickly when the paper wasp attacked. In many times the spider had ran away but the paper wasp still kept attacking the decoration. If not predated, usually went back to the webs after around 30 seconds.

Spectral Properties and Visual Signals of *Apis mellifera*

The dorsum and ventrum of *Cyclosa confusa* and decoration spectral reflectance and the five average spectral reflections of various leaves (solid line) and barks (dash line) in the study sites were shown in Figure 4. When using the chromatic three cone colour-vision system, *A. mellifera* could not distinguish the detritus decoration against spider dorsum, spider ventrum, barks of *Artocarpus altilis*, *Pometia pinnata*, and *Terminalia catapa*; and leaves of *P. pinnata*, *Areca catechu*, and *Alocasia odora*

(Table 4). The detritus decorations showed strong colour contrast against the bark of *A. catechu*, and the leaves *A. altilis* and *T. catapa*. When viewed under achromatic system, the contrasts of decorations against various backgrounds seemed to be higher when using one cone colour-vision system. *A. mellifera* can distinguish the detritus decoration against spider dorsum, and barks of *A. catechu*, *A. altilis* and *P. pinnata*; and leaves of *A. catechu*, *P. pinnata*, *T. catapa* and *A. odora*. However, *A. mellifera* may not be able to distinguish the detritus decoration from spider ventrum, bark of *T. catapa* and leaves of *A. altilis* (Table 4, Figure 5).

When using the chromatic three cone colour-vision system**,** *A. mellifera* seemed not able to distinguish the spider dorsum against barks of *P. pinnata*, *T. catapa,* and leave of *A. altilis*. However, the spider dorsum showed strong colour contrast against barks of *A. catechu* and *A. altilis*; and the leaves of *A. catechu*, *P. pinnata*, *T. catapa* leaves and *A. odora*. Under achromatic vision, *A. mellifera* can distinguish the spider dorsum against barks of *A. altilis* and *T. catapa*; and leaves of *A. altilis* and *P. pinnata*. *Apis mellifera* may not be able to distinguish the spider dorsum from barks of *A. catechu*, *P. pinnata*, and *T. catapa*; and leaves of *A. catechu*, *T. catapa* and *A. odora* (Table 5a, Figure 6).

When using the chromatic three cone colour-vision system, *A. mellifera* seemed not able to distinguish the spider ventrum against barks of *A. altilis*, *P. pinnata* and *T.*

catapa; and leaves of *A. catechu*, *P. pinnata* and *A. odora*. However, the spider ventrum showed strong colour contrast against barks of *A. catechu* and the leaves of *A. altilis* and *T. catapa*. Under achromatic vision, *A. mellifera* can distinguish the spider ventrum against the barks of *Areca catechu* and *P. pinnata* bark; and leaves of *A. catechu*, *A. altilis*, *P. pinnata, T. catapa* and *A. odora*. *Apis mellifera* may not be able to distinguish the spider dorsum and the barks of *A. altilis* and *T. catapa* (Table 5b, Figure 7).

Spectral Properties and Visual Signals of *Vespa* sp.

When using the chromatic three cone colour-vision system, *Vespa* sp. could not distinguish the detritus decoration against spider dorsum, spider ventrum, barks of *Artocarpus altilis*, *Pometia pinnata*, and *Terminalia catapa*; and leaves of *P. pinnata*, and *Alocasia odora* (Table 6). The detritus decorations showed strong colour contrast against the bark of *A. catechu*, and the leaves and *A. catechu*, *A. altilis*, *T. catapa* and *A. odora*. When viewed under achromatic system, the contrasts of decorations against various backgrounds seemed to be higher when using one cone colour-vision system. *Vespa* sp. can distinguish the detritus decoration against spider dorsum, and barks of *A. catechu*, and *P. pinnata*; and leaves of *A. catechu*, *A. altilis, P. pinnata*, *T. catapa* and *A. odora*. However, *Vespa* sp. may not be able to distinguish the detritus decoration from spider ventrum, bark of *A. altilis* and *T. catapa* (Table 6, Figure 8).

When using the chromatic three cone colour-vision system**,** *Vespa* sp. seemed not able to distinguish the spider dorsum against leaves of *A. altilis*. However, the spider dorsum showed strong colour contrast against barks of *A. catechu*, *A. altilis, P. pinnata, T. catapa*; and the leaves of *A. catechu*, *P. pinnata*, *T. catapa* leaves and *A. odora*. Under achromatic vision, *Vespa* sp. can distinguish the spider dorsum against barks of *A. altilis* and *T. catapa*; and leaves of *A. altilis*, *P. pinnata* and *A. odora.* *Vespa* sp. may not be able to distinguish the spider dorsum from barks of *A. catechu* and *P. pinnata*; and leaves of *A. catechu* and *T. catapa* (Table 7a, Figure 9).

When using the chromatic three cone colour-vision system, *Vespa* sp. seemed not able to distinguish the spider ventrum against barks of *A. altilis*, *P. pinnata* and *T. catapa*; and leaves of *P. pinnata* and *A. odora*. However, the spider ventrum showed strong colour contrast against barks of *A. catechu* and the leaves of *A. catechu, A. altilis*, and *T. catapa*. Under achromatic vision, *Vespa* sp. can distinguish the spider ventrum against the barks of *Areca catechu* and *P. pinnata* bark; and leaves of *A. catechu*, *A. altilis*, *P. pinnata, T. catapa* and *A. odora*. *Vespa* sp. may not be able to distinguish the spider dorsum and the barks of *A. altilis* and *T. catapa* (Table 7b, Figure 10)

Diversity of Distribution Pattern of Yeasts

After seven days at 26 ℃ the streak culture of 31 groups were showed in Figure

11 A-P and Figure 12 Q-e. Twenty-eight yeast strains were evaluated with Biolog (Biolog, USA). After comparing the result of 48 hours and 72 hours (Table 8), nine species were identified from 13 yeast strains: *Candida catenulate, C. parapsilosis, C. sake, C. zeylanoides, Cryptococcus albidus, Cr. luteolus, Debaryomyces hansenii, Pichia mexicana,* and *Williopsis saturnus* var. *mrakii* (Table 9). Using restriction fragment sizes digested with the endonucleases *Hinf*I, *Hae*III, and *Hha*I, seventy-four yeast strains were separated into 31 groups. The gel detectable restriction fragment sizes (number of base pairs) are listed in Table 10. Yeast group 1, the black yeast *Aureobasidium pullulans*, existed on webs, spiders and decorations of *Cyclosa mulmeinensis*, pineapple and scrwepine. Yeast group 2 was only found on *C. confusa* and their webs. Yeast group 3, *Pichia guilliermondii*, and yeast group 4 existed both on *C. mulmeinensis*, *C. confusa* and their decorations and webs. Yeast group 5, 8, 9, 10, 12, 18, 19, 22, and 30 existed only on plants. Yeast group 6, 20, and 21 existed on *Cyclosa* decorations. Yeast group 7, 11, 16, 23, 25, 27, and 28 existed on *Cyclosa* spider body. Yeast group 13, 14, 15, 17, 24, 26, and 29 existed on *Cyclosa* webs.

DISCUSSION

Results of this study show that the decorations function as hiding and concealing devices, but at the cost of reduced foraging success. The detritus decorations made by *Cyclosa confusa* did not increase the prey capture rate no matter in February, April, and August. Results from video recording even showed that the prey interception rate of experimental group was significantly higher than that of the control group. These results suggested that detritus decoration built by *C. confusa* does not function to attract prey. This structure may even generate some foraging cost by reducing prey interception rate. However, observations made by video recording provided evidence that detritus decoration helped conceal the spider by tricking *Vespa affinis* into attacking the wrong target. Without the decoration, *V. affinis* either successfully attacked *C. confusa* or forced *C. confusa* to abandon its web. Our observation showed that after the *V. affinis* attacked a web without decorations the spider disappeared. Previous attacking experience can influence *Sceliphron caementarium* and *Chalybion caeruleum* when choosing a hunting site (Eberhard 1970; Coville, 1987; Fontenelle & Martins 2002). In my study area, the same *V. affinis* probably made attacks on some *C. confusa*. According to the recorded observations, some *C. confusa* was attacked at

similar times of the day, suggesting that the wasp can remember the location of previous encounter with prey.

Colour signal plays an important role in Hymenoptera when they are foraging or avoiding the predator (Craig 1990; Craig 1994; Craig & Ebert 1994; Blackledge 1998b; Coville 1987; Kevan et al. 2001). If the Hymenoptera was away from the objects, it uses achromatic vision, if the object is closer, then it uses chromatic vision (Giurfa & Lehrer 2001; Heiling et al. 2003; Kevan et al. 2001). When using chromatic vision, the detritus decoration showed strong colour contrast against spider if viewed by Hymenoptera under achromatic vision. This result suggests that when *V. affinis* was searching for prey from a long distance using achromatic vision, it could distinguish the colour of *C. confusa* from the decoration. However, since *V affinis* had compound eyes, when viewed from a long distance the image of the spider decoration combination might be quite blurred. As *V. affinis* approached the prey and switched to chromatic vision, the spider became indistinguishable from the detritus decoration. Moreover, the visibility of spider and decoration might vary when viewed by *V. affinis* against different vegetations. Results of our colour contrast calculations showed that decoration against some vegetation were chromatically distinguishable, but against the others are indistinguishable. For example, when the spider and decoration were hung in front of the *Pometia pinnata* bark, they were chromatically indistinguishable

in the colour space of Hymenoptera. Therefore, visibility of the spider and decoration to parasitioid hymenopterans was greatly influenced by vegetation types and distance. Coville (1987) reported that sphecids can detect spiders by identifying the sparkling dot against the background and destroy the webs, and this might be the tactic used by *V. affinis* to detect *C. confusa* from a long distance. However, even though *V. affinis* could locate the spider by achromatic vision, it may have trouble successfully targeting the real prey when approaching. Therefore, judged from the video taped observations and colour contrast calculations, detritus decoration may enhance survival of *C. confusa* in two ways. First, the similarity in colour signals of decoration and *C. confus*a to certain vegetation makes them very hard to be chromatically distinguished by the predator. Secondly, when the spider was spotted and the wasp approached, the decoration may help redirect the attack of wasp thus giving the spider time to escape. In the Yung-Hsing Farm on Orchid Island, *C. confusa* always built their webs in the forest understory. The dim light made the spiders, webs and decorations hard to see. Further more, most webs hung in front of leaf litter or tree bark, which makes the web even more indistinguishable form backgrounds to hymenopteran predators.

Results of this study also demonstrate that video recording should be extensively used in studying the foraging behaviours of stationary predators, such as orb-weaving

spiders. In this study, the prey interception rates estimated by the traditional monitoring and video recording were quite different. Under good weather condition, the prey interception rate obtained by video recording could be as high as 25 insects per day. However, the rate estimated from traditional hourly-monitoring was much lower. Monitoring the orb periodically might not be able to accurately measure prey interception rate, especially for small tropical spiders foraging on tiny prey. The preys of *C. confusa* were mainly small plant hopper and white fly (Homoptera), the body size of which was about 0.3 mm. They were quite hard to identify if they were half digested. During the interval of successive monitoring spiders may have caught and completely consumed small soft-bodied prey. Therefore the traditional monitoring method severely underestimate the foraging success of spiders.

Results of the yeast-diversity part of this study showed that yeast inhabiting *Cyclosa* webs, spiders, detritus decoration and plants were quite diverse. Spider, detritus decoration, and web are an unexplored microhabitat for yeast. In terrestrial ecosystem, leaf litters, rotten wood, plants and sand are good environment for fungi to grow while insects also occur in these microhabitats. The decoration of *Cyclosa* may provide a suitable microhabitat for yeasts. In this study we focused on specific plants, such as pineapple, betel palms, and screw pine, and specific location of *Cyclosa.* Rarely did study focus on the relationship between the yeast and spiders. The

potential specificity between yeast and plants, and spiders and yeasts were examined.

The restriction fragment length polymorphism (RFLP) is the faster and cheaper way to cluster yeast strains into different groups (Esteve-Zarzoso et al. 1999; Fernández-Espinar et al. 2000; Granchi et al. 1999; Molina et al. 1992). The advantage of biolog is that it can provide various biochemical and physiological tests for yeasts and it save time. For the purpose of this study biolog is not a suitable way to identify yeast: the database is not large and its primary use is clinical or industrial. The database does not include taxa inhabiting unexplored natural habitats, such as black yeasts, thus identification error may arise. The dominant *Cyclosa* spider in pineapple and screwpine habitat is *C. mulmeinensis,* while the dominant *Cyclosa* spiders in betel palm forest is *C. confusa*. The decorations of *C. mulmeinensis* are composed major of egg sacs. A few *C. mulmeinensis* also inhabited betel palm forest, and they were collected for yeast culture. The results showed that the yeast population in pineapple and screwpine habitat was primarily *Aureobasidium pullulans*. Even in betel palm habitat, *A. pullulans* exists only on *C. mulmeinensis* but not in the abundant *C. confusa*. *Aureobasidium* spp. has been well studied. This yeast appears mostly on leaves, but can exist on humid substrates, painted wood, and rocks (Deshpande et al 1992; Jager et al 2001). *Cyclosa mulmeinensis* is quite dominant specie in Orchid Island, especially in pineapple and screwpine. It seems that the

habitat type might influence *C. mulmeinensis* to choose the web-building site. The fruit of both pineapple and scrwepine can make strong odor, it might be the attractant to the insect. In this study, *A. pullulans* may be dispersed by insects to plants to reach spiders and their webs. The main prey of *C. mulmeinensis* is still unknown, the interaction between *C. mulmeinensis* and *A. pullulans* is worthy for further study

Many of the yeast culture from spider and their web were new or newly recorded species. The newly recorded species were *Candida melibiosica, Kluveromyces thermotolerans*, and *Lodderomyces elongisporus*. Our study reveals that the detritus decoration-building spiders are still an unknown microbial environment for yeast, because most of the yeast groups obtained are still unknown and so far only one study had ever tested such type of microhabitat (Tietjen et al. 1987). The decoration yeast composition of *C. mulmeinensis* is obviously different from that of *C. confusa*. We hypothesized that the function of the decoration on *C. mulmeinensis* webs may be protecting egg sac from predation and parasitism (Elgar et al. 1983). After *C. mulmeinensis* finish laying egg sac, the outer wrapped silk colour is purely yellowish-white. But few days later the colour of egg sac became dark yellow, which may provide a protection from predator (I M. Tso personal observation). The yeasts cultured from egg sac, spiders, and webs of *C. mulmeinensis*, *A. pullulans*, might play an important role for the egg sac colour change. More behavioural and physiological

studies are needed to understand the function of egg sac decoration made by *C. mulmeinensis* and the specificity between *C. mulmeinensis* and *A. pullulans.*

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Table 1. Insect composition of the study site and web decorations of *Cyclosa confusa* in the Yung-Hsing Farm on Orchid Island from August 2001 to April 2002

Month	Malasie trap	Web decorations		
Order	Aug. 2001	Aug. 2001	Feb. 2002	Apr. 2002
Diptera	94	7	16	23
Collembola	41	0	0	0
Hymenoptera (Formicidae)	65 (56)	12 (12)	0	3 (1)
Homoptera	27	1	98	23
Coleoptera	9	35	35	39
Lepidoptera	10	0	0	4
Hemiptera	1	0	11	2
Orthoptera	2	0	0	0
Araneae	3	1	2	1
Blattaria	0	1	0	0
Ephemeroptera	0	0	7	0
Thysanoptera	0	0	5	1
Caterpillar	0	0	0	1
Total	252	57	174	97

Table 2. Results of Poisson regression comparing prey interception rates estimated from hourly-monitoring between decoration removed (experimental group) and decoration remained (control group) webs built by *Cyclosa confusa* in the Yung-Hsing Farm on Orchid Island in February, April 2001, and August 2002. (C): Cloudy (S): Sunny day

Parameter	Estimate	SE	Chi-square	*P*-value
(a) February				
Intercept	-2.191	0.214	104.970	< 0.0001
Web	0.001	0.000	3.500	> 0.05
Weather (C)	-1.069	0.161	43.990	< 0.01
Weather (S)	0.000	0.000	-	-
NoDecoration	0.087	0.133	0.430	> 0.05
Decoration	0.000	0.000	-	-
(b) April				
Intercept	-2.812	0.181	242.040	< 0.0001
Web	0.001	0.000	9.700	< 0.01
Weather (C)	0.010	0.112	0.010	> 0.05
Weather (S)	0.000	0.000	-	-
NoDecoration	0.005	0.106	0.000	> 0.05
Decoration	0.000	0.000	-	-
(c) August				
Intercept	-2.424	0.323	56.200	< 0.0001
Web	0.001	0.001	0.650	> 0.05
NoDecoration	-0.116	0.225	0.270	> 0.05
Decoration	0.000	0.000	-	-

Table 3. Results of Poisson regression comparing prey interception rates estimated from video recordings between decoration removed (experimental group) and decoration remained (control group) webs built by *Cyclosa confusa* in the Yung-Hsing Farm on Orchid Island in August 2002

Parameter	Estimate	SE	Chi-square	*P*-value
Intercept	-4.474	0.3281	185.90	< 0.0001
Web 200-300	-1.158	0.641	3.27	> 0.05
Web 300-400	-0.217	0.353	0.38	> 0.05
Web 400-500	0.253	0.338	0.56	> 0.05
Web 500-600	0.493	0.306	2.60	> 0.05
Web 600-700	0.057	0.354	0.03	> 0.05
Web 700-	0.000	0.000	-	-
NoDecoration	0.347	0.175	3.91	< 0.05
Decoration	0.000	0.000	-	-

Table 4. Results of one tailed t-test comparing the colour contrasts of detritus decoration against different backgrounds viewed by chromatic and achromatic visions of *Apis mellifera* with the discrimination threshold of 0.05

	Chromatic		Achromatic	
	Student-t	*P*-value	Student-t	*P*-value
Spider dorsum	1.216	0.247	3.047	0.01
Spider ventrum	-0.418	0.684	2.015	0.069
Bark				
Areca catechu	7.558	0	5.042	0
Artocarpus altilis	-3.675	0.003	8.725	0
Pometia pinnata	-7.108	0	5.612	0
Terminalia catapa	-8.195	0	1.755	0.105
Leave				
Areca catechu	1.74	0.108	4.729	0
Artocarpus altilis	7.016	0	0.759	0.463
Pometia pinnata	-1.764	0.103	2.843	0.015
Terminalia catapa	5.386	0	6.712	0

Table 5. Results of one tailed t-test comparing the colour contrasts of *Cyclosa confusa* dorsum (a) and ventrum (b) against the different backgrounds with the discrimination threshold of 0.05 viewed by chromatic and achromatic visions of *Apis mellifera*

		Student-t	*P*-value	Student-t	*P*-value
(a) Dorsum		Chromatic		Achromatic	
Bark	*Areca catechu*	2.669	0.02	2.053	0.063
	Artocarpus altilis	2.201	0.048	3.117	0.009
	Pometia pinnata	1.645	0.126	1.489	0.162
	Terminalia catapa	1.917	0.079	4.615	0.001
Leave	*Areca catechu*	3.19	0.008	2.108	0.057
	Artocarpus altilis	1.632	0.129	2.493	0.017
	Pometia pinnata	2.325	0.038	2.77	0.028
	Terminalia catapa	4.226	0.001	1.975	0.072
	Alocasia odora	4.339	0.001	2.175	0.05
(b) Ventrum					
Bark	*Areca catechu*	3.456	0.005	7.211	0
	Artocarpus altilis	0.307	0.765	2.065	0.063
	Pometia pinnata	-0.191	0.852	7.807	0
	Terminalia catapa	-0.284	0.782	0.528	0.608
Leave	*Areca catechu*	1.954	0.077	6.887	0
	Artocarpus altilis	2.905	0.014	11.053	0
	Pometia pinnata	0.777	0.454	4.988	0
	Terminalia catapa	3.343	0.007	8.955	0
	Alocasia odora	1.206	0.253	9.614	0

Table 6. Results of one tailed t-test comparing the colour contrasts of detritus decoration against different backgrounds viewed by chromatic and achromatic visions of *Vespa* sp. with the discrimination threshold of 0.05.

	Chromatic		Achromatic	
	Student-t	*P*-value	Student-t	*P*-value
Spider dorsum	2.062	0.062	3.047	0.010
Spider ventrum	-0.224	0.827	1.600	0.138
Bark				
Areca catechu	7.166	0.000	5.042	0.000
Artocarpus altilis	-1.916	0.079	0.759	0.463
Pometia pinnata	-5.676	0.000	5.612	0.000
Terminalia catapa	-5.222	0.000	1.755	0.105
Leave				
Areca catechu	3.708	0.003	4.729	0.000
Artocarpus altilis	7.340	0.000	8.725	0.000
Pometia pinnata	-0.013	0.990	2.843	0.015
Terminalia catapa	6.882	0.000	6.712	0.000
Alocasia odora	2.790	0.016	7.345	0.000

Table 7. Results of one tailed t-test comparing the colour contrasts of *Cyclosa confusa* dorsum (a) and ventrum (b) against the different backgrounds with the discrimination threshold of 0.05 viewed by chromatic and achromatic visions of *Vespa* sp.

		Student-t	*P*-value	Student-t	*P*-value
(a) Dorsum		Chromatic		Achromatic	
Bark	*Areca catechu*	2.795	0.016	2.053	0.063
	Artocarpus altilis	2.593	0.024	3.117	0.009
	Pometia pinnata	2.236	0.045	1.933	0.077
	Terminalia catapa	2.647	0.021	4.615	0.001
Leave	*Areca catechu*	3.887	0.002	2.108	0.057
	Artocarpus altilis	1.916	0.080	2.770	0.017
	Pometia pinnata	2.995	0.011	2.493	0.028
	Terminalia catapa	4.453	0.001	1.975	0.072
	Alocasia odora	4.471	0.001	2.175	0.050
(b) Ventrum					
Bark	*Areca catechu*	3.902	0.002	7.211	0.000
	Artocarpus altilis	0.647	0.531	2.065	0.063
	Pometia pinnata	0.104	0.919	7.807	0.000
	Terminalia catapa	0.139	0.892	0.528	0.608
Leave	*Areca catechu*	2.509	0.029	6.887	0.000
	Artocarpus altilis	3.387	0.006	11.053	0.000
	Pometia pinnata	1.132	0.282	4.988	0.000
	Terminalia catapa	3.800	0.003	8.955	0.000
	Alocasia odora	1.558	0.148	9.614	0.000

Table 8. Summary of 30 groups yeast characteristics. A1-C12: oxidation tests, D2-H12: assimilation tests on Biolog YT MicroPlate

Group	Species	A2 acetic acid	A3 formic acid	A4 propionic acid	A5 succine	A6 methyl succinate	A7 L-aspartic acid	A8 L-glutamic acid	A9 L-proline	A10 D-gluconic acid	A11 dextrin	A12 inulin	B1 cellobiose	B2 gentiobiose	B3 maltose	B4 maltotriose	B5 D-melezitose	B6 D-melibiose	B7 palatinose	B8 D-raffinose	B9 stachyose	B10 sucrose	B11 D-trehalose	B12 turanose	C1 N-acetyl-D-glucosamine	C2 α-D-glucose	C3 D-glactose	C4 D-psicose	C5 sorbose
1	*Aureobasidium pullulans*	-	-	-	v	-	v	v	v	v	v	-	+	v	+	+	+	v	v	v	v	v	v	+	-	+	v	v	v
2		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	+	+	+	-	-
3	*Pichia guilliermondii*	-	-	-	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
4		-	-	-	-	-	-	v	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	-	-
5	*Candida pseudointermedia*	-	-	-	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
6																													
7																													
8	*Candida rugosa*																												
9	*Rhodotorula marina*																												
10																													

Table 8. Continued

Group	Species	A2 acetic acid	A3 formic acid	A4 propionic acid	A5 succine	A6 methyl succinate	A7 L-aspartic acid	A8 L-glutamic acid	A9 L-proline	A10 D-gluconic acid	A11 dextrin	A12 inulin	B1 cellobiose	B2 gentiobiose	B3 maltose	B4 maltotriose	B5 D-melezitose	B6 D-melibiose	B7 palatinose	B8 D-raffinose	B9 stachyose	B10 sucrose	B11 D-trehalose	B12 turanose	C1 N-acetyl-D-glucosamine	C2 α-D-glucose	C3 D-glactose	C4 D-psicose	C5 sorbose
11																													
12	*Candida* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-
13	*Kluveromyces thermotolerans*	+	-	-	-	-	-	-	-	+	+	-	-	-	+	-	+	+	+	+	+	+	+	+	-	+	+	-	-
14	*Lodderomyces elongisporus*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	+	+	+	+	-	+
15	*Williopsis saturnus*	-	-	-	+	-	-	-	-	+	-	-	+	+	-	-	-	-	-	+	+	+	-	-	-	+	-	-	-
16		-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-	-
17	*Candida* sp.																												
18	*Candida* sp.	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-
19		-	-	-	-	-	-	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-
20	*Candida melibiosica*	-	-	-	-	+	-	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+

Table 8. Continued

Group	Species	A2 acetic acid	A3 formic acid	A4 propionic acid	A5 succine	A6 methyl succinate	A7 L-aspartic acid	A8 L-glutamic acid	A9 L-proline	A10 D-gluconic acid	A11 dextrin	A12 inulin	B1 cellobiose	B2 gentiobiose	B3 maltose	B4 maltotriose	B5 D-melezitose	B6 D-melibiose	B7 palatinose	B8 D-raffinose	B9 stachyose	B10 sucrose	B11 D-trehalose	B12 turanose	C1 N-acetyl-D-glucosamine	C2 α-D-glucose	C3 D-glactose	C4 D-psicose	C5 sorbose
21																													
22	*Rhodotorula* sp.																												
23																													
24																													
25		-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-
26		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-
27		-	-	-	-	+	-	-	+	+	-	-	+	+	+	+	+	-	+	-	-	+	-	+	+	+	+	-	+
28		-	-	-	+	-	+	+	+	+	-	-	+	+	-	-	-	-	-	+	+	+	+	-	-	+	+	-	-
29	*Candida* sp.																												
30	*Cryptococcus* sp.																												

Table 8. Continued

Group	Species	C6 salicin	C7 D-mannitol	C8 D-sorbitol	C9 D-arabitol	C10 xylitol	C11 glycerol	C12 Tween 80	D2 fumaric acid	D3 L-malic acid	D4 methyl succinate	D5 bromosuccinic acid	D6 L-glutamic acid	D7 γ-aminobutyric acid	D8 α-keto-glutaric acid	D9 α-keto-D-gluconic acid	D10 D-gluconic acis	D11 dextrin	D12 Inulin	E1 cellobiose	E2 gentiobiose	E3 maltose	E4 maltotribose	E5 D-melezitose	E6 D-melibiose	E7 palatinose	E8 D-raffinose	E9 stachyose	E10 sucrose
1	*Aureobasidium pullulans*	v	v	v	v	v	-	v	-	-	-	-	-	-	-	+	-	+	-	+	+	+	+	+	+	+	+	+	+
2		-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	+	-	+	-	-	+
3	*Pichia guilliermondii*	+	+	+	+	+	+	-	+	+	+	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+
4		-	+	+	+	-	-	-	v	v	-	-	v	-	-	v	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Candida pseudointermedia*	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
6																													
7																													
8	*Candida rugosa*																												
9	*Rhodotorula marina*																												
10																													

Table 8. Continued

Group	Species	C6 salicin	C7 D-mannitol	C8 D-sorbitol	C9 D-arabitol	C10 xylitol	C11 glycerol	C12 Tween 80	D2 fumaric acid	D3 L-malic acid	D4 methyl succinate	D5 bromosuccinic acid	D6 L-glutamic acid	D7 γ-aminobutyric acid	D8 α-keto-glutaric acid	D9 α-keto-D-gluconic acid	D10 D-gluconic acis	D11 dextrin	D12 Inulin	E1 cellobiose	E2 gentiobiose	E3 maltose	E4 maltotribose	E5 D-melezitose	E6 D-melibiose	E7 palatinose	E8 D-raffinose	E9 stachyose	E10 sucrose
11																													
12	*Candida* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
13	*Kluveromyces thermotolerans*	-	+	+	-	+	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	+	-	+	+	+	+	+	+
14	*Lodderomyces elongisporus*	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	-	-	+
15	*Williopsis saturnus*	+	-	-	-	+	+	-	+	+	+	-	-	+	-	-	+	-	-	+	+	-	-	-	-	-	+	+	+
16		-	-	-	-	-	-	-	+	+	+	-	-	+	-	+	-	-	-	-	-	+	+	+	-	+	-	-	+
17	*Candida* sp.																												
18	*Candida* sp.	-	+	-	-	-	-	-	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19		-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+
20	*Candida melibiosica*	+	+	+	+	-	-	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+

Table 8. Continued

Group	Species	C6 salicin	C7 D-mannitol	C8 D-sorbitol	C9 D-arabitol	C10 xylitol	C11 glycerol	C12 Tween 80	D2 fumaric acid	D3 L-malic acid	D4 methyl succinate	D5 bromosuccinic acid	D6 L-glutamic acid	D7 γ-aminobutyric acid	D8 α-keto-glutaric acid	D9 α-keto-D-gluconic acid	D10 D-gluconic acis	D11 dextrin	D12 Inulin	E1 cellobiose	E2 gentiobiose	E3 maltose	E4 maltotribose	E5 D-melezitose	E6 D-melibiose	E7 palatinose	E8 D-raffinose	E9 stachyose	E10 sucrose
21																													
22	*Rhodotorula* sp.																												
23																													
24																													
25		-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-
26		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
27		-	+	+	+	+	+	+	-	-	+	-	-	-	+	+	+	+	-	+	+	+	+	+	-	+	-	-	+
28		+	-	-	+	+	-	-	-	+	-	-	-	-	-	+	+	-	-	+	+	+	+	-	-	+	+	+	+
29	*Candida* sp.																												
30	*Cryptococcus* sp.																												

Table 8. Continued

Group	Species	E11 D-trehalose	E12 turanose	F1 N-acetyl-D-glucosamine	F2 D-glucosamine	F3 α-D-glucose	F4 D-glactose	F5 D-psicose	F6 L-rhamnose	F7 L-sorbose	F8 α-methyl D-glucoside	F9 β-methyl D-glucoside	F10 amygdalin	F11 arbutin	F12 salicin	G1 maltitol	G2 D-mannitol	G3 D-sorbitol	G4 adonitol	G5 D-arabitol	G6 xylitol	G7 L-erythritol	G8 glycerol	G9 Tween 80	G10 L-arabinose	G11 D-arabinose	G12 D-ribose	H1 D-xylose	H2 Methyl succinate + D-xylose
1	*Aureobasidium pullulans*	+	+	+	v	+	-	v	-	v	-	+	-	-	+	+	+	-	-	+	+	-	-	-	-	-	+	+	-
2		+	+	-	-	+	+	-	-	-	-	+	-	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-
3	*Pichia guilliermondii*	+	+	+	+	+	+	+	-	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	-	v	-	-	+	+
4		+	-	+	-	+	v	-	-	-	-	-	-	-	-	-	+	+	v	+	-	-	v	-	-	-	-	-	+	+
5	*Candida pseudointermedia*	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
6																														
7																														
8	*Candida rugosa*																													
9	*Rhodotorula marina*																													
10																														

Table 8. Continued

Group	Species	E11 D-trehalose	E12 turanose	F1 N-acetyl-D-glucosamine	F2 D-glucosamine	F3 α-D-glucose	F4 D-glactose	F5 D-psicose	F6 L-rhamnose	F7 L-sorbose	F8 α-methyl D-glucoside	F9 β-methyl D-glucoside	F10 amygdalin	F11 arbutin	F12 salicin	G1 maltitol	G2 D-mannitol	G3 D-sorbitol	G4 adonitol	G5 D-arabitol	G6 xylitol	G7 L-erythritol	G8 glycerol	G9 Tween 80	G10 L-arabinose	G11 D-arabinose	G12 D-ribose	H1 D-xylose	H2 Methyl succinate + D-xylose
11		+	+	-	-	+	+	-	-	+	-	+	-	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	+
12	*Candida* sp.	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
13	*Kluveromyces thermotolerans*	+	+	-	-	+	+	-	-	-	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	+
14	*Lodderomyces elongisporus*	-	+	+	-	+	+	-	-	+	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	+
15	*Williopsis saturnus*	-	-	-	-	+	-	-	-	-	-	+	+	+	+	-	+	+	-	-	+	-	+	-	-	-	-	+	
16		-	+	-	-	+	+	-	-	+	+	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	+	+
17	*Candida* sp.																												
18	*Candida* sp.	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
19		+	+	-	-	+	-	+	-	-	-	+	-	-	+	+	+	+	-	+	+	+	-	-	+	-	-	+	-
20	*Candida melibiosica*	+	+	-	-	+	+	-	+	-	-	+	-	-	+	+	+	-	-	+	-	-	-	-	-	-	-	-	+

Table 8. Continued

Group	Species	E11 D-trehalose	E12 turanose	F1 N-acetyl-D-glucosamine	F2 D-glucosamine	F3 α-D-glucose	F4 D-glactose	F5 D-psicose	F6 L-rhamnose	F7 L-sorbose	F8 α-methyl D-glucoside	F9 β-methyl D-glucoside	F10 amygdalin	F11 arbutin	F12 salicin	G1 maltitol	G2 D-mannitol	G3 D-sorbitol	G4 adonitol	G5 D-arabitol	G6 xylitol	G7 L-erythritol	G8 glycerol	G9 Tween 80	G10 L-arabinose	G11 D-arabinose	G12 D-ribose	H1 D-xylose	H2 Methyl succinate + D-xylose
21																													
22	*Rhodotorula* sp.																												
23																													
24																													
25		-	-	-	-	+	+	-	-	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	+	+
26		-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	+	-
27		+	+	+	-	+	+	-	-	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	-	-	-	+	+
28		+	+	-	-	+	-	-	-	-	-	+	-	+	+	+	+	-	+	+	+	-	-	-	-	-	+	+	-
29	*Candida* sp.																												
30	*Cryptococcus* sp.																												

Table 8. Continued

Group	Species	H3 N-acetyl –L-glutamic acid + D-xylosed	H4 Quinic acid + D-xylose	H5 D-glucuronic acid +	H6 Dextrin + D-xylose	H7 α-D-lactose + D-xylose	H8 D-melibiose + D-xylose	H9 D-glactose + D-xylose	H10 m-inositol + D-xylose	H11 1,2-propanediol + D-xylose	H12 acetoin + D-xylose
1	*Aureobasidium pullulans*	v	v	+	+	v	v	+	v	v	v
2		-	-	-	+	-	-	+	-	-	-
3	*Pichia guilliermondii*	-	+	+	+	+	+	+	+	+	+
4		-	-	-	-	-	-	+	-	-	-
5	*Candida pseudointermedia*	+	+	+	+	+	+	+	+	+	+
6											
7											
8	*Candida rugosa*										
9	*Rhodotorula marina*										
10											

Table 8. Continued

Group	Species	H3 N-acetyl –L-glutamic acid + D-xylosed	H4 Quinic acid + D-xylose	H5 D-glucuronic acid +	H6 Dextrin + D-xylose	H7 α-D-lactose + D-xylose	H8 D-melibiose + D-xylose	H9 D-glactose + D-xylose	H10 m-inositol + D-xylose	H11 1,2-propanediol + D-xylose	H12 acetoin + D-xylose
11											
12	*Candida* sp.	-	-	-	-	-	-	+	-	-	-
13	*Kluveromyces thermotolerans*	+	+	-	+	-	+	+	-	-	-
14	*Lodderomyces elongisporus*	-	-	-	-	-	-	+	-	-	-
15	*Williopsis saturnus*	-	-	-	-	-	-	-	+	+	-
16		-	-	-	-	-	-	+	-	-	-
17	*Candida* sp.										
18	*Candida* sp.	-	-	-	-	-	-	+	-	-	-
19		-	+	+	+	+	+	+	+	+	+
20	*Candida melibiosica*	-	+	-	-	-	+	+	-	-	-

Table 8. Continued

Group	Species	H3 N-acetyl –L-glutamic acid + D-xylosed	H4 Quinic acid + D-xylose	H5 D-glucuronic acid +	H6 Dextrin + D-xylose	H7 α-D-lactose + D-xylose	H8 D-melibiose + D-xylose	H9 D-glactose + D-xylose	H10 m-inositol + D-xylose	H11 1,2-propanediol + D-xylose	H12 acetoin + D-xylose
21											
22	*Rhodotorula* sp.										
23											
24											
25		-	-	-	-	-	-	-	-	-	-
26		-	-	-	+	-	-	-	+	-	+
27		+	+	+	+	+	+	+	+	+	+
28		-	+	-	+	+	-	+	+	-	+
29	*Candida* sp.										
30	*Cryptococcus* sp.										

Table 9. Biolog identification of 34 yeast strains isolated from body, web decoration and silk of *Cyclosa confusa* and host plants in Yung-Hsing Farm on Orchid Island. The biolog microplates were incubated after 48 hours and 72 hours, the interpretations were performed by Biolog's MicroLog 3™

Isolation number.	48 hour			72 hour		
	Species	Similarity	Probability	Species	Similarity	Probability
S63W	*Candida insectorum*	0.62	65%	*Pichia stipitis*	0.68	78%
S53W	*Cryptococcus curvatus*	0.64	68%	NID		
A2D	*Cryptococcus albidus*	0.69	74%	*Cryptococcus albidus*	0.85	90%
A1	*Debaryomyces hansenii*	0.98	100%	*Debaryomyces hansenii*	0.83	98%
S63D	NID			NID		
A2	*Dekkera anomala*	0.66	69%	*Pichia mexicana*	0.73	79%
A1	*Candida famata*	0.55	58%	*Cryptococcus albidus*	0.90	99%
S13W	*Candida zeylanoides*	0.80	88%	*Dekkera naardenensis*	0.64	77%
A3SP	*Debaryomyces hansenii*	0.89	90%	*Debaryomyces hansenii*	0.92	100%
B2SP	*Candida zeylanoides*	0.77	98%	*Candida zeylanoides*	0.56	76%
C3	*Candida catenulata*	0.85	98%	*Candida catenulata*	0.77	96%
A3	*Cryptococcus albidus*	0.94	97%	*Cryptococcus albidus*	0.93	100%
S014W	*Williopsis saturnus* var. *mrakii*	0.87	98%	*Williopsis saturnus* var. *mrakii*	0.83	94%
B2D	NID			*Pichia mexicana*	0.85	94%
A1	*Cryptococcus luteolus*	0.83	99%	*Cryptococcus luteolus*	0.74	93%
A3SP	NID			*Cryptococcus albidus* var. *aerius*	0.84	90%
A1	*Cryptococcus luteolus*	0.93	98%	*Filobasidiella neoformans neoformans*	0.94	95%
S12SP	NID			*Cryptococcus albidus* var. *aerius*	0.57	70%
S!2D	NID			*Clavispora lusitaniae*	0.67	70%
A1D	*Cryptococcus luteolus*	0.58	62%	*Cryptococcus albidus*	0.52	60%

NID: Not identified

Table 9. Continued

Isolation number	48 hour			72 hour		
	Species	Similarity	Probability	Species	Similarity	Probability
B3SP	*Candida parapsilosis*	0.75	95%	*Candida parapsilosis*	0.66	93%
A3	*Cryptococcus albidus*	0.77	82%	*Cryptococcus albidus*	0.82	99%
A1SP	*Debaryomyces hansenii*	0.90	99%	*Debaryomyces hansenii*	0.85	98%
S014SP	*Cryptococcus dimennae*	0.66	70%	NID		
A1	*Debaryomyces hansenii*	0.61	63%	*Cryptococcus albidus*	0.71	85%
B4D	*Phaffia rhodozyma*	0.57	57%	*Rhodotorula bacarum*	0.77	90%
A2	*Pichia mexicana*	0.69	78%	*Pichia mexicana*	0.77	96%
A2	NID			NID		
S9W	NID			*Debaryomyces maramus*	0.61	99%
A2SP	NID			*Pichia guilliermondii*	0.77	90%
A2	*Dekkera anomala*	0.66	69%	*Pichia mexicana*	0.73	79%
A1	NID			NID		
B3SP	*Candida sake*	0.73	81%	*Candida sake*	0.75	92%

NID: Not identified

Table10. Gel detectable restriction fragment sizes (in base pair) of ITS from yeast species. The yeast ITS rDNA where digested with three endonucleases *Hinf*I, *Hae*III, and *Hha*I (A: Pineapple, B: Screwpine, C: Betel palm, S: Spider, D: Decoration, SP: Spider individual, W: Spider web).

Group/Species	Source	PCR	*Hinf*I	*Hae*III	*Hha*I
1 *Aureobasidium pullulans*	A1	625	300, 193, 153	449, 161	175, 175, 100, 53
	A2	600	293, 193, 146	459, 159	178, 178, 100, 65
	A3	586	294, 177, 130	466, 171	177, 177, 106, 60
	A2W	593	300, 185, 143	436, 146	181, 181, 108
	A1SP	658	293, 171, 136	466, 171	206, 206, 117, 73
	A3SP	616	293, 200, 153	466, 172	177, 177, 103, 62
	A1D	625	300, 200, 136	444, 155	168, 168, 103, 59
	A2D	634	287, 183, 136	450, 156	180, 180, 106, 62
	B2D	619	311, 197, 150	448, 150	181, 181, 102
	B3D	609	296, 182, 137	448, 146	183, 183, 100, 66
	B4D	666	308, 196, 136	419, 156	171, 171, 95, 59
	B3W	574	300, 176, 136	466, 162	171, 171, 95, 64
	B3SP	565	308, 177, 138	473, 159	189, 189, 96, 57
	S014W	574	312, 192, 141	444, 158	181, 181, 100, 65
2	S9W	680	325, 325	417, 124,	300, 182, 142, 68
	S63W	582	324, 324	426, 141, 91	287, 174, 133, 71
	S12SP	700	293, 293	413, 132, 88	293, 177, 135, 61
	N18W	651	327, 327	448, 139, 97	276, 184, 134, 68
3 *Pichia guilliermondii*	A2SP	540	353, 308	408, 135, 100	303, 261
	S12D	623	327, 300	403, 128, 97	309, 255, 82
	S53W	609	341, 315	400, 112, 77	292, 258
	C2	574	319, 290	404, 116, 83	303, 267
4	B2SP	506	240, 131, 93	474	257, 222
	B2W	451	230, 134, 83	461	244, 200
	S13W	533	240, 136, 93	464	253, 210
5 *Candida pseudointermedia*	A1	491	237, 192, 86	324, 256, 190	253, 230
	B4	541	240, 191, 80	315, 246, 195	253, 226

* PCR-amplified product

Table 10. Continued

Group/ Species	Source	PCR*	*Hinf*I	*Hae*III	*Hha*I
6	S9D	455	224, 224	382	192, 192
7	S63SP	529	288, 153, 112	288, 159, 111	289, 168, 105
8 *Candida rogusa*	C3	408	183, 150, 80	185, 161, 85	196, 56
9 *Rhodotorula marina*	A2	606	275, 186, 144	332, 273	269, 144, 104,
	A1	612	213, 164	337, 265	210, 162, 97
10 *Cryptococcus flavus*	A1	523	231, 164, 72	253, 188, 100	184, 100
	A3	561	253, 185, 91	480, 59	182, 96
11	B4SP	523	300, 172, 68	300, 175, 67	204, 174, 73
12 *Candida* sp.	A2	640	324, 324	419, 150, 88	289, 171, 135, 65
13 *Kluveromyces thermotolerans*	S12W	678	338, 338	303, 211, 171	318, 296, 84
14 *Lodderomyces elongisporus*	C3W	547	297, 269	300, 270	330, 250
15 *Williopsis saturnus*	S014W	623	313, 313	332, 142, 92	511, 68
16	B3SP	370	194, 184	282, 157	250, 200
17 *Candida* sp.	S9W	376	197, 173, 52	273, 146	185, 70
18 *Candida* sp.	C3	425	179, 163, 82	200, 173, 107	225, 150, 93
19	A2	617	307	294, 126	290, 171
20 *Candida melibiosica*	S63D	392	194, 194	285, 119	205, 121, 85
21	S12D	426	227, 203	314, 128	210, 152, 78
22 *Rhodotorula* sp.	B4	600	275, 194, 155	262, 181, 141, 59	263, 197, 85
23	N26SP	593	313, 313	278, 153, 57	288, 197, 157
24	A3W	391	205, 205	190, 190	230, 175
25	B3SP	440	202, 202	303, 120, 62	220, 191
26	S9W	734	330, 330	417, 138, 83	312, 276
27	S014SP	404	213, 188	227, 202	210, 190
28	S63SP	582	274, 146, 103, 60	555	303, 230
29 *Candida* sp.	B4W	463	235, 132, 89	381, 250	238, 111
30 *Cryptococcus* sp.	B4	506	238, 189, 79	500	263, 240

* PCR-amplified product

(a) (b)

Figure 1. ***Cyclosa confusa*** **and its detritus decoration (a) Control group (b) Experimental group.**

Figure 2. ***Cyclosa mulmenensis*** **and its egg sac decoration.**

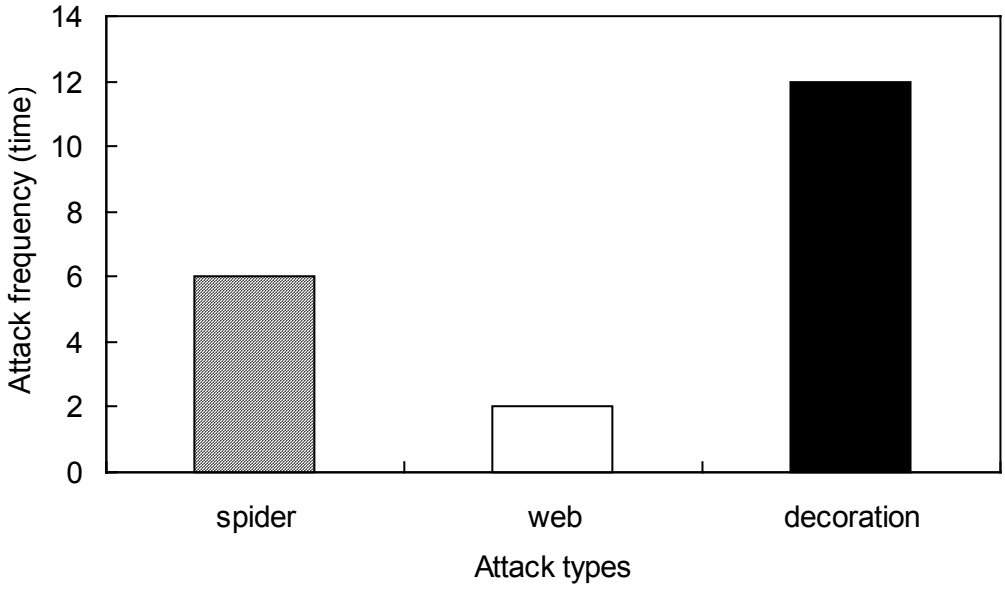

Figure 3. Frequencies of different attack types performed by *Vespa affinis* on *Cyclosa confusa* recorded by videos from Yung-Hsing Farm on Orchid Island in August 2002. Three attack types are attack on spiders, attack on web and attack on decoration.

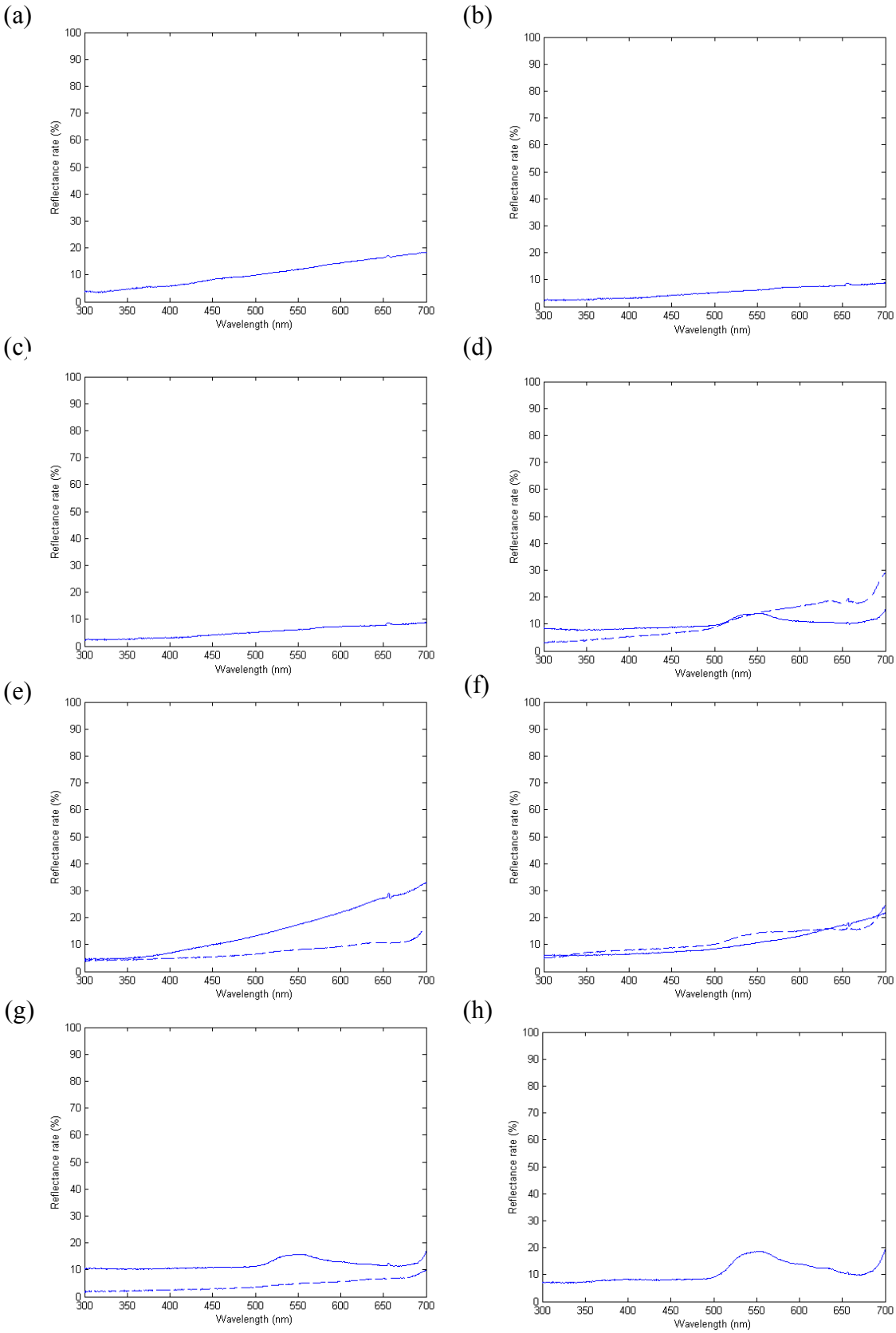

Figure 4. Mean reflectance spectra of *Cyclosa confusa*, web decorations and various background vegetations. (a), spider dorsum; (b), spider ventrum; (c), decoration, and various barks (dash line) and leaves (solid line): (d), betel palm *Areca catechu*; (e), breadfruit *Artocarpus communis* (f), figi longan *Pometia pinnata* (g), Indian almond *Terminalia catapa* and (h), giant elephant ear *Alocasia odora*.

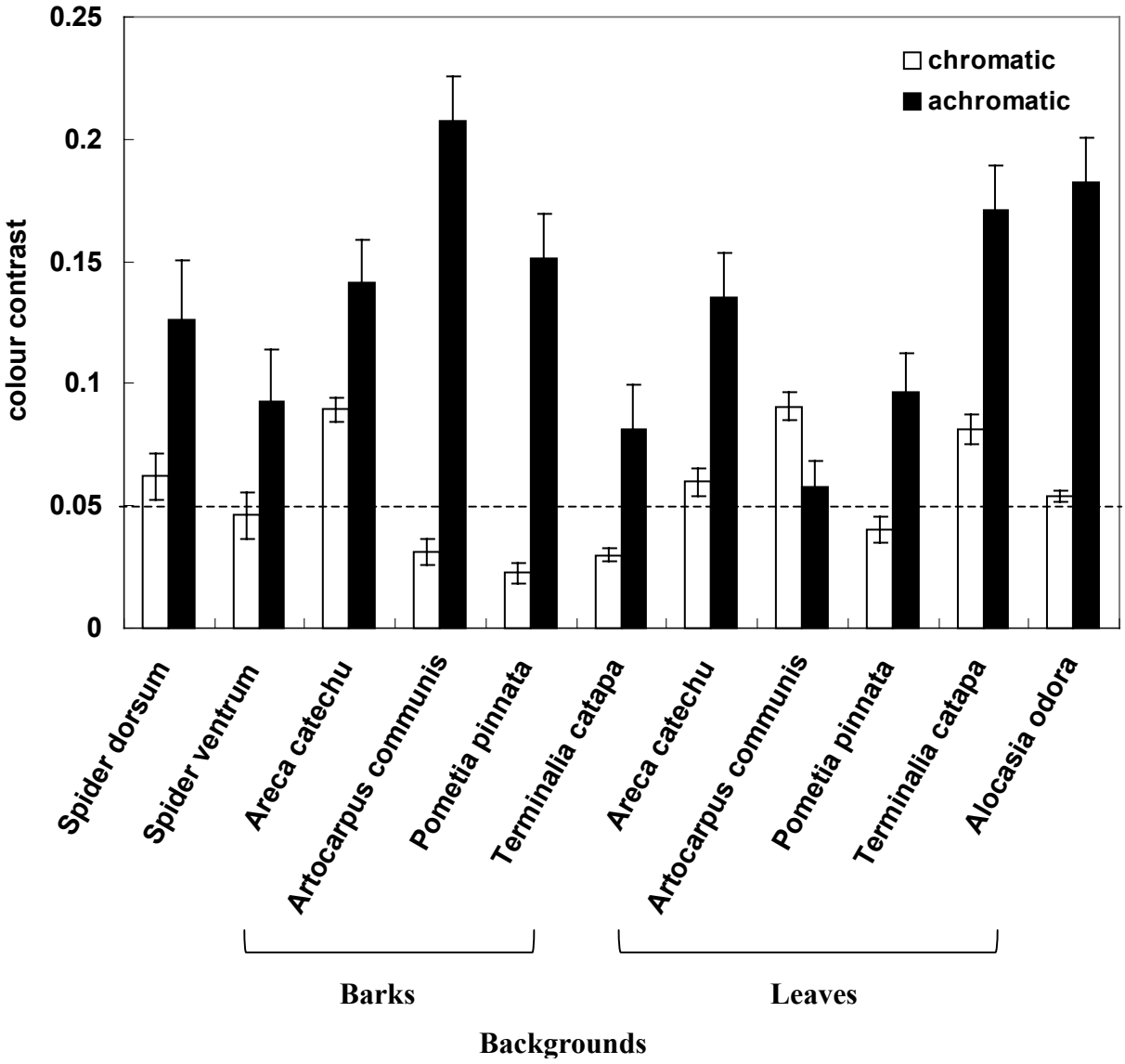

Figure 5. Colour contrast values ($\overline{X} \pm SE$) of detritus decoration spun by *Cyclosa confusa* (N=13) against different background types as viewed by *Apis mellifera* using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

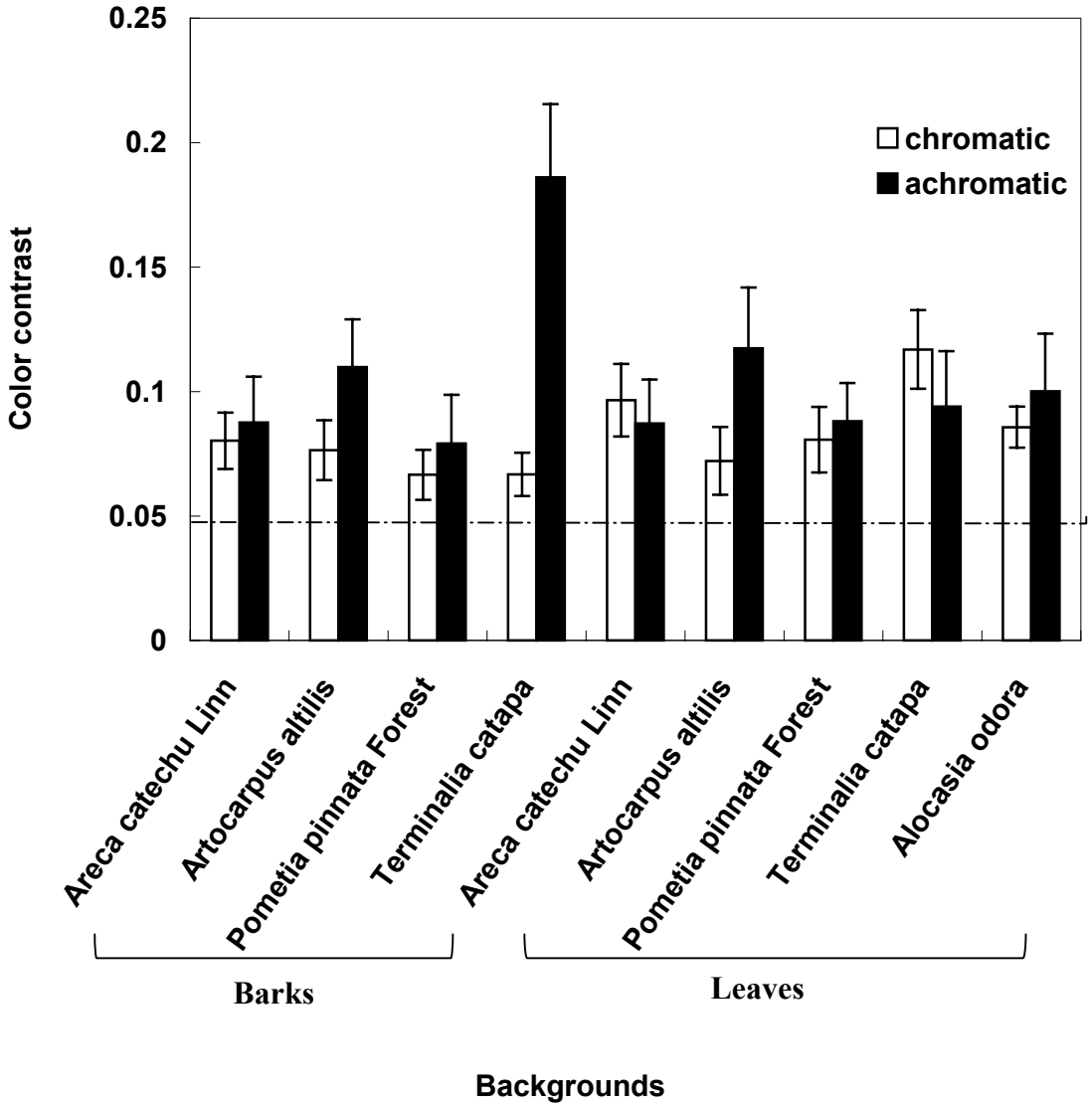

Figure 6. Colour contrast values ($\overline{X} \pm SE$) of dorsum of *Cyclosa confusa* spider (N=13) against different background types as viewed by *Apis mellifera* using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

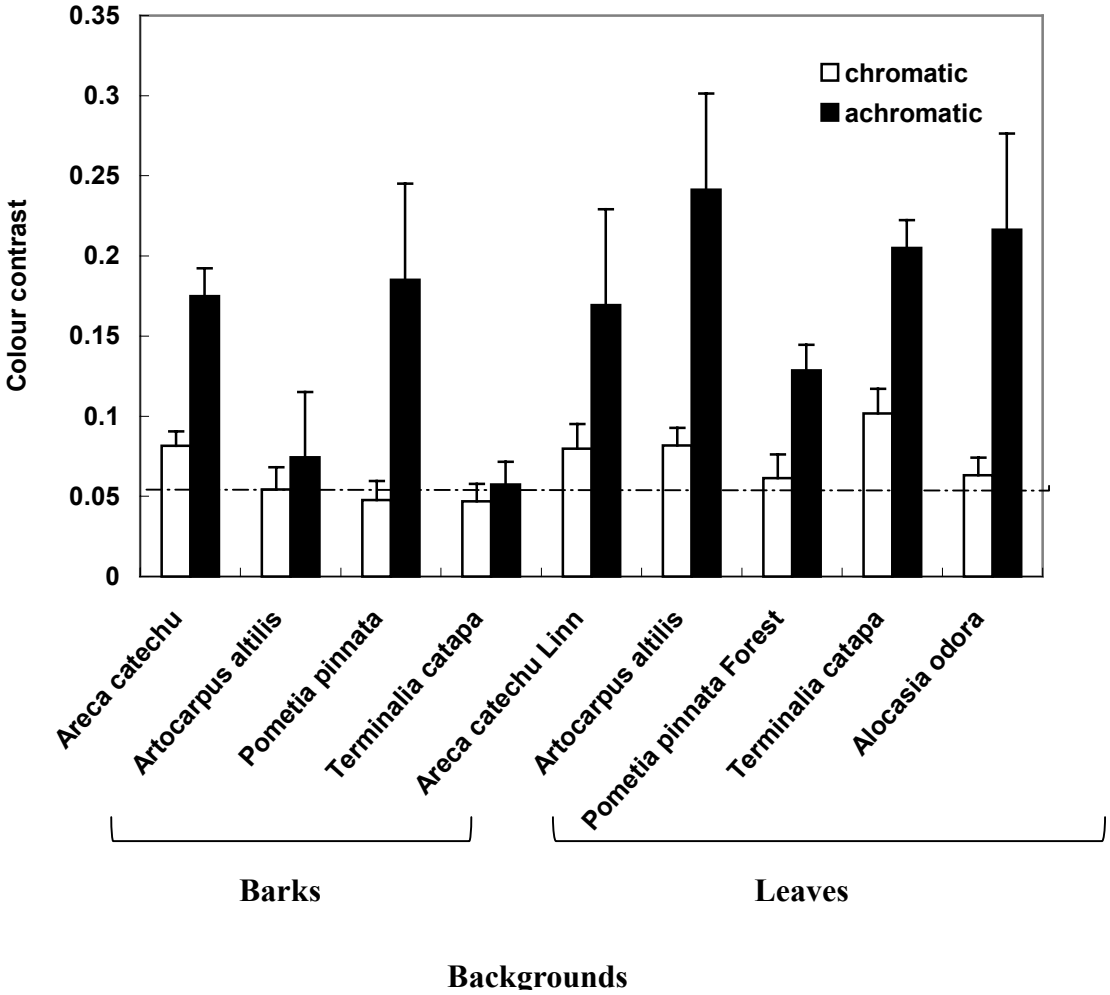

Figure 7. Colour contrast values ($\overline{X} \pm SE$) of the ventrum of *Cyclosa confusa* (N=12) against different background types as viewed by *Apis mellifera* using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

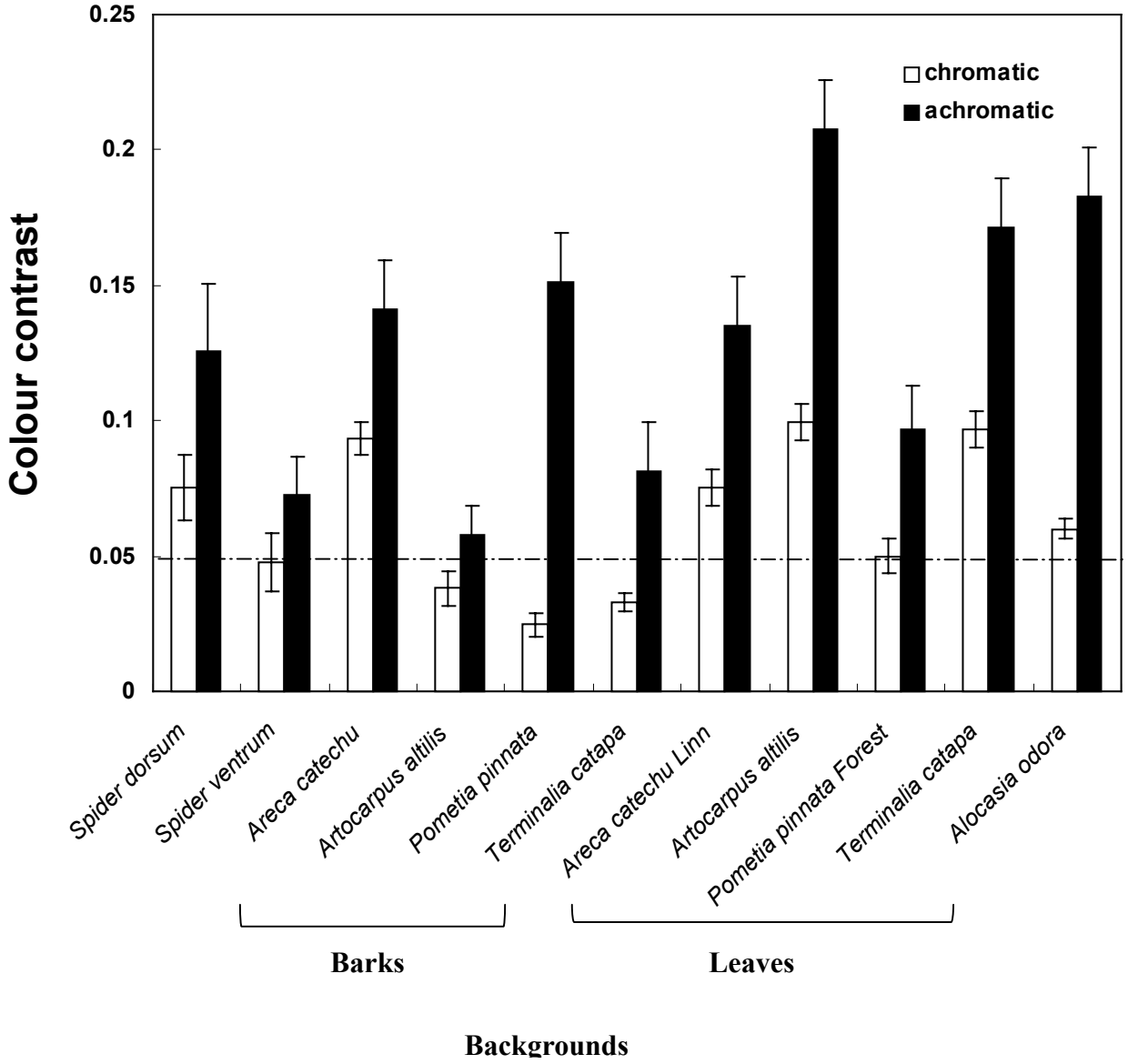

Figure 8. Colour contrast values ($\overline{X} \pm SE$) of detritus decoration spun by *Cyclosa confusa* (N=13) against different background types as viewed by *Vespa* sp. using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

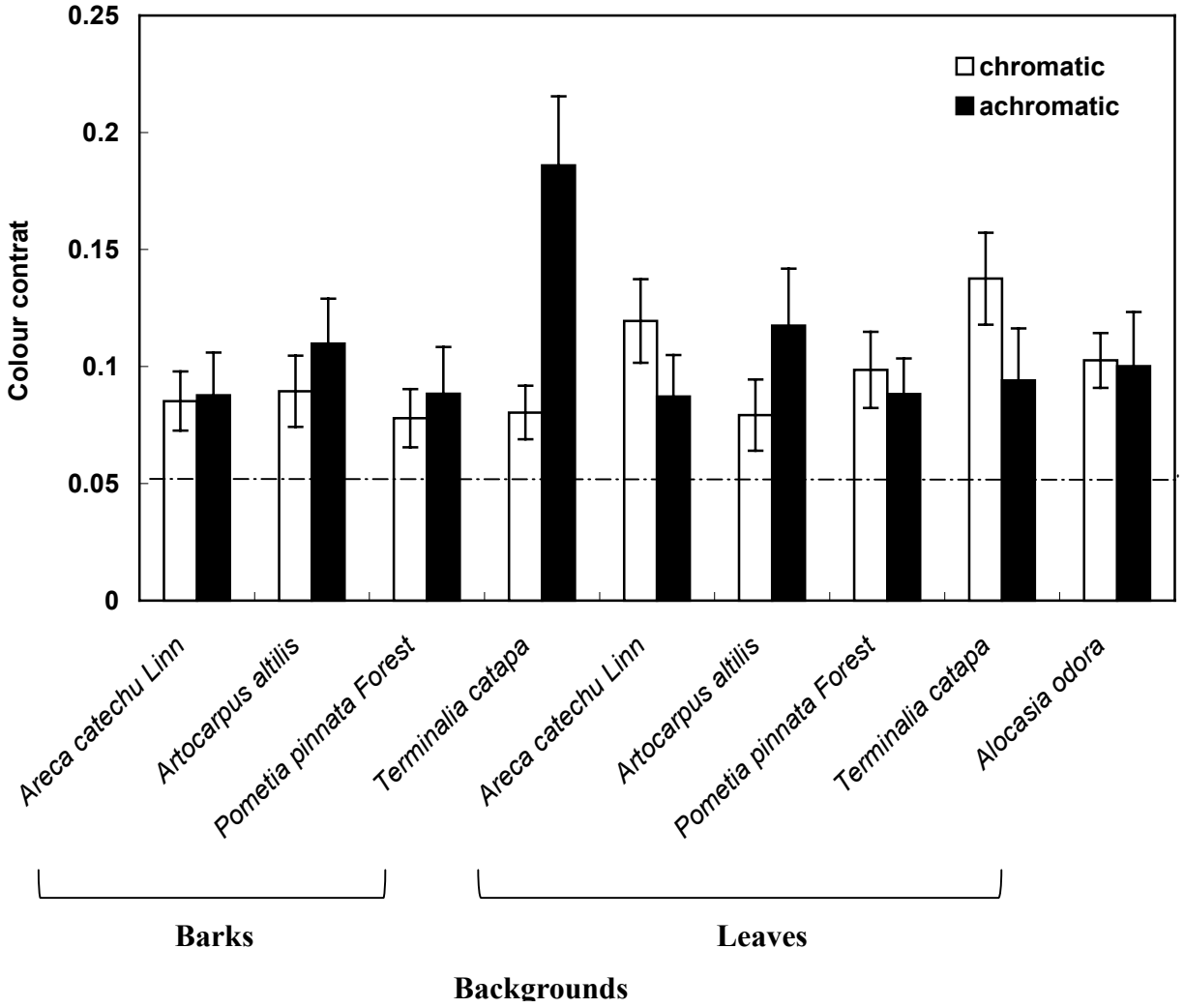

Figure 9. Colour contrast values ($\overline{X} \pm SE$) of dorsum of *Cyclosa confusa* spider (N=13) against different background types as viewed by *Vespa* sp. using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

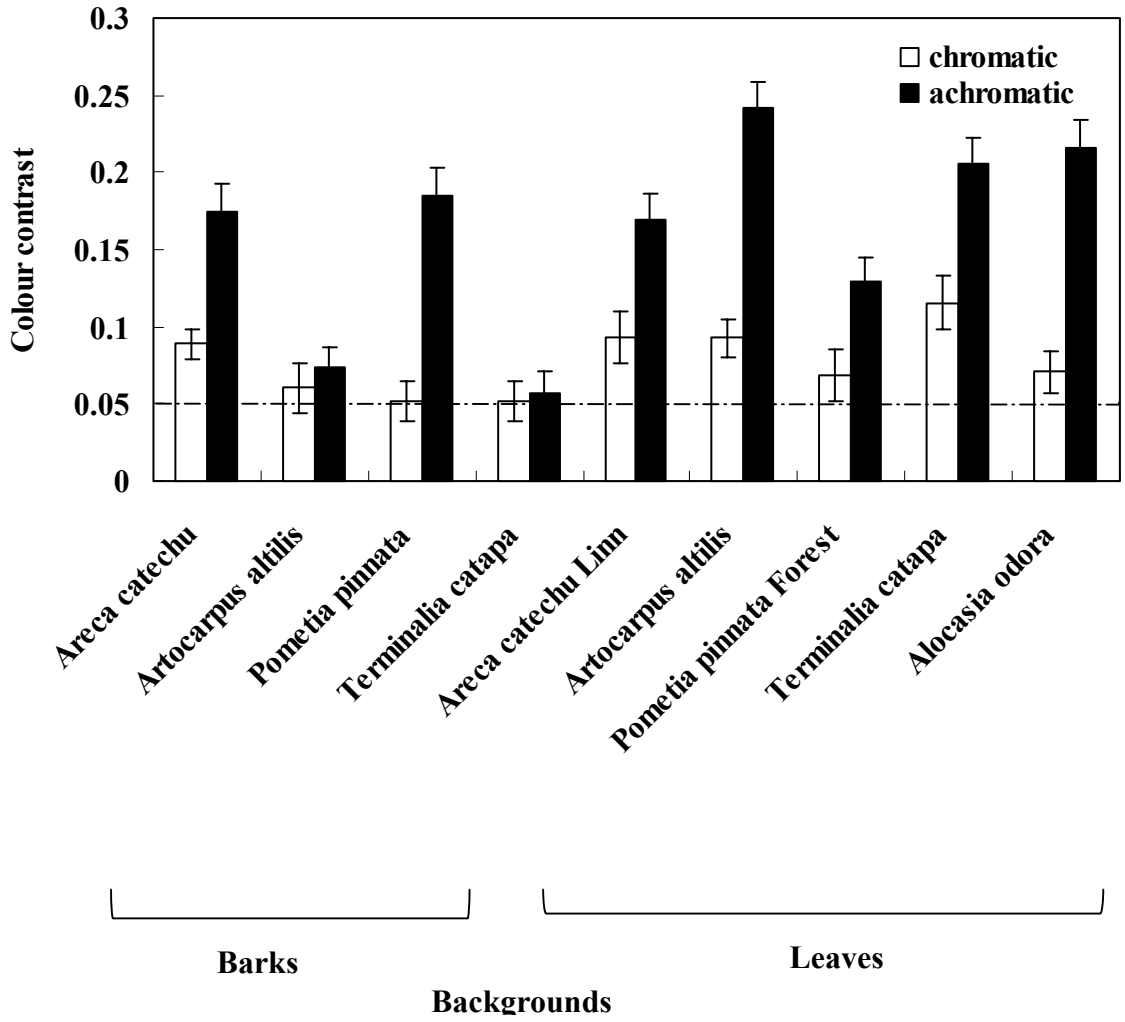

Figure 10. Colour contrast values ($\overline{X} \pm SE$) of the ventrum of *Cyclosa confusa* (N=12) against different background types as viewed by *Vespa* sp. using chromatic or achromatic vision. Dash line represented the threshold for colour contrast detection calculated for *Apis mellifera*.

APPENDIX

Sequence of 31 groups

G1-22

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G2-62

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G3-67

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G4-43

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G5-15

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G6-46

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G7-25

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G8-23

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G9-14

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G10-2

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G11-63

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G12-29

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G13-26

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G14-4

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G15-44

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G16-30

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G17-75

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G18-32

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CCA

G19-53

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G20-60

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G21-61

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G22-51

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G23-10

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G24-5

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G25-57

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G26-13

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G28-68

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TGAAACAGTACGTGAAATTGTTGAAAGGGAAGGGCTTGCAAGCAGACACGGCCTTCGT
GCCGGGCCAGCATCGGTTGCTAGGGGTGGATAAGGAACAAGGAATGTAGCTCCTCGGA
GTATTATAGCCTTGCGCGATACACCCACTGGCGACCGAGGCCTGCGGTATTCCTACCTA
GGATGCTGGCGTAATGGTTGCAAGCCGCCCGTCTTGAAACCACGGACCA

G29-55

NNATGGGTCCGGTGTTTCAAGACGGGGCGACTTAAGATCCATTATGCCAACATCCTAGA
GTAAAAATCGCAGTCCTCGGTCTAAACTGGCAGTATCAATAAAGACTATAACACATCACA
AGTGATGCCACATgTTCTTTACCATTATCCTACCGTTCAAACCGATGCTGGCCCGATAAAC
TGTAGAGGCTGCCCCCGAAAGAACAACATACAAAATATCAAGTCTGATCTCAAGCCCTT
CCCTTTCAACAATTTCACGTACTTTTTCACTCTCTTTTCAAAGTTCTTTTCATCTTTCCATC
ACTGTACTTGTTCGCTATCGGTCTCTCGCCAATATTTAGCTTTAGATGGAATTTACCACCC
ACTTAGAGCTGCATTCCCAAACAACTCGACTCTTCGAAGGAACTTTACATAGACCTGGA
GCATCTCATCGCACGGGATTCTCACCCTCTGTGACGTCCTGTTCCAAGGAACATAGACA
AGAGCCAGGTCCAAAGATACCTTCTTCAAATTACAACTCGGGCACTGAAAGTACCAGAT
TTCAAATTTGAGCTTTTGCCGCTTCACTCGCCGCTACTAAGGCAATCCCTGTTGGTT

G30-47

GCTCAGTACGGCGAGTGAAGCGGCAAAAGCTCAAATTTGAAATCTGGCCCTTGCGGGT
CCGAGTTGTAATTTGAAGAAGCGACTTTGGTGTGGGCTCTTGTCTATGTTCCTTGGAACA
GGACGTCACAGAGGGTGAGAATCCCGTGCGATGAGATGCCCATTGCCGTGTAAAGCGTT
TTCGACGAGTCGAGTTGTTTGGGAATGCAGCTCTAAGTGGGTGGTAAATTCCATCTAAA
GCTAAATATTGGCGAGAGACCGATAGCGAACAAGTACAGTGATGGAAAGATGAAAAGA
ACTTTGAAAAGAGAGTGAAAAAGTACGTGAAATTGTTGAAAGGGAAGGGCTTGAGATC
AGACTTTGTTTTTCCATGGTGTTCTTTCGGGGACGCCCTCTGGGTCTACAGGGCCAGCAT
GGGTTTTGCGGGCGAGACAATAGCTCAGGAATGTGGCTCTGCTTCGGTGGAGTGTTATA
GCCTGGGATGATGTCGCCACGCGGGACCGAGGACTGCGGTACTAGGATGCTGGCATAAT
GATCTTAAGCCGCCCGTCTTGAAACACGGACCA

G31-41

GGTCGGTGTTTCAAGACGGGTCGGTTTAAAGCCATTATGGTCCAACATCCTAAGCTCGA
ACGTGGGCGAACCCCGGCCATAAAGGCGAGCTGCATTCCTCAGTCACGTCCAGTGTATG
AGACACAGAGCTATAACACACCCGGAGGTGCTACATTCTCTATGCCTTTTTCCACCGAAT
ATAACTGATGTTGACCCGTTGACCAGCAATACACTAGCAGAACTAGCTGAAACTGATCA
ACACGACTGACTTCAATCGTTTCCCTTTCAACAATTTCACGTACTGTTTAACTCTCTTTC
CAAAGTGCTTTTCATCTTTCCCTCACGGTACTTGTTCGCTATCGGTCTCTCGCCTATATTT
AGCTTTAGATGGAATTTACCACCCATTTTGAGCTGCATTCCCAAACAACTCGACTCGTAG
AACACGTATCACAGAGCACTGGTTGTTGTGTCAAGTACGGGATTGTCACCCTCTTTGAT
ACCCTATTCCAAGGGACTTGGACACAGTCCAGCGCAGAAAACGCGTCTGTAGATTACA
ACTCGAACGCCCTGAGGACGCTAGATTTTAAATTTGAGCTCTTCCCGCTTCGCTCGCCG
CTACTAGGGGAATCCTTGTTAG

94 biochemical tests of Biolog YT MicroPlate

A1 water	**A2 acetic acid**	**A3 formic acid**	**A4 propionic acid**	**A5 succinic acid**	**A6 methyl succinate**	**A7 L-aspartic acid**	**A8 L-glutamic acid**	**A9 L-proline**	**A10 D-gluconic acid**	**A11 dextrin**	**A12 inulin**
B1 cellobiose	**B2 gentiobiose**	**B3 maltose**	**B4 maltotriose**	**B5 D-melezitose**	**B6 D-melibios**	**B7 palatinose**	**B8 D-raffinose**	**B9 stachyose**	**B10 sucrose**	**B11 D-trehalose**	**B12 turanose**
C1 N-acetyl-D-glucosamine	**C2 α-D-glucose**	**C3 D-glactose**	**C4 D-psicose**	**C5 L-sorbose**	**C6 salicin**	**C7 D-mannitol**	**C8 D-sorbitol**	**C9 D-arabitol**	**C10 xylitol**	**C11 glycerol**	**C12 Tween 80**
D1 water	**D2 fumaric acid**	**D3 L-malic acid**	**D4 methyl succinate**	**D5 bromosuccinic acid**	**D6 L-glutamic acid**	**D7 γ-aminobutyric acid**	**D8 α-keto-D-glutaric acid**	**D9 α-keto-D-gluconic acid**	**D10 D-gluconic acid**	**D11 dextrin**	**D12 Inulin**
E1 cellobiose	**E2 gentiobiose**	**E3 maltose**	**E4 maltotribos**	**E5 D-melezitos**	**E6 D-melibios**	**E7 palatinose**	**E8 D-raffinose**	**E9 stachyose**	**E10 sucrose**	**E11 D-trehalose**	**E12 salicin**
F1 N-acetyl-D-glucosamine	**F2 D-glucosamine**	**F3 α-D-glucose**	**F4 D-galactose**	**F5 D-psicose**	**F6 L-rhamnose**	**F7 L-sorbose**	**F8 α-methyl D-glucoside**	**F9 β-methyl D-glucosidas**	**F10 amygdalin**	**F11 arbutin**	**F12 salicin**
G1 maltitol	**G2 D-mannitol**	**G3 D-sorbitol**	**G4 adonitol**	**G5 D-arabitol**	**G6 xylitol**	**G7 i-erythritol**	**G8 glycerol**	**G9 Tween 80**	**G10 L-arabinose**	**G11 arabinose**	**G12 D-ribose**
H1 D-xylose	**H2 Methyl succinate + D-xylose**	**H3 N-acetyl-L-glutamic acid + D-xylose**	**H4 Quinic acid + D-xylose**	**H5 D-glucuronic acid + D-xylose**	**H6 Dextrin + D-xylose**	**H7 α-D-lactose + D-xylose**	**H8 D-melibiose + D-xylose**	**H9 D-glactose + D-xylose**	**H10 m-inositol + D-xylose**	**H11 1,2-propanesiol + D-xylose**	**H12 Acetoin + D-xylose**