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Efficacy of Entomopathogenic Fungi against Sapota Fruit Mite, *Tuckerella kumaonensis* Gupta (Tuckerellidae: Acari) under Laboratory Condition

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***Abstract*—** *A laboratory investigation was conducted during 2020 and 2021 at Biocontrol Laboratory, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, to test the efficacy of different entomopathogenic fungi against sapota fruit mite, Tuckerella kumaonensis Gupta infesting sapota. Among the various entomopathogenic fungi, the treatment of Beauveria bassiana (1×10^8 cfu/g) @ 4g/l found significantly superior (62.03% mortality) over the rest of the treatments. However, the treatment of Lecanicillium lecanii (1×10^8 cfu/g) @ 4g/l registered 45.41 per cent mortality and found the next best treatment against sapota fruit mite and was statistically at par with the treatment of Metarhizium anisopliae (1×10^8 cfu/g) @ 4g/l (42.39% mortality). The treatments of Hirsutella thompsonii (1×10^8 cfu/g) @ 4g/l found to be least effective against sapota fruit mite (31.04% mortality).*

Keywords*— *Sapota, fruit mite, Tuckerella kumaonensis, entomopathogenic fungi, bio-efficacy.

I. INTRODUCTION

Sapota [*Manilkara achras* (Mill.) Fosberg] belongs to family Sapotaceae is an important tropical fruit crop having 2n=26 chromosome number. It is a native of Mexico and Tropical America. It is commonly known as chiku. The sapota is a climacteric fruit. Fully ripen fruits of sapota are delicious and sweet in taste used as dessert fruits. It is a commercial orchard crop where the fruits are used for preparation of many value-added products viz. squash, jam, slices, butter, cheese, candy, milk shake, powder, biscuit, ice-cream, shrikhand, pulp, juice, dehydrated sapota slices, nectar, lassie, chocolate and bar. The latex obtained from stems and immature fruits is used in the preparation of chewing gum. Besides food values, the sapota fruits are also used in some ayurvedic preparations. Sapota is supposed to be medicinal also seeds as diuretic, bark as tonic, antipyretic, febrifuge and in curing biliousness and febrile attacks. The fruit is a good source of digestible sugar (12 to 18%) and appreciable source of protein, fat, fibre and minerals like calcium, phosphorous and iron (Chadha, 2001). In Gujarat state, it is cultivated in districts viz. Valsad, Navsari, Surat, Mehsana, Junagadh, Bhavnagar, Gir Somnath and Kachchh.

Among the various factors affecting the yield and quality of fruit, the damage caused by insect pests is considered as a major constraint. The yield and economic value of sapota fruits have been affected by number of insect pests as well as non-insect pests. More than 25 insect pests have been reported to attack on sapota tree at different crop stages during both on season and off seasons (Butani, 1979). Among them, about 16 insect pests and mites were identified in last two decades from sapota orchards in Gujarat (Patel et al., 2002) and their numbers reached to 33 insect pests and non-insect pests in sapota orchard with increase in the acreage (Bisane et al., 2018).

Sapota fruit mite, *Tuckerella kumaonensis* (Gupta) is responsible for qualitative losses to sapota fruits. The immature and adults of red coloured mite suck the cell sap from the fruit surface starting from marble size fruit stage thereby fruit surface become corky rough and black or dark colour with encrustation on fruits, which leads to qualitative loss of harvested products. This mite remains active throughout the year on sapota cv. Kalipatti under south Gujarat agro-climatic conditions. It is well known fact that in South Gujarat, the sapota crop has played a significant role in socio-economic upliftment of both marginal and big farmers.

To mitigate these losses, chemical control remains the most practical option under field conditions, although overuse of conventional insecticides has led to concerns such as insecticide resistance, environmental hazards, and effects on natural enemies. In this context, evaluation of various entomopathogenic fungus is necessary to achieve effective mite management, enhance crop productivity and ensure economic viability. Therefore, the present investigation was undertaken to test the efficacy various entomopathogenic fungus against sapota fruit mite, *T. kumaonensis* under the laboratory condition.

II. MATERIALS AND METHODS

The laboratory trial was conducted to test the efficacy of various entomopathogenic fungi against sapota fruit mite during the year 2020 and 2021 at Biocontrol Laboratory, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India. The experiment was laid out in Completely Randomized Design with four repetitions and six treatments. The treatments are as follow: *Hirsutella thompsonii* (1×10^8 cfu/g), *Beauveria bassiana* (1×10^8 cfu/g), *Lecanicillium* (*Verticillium*) *lecanii* (1×10^8 cfu/g), *Metarhizium anisopliae* (1×10^8 cfu/g), water spray and control. The dose of each treatment was 4g/l of water under the laboratory. The fungal cultures were obtained from the Biocontrol Laboratory culture collection; however, the specific strain designations and original sources are not recorded and should be considered a limitation of this study.

2.1 Maintenance of Laboratory Culture

The laboratory culture was maintained on healthy unripe sapota fruit. Healthy unripe ten sapota fruits as well as fruit mites affected fruits with peduncle per twig were collected from the Organic Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari from the unsprayed sapota orchard. Moist cotton swab was covered on peduncle per twig to avoid desiccation of fruit. On each fruit, 2 x 2 square cm arena was marked and the boarder of the arena was demarked with vaseline jelly to avoid the escape of fruit mite. For egg laying, fifteen adult mites were released with the help of "0" number camel hair brush in the evening on the marked surface of each fruit. The adults were removed when sufficient number of eggs were laid. Mass rearing of fruit mite was initiated with these eggs and same were utilized for further efficacy trial. Sapota fruits were changed at an interval of two to three days with new fresh unripe fruits to avoid the secondary growth of fungus as well as rotting of the fruits.

2.2 Method of Observations

The laboratory experiment was conducted at temperature 31.5±4.0°C and relative humidity ranging between 72.0±5.0 per cent during March, 2020 and March, 2021. Healthy unripe thirty sapota fruits along with peduncle per twig were brought to the laboratory from unsprayed orchard from Organic Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. The fruit mites were released with the help of "0" number camel hair brush on 5mm thick pieces of unripe sapota fruits of the size 2.5 x 1.5 square cm arena with outer surface intact. Above mentioned treatments of entomopathogenic fungi were imposed by dipping the pieces of sapota fruits for five minutes in previously prepared conidial solution of respective entomopathogenic fungi treatments. For the water spray treatment, fruit pieces were dipped in distilled water for five minutes, while the control treatment received no dipping or treatment. After taking out from the solution the pieces were allowed to dry under ceiling fan. Five dried pieces for each repetition per treatment were placed on a wad of wet cotton to maintain turgidity of pieces of sapota fruits in petri dish (15cm x 2cm). In each treatment, hundred adult mites were released with the help of "0" number camel hair brush during evening hour on the outer surface of each treated piece. Thus, twenty-five adult mites were equally released on five treated pieces of unripe sapota fruits placed in each repetition of respective treatments (Photograph A). After 30 minutes of exposure, the fruit mites on treated pieces were transferred to fresh untreated pieces of sapota fruit. The per cent mortality were recorded at 3, 5, 7, 10 and 14 days after the treatments. Each treated pieces of sapota fruit were changed with new fresh untreated pieces of sapota fruit in same petri dish at alternate day. The data obtained on cumulative dead mite counts were summed up and utilized for calculation of per cent corrected mortality. Thus, the data on per cent mortality of the sapota fruit mites were corrected as per formula given by Henderson and Tilton (1955) by employing completely randomized design with four repetitions.

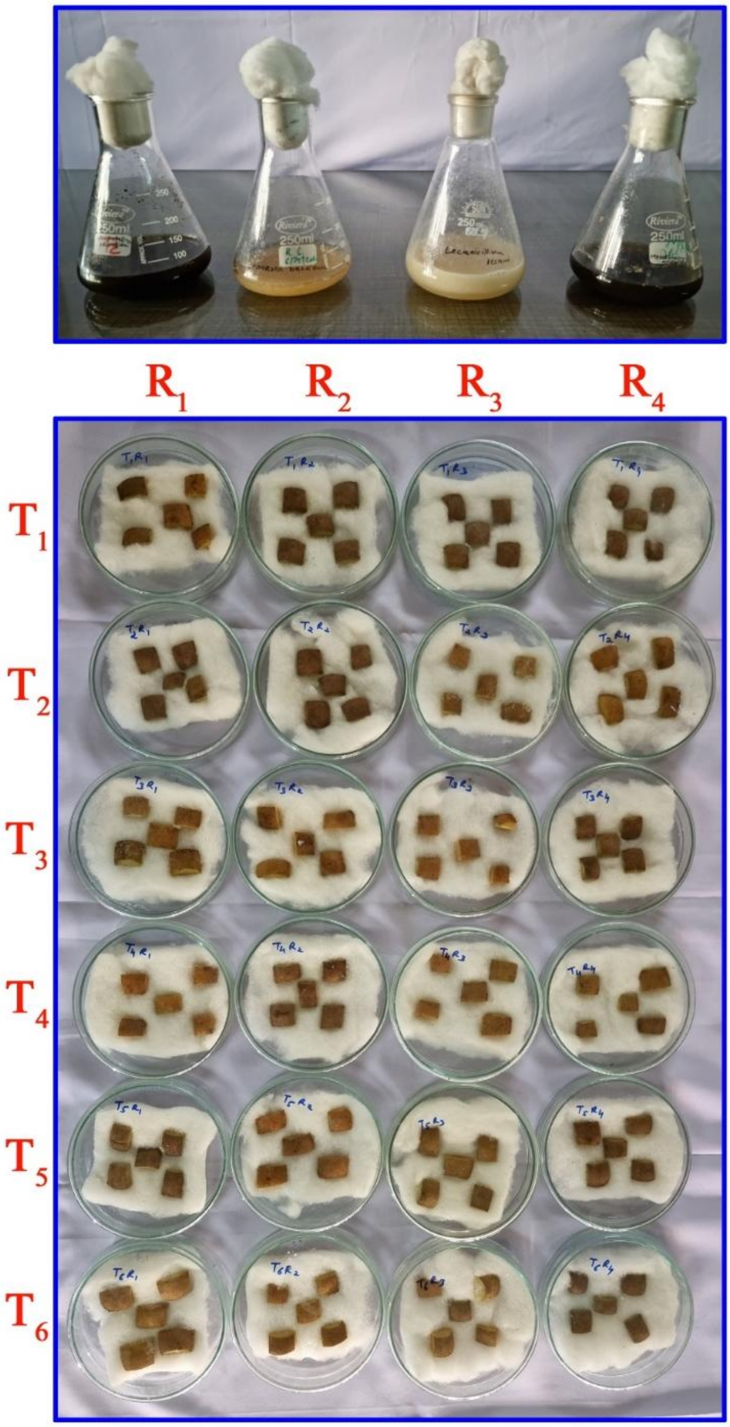
$$\text{Corrected per cent mortality } = \left(1-\frac{\text{Ta}\times\text{Cb}}{\text{Tb}\times\text{Ca}}\right)\times 100 \tag{1}$$

Where,

- Tb = Number of mites observed before treatment

- Ta = Number of mites observed after treatment
- Cb = Number of mites observed from untreated control before treatment
- Ca = Number of mites observed from untreated control after treatment

All statistical analyses were performed using analysis of variance (ANOVA) appropriate for CRD. Treatment means were compared using the Least Significant Difference (LSD) test at 5% level of significance. The statistical software used for analysis was WASP-2.



PHOTOGRAPH A: Laboratory experiment on efficacy of various entomopathogenic fungi against sapota fruit mite, *T. kumaonensis*

III. RESULTS AND DISCUSSION

The overall pooled data was calculated on the basis of pooled value of mean corrected per cent mortality of sapota fruit mite, *T. kumaonensis* during the year 2020 and 2021 are presented in Table 1 and depicted in Fig. 1 indicated that all the entomopathogenic fungi treatments were found significantly effective over the water spray and control.

TABLE 1
EFFICACY OF ENTOMOPATHOGENIC FUNGI AGAINST SAPOTA FRUIT MITE, *TUCKERELLA KUMAONENSIS* UNDER LABORATORY CONDITION

Sr. No.	Treatments	Conc.	Corrected per cent mortality					
			3 DAT	5 DAT	7 DAT	10 DAT	14 DAT	Overall Pooled
1.	*H. thompsonii*	4g/l	28.47 (22.76)*	30.71 (26.11)	34.35 (31.88)	36.14 (34.82)	38.99 (39.62)	33.85 (31.04)
2.	*B. bassiana*	4g/l	38.81 (39.32)	41.93 (44.65)	54.14 (65.62)	61.52 (77.08)	66.09 (83.47)	51.97 (62.03)
3.	*L. lecanii*	4g/l	33.61 (30.66)	37.86 (37.69)	43.60 (47.57)	47.64 (54.57)	48.80 (56.54)	42.36 (45.41)
4.	*M. anisopliae*	4g/l	32.24 (28.50)	36.17 (34.87)	41.72 (44.30)	45.57 (50.99)	46.91 (53.31)	40.61 (42.39)
5.	Water spray	-	10.89 (3.69)	12.01 (4.51)	13.43 (5.49)	14.15 (6.09)	14.56 (6.50)	13.14 (5.26)
6.	Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.Em. ±								
		Treatment (T)	0.52	0.65	1.10	1.89	1.84	1.16
		(Y×T)	0.73	0.92	0.89	0.98	1.00	0.60
C.D. at 5 %								
		Treatment (T)	1.49	1.86	4.00	6.86	6.70	4.23
		(Y×T)	NS	NS	NS	NS	NS	NS
		C.V. %	6.12	6.95	5.71	5.71	5.59	3.97

Figures in parentheses are retransformed values; those outside are arcsine transformed values, DAT: Days After Treatment

Among the various treatments, the treatment *B. bassiana* (1×10^8 cfu/g) @ 4g/l was found significantly superior than rest of the entomopathogenic fungi treatments as it recorded 62.03 per cent mortality, which was significantly highest all over the tested entomopathogenic fungi as well as treatment of water spray and control. However, the treatment of *L. lecanii* (1×10^8 cfu/g) @ 4g/l registered 45.41 per cent mortality and found best next in order for their effectiveness against sapota fruit mite and was statistically at par with the treatment of *M. anisopliae* (1×10^8 cfu/g) @ 4g/l exhibited 42.39 per cent mortality. The treatments of *H. thompsonii* (1×10^8 cfu/g) @ 4g/l found least effective against sapota fruit mite, which indicated 31.04 per cent mortality. The lowest per cent mortality (5.26%) was found in treatment of water spray. Further, in case of untreated control no mortality of sapota fruit mite was recorded.

The descending order of effectiveness of treatments based on corrected per cent mortality of sapota fruit mite, *T. kumaonensis* was:

B. bassiana (1×10^8 cfu/g) @ 4g/l > *L. lecanii* (1×10^8 cfu/g) @ 4g/l > *M. anisopliae* (1×10^8 cfu/g) @ 4g/l > *H. thompsonii* (1×10^8 cfu/g) @ 4g/l > water spray > control.

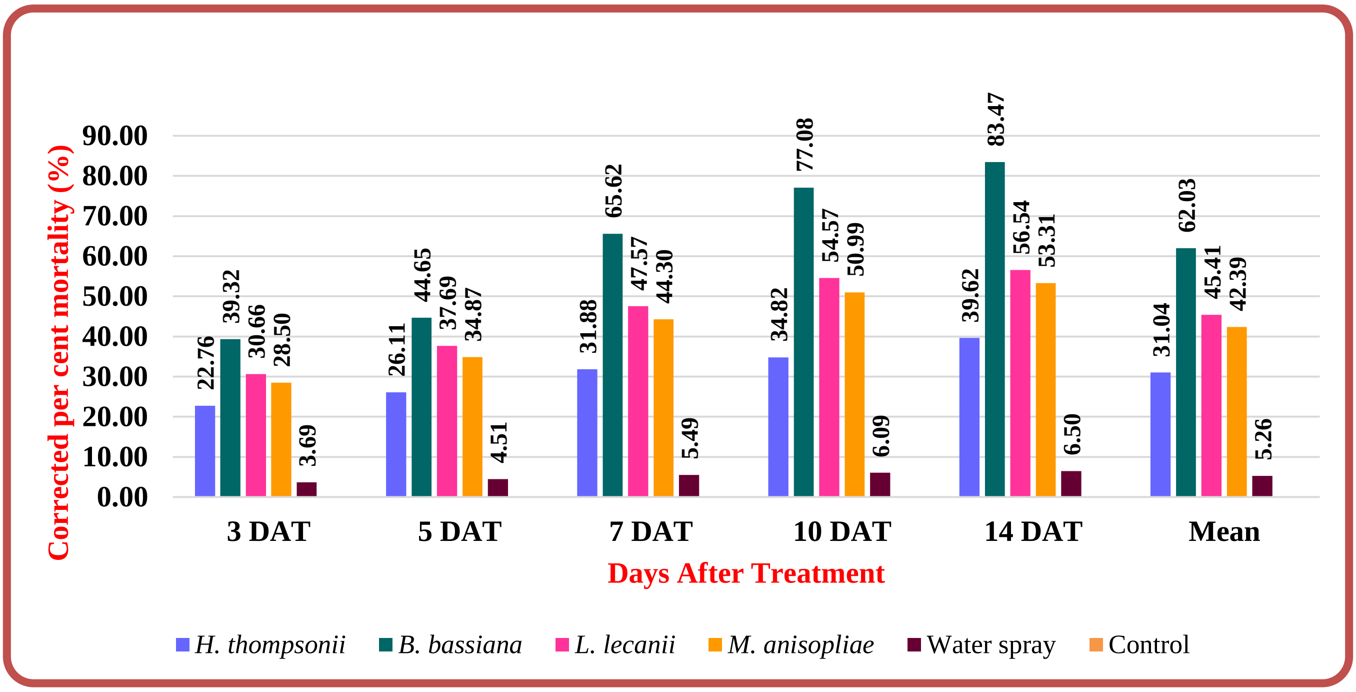


FIGURE 1: Efficacy of entomopathogenic fungi against fruit mite, *T. kumaonensis* under laboratory condition (Pooled)

The higher efficacy of *B. bassiana* against sapota fruit mite, *T. kumaonensis* was supported by various workers. In a study, Ghosh et al. (2007) exhibited *B. bassiana* more virulent against adults of *T. urticae*. Negash et al. (2014) found highest mortality of *T. urticae* by applying *B. bassiana* 9614 (82.38±3.44%) and *B. bassiana* 9609 (65.39±0.77%). Further, *B. bassiana* @ 5g/l registered 32.68 per cent mortality of coconut eriophyid mite, *A. guerreronis* (Sathish et al., 2019). The entomopathogenic fungi, *B. bassiana* @ 4g/l exhibited highest per cent mortality of sorghum mite, *O. indicus* (58.03%) by Prajapati et al. (2022).

The efficacy of *L. lecanii*, *M. anisopliae* and *H. thompsonii* against sapota fruit mite, *T. kumaonensis* was reported by different workers. *H. thompsonii* registered 78.70 per cent mortality against *A. guerreronis* (Wijesinghe and Rubasinghe, 2003), *V. lecanii* and *H. thompsonii* were found second best treatments (Ghosh et al., 2007), 90.00 per cent reduction in the coconut eriophyid mite population (Kumar, 2009). Negash et al. (2014) revealed maximum mortality of *T. urticae* by imposing *M. anisopliae* MM (76.63±1.07%) and *M. anisopliae* PPRC 6 (61.19±1.86%), *H. thompsonii* @ 5g/l registered maximum mortality (38.75%) of coconut eriophyid mite, *A. guerreronis* (Hegade et al., 2016); Hegade et al. (2016) reported maximum mortality of coconut eriophyid mite, *A. guerreronis* by *V. lecanii* @ 5g/l (12.75% mortality), *B. bassiana* @ 5g/l (12.25% mortality) and *M. anisopliae* @ 5g/l (7.0% mortality). *H. thompsonii* @ 5g/l and *V. lecanii* 5g/l found effective (58.89% and 32.55% mortality, respectively) against *A. guerreronis* (Sathish et al., 2019), *V. lecanii*, *M. anisopliae* and *H. thompsonii* @ 4g/l recorded 40.78, 37.64 and 28.43 per cent mortality of *O. indicus*, respectively (Prajapati et al., 2022).

The present findings are in accordance with the findings of Ghosh et al. (2007), Negash et al. (2014), Sathish et al. (2019) and Prajapati et al. (2022). While, findings of Wijesinghe and Rubasinghe (2003), Ghosh et al. (2007), Kumar (2009), Negash et al. (2014), Hegade et al. (2016), Sathish et al. (2019) and Prajapati et al. (2022) are not in accordance with present investigation, it might be due to different ecological conditions as well as change in the mode of action of tested biopesticides used during the course of investigation on targeted pest.

The superior efficacy of *B. bassiana* over other entomopathogenic fungi may be attributed to its higher virulence, efficient sporulation, and ability to produce cuticle-degrading enzymes such as chitinases and proteases that facilitate penetration of the mite cuticle. Additionally, *B. bassiana* produces secondary metabolites (beauvericin and bassianolide) with insecticidal and acaricidal properties. The relatively lower efficacy of *H. thompsonii* observed in this study could be due to strain-specific differences, environmental conditions, or the particular susceptibility of *T. kumaonensis* to different fungal species. These differences highlight the importance of strain selection and screening for specific pest-pathogen combinations.

IV. CONCLUSION

Among the various treatments of entomopathogenic fungi, the treatment of *B. bassiana* (1×10^8 cfu/g) @ 4g/l found significantly superior than rest of the entomopathogenic fungi treatments as it recorded 62.03 per cent mortality, which was significantly highest all over the tested entomopathogenic fungi as well as treatment of water spray and control. However, the treatment of *L. lecanii* (1×10^8 cfu/g) @ 4g/l registered 45.41 per cent mortality and found best next in order for their effectiveness against sapota fruit mite which was statistically at par with the treatment of *M. anisopliae* (1×10^8 cfu/g) @ 4g/l exhibited 42.39 per cent mortality. The treatments of *H. thompsonii* (1×10^8 cfu/g) @ 4g/l found least effective against sapota fruit mite which indicated 31.04 per cent mortality. The lowest per cent mortality (5.26%) was recorded in treatment of water spray, while in case of control, mortality was not recorded.

The study demonstrates that *B. bassiana* has significant potential as a biological control agent against sapota fruit mite, *T. kumaonensis* under laboratory conditions. However, field validation studies are essential to confirm the efficacy of these entomopathogenic fungi under natural conditions, considering the challenges of temperature, humidity, UV radiation, and application technology. Future research should focus on developing appropriate formulations, optimizing application methods, and evaluating the compatibility of these fungi with other pest management strategies.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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