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Farmers towards integrated pest management practice for disease vectoring mealy bug management in grapefruit vineyards (*Vitis vinifera*)

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Abstract
The perspective of farmers regarding Integrated Pest Management (IPM) for disease vectoring mealy bug management in grape vineyards has not been surveyed in Jumla, district. Thus, a survey was carried out during May 2021 to October 2021 to assess the farmers perspective in various control methods including Integrated Pest Management (IPM) of mealy bugs in grape vineyards (*Vitis vinifera*). Primarily two methods were used to conduct the research namely, KIIs (Key Informant Interview) and FGDs (Focus Group Discussions) in two farmer groups (each with 25 participants), where prospects of practices of mealy bug management and its consequences in grape production were discussed. Information and data were harvested from the past three years. Approximately 40% of farmers were found using imidacloprid followed by 28% neem extract (*Azadirachta indica*), 25% *Beauveria bassiana,* 5% handpicking and 2% Integrated Pest Management (IPM) during the year 2018. This increased, and changed to 21% for IPM, 27% for *B. bassiana*, 34% for neem extracts, 17% for imidacloprid, and 1% for handpicking in the year 2021. The percentage of farmers significantly increased in the application of Integrated Pest Management (IPM) in managing grape mealy bugs. Highest percentage of farmers revealed knowledge of IPM (60%) followed by climate change (30%) and biological control agents (10%) with respect to grape mealy bugs. Though initially the production of grapevines was lower through the application of Integrated Pest Management (IPM) method, it gradually increased and later became an effective strategy to manage the population of mealy bug thereby increasing the production of grapevine compared with other methods of the pest control. Therefore, Integrated Pest Management (IPM) would be an effective management method for reducing disease vectoring mealy bugs in grape vineyards for the farmers in the district.

Keywords: *Beauveria bassiana*, climate change, imidacloprid, neem extract, pest

Introduction

A grape is a fruit, botanically called a berry, of the deciduous woody vines of the flowering plant genus Vitis. There are many multi-applications of grapes that includes making wine, juice, raisins, vinegars, oil, etc. Grapes are a non- climatic type of fruit, generally occurring in clusters. According to the Food and Agriculture Organization (FAO), 75,866 square kilometers of the world are dependable in grape production. About 71% of world grape products are used for wine, 27% as fresh fruit, and 2% as dried fruit.

The vine mealy bug (VMB) is considered a the significant pest of grape in highly grape producing regions of the world (Argentina, California, Europe, Mediterranean Africa, Mexico, the Near and Middle East and South Africa) (Daane *et al*. 2008, 2012) [10, 11]. The vine mealy bug is regarded as the key economic scale insect pest species occurring in vineyards worldwide, including the Mediterranean basin, that is known for its native extension (Daane *et al*. 2012; Dalla Montà *et al*. 2001; Güleç *et al*. 2007; Mansour *et al*. 2017; Reineke and Thiéry 2016; Sforza *et al*. 2005; Walton *et al*. 2009) [11, 13, 19, 26, 37, 42]. Many diseases transmitted by mealy bugs have been documented in numerous parts of the word. These are transformed through complex viruses from the families Closteroviridae and Flexiviridae. In New Zealand, the most famous viruses are GLRaV-3 (Petersen & Jordan 1992) [33], which belongs to the Closteroviridae in the genus Ampelovirus. The consequence of such viruses tends to decline yield, minimize the sugar levels and changes in color, and forces in late ripening of berries.

Both red and white grape varieties are infected, however, the peculiar symptoms are rolled leaves and reddening of the inter-vein area in red varieties. The feeding damage on the developing parts of the plant that tends to malformation of the shoots (Kairo *et al*., 2000) [23]. Occurrence of black sooty mould fungus could be seen after the sugary honey dew being produced by the mealy bug in fruit trees (Alleyne, 2004) [2]. This mould creates covering of leaves and lowering of photosynthesis by proving stress to the vines. Ultimately, the production and market quality of the vines decreases.

A study by Dara *et al*. (2016) [14] found that the health of plant improved due to the application of entomopathogenic fungi, *Beauveria bassiana* that resulted with enhanced shoot-root ratio for plants *Metarhizium robertsii* and *B. bassiana*, two well recognized entomopathogenic fungal species, have strains that lowers the pest population including mealy bugs (Sandhu et. al., 2012) [38]. At present context many people spray insecticides that have unlimited threats in soil, crops including emergence of insecticide resistance in pest population (Venkatesan *et al*. 2016) [41] and pose a significant challenges in mealy bug mass management programs. Repeated application of insecticides has posed residual effect including negative consequence in the population of predators, non-target insects like bees, etc. However, the effective results of insecticides such as imidacloprid are still praised against the mealy bug population (Franco *et al*. 2009) [17]. The intensive application of botanical oils have also helped in integrate pest management of insects like mealy bugs, it may be due to their repellent property, antifeedant nature, growth-inhibiting activity, easy biodegradability, and safety to non-target insects (Oparaeke *et al*. 2005) [31]. Some plant species that fall in EOs have aromatic smell, especially in mint spp. (*Mentha* spp.) and have adulticidal, larvicidal, and growth and reproduction inhibitory effects, as well as repellent intervention against various stored product pests and vectors including malybugs (Rajendran and Sriranjini 2008; Kumar *et al*. 2010, Michaelakis *et al*. 2012) [36, 24, 30]. It has been long time that some farmers and entrepreneurs practice integrated pest management as a combination of chemical, biological, physical and pesticidal method to control mealy bug population and their devastating effect in grape vineyards (Daane *et al*. 2003; Walton 2003; Castillo *et al*. 2005; Gülec *et al*. 2007) [12, 43, 9, 20]. Integrated Pest Management (IPM) have provided a strategic tool to control the pest sustainably as an eco-friendly method to protect negative effects of standalone insecticide in our environment and associated structure.

This survey was carried out to understand the perception of farmers in Integrated Pest Management (IPM) in controlling mealy bug population in grape vineyards in Jula district.

Materials and Methods

A survey was conducted during May 2021 to October 2021 in Chandannath, Jumla district to understand farmers perspective in various control methods and Integrated Pest Management (IPM) of mealy bugs in grape vineyards (*Vitis vinifera*). KIIs (Key Informant Interview) and FGDs (Focus Group Discussions) were done with two farmer groups (each with 25 participants), where methods of mealy bug management and its opportunities in grape production were enquired. Grape producing commercial farmer groups were selected for the survey. Secondary data were collected from the government body and stakeholders in the district regarding the practices and return of grape vine. Information and data were harvested from past three years. Old literatures, previous studies and research were reviewed as a source of secondary information.

The recorded data were arranged and analyzed by using M. S. Excel 2013 and R studio.

Results and Discussion

Farmers methods in controlling disease vectoring mealy bugs in grape vineyards

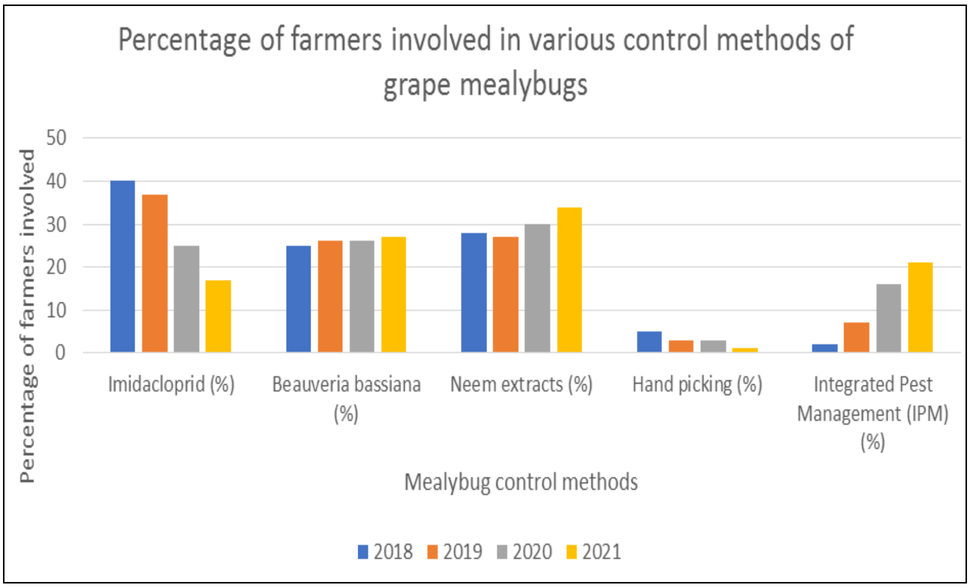

Fig 1: Farmers methods in controlling mealy bugs in grape vineyards

The percentage of farmers applying Imidacloprid, *Beauveria bassiana*, neem extracts (*Azadirachta indica*), hand picking, and Integrated Pest Management (IPM) to control disease vectoring grape mealy bugs were revealed to be 40, 25, 28, 5, and 2 respectively during 2018. Similarly, during 2019 the farmers found using Imidacloprid, *Beauveria bassiana*, neem extracts (*Azadirachta indica*), hand picking, and Integrated Pest Management (IPM) to control mealy bugs equals to 37, 26, 27, 3, and 7% respectively. In 2020 farmers applied Imidacloprid, *Beauveria bassiana*, neem extracts (*Azadirachta indica*), hand picking, and Integrated Pest Management (IPM) in reducing mealy bug population, which is equals to 25, 26, 30, 3, and 16% respectively. Finally, the percentage of farmers deploying Imidacloprid, *Beauveria bassiana*, neem extracts (*Azadirachta indica*), hand picking, and Integrated Pest Management (IPM) in reducing mealy bug population were 17, 27, 34, 1 and 21 respectively during 2021 (Figure 1).

The ratio of farmers using botanical pesticides and Integrated methods were significantly increasing. Effective increment of farmers engaged were observed in Integrated Pest Management (IPM) followed by botanical pesticides, while peak decline in the users of Imidacloprid alone were assessed including almost constant ratio of grape producers with application of *B. bassiana* and negligible hand pickers of grape mealy bugs in each progressive year. Standalone application of insecticides have numerous side effects including growth of insecticide resistance (Belzunces *et al*. 2012; Biondi *et al*. 2012, Desneux *et al*. 2007; Gill and Garg 2014; Pisa *et al*. 2015) [4, 18, 15, 18, 34]. Integrated Pest management has been successfully working to manage mealy bugs in grape farms in sustainable and eco-friendly manner (Johnson and Tabashnik 1999; Stark *et al*. 2007) [22, 40].

Integrated Pest Management (IPM) has been emerged as the process to maintain and increase agricultural productivity without dependence on synthetic chemical inputs. Most of the producers are reliant on botanical pesticides, and integrated management of pest due to their effective nature and cost-effective output for invasive insect pest management such as mealy bugs.

Earlier study in Kenya found that most of the farmers were known on the quick effect of insecticides (Abong'o *et al*., 2014; Marete *et al*., 2021) [1, 27]. at earlier time. It may be the knowledge gap at those days, while later same producers applied non-agrochemicals to control the insect pest later days (Marete *et al*., 2021) [27]. Such studies are in line with our survey that the attitudes of farmers have been changing gradually to minimize the application of insecticides, while promoting botanical pesticides and Integrated Pest Management (IPM).

Farmers knowledge on Integrated Pest Management (IPM), climate change and biological control agents with respect to disease vectoring grape mealy bugs

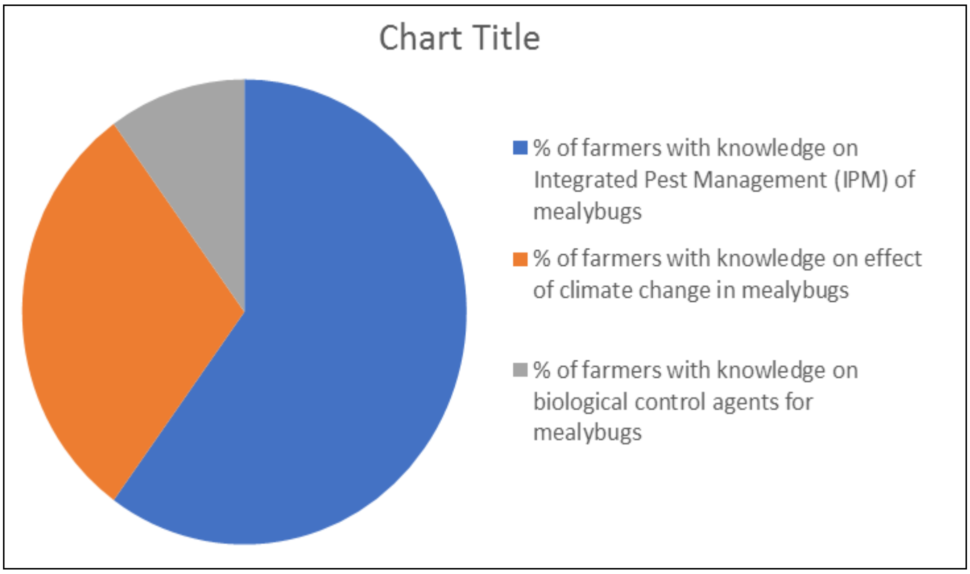

Fig 2: Farmers knowledge on Integrated Pest Management (IPM), climate change and biological control agents with respect to grape mealy bugs

The highest percentage of farmers (60%) were found with knowledge of Integrated Pest Management (IPM) of disease vectoring grape mealy bugs followed by knowledge on effect of climate change in mealy bug population (30%) and knowledge on biological control agents for mealy bugs (10%) (Figure 2).

Negligible ratio of farmers has idea on natural enemies, their implications, benefits, and combination in Integrated Pest Management (IPM). Improving numbers of farmers found with appropriate ideas on Integrated Pest management, mostly the combination of synthetic insecticides, botanical pesticides and entomopathogenic fungi sometimes addition of physical methods in response of mealy bug management in grape vineyards. Good percentage of farmers were observed with experience and knowledge on climate change such as variable temperature, rainfall, and drought with certain effect in growth, development, and activities of mealy bug in the yards. The perception of the farmers that relies on the information related with climate change (variable temperature) affects the population of mealy bugs (Prasad *et al*., 2012) [35]. In many studies it was found that the farmers aware on climate change are also more cautious in promptly initiating measures like pruning and destroying of mealy bug infested plants or their parts, and soon carry measures to control the spread of mealy bug infestation in the grape field. Some other investigation from other parts of world found that temperature and other factors of weather that are changing each year have significant or non-significant implication in the growth and development of mealy bug population (Mertz *et al*., 2009; Kusakari *et al*., 2014) [29, 25], and such ideas were brought at front by the producers themselves. The importance of natural enemies such as ladybugs in controlling mealy bugs have been described in various literature (McIlveen *et al*., 1252) [28]. Most of the studies revealed that mealy bugs have positive correlation with temperature and negative correlation with rainfall and humidity such information have been well known by farmers. In our study also average ratio of participants have knowledge on various aspects of climate change and environmental factors that related with the mealy bugs and its damage.

Average production of grape vineyard (*Vitis vinifera*) with different mealy bug control methods

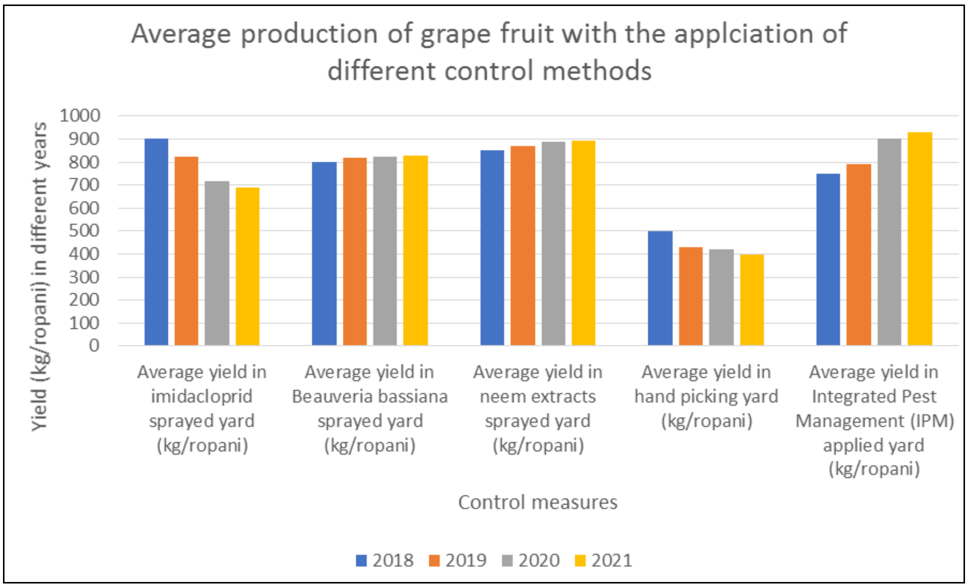

Fig 3: Average production of grape vineyard (*Vitis vinifera*) with different mealy bug control methods

The average yield (kg/ropani) of grapefruit found to be 900, 800, 850, 500, and 750 in imidacloprid sprayed, *Beauveria bassiana* sprayed, neem extract sprayed, hand picking and Integrated Pest Management (IPM) method of mealy bug control yards respectively during 2018. During 2019, the average yield kg/ropani) of grapefruit found to be 825, 820, 870, 430, and 790 in imidacloprid sprayed, *Beauveria bassiana* sprayed, neem extract sprayed, hand picking and Integrated Pest Management (IPM) method of mealy bug control yards respectively. Similarly, during 2020, the average yield kg/ropani) of grapefruit found to be 717, 825, 890, 420, and 900 in imidacloprid sprayed, *Beauveria bassiana* sprayed, neem extract sprayed, hand picking and Integrated Pest Management (IPM) method of mealy bug control yards respectively. Finally, during 2021, the average yield kg/ropani) of grapefruit found to be 690, 830, 895, 400, and 930 in imidacloprid sprayed, *Beauveria bassiana* sprayed, neem extract sprayed, hand picking and Integrated Pest Management (IPM) method of mealy bug control yards respectively (Figure 3).

Though initially the highest production of grapevine was known with the application of imidacloprid, however, it gradually decreased in each year; at the same time the production of fruits increased slowly in Integrated pest Management (IPM) deployed yards in each year even though they have lower production at early years (in IPM deployed field). The investigation of Arnold *et al*. 2014 found that participatory and integrated approach of insect management is more effective in controlling mealy bugs in grape vines. Application of single dose of insecticides have always reflected negative consequence either of insecticide resistance or residual effect or other. The residual effect of insecticides has many consequences on grape quality, and thus human health, is unknown (Benheim *et al*. 2012) [5]. Other negative effect in production including non-target pest of such insecticides (when applied singly) were described by Bordelon *et al*. 2018 [8].

The application of IPM strategy (i.e., an insecticide applied based on weekly scouting and an economic threshold) may cost high but regarded effective and profitable in comparison with insecticidal treatments alone (KD Johnson *et al*. 2009) [21]. Such activities to incorporate Integrated Pest Management always enhance quality, quantity and marketable product of grapefruit reducing the effect of mealy bugs. Improved knowledge and practice of IPM methods n mealy bug management has provided effective return than application of single control methods in the grape vineyard.

Conclusion

A survey was carried out during May 2021 to October 2021 in Chandannath, Jumla district to determine the farmers perspective in various control methods including Integrated Pest Management (IPM) of mealy bugs in grape vineyards (*Vitis vinifera*). KIIs (Key Informant Interview) and FGDs (Focus Group Discussions) were conducted with two farmer groups (each with 25 participants), where methods of mealy bug management and its opportunities in grape production were discussed. During previous years, highest farmers found applying Imidacloprid to control grape mealy bugs followed by farmers using neem extracts (*Azadirachta indica*), *Beauveria bassiana*, hand picking and Integrated Pest Management (IPM). Later, the ratio of farmers increased in applying IPM practice compared with other methods in controlling the mealy bugs. Highest percentage of farmers noticed with knowledge of IPM followed by climate change and biological control agents with respect to grape mealy bugs. Though initially the production of grapevines was lower through the application of Integrated Pest Management (IPM) method, it gradually increased and later became an effective strategy to manage the population of disease vectoring mealy bug thereby increasing production of grapevine compared with other methods of pest control.

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