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Research Article

Sustainable Management of Mealybugs *Maconellicoccus hirsutus* in Grapes (*Vitis vinifera*) and Influence of Environmental Factors in Growth of the Pest Population

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Abstract

The efficacy of different pesticides in grape mealybugs *Maconellicoccus hirsutus* have not been investigated clearly in Nepal. This research intended to outreach effectiveness of possible pesticides in mealybugs *M. hirsutus* infesting grape vines. The research was conducted in Chandannath, Jumla district in the selected grape vineyards (*Vitis vinifera*). Four treatments namely, insecticide (soil drenching of Imidacloprid 200 SL @1.5 ml/l of water/plant), botanical pesticide (neem oil *Azadirachta indica* 2 tablespoon mixed with one quarter water and few drops of dish soap), entomopathogenic fungi (*Beauveria bassiana* WP with 2×10^8 cfu/g)), and untreated control were applied in the research plots to investigate their efficacy in the mealybugs *M. hirsutus.*At the minimum temperature of 10^0C the average numbers of mealybugs *M. hirsutus* were 120, which then gradually increased to 300 and 470 at 11 and 12^0C respectively. At 19 and 20^0C the insect population rose to 2400 and 300 on an average respectively. With increase in relative humidity (%) from 50 to 60 the population of mealybug *M. hirsutus* also increased to 4100 from 1100 on an average. The temperature and relative humidity have non-significant and significant relationship respectively with the population of mealybug *M. hirsutus* in grape vines. Imidacloprid has highest effectiveness in comparison to neem oil, *B. bassiana*, and untreated control, though it has numerous negative consequences including growth of insecticide resistance in the pest population. Therefore, Imidacloprid would be the best control strategy for mealybug *M. hirsutus*, however, neem oil (*Azadirachta indica*) could be the most efficient and sustainable option for managing mealybug *M. hirsutus* in grape vineyard.

Keywords: Grape; pest; relative humidity; temperature; yield.

Introduction

Grape (*Vitis vinifera*) is regarded as one of the popular fruit crops in world and is cultivated in tropical, subtropical, and temperate region. Grapes are recognized for early fruit for some civilization, and is famous for its quality, juice, deliciousness, and refreshment (Jegadeeswari *et al.*, 2010). There are many applications of grapes such as this can be consumed as fresh fruit, drinks as juices, wines, beverages, and medicines, and stored as raisin so, has been determined for world class fruit as worldly fruit (Dahal *et al.*, 2017). The cultivation and practice of grapes in Nepal has been started before 70 years at the period of Rana regime (Dahal *et al.*, 2017). Rana's may have imported some varieties of grapes for specific purpose. The area covered by the grape production in Nepal is about 20 ha with all fresh grapes that produces approximately 76 tones yearly (Atreya *et al.*, 2015). The opportunities of grapes farming due to its attractive quality and quantity have enhanced numerous farmers to grow different varieties of grape vines (Acharya & Yang, 2015).

The vine mealybug is the major grape pest in the most important grape-growing regions of the world (Argentina, California, Europe, Mediterranean Africa, Mexico, the Near and Middle East and South Africa) (Daane *et al.,* 2008, 2012). It has been considered that the spread of *P. ficus* in Brazil (Pacheco da Silva *et al.,* 2016, 2017) recognized mealybug as a dangerous invasive species in grape-growing sites worldwide (Daane *et al*., 2012). Vineyard mealybugs feed on phloem pests which causes economic loss by feeding damage to leaves with the consequences in lower photosynthetic capability, and the excretion of carbohydrate-rich honeydew that again leads in making leaves foul including stems and fruit with the accumulation of sooty molds (Charles, 1982; Daane *et al*., 2012). Along with such losses the insect pest transmits viruses called grapevine leafroll associated viruses (GLRaVs), that results in leafroll diseases with the consequence to increase the cost of growing for the farmers as well (Engelbrecht & Kasdorf, 1990; Almeida *et al.,* 2013; Ricketts *et al.,* 2015). About 10 mealybug species have been identified in the world that have risen to the level of economic pest in vineyards (Daane *et al.,* 2012). They have not only declined the product but also minimized the marketable quality of the vines.

The study on environmental factors still lacks for the effect in mealybugs in grape vines. Some past studies only focused either in constant temperature or fluctuating regimes that influence the population of these mealybugs *M. hirsutus* (Persad & Khan, 2002; Serrano & Lapointe, 2002; Babu & Azam, 1987). Hot and dry condition also favors the insect pest in vineyard.

Traditionally to control the grape vine mealybugs synthetic insecticides were sprayed throughout the season that include organophosphates and neonicotinoids (Walton *et al*., 2004, 2006; Daane *et al.,* 2012), and revealed that these have non-target effect in bees and pollinators (Manasour *et al.,* 2018). The effectiveness of the insecticides has been considered lethal because the insects are difficult to recognize and control as they are primarily located in complex areas (i.e., under the bark and in bark crevices) and on the roots up to 30 cm deep (Walton & Pringle, 2004; Walton *et al.,* 2004; Daane *et al.,* 2012; Sharon *et al.,* 2016) protected from contact insecticides. At current period systemic insecticide such as Spirotetramat and Imidacloprid has been considered as an effective in controlling vines Mealybugs without any side effects on non-target fauna (Brück *et al.,* 2009; Mansour *et al.,* 2018). The oils from botanicals are heavily used to manage these insect pests due to the presence of their growth-inhibiting interventions, safety to non-target insects, zero residual effect, etc. (Oparaeke *et al.,* 2005). Similarly, entomopathogenic fungi (EPF) are considered as effective source of pest control mechanisms which have relatively broader in the mode of entry (both contact and systemic) and target group in comparison with other methods. Semio- chemicals can be used to reduce the population of these scale insects with proper strategy. The use of semiochemicals for controlling vine have promising control mechanism where insecticide resistance in insects are observed (Cocco *et al.,* 2014; Daane *et al.,* 2006; Mansour *et al.,* 2017; Walton *et al.,* 2004, 2006).

In this study efficacy of various insecticides has been investigated for the management of mealybugs *Maconellicoccus hirsutus* in grapes (*Vitis vinifera*) in Jumla district.

Materials and Methods

The research was conducted during May to October 2021 in Chandannath, Jumla district in selected grape vineyards (*Vitis vinifera*). Four treatments namely, insecticide (soil drenching of Imidacloprid 200 SL @1.5 ml/l of water/plant), botanical pesticide (neem oil *Azadirachta indica* 2 tablespoon mixed with one quarter water and few drops of dish soap), entomopathogenic fungi (*Beauveria bassiana* WP with 2×10^8 cfu/g)), and untreated control were applied in the research plots to understand their efficacy in the management of mealybugs *Maconellicoccus hirsutus.* In already installed vine field the investigation was carried out in 5 sample plants form middle rows. The data on population of mealybugs *M. hirsutus* with respect to fluctuating temperature and relative humidity were assessed in a regular manner. Regular weather data were collected from Department of Hydrology and Meteorology (DHM) through the district. The collected data were all tabulated and systematically arranged treatment wise applying MS-Excel which were subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT-0.05 level) for mean separations using Gen stat software.

Results and Discussion

Effect of temperature in the population of mealybugs M. hirsutus

The average numbers of mealybugs *Maconellicoccus hirsutus* were recorded to be 120, 300, 470, 700, 980, 1100, 1330, 1500, 1800, 2400, and 3000 at the temperature 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20^{o}C. The temperature was tallied during the summer season in the district. Mean numbers of *M. hirsutus* was 1246 at the mean temperature of 15^{o}C (Fig. 1).

In our investigation the average numbers of mealybugs improve with respect to the temperature. Still at lower temperature their population were checked. Only after 19 or 20^{o}C the growth and development of mealybugs started improving at better pace. The study of (Babu & Azam, 1987) found that at higher temperature the reproduction and growth of the mealybugs *M. hirsutus* increases in grapevines. In one of the research Mani and Thontadarya (1987) recorded high population of the mealybug, *M. hirsutus* from January to May and gradual decrease during June to December in some vineyards of India. This is due to the declined activity of these scale insects a lower temperature. Analysis of Dwivedi *et al.* (2003) revealed the non-significant relationship of mealybugs with the temperature. Only a limited higher temperature favors the growth and development of these pests.

Koli (2003) opined that grape mealybug were most active and increase their population during September to March in Rahuri (Maharashtra), India. Kulkarni *et al.* (2008) studied the seasonal incidence of grape mealybug in National Centre for Grapes, Pune and found that their population are distributed sporadically where highest population of mealybugs are observed (5–6 colonies per vine) at last week of February to the last week of March. It means the numbers of mealybugs surge during warmer and lowered during cooler temperature.

Effect of relative humidity in the population of mealybugs M. hirsutus

The average numbers of mealybugs *M. hirsutus* were recorded to be 1100, 1400, 1600, 1950, 2100, 2470, 2730, 2900, 3400, 3700, and 4100 at the relative humidity (RH %) 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, and 60 respectively. The mean numbers of mealybugs were 2496 at 55% RH (Fig. 2).

The population of mealybugs M. hirsutus rises with increases in relative humidity (RH) between 50-60%. Such pest has significant relationship with environmental factor of relative humidity. Koli (2003) found that the mass of mealybugs is positively correlated with the relative humidity in the atmosphere. A study from Yadav et al. (2004) reported that higher RH have positive effect in the growth and fecundity of mealybugs whereby their numbers influence with increasing RH and may decrease after very higher relative humidity. Investigation from Katke et al. (2009) have also supported our study that the population of mealybugs are in line with rising relative humidity. Shelke (2001) concluded that environmental parameters especially temperature and relative humidity have direct effect in the mass of mealybug population.

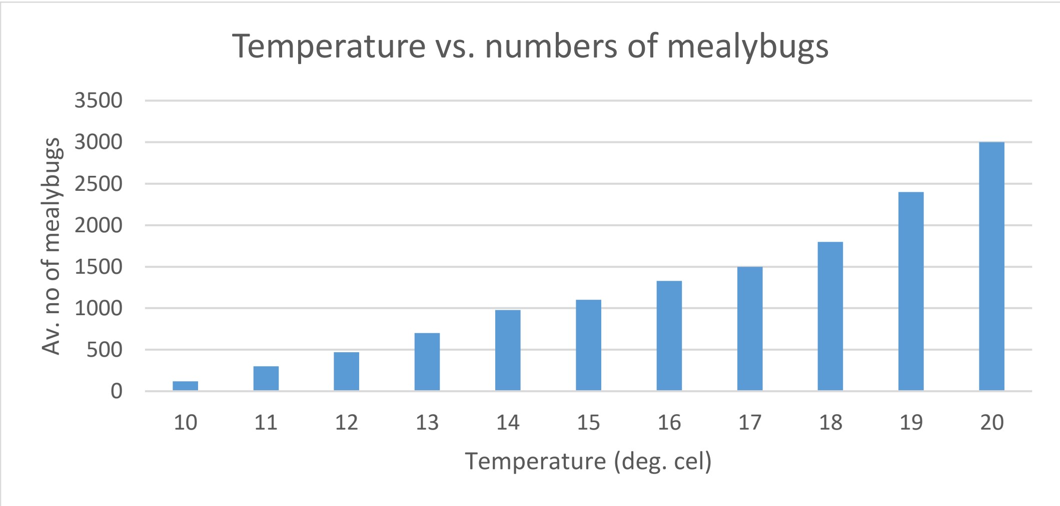

Fig. 1: Effect of temperature in the population of mealybugs *M. hirsutus*

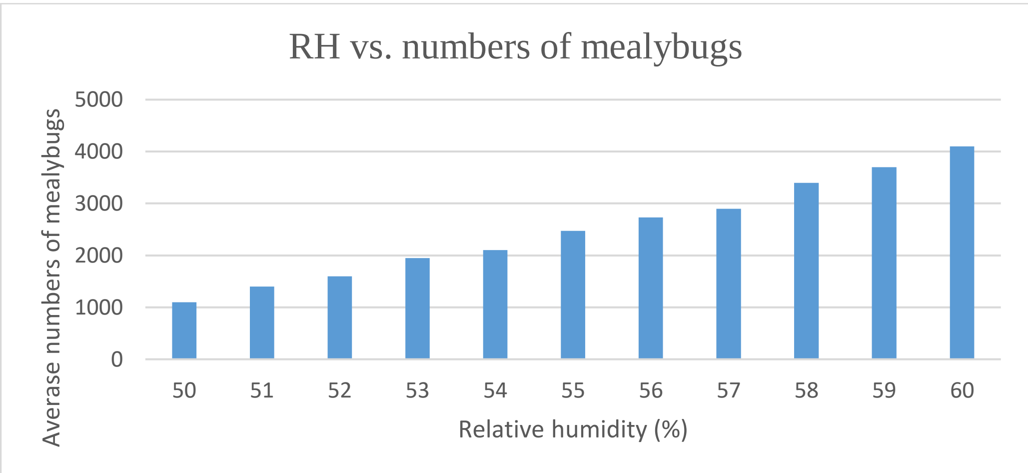

Fig. 2: Effect of relative humidity (RH) in the population of mealybugs *M. hirsutus*

Effect of Treatments in The Population of Mealybugs M. Hirsutus

The average numbers of mealybugs *M. hirsutus* were found to be 2000 in each vineyard with different treatments before the spray. In 4 days after first treatment the average numbers of mealybugs were recorded as 1700, 1800, 1800, and 2250 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively. Similarly, the average numbers of mealybugs were recorded as 1700, 1750, 1770, and 2300 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively after 8 days of first treatment. After 12 days of first treatment the average numbers of mealybugs noticed were 1650, 1700, 1720, and 2470 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively. After 4 days of third treatment the average numbers of pest found to be 800, 870, 888, and 3250 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively. Similarly, after 8 days of third treatment the average numbers of pest were 790, 820, 827 and 3400 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively. Finally, after 12 days of third treatment the average numbers of pest were 790, 817, 819 and 3700 in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard respectively (Table 1).

In our investigation the efficacy of imidacloprid was found highest followed by neem oil, *B. bassiana* and untreated control. In study is in agreement with the findings of Banu *et al.*, (2010) and Kanitkar *et al.*, (2020) according to whom the effectiveness of botanicals are at the top after insecticides in controlling mealybugs. The neem oils are effective and do not leave any residues as that of imidacloprid, and regarded appropriate in managing mealybugs in grapes (Verghese, 1997). Halder *et al.* (2013) reported that neem oils are potential pesticides in killing mealybugs compared with entomopathogenic fungi (*B. bassiana*).

Many researchers found that neem oil is result oriented (Hussain *et al*., 1996; (Verghese, 1997), and the extracts from *Azadirachta indica* (Satyanarayana *et al*., 2003) were effective against mealy bugs on various fruit crops, however, lower than insecticides, which coincides the results of our study.

Tanwar *et al*. (2007) and Sunitha *et al.* (2009) reported that Imidacloprid was found most effective insecticide in minimizing the mealybug attack in grape plants both in lab and field. According to Ghorpade & Khilari (2010) also convince that the relevant amount of imidacloprid sprays control the insect pest population at higher rate in comparison with other types of pest control mechanisms.

Effect of Treatments in Yield and Yield Attributes of Grape Vitis vinifera

It was found that the average numbers of grape clusters in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard were 41, 40, 38, and 34 respectively. Similarly, the average total yield of grape (kg/plant) in imidacloprid, neem oil, *B. bassiana*, and untreated control sprayed grape vineyard were 7, 4, 3 and 1 respectively (Fig. 3).

Our investigation confirms the highest efficacy was with imidacloprid followed by neem oil, *B. bassiana*, and untreated control in increasing numbers of grape cluster and per plant yield by controlling mealybugs *M. hirsutus* in the yard. A study of Mansour *et al.* (2010) confirms that the phenology and production of grape could be found at top level with the application of insecticides and botanical pesticides. Amala *et al.* (2014) reported that *B. bassiana* was least effective in controlling the mealybugs, and declining the yield and quality of crop. In the study of Daane *et al.* (2006) we found the effectiveness of insecticides not only managed mealybugs *M. hirsutus* in grape vines but also improved the quality and quantity of lant product. Despite of insecticide resistance in the pest (mealybugs) Felsot *et al.* (1998) reflected the quick and effective result of imidacloprid in phenological attribute of grape crops. This was possible through the foliar application of the treatment as per the recommendation of insecticides. So, many researchers have provided the significant results that is aligned with our investigation.

Table 1: Effect of treatments in the population of mealybugs *M. hirsutus*

	Average numbers of mealybugs in imidacloprid sprayed vineyard	**Average numbers of mealybugs in neem oil sprayed vineyard**	**Average numbers of mealybugs in *B. bassiana* sprayed vineyard**	**Average numbers of mealybugs untreated control vineyard**
Before the spray	2000	2000	2000	2000
First (4 DAT)	1700	1800	1800	2250
First (8 DAT)	1700	1750	1770	2300
First (12 DAT)	1650	1700	1720	2470
Second (4 DAT)	1400	1580	1623	2600
Second (8 DAT)	1330	1450	1470	2740
Second (12 DAT)	1300	1390	1390	2900
Third (4 DAT)	800	870	888	3250
Third (8 DAT)	790	820	827	3400
Third (12 DAT)	790	817	819	3700

Note DAT: Days After Treatment

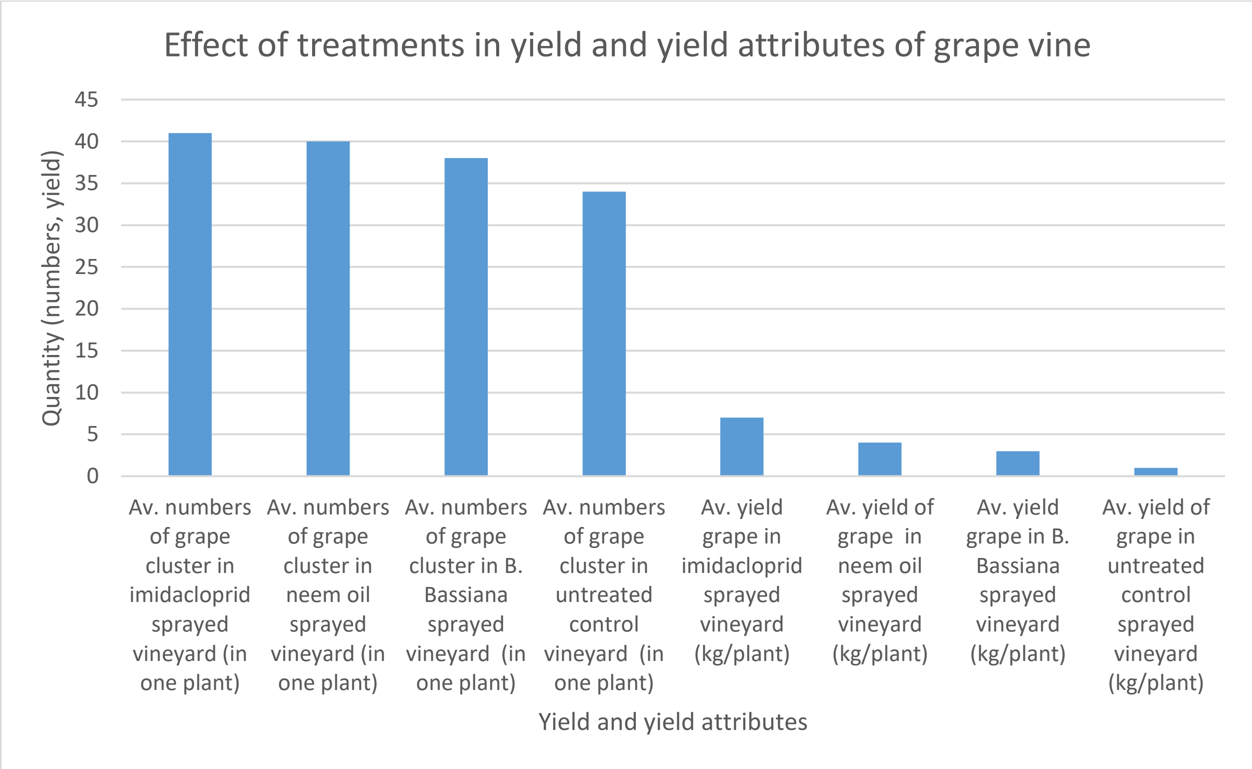

Fig. 3: Effect of treatments in yield and yield attributes of grape *Vitis vinifera*

Conclusion

The investigation was carried out during May to October 2021 in the selected grape vineyards (*Vitis vinifera*). Four treatments namely, insecticide (soil drenching of Imidacloprid 200 SL @1.5 ml/l of water/plant), botanical pesticide (neem oil *Azadirachta indica* 2 tablespoon mixed with one quarter water and few drops of dish soap), entomopathogenic fungi (*Beauveria bassiana* WP with 2 × 10^8 cfu/g)), and untreated control were applied to understand their efficacy in controlling mealybugs *Maconellicoccus hirsutus*. The effect of temperature and relative humidity in the population of mealybugs *M. hirsutus* were found to be non-significant and significant respectively. The population of mealybugs *M. hirsutus* were found effectively controlled by Imidacloprid followed by neem oil, *B. bassiana* and untreated control. The grape clusters and yield were observed highest in imidacloprid sprayed vineyards followed by neem oil, *B. bassiana* and untreated control.

Authors' Contribution

J. Pant designed the research plan; P. Dawadi & B. Devkota performed experimental works & collected the required data. All authors analysed the data; P. Dawadi & B. Devkota prepared the manuscript. J. Pant critically revised and finalized the manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare no conflict of interest.

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References

Acharya TD and Yang I (2015) Vineyard suitability of Nepal. *International Journal of Environmental Sciences* 6: 13. DOI: 10.6088/ijes.6002

Almeida RP, Daane KM, Bell VA, Blaisdell GK, Cooper ML, Herrbach E and Pietersen G (2013) Ecology and management of grapevine leafroll disease. *Frontiers in Microbiology* **4**: 94. DOI: 10.3389/fmicb.2013.00094

Amala U, Chinniah C, Sawant IS, Muthukrishnan N, and Muthiah C (2014) Bio-efficacy and lethal reproductive effects of three entomopathogenic fungi and botanicals against pink mealy bug, *Maconellicoccus hirsutus* (Green) infesting grapes. *Green Farming* **5**(4): 697–700.

Atreya PN, Lamichhane M, and Kafle K (2015) Commercial grape production: Technical bulletin (Nepali). FDD/DOA/MOA/Government of Nepal. 70.

Babu TR and Azam KM (1987) Studies on biology, host spectrum and seasonal population fluctuation of the mealy bug, *Maconellicoccus hirsutus* (Green) on grapevine. *Indian Journal of Horticulture* **44**(3-4): 284-288.

Banu JG, Surulivelu T, Amutha M, and Gopalakrishnan N (2010) Laboratory evaluation of insecticides and biopesticides against *Phenococcus solenopsis* and *Paracoccus marginatus* infesting cotton. *Journal of Biopesticides* **3**(1): 343–346.

Brück E, Elbert A, Fischer R, Krueger S, Kühnhold J, Klueken AM *et al.* (2009) Movento®, an innovative ambimobile insecticide for sucking insect pest control in agriculture: biological profile and field performance. *Crop Protection* **28:** 838–844. DOI: 10.1016/j.cropro.2009.06.015

Charles JG (1982) Economic damage and preliminary economic thresholds for mealybugs (*Pseudococcus longispinus* T-T.) in Auckland vineyards. *N. Z. J. Agric. Res* 25: 415–420. DOI: 10.1080/00288233.1982.10417905

Cocco A, Lentini A, and Serra G (2014) Mating disruption of *Planococcus ficus* (Hemiptera: Pseudococcidae) in vineyards using reservoir pheromone dispensers. *J Insect Sci* **14**: 144. DOI:10.1093/jisesa/ieu006.

Daane KM, Almeida RPP and Bell VA et al (2012) Biology and management of mealybugs in vineyards. In *Arthropod Management in Vineyards*; Bostanian, N.J., Isaacs, R., Vincent, C., Eds.; Springer Science and Business Media: Dordrecht, The Netherlands, 271–30.

Daane KM, Almeida RPP, Bell VA, Walker JTS, Botton M, and Fallahzadeh M *et al.* (2012) Biology and management of mealybugs in vineyards. In: Bostanian N, Vincent C, Isaacs R (eds) Arthropod management in vineyards: pests, approaches, and future directions. Springer, Dordrecht, pp 271–307. DOI: 10.1007/978-94-007-4032-7_12

Daane KM, Bentley WJ, Walton VM, Malakar-Kuenen R, Yokota GY, Millar JG, Ingels CA, Weber EA, and Gispert C (2006) New controls investigated for vine mealybug. *Calif Agric* **60**: 31–38. DOI:10.3733/ca.v060n01p31.

Daane KM, Cooper ML, Sime KR, Nelson E, Battany MC and Rust MK (2008) Testing baits to control Argentine ants (Hymenoptera: Formicidae) in vineyards. *J Economic Entomology* **10**: 699–709.

Dahal KC., Bhattarai SP, Midmore D, Oag JD and Walsh KB (2017) Table grape production in the subtropics and the prospects for Nepal. *Nepalese Horticulture* 12: 6–15.

Dwivedi SC, Kuldeep SM, Singh R and Katiyar RR (2003) Seasonal incidence of insect pests associated with mango crop. Department of Entomology, C.S.A. Univ. Agri. and Tech., Kanpur 208 002, hidia. *Ann. Pl. Prot. Sci.,* **11**(1): 159-160.

Engelbrecht DJ, and Kasdorf GGF (1990) Transmission of grapevine leafroll disease and associated closteroviruses by the vine mealybug, *Planococcus ficus*. *Phytophylactica* 22: 341–346. DOI: 10.1094/PHYTO-98-10-1093

Felsot AS, Cone W, Yu J, and Ruppert JR (1998) Distribution of imidacloprid in soil following subsurface drip chemigation. Bull. Environ. *Contam. Toxicol*. **60** (3): 363–370. Doi: 10.1007/s001289900635

Ghorpade SA and Khilari JM (2010) Evaluation of insecticides against pink mealybugs and thrips in grape ecosystem in Maharashtra. *J. Maharashtra Agric. Univ*. **35**(2): 257-261.

Halder J, Rai AB, and Kodandaram MH (2013) Compatibility of neem oil and different entomopathogens for the management of major vegetables sucking pests. *Nat Acad Sci Lett* **36** (1): 19–25. DOI:10.1007/s40009-012-0091-1.

Hussain MA, Puttaswamy C and Viraktamath CA (1996) Managemep.t of citrus mealy bug, Planococcus citri Risso on guava using botanical oils. *Insect Environment* **2** (3): 73-74.

Jegadeeswari VTN, Balamohan RM, Vijayakumar S, and Kuttalam S (2010) Fruit quality of grape (Vitis vinifera L.) cv. c. Department of Fruit Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India, 218–224. Website: http://www.pgia.pdn.ac.lk/files/Annual_congress/journel/v21-2/218.pdf (Retrieved on February, 2021).

Kanitkar S, Raut VM, Sawant SD, Yadav DS, Kulkarni M and Kadam M (2020) Field bio-efficacy of “Brigade-BL” (*Beauveria bassiana*) an Entomopathogenic fungi for the management of mealy bugs on Thompson Seedless Grapes. *Int J Res Appl Sci Biotechnology* **7**(5): 306–314. DOI:10.31033/ijrasb.7.5.40.

Katke M, Balikai RA and Venkatesh H (2009) Seasonal incidence of grape mealybug, *Maconellicoccus hirsutus* (Green) and its relationship with weather parameters. *Pest Management in Horticulture Ecosyst*em **15** (1): 9-16.

Koli HR (2003) Seasonal incidence and management of grape mealybug, Maconellicoccus hirsutus (Green). M.Sc. (Agri.) Thesis submitted to Mahatma Phule Krishi Vidhyapeeth, Rahuri, Maharashtra, India.

Kulkarni NS, Sawant SD and Adsule PG (2008) Seasonal incidence of insect pests on grapevine and its correlation with weather parameters. *Acta Horticulturae (ISHS)* **785**: 313-320. DOI: 10.17660/ActaHorti.2008.785.39

Mani M and Thontadarya TS (1987) Population dynamics of the mealybug, Maconellicoccus hirsutus (Green) and its natural enemies in the grapevine ecosystem. *Journal of Biological Control* **1**(2): 93-97.

Mansour R, Belzunces LP, Suma P, Zappalà L, Mazzeo G, Grissa-Lebdi K, Russo A and Bioni A (2018) Vine and citrus mealybug pest control based on synthetic chemicals. A review. *Agronomy for Sustainable Development* **38:** 37. DOI: 10.1007/s13593-018-0513-7.

Mansour R, Grissa Lebdi K, and Rezgui S (2010) Assessment of the performance of some new insecticides for the control of the vine mealybug *Planococcus ficus* (Signoret) in a Tunisian vineyard. *Entomologia Hellenica* **19**: 21–33. DOI: 10.12681/eh.11591

Mansour R, Grissa-Lebdi K, Suma P, Mazzeo G, and Russo A (2017) Key scale insects (Hemiptera: Coccoidea) of high economic importance in a Mediterranean area: host plants, bio-ecological characteristics, natural enemies and pest management strategies—a review. *Plant Protection Science* **53:** 1–14. DOI:.17221/53/2016-PPS.

Oparaeke AM, Dike MC, and Amatobi CI (2005) Evaluation of botanical mixtures for insect pests management on cowpea plants. *J Agriculture Rural Development in the Tropics and Subtropics* **106** (1): 41–48.

Pacheco da Silva V, Galzer ECW, Malausa T, Germain JF, Kaydan MB, and Botton M (2016) The vine mealybug *Planococcus ficus* (Signoret) (Hemiptera: Pseudococcidae) damaging vineyards in Brazil. *Neotropical Entomology* **45**: 449–451. DOI:

10.1007/s13744-016-0396-8. DOI: 10.1038/s41598-017-15983-5

Pacheco da Silva VC, Kaydan MB, Malausa T, Germain JF, Palero F, and Botton M (2017) Integrative taxonomy methods reveal high mealybug (Hemiptera: Pseudococcidae) diversity in southern Brazilian fruit crops. *Scientific Reports* **7**: 15741. DOI: 10.1038/s41598-017-15983-5

Persad A and Khan A (2002) Comparison of life table parameters for *Maconellicoccus hirsutus, Anagyrus kamali. Cryptolaemus montrouzieri* and *Scymnus coccivora*. *Bio-Control* **47:** 137–149. DOI: 10.1023/A:1014581616965

Ricketts KD, Gomez MI, and Atallah SS et al (2015) Reducing the economic impact of grapevine leafroll disease in California: Identifying optimal disease management strategies. *American Journal of Enology and Viticulture* 66: 138–147. DOI: 10.5344/ajev.2014.14106

Satyanarayana C, Babu RKY and Manjunatha M (2003) Preliminary studies on botanicals against Maconellicocclls hirsutlls (Green*). Insect EnVironment* **9** (3): 114-115.

Serrano MS and Lapointe SL (2002) Evaluation of host plants and a meridic diet for rearing *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae) and its parasitoid *Anagyrus kamali* (Hymenoptera: Encyrtidae). *Florida. Entomologist* **85**: 417–425. DOI: 10.1653/0015-4040(2002)085[0417:EOHPAA]2.0.CO;2

Sharon R, Zahavi T, Sokolsky T, Sofer-Arad C, Tomer M, Kedoshim R and Harari AR (2016) Mating disruption method against the vine mealybug, *Planococcus ficus*: effect of sequential treatments on infested vines. *Entomologia Experimentalis et Applicata* **161**: 65–69. DOI: 10.1111/eea.12487

Shelke RK (2001) Biology and Biointensive methods of management of grapevine mealy bug, Maconellicoccus hirsutus (Green). MSc. (Agri.) Thesis, Mahatma Phule Krishi Vidyapecth, Rahuri, Maharashtra (India).

Sunitha ND, Jagginavar SB and Biradar AP (2009) Bio efficacy botanicals and newer insecticides against grape vine mealy bug, Maconellicoccus hirsutus (Green). Karnataka *Journal of Agriculture Science* **22**(3): 710-711.

Tanwar RK, Jeyakumar P and Monga D (2007) Mealybugs and their management. NCIPM, New Delhi (India). *Bulletin of Science, Technology & Society* **19**: 1-2.

Verghese A (1997) Colony number, size and reproductive potential of the grape mealy bug, *Maconellicoccus hirsutus* (Green) on laboratory host pumpkin. *Insect Environment* **2**: 139–140.

Walton VM and Pringle KL (2004) A survey of mealybugs and associated natural enemies in vineyards in the Western Cape Province, South Africa. *South African Journal of Enology and Viticulture* **25**: 23–25. DOI: 10.21548/25-1-2134

Walton VM, Daane KM, and Pringle KL (2004) Monitoring *Planococcus ficus* in South African vineyards with sex pheromone-baited traps. *Crop Protection* **23:** 1089–1096. DOI: 10.1016/j.cropro.2004.03016

Walton VM, Daane KM, Bentley WJ, Millar JG, Larsen TE, and Malakar-Kuenen R (2006) Pheromone–based mating disruption of *Planococcus ficus* (Hemiptera: Pseudococcidae) in California vineyards. *Journal of Economic Entomology* **99**: 1280–1290. DOI: 10.1603/0022-0493-99.4.1280

Yadav JL, Singh SP and Kumar R (2004) The population density of the mango mealy bug (Drosicha mangiferae G.) in mango. *Progressive agriculture* 4: 35- 37.