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Species richness and seasonal abundance of thrips (Thysanoptera) on different tea cultivars in Xishuangbanna, Yunnan Province, China

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Abstract
Tea is one of the major cash crops of Yunnan province. It damaged by the thrips infestation that causes minor to severe losses. The present study proposed to check the diversity index of thrips and their seasonal activity. The experiments were carried out at the Tea Research Institute of Yunnan Academy of Agricultural Science Farm located in Xishuangbanna, from October 2018 to the January 2019. Three tea cultivars *Camellia sinensis var.assamica cv Yunkang* No.10 (CY), *Camellia sinensis var.assamica cv Changye baihao (CC),* and *Camellia sinensis var.assamica cv Zijuan* (CZ) were used in the study. The three tea cultivars were grown within the same agricultural conditions. A total of 21957 thrips adults specimens belonging to 8 species (*Lefroyothrips lefroyi, Thrips hawaiiensis, Thrips anderwsi, Thrips flavus, Ernothrips lobatus, Megalurothrips usitatus, Dendrothrips minowai, and Haplothrips tenuipennis*) representing 5 genera were collected by a weekly survey. The results showed that the predominant species were *L. lefroyi* and *T. hawaiiensis* with a relative abundance of 89.36% and 6.37%, respectively with an increase in population abundance from December to January. The CC tea cultivar showed high thrips diversity (Simpson 1-D=0.1583), Dominance D=0.8417, Evenness (E=0.2057) and diversity richness (Shannon H=0.3645). However, CY showed the highest diversity richness (Shannon H=0.5151) and the lowest abundance index (Simpson 1-D=0.2983) with an evenness of (E=0.2391). This information is not only useful for agricultural purposes; it will also give an insight into the insect species richness of tea varieties which is critical information to the tea production system, pest management, and conservation purposes.

Keywords: Thrips, tea cultivars, seasonal abundance, diversity index, species composition, pest management

1. Introduction

Tea is amongst important Agricultural crops in China; it is one of the major cash crops of Yunnan Province. This province has 16 prefectures, 129 counties of urban districts with 15 prefectures, 110 counties grow tea as the main cash crop. Recently, the tea planted areas have achieved a rapid expansion in Yunnan Province. In 2018, the entire area under tea production system was 420,000 ha with the total production of 387,000,000 kg and the comprehensive output value amounts to about $2.5 billion. The main challenge for tea production system is that under the widely varying climatic conditions, tea plants harbour diverse types of pests, where a particular pest may cause major damage in one locality, while in other areas, it may be observed as a minor pest [40]. Every part of the tea plant is subjected to the attack by the specific pests. The pests which act as minor and cause negligible damage at one time in a given area may become destructive at a certain period due to the changes in the ecological conditions [38]. It is estimated that 1034 species of arthropods and 82 species of nematodes are associated with tea plants globally, where approximately 3% of these arthropods are common pests [29]. The tea yield loss due to thrips attack may vary from 11%–55% [20] with estimated costs of $500 million to $1 billion [39].

Thrips (Thysanoptera) are polyphagous insects that infest diverse plant species [32] and are serious pests that causing huge losses to agricultural, ornamental and forestry commodities by direct feeding or diseases transmission [28, 3]. Thrips infestation causes minor to serious damage to tea plants [4]. They transmit plant viruses in the form of Tospovirus, Ilarvirus, Carmovirus, Sobemovirus, and Machlomovirus gener [25]. Thrips infest and damages the chilli plants (*Capsicum annuum* L.) in the young leaves and flowers and cause leaf curling upward which characterized by a silvery white colour [24]; *Scirtothrips dorsalis* and *Frankliniella schultzei* have been confirmed as Tomato spotted wilt virus transmitting agents [56] and are the causal agents of bud necrosis of peanut [2]; *Frankliniella occidentalis* and *Thrips tabaci* have been assessed to transmit the tospoviruses Tomato spotted wilt virus (TSWV) and Impatiens necrotic spot virus (INSV) in *Datura stramonium* (Family: Solanaceae) from North to West of Italy [50]; *Taeniothrips eucharii* have been confirmed as vector of Hippeastrum chloritic ringspot virus infecting *Hymnocallis littoralis* (Family: Amaryllidaceae) in Yunnan Province, South-eastern China [52]; *Thrips hawaiiensis* and *Scirtothrips dorsalis* are the main thrips species pests of mango fruits and normally oviposit on the pericarp of the fruits [55] which causes bronzing of the fruit surface, severe infestations result in the cracking of the fruit skin which reduces the economic worth and market value of mango fruits [1]. Different thrips species were reported as vectors of the tea phloem necrosis virus [15]; *Heliothrips haemorrhoidalis* have reported causing the serious damage on different parts of tea plant if not well managed [7] as demonstrated from *Scirtothrips kenyensis* tea damage in

Africa [23], *Taenothrips setiventris* and *Scirtothrips bispinosus* in India [18], they feed on tea plant and caused the blister blight and black blight; the long time and mass infestation causes plant twigs to turn brown and dead leaves [9] which affect the quality and quantity of tea products on market. Accurate information about the thrips-tea tree interaction would have the potential to the progress of Integrated Pest Management in the terms of developing new pest control and species targeting technologies. At present, many studies have been conducted on thrips-plant interaction; however, the information of thrips fauna on different tea cultivars is rare compared to other insect orders such as Lepidoptera, Coleoptera, and Diptera [19]. The current study was designed to investigate and compare the thrips diversity and species composition of three tea cultivars and their seasonal activity. This information is not only useful for agricultural purposes; it will also give an insight into the insect species richness of tea varieties which is critical information to the tea production system, pest management and conservation purposes.

2. Materials and Methods

2.1 Description of Study Areas

The study was conducted in tea garden at Mengla County, Xishuangbanna, Yunnan Province in South-eastern China. Xishuangbanna is located in tropical Northern edge of the Southern tip of traverses Mountains. By the Indian Ocean, the Pacific monsoon climate is continental and maritime with tropical rainforest climate, warm and humid year round, wetter less cold static wind, wet and dry quarter clear zone. The average annual temperature ranges from 18℃ to 21℃, rainfall from 1,100 mm to 1,900 mm, and the annual sunshine was from 1,700 to 2,300 hours. Tilt the entire topography of the whole style descending from North to South. The highest elevation was 2,429 m and the lowest elevation was 477 m. All 36 towns of Xishuangbanna grown tea plants as economic and commercial crop which makes it to be the largest tea producer Prefecture of Yunnan Province. The *Camellia sinensis var.assamica* cv Yunkang No.10 (CY), *Camellia sinensis var.assamica* cv Changye baihao (CC), and *Camellia sinensis var.assamica* cv Zijuan (CZ) tea cultivars were used in this study and were grown at Tea Research Institute of Yunnan Academy of Agricultural Science (21°33′N, 100°40′E, 1176.3m H). Tea plants were planted at 3,081 hm^2 and grown at the flowering stage with the crown diameter of 45×70 cm^2. The thrips were collected from 4th October 2018 to 20th January 2019. The five spot sampling methods were applied with the random selection of a single tea tree at every point and five flowers were selected from each tea plant from three cultivars. All the recommended agronomical practices were performed in tea field. The collected thrips samples were transported to Laboratory of insect Taxonomy College of Plant Protection, Yunnan Agricultural University , Kunming for further analysis.

2.2 Collection and identification Technique

Methods for thrips collection and slide preparation followed [53]. All specimens were observed with a Carl Zeiss-Axiostar plus microscope.

The adult thrips were mounted as permanent slides and identified based on [33, 34, 37] and https://thrips.info/wiki 2020 with associated links [27].

Slide-mounted specimens were deposited in Insect Taxonomy laboratory at Yunnan Agricultural University, Kunming, China.

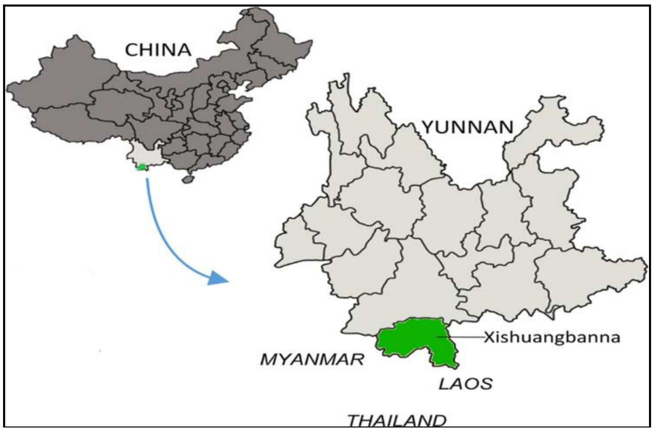

Fig 1: Location of Xishuangbanna, Yunnan Province, Southern East of China

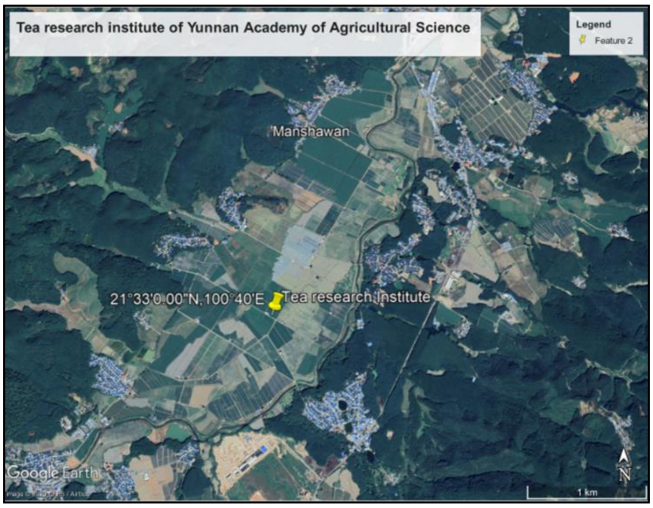

Fig 2: Location of Tea Research Institute of Yunnan Academy of Agricultural Science (21°33′N, 100°40′E, 1176.3m H)

2.3 Statistical analysis

A species-accumulation curve and species-richness were calculated using the Past3 software. A community characteristic index analysis including the relative abundance, dominance index, diversity index, richness and evenness indices were calculated using the formula developed by (Hurlbert, 1971; MacArthur, 1964):

$$Shannon\ Index\ (H) = NlnN - \sum(\text{ni}ln \times \text{ni})\text{N}$$

$$Simpson's\ index\ \ (D) = \sum ni(ni-1)/N(N-1)$$

Where: ni is the total number of individuals in species i, N is the total number of species involved in the samples Simpson's index calculation was referred to 1-D

3. Results

A total of 21,957 adult thrips specimens representing 8 species belonging to 5 genera were identified. The thrips abundance varies within the three tea cultivars; CC has the higher population outbreak of thrips individuals while CY has a lower number of the total collected thrips individuals as shown in (Tab. 1). In this study, the larvae have not been counted due to their identification difficulties.

Table 1: The population dynamics of Thrips species associated with tea cultivars

Genera	species	CY	CZ	CC
Thrips	*T.hawaiiensis*	404	664	331
	T.andrewsi	13	207	593
	T.fusca	1	1	2
	T.flavus	1	3	31
Megalurothrips	*M.typicus*	0	1	1
Lefroyothrips	*L. lefroyi*	1930	7090	10637
Haplothrips	*H.tenuipennis*	3	22	24
Dendrothrips	*D.minowai*	2	0	0

Note: *Camellia sinensis var. assamica* cv Yunkang No.10 (CY), *Camellia sinensis var.assamica* cv Changye baihao (CC), and *Camellia sinensis var. assamica* cv Zijuan (CZ)

The result showed that *L. lefroyi* was the most abundant and predominant thrips species on tea flowers, occupying 89.36%. *T. hawaiiensis* with 6.37% and *T. andrewsi with* 3.7% of the total recorded thrips individuals. Other species have a weak population dynamics (Tab. 2).

Table 2: Relative abundance of the total thrips species collected

Genus	Species	Total individuals	Abundance (%)
Thrips	*T.hawaiiensis*	1399	6.37
	T.andrewsi	813	3.7
	T.fusca	4	0.02
	T.flavus	31	0.14
Megalurothrips	*M.typicus*	2	0.09
Lefroyothrips	*L. lefroyi*	19657	89.36
Haplothrips	*H.tenuipennis*	49	0.22
Dendrothrips	*D. minowai*	2	0.09

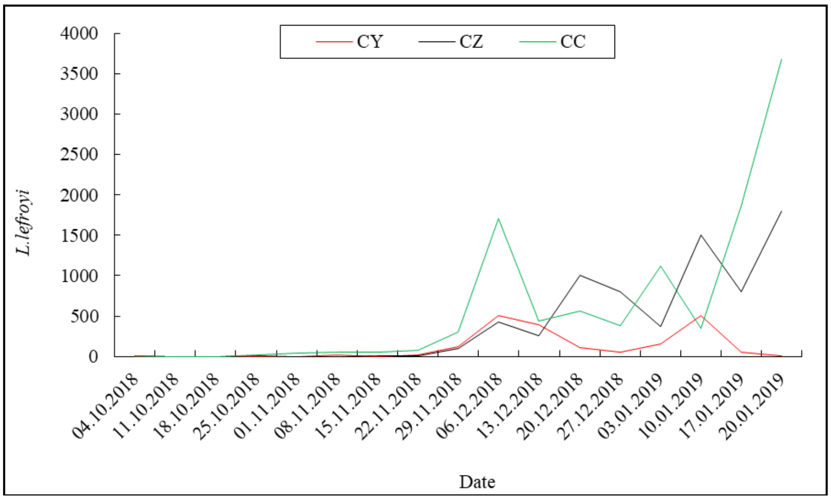

Fig 3: Population fluctuation of *L. lefroyi* in three tea cultivars from October 2018 to January 2019

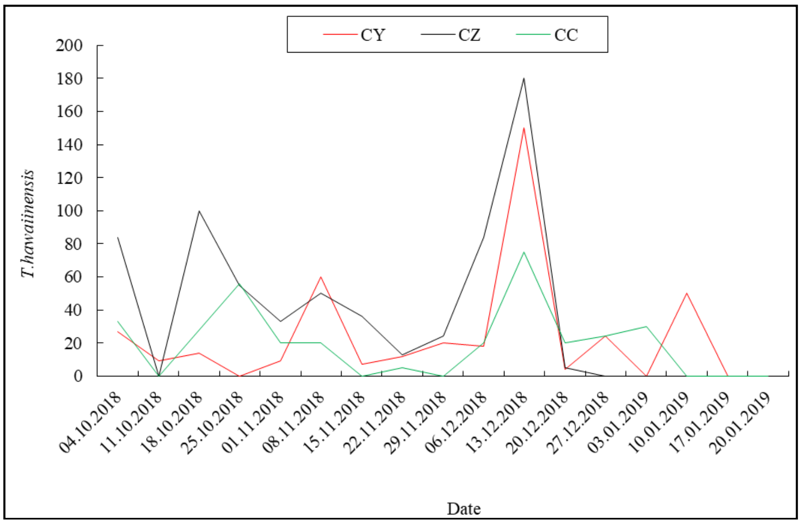

Fig 4: *T. hawaiinensis* in three tea cultivars from October 2018 to January 2019

The tea blooming season commenced from late September 2018, and the populations of *L. lefroyi* and *T. hawaiiensis* increased from December to January. In mid-January, *L. lefroyi* showed an exponential growth and began colonizing CC and CZ in large numbers (Fig. 3).
Whereas *T. hawaiiensis* showed increase in number in mid-December and decrease in late of December with a high dominance in CZ and CY cultivar compared to the rest (Fig. 4).
The CC tea cultivar showed the high Simpson's value (1-D= 0.1583) with D=0.8417, E=0.2057 with the lower diversity richness (H =0.3645), CY showed the highest diversity richness (H= 0.5151), and the lowest dominance (1-D= 0.2983) with evenness (E= 0.2391) (Tab. 3).

Table 3: Diversity indices on thrips species within three tea habitats

Tea variety	Dominance (D)	Simpson (1-D)	Shannon (H)	Evenness (E)
CY	0.7017	0.2983	0.5151	0.2391
CZ	0.796	0.204	0.4255	0.2551
CC	0.8417	0.1583	0.3645	0.2057

Kruskal-Wallis test showed the equal medians H (chi2) =0.8354 and p value =0.6511. There is no significant difference between thrips species distribution in CY, CZ, and CC tea cultivars.

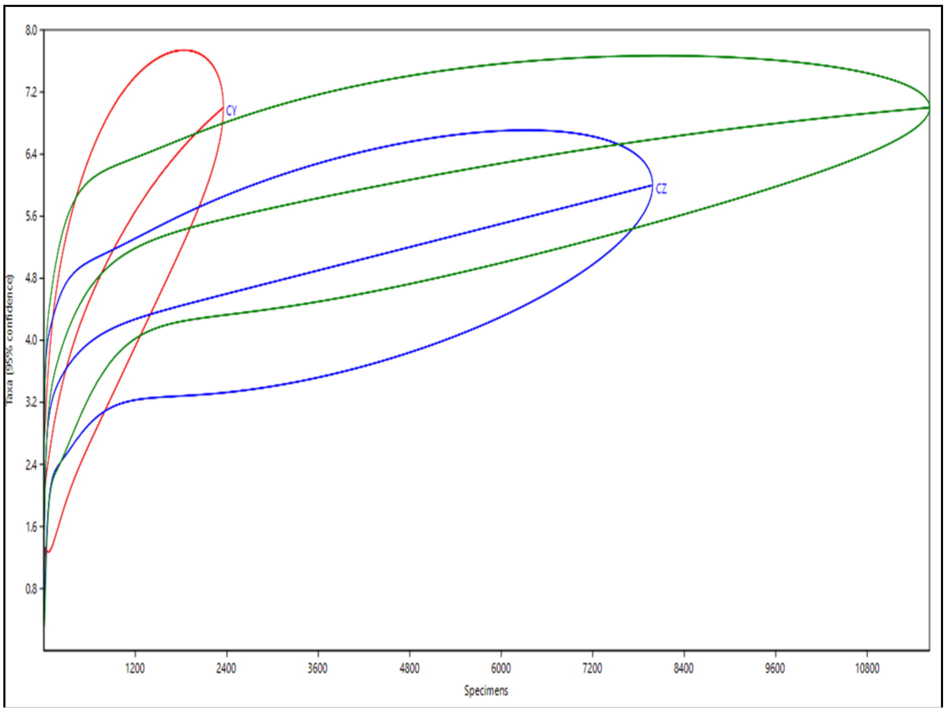

Fig 5: Comparisons of species diversity of thrips communities using rarefaction measurements (CY: Red curve, CZ: Blue curve and CC: Green curve).

Rarefaction analysis verified that each sample had a distinct species composition and (Fig. 5) also showed that the CC tea cultivar has an expended and closer to straight curve, confirming significant differences in species richness among studied tea cultivars.
The rarefaction curves showed that CY has the lower species richness estimates, whereas CC tea cultivar exhibited higher species richness in all instances (Approximately with 95% confidence interval).

4. Discussion

Thrips species and species composition have shown the variable pattern within three tea plants cultivars grown in the same conditions (Tab. 2) and matched with the results of [42, 44] and as demonstrated in chilli plant [6]. Different thrips species have shown the preference on tea plant cultivars as they require feeding and pollen to complete the development and to optimize the production of eggs [41]. Previous research conducted on tea garden at Yunnan Agricultural University has reported six species representing four genera with *L. lefroyi* and *T. flavus* as predominant species [54], whereas in this study, 8 species representing five genera are reported with *L. lefroyi*, *T. hawaiiensis* as predominant species (Fig. 3; Fig. 4). Other species are *T. anderwsi*, *T. flavus*, *E. lobatus*, *M. usitatus*, *D. minowai* Priesner, and *H. tenuipennis* identified to be the common thrips species in the study area and attacking tea plants (Tab. 1; Tab. 2). So this may explain the thrips species variation within tea plantation in Yunnan Province. Most of these thrips species were reported to feed on different plant varieties and causing different level of damage and diseases as [26] demonstrated that *L. lefroyi* and *T. flavus* were predominant thrips species on tea plantation [54]; *Scirtothrips dorsalis* (Chilli thrips) [43] and *T. hawaiiensis* on tea reported to feed primarily on new plant foliage growth, buds and flower or on fruit [17] and, they are vector of peanut bud necrosis virus, peanut chlorotic fan virus, and peanut yellow spot virus [31]. Although the species identified were common on other cultivated plants in Yunnan Province. The failure to find other thrips species in the study area was maybe related to the environmental alteration or agronomical practices as reported in bees' population [30, 49], on cereal stem borer populations [26], in ground beetles community [8]. In warm area like Xishuangbanna, due to their small size and very short life cycle, thrips population may exponentially increase and cause serious damage on crops, ornamental and forests if they are not well managed. In this study, *L. lefroyi* showed the high exponential growth of population in CC and CZ tea cultivars in January (Fig. 3) whereas *T. hawaiiensis* showed increase in mid-December and decrease in late of December with dominance in CZ cultivar compared to the rest (Fig. 4) as reported that the thrips incidence increase in January/February during budding and flowering period [1]. Even if thrips considered being the pest, some were considered as beneficial in tea garden and other flowering plants, thrips pollinators have a mutualism interaction with their host plants [16, 14]. *H. tenuipennis* and *Haplothrips leucanthemi* have been found to carry the pollens on their bodies from Clover (daisy) [11] same as observed in *Thrips hawaiiensis* and *H. tenuipennis* found having the petal coloration effect, and the only pollinators found inside yellow flowers scarlet in Lantana inflorescences [35]. Thrips have been reported to be the special pollinators in specific plants such as *Thrips setipennis* in eastern Australia is the only insect able to enter the tightly closed flowers of *Wilkiea huegeliana* for pollination [5] and in *Macrozamia macdonnellii* (Cycadales) [36].

This study suggest that all 8 thrips species recorded from the tea plant may not only be treated as pest but the detail of their interaction with different tea cultivars should be taken into consideration to conserve the small insect such as pollinators like *Karnyothrips merrillii, Haplothrips gowdeyi,* and some species of *Frankliniella* genus reported to be successful coffee pollinators [22, 46], and matching with some suggestions provided by different researchers to conserve and restore wild bee diversity [49], about inflorescences and flower-visiting insects conservation [12], natural enemies [10] and contribution of insect in Ecosystem Service [5, 45].

The intergeneric hybridizations done to generate an excellent cultivars which may resist to pest damage, diseases, cold tolerance, and quality products [21, 48]; In this study, CC cultivar had shown the high thrips population dynamic, followed by CZ, whereas CY cultivar has the lower thrips species population dynamics during the study period (Tab.1 and Fig.2). The diversity indices calculated in our study indicates that some species showed variation in dynamicity and specific selection on tea cultivars studied (Tab.3). The species composition within tea plant with the highest richness of thrips species was slightly higher while the Shannon-Weiner index indicated a low diversity (Tab.3). The rarefaction cure showed the different species composition within community species richness (Fig.3). A severe attack affects both young and old plants and causes considerable stunting and malformation of the shoots; leaf size reduction, the internodes shortened, and flowers malformation [13], which match with the CC cultivar to be at high risk of damage from Thrips pest, this also were demonstrated in cotton cultivars (Shahzad *et al*, 2016) [47]. In contrast, the cultivar obtained from the crossings of *C. sinensis with C. japonica, C. pitardii, C. assimilis, C. caudata, C. salicifolia, C. irrawadiensis* and *C. taliensis* have showed very low pollen fertilities [47, 48], which means that the low thrips population dynamics in tea CY cultivar does not make it to be the resistance cultivar but maybe due to the low capacity of pollen and additional substances production for thrips attraction. So this suggests that the post-harvest quantity and quality products from three cultivars should be in consideration to understand the thrips-tea interaction.

5. Conclusion

This study suggests that different tea cultivars grown in same conditions could hold the same or closely similar Thysanoptera species composition with different frequency of dominance, *L. lefroyi* and *T. hawaiiensis* showed a high predominance distribution within all tea cultivars, *D. minowai* showed the lowest distribution and recorded in only CY tea cultivar, the mean of population outbreak was maximum in December as well as January. In addition, the thrips population showed a strong variation within species composition in tea plantation in comparison to the previous 10 years investigations done on tea thrips fauna in Yunnan province. This information will assist tea growers to optimize targeting and managing specific noxious thrips and the study suggest that further research on tea-thrips interaction for more understanding of their composition and relationship with tea plant resistance and different thrips species attraction properties which will contribute in conservation of beneficial thrips species within tea production system.

6. Acknowledgments

These authors contributed equally to this work. EN, ZH and MH designed the experiments. EN, MJ and XY performed the research. EN and MJ analyzed the data. While EN, ZH and MH wrote the paper. All authors read and approved the final manuscript. This work was supported by Young Program of Science and Technology Agency of Yunnan Province (No. 2019FD122).

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