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Pesticides use and its effects on grape production: A review

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ABSTRACT
To meet both qualitative and quantitative production standards, pests and diseases in grape cultivation must be actively controlled by an intensive schedule of pesticide applications. The use of pesticides can have both positive and negative effects on grape production and the environment. The harmful effects of pesticides on human health, the environment, and chemical residues in food have sparked this review to focus on the pesticide circumstances in grape production globally. Information reviewed reveals that, the use of pesticides in grape production is the most efficient method for controlling pests and diseases. These agro-chemicals tend to leave poisonous residues that pose serious problems to the environment and human health when applied in inappropriate ways. Furthermore, some fungal pathogens and other grapevine pests develop resistance to pesticides which makes it difficult to control. Additionally, the majority of grape producers' lack awareness on the impacts of chemical residues in grapes and their products. Grape value chain actors should follow pesticide handling procedures and the instructions available on the labels for effective application of pesticides to reduce contamination of grape products and prevent pesticide residue levels from exceeding the Maximum residue limits (MRLs) which is the standard. Grapevine growers should consider cultural, physical/mechanical, biological, and chemical methods for controlling pests and diseases in grapes.

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1. Introduction

Grape (*Vitis vinifera*) is one of the most significant horticultural crops which produce clusters of rounded, tiny, smooth-skinned, and edible berries of different colours (Reisch et al., 2012). It belongs to the family Vitaceae and has many uses such as raw materials for manufacturing wine, jam, juice, jelly, grape seed extracts, raisins, vinegar, and grape oil seed. The fruits are rich in sugar, particularly fructose, have low caloric output, and are easily digestible (Georgiev et al., 2014; Kalimangasi et al., 2014). Around 7.9 million hectares of land are used to grow grapes globally, with China producing the majority of the world's grapes (12.85%), Italy producing 11.5%, the USA producing 9.24%, Spain producing 9.07%, and France 8.69%, all of which together account for about 51.42% of the world's total grape production (Kulwijila et al., 2018). Grapes are easily infected by fungi, bacteria, and insects, that pose a significant threat to the quality and yield of the grapes including reduced fruit set, loss of fruit integrity, and flavors that affect the taste and appearance of grapes. In addition, fungi, bacteria, and insects impact the wine's sensory characteristics, and may cause economic losses to grape growers (Calonnec et al., 2004; Jermini et al., 2010; Puga et al., 2020). Resulting in a large amount of pesticide consumption, pesticides can effectively reduce grape diseases and pests, ensure grape quality, and increase yield. Therefore, the use of pesticides in grape cultivation is essential (González et al., 2022). The number of vineyards in the area may also be attacked by powdery mildew (*Uncinula necator*), downy mildew (*Plasmopara viticola*), and grey mold (*Botrytis cinerea*) as most common grape diseases (González et al., 2022). According to Gessler et al. (2011) and Gadoury et al. (2012), the fungi responsible for causing powdery (*U. necator*) and downy mildew (*P. viticola*) are specialized obligate pathogens of the genus *Vitis* and the Vitaceae family, respectively, and the damage they cause to the plant is not economically acceptable. These diseases can infect grapevines and spread to healthy grapevines which may cause significant yield losses if left untreated and can impact to overall loss of income. Managing these diseases is inevitable and it often requires intensive labor, including scouting for symptoms, applying chemicals, and other cultural practices (Calonnec et al., 2004; Ky et al., 2012; Leroy et al., 2013). For these, pesticide use is prevalent, and numerous sprayings are frequently necessary to safeguard the

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grapevine and successfully produce high-quality grapes at harvest (González et al., 2022). The disease pathogens such as bacteria, viruses, and fungi or fungus-like organisms, can attack and harm the grapevine or berries, causing quality loss and altering the flavor of the wine (Kassemeyer, 2017). Together with these factors, weeds have been a problem in grape fields as they compete with grapevines for soil nutrients, water, and light which results in reducing yield and affect the growth of the grapevine if not controlled (DeVetter et al., 2015; Sanguankeo et al., 2009). Therefore, this review discusses the use of pesticides in grape production and its effects on grapes and the environment.

1.1. Pesticides

Pesticides are chemically harmful materials used to control pests and are sometimes used interchangeably with other 'plant protection products' (Carvalho, 2017). Pests and diseases in grapes are controlled by applying pesticides to manage a wide range of agricultural pests which harm crops (Oberti et al., 2016). The pesticides used to control pests in agriculture include various categories such as insecticides for the management of insects, herbicides for the management of weeds, rodenticides for the management of rodents, and fungicides for the management of fungi (Yadav & Devi, 2017).

2. Chemical pesticides in controlling insect pests, weeds, and diseases

Pesticides are essential to agricultural production whereby the methods used to apply these pesticides range from manual spraying to truck- and aerial-based methods (Tudi et al., 2022). Farmers have used them to manage weeds, diseases, and insects in agricultural production, and it has been reported that this has led to noticeably higher yields of agricultural products (Popp et al., 2013). Even in small farming and family farming the use of pesticides in vineyards it is normal and sometimes uncontrolled" (Neto et al., 2022). The following are the pesticide categories that are commonly used in grape production.

2.1. Herbicides

Weed menace is regarded as one of the key obstacles in grape production, the weeds are in their natural environment, they are resilient to harsh environmental conditions and have a higher potential for continuation than cultivated plant species. Studies conducted by Helali et al. (2020), in India have demonstrated that full-season weed competition lowers grape yields by up to 37%, cane weight by 68%, the number of clusters per vine by 28%, and berry weight by 3%. Weeds such as horseweed (*Conyza canadensis*), field bindweed (*Convolvulus arvense*), hedge bindweed also known as wild morning-glory (*Calystegia sepium*), common ragweed (*Ambrosia artemisiifolia*) and foxtail (*Setaria* spp.) are commonly found in grapevines (Alcorta et al., 2011; Delić et al., 2011). With an increasing intensification of viticulture, chemical weed control within and between grapevine rows is more widely used (Keller, 2015). According to Mandl et al. (2018) and Golubev et al. (2019), herbicides with active ingredients; glyphosate, glufosinate, and flazasulfuron are some of the most often used in vineyards and prove to be effective against grapevine weeds.

2.2. Insecticides

Chemical insecticides are considered the mainstay of agricultural insect pest control. Table 1 below shows some of the most effective registered pesticides in the world that have been used to control insect pests of grapes.

Table 1. Registered insecticides use in grape production

S/NO	Active ingredient	Contact or Systemic nature	Group name
1	Carbaryl	Contact	Carbamate
3	Zeta-cypermethrin	Contact	Pyrethroids
4	Cypermethrin	Contact	
5	Acetamiprid	Contact/Systemic	Neonicotinoid
6	Dinotefuran	Contact/Systemic	
7	Imidacloprid	Contact/Systemic	
8	Thiamethoxam	Contact/Systemic	
9	Phorate	Systemic	Organophosphate
10	Malathion	Contact	
11	Dimethoate	Contact	
12	Chlorpyriphos	Contact	
13	Dichlorvos		
14	Malathion	Contact	
15	Acephate	Systemic	
16	Fipronil	Systemic	Phenylpyrazole

Source: (Maier & Sutherland, 2013; Mani et al., 2014).

2.3. Fungicides

Grapevines are commonly affected by various diseases such as grapevine trunk diseases (eutypa dieback, esca, and botryosphaeria dieback), powdery mildew, downy mildew, and anthracnose (Bertsch et al., 2013). Some fungi cause serious losses in a short period of time by infecting young, delicate green leaves, twigs, and fruit tissues. When the humidity and temperature are ideal, these infections can destroy up to 40–90% of plants in the field (Toffolatti et al., 2018). To avoid loss of quality and yield, pathogens have to be controlled by targeted chemicals to eradicate the disease or causative agents (Kassemeyer, 2017).

2.3.1. Fungicides for powdery mildew

The fungi responsible for powdery mildew (*U. necator*) are among the most prevalent and significant plant fungal diseases. The following are some of the frequently used fungicides that offer superior results in controlling powdery mildew, as shown in Table 2 below.

2.3.2. Fungicides for downy mildew

Downy mildew is among the economic important diseases which affect grapevine, the disease is caused by obligate biotrophic oomycete *P. viticola* (Gessler et al., 2011). It is harmful, particularly in areas, where the ideal environment for producing grapes has high humidity and copious springtime rain (Caffi et al., 2010). Various fungicides have been registered for downy mildew in grapevines worldwide, the following are some of the commonly used fungicides which provide better results in downy mildew control as indicated in Table 3 below.

3. Harmful impacts of pesticides

Chemical pesticides control a range of pests, such as weeds, insect pests, and diseases, in the grape industry in order to minimize or completely eradicate yield losses and preserve a high standard of product quality. The toxicity levels of the pesticide residues left in the grapes and the surrounding ecosystems are proven to be a potential issue when chemical pesticides are used on grapevines. Pesticide residues also affect quality wine, pesticide residues have been linked to environmental issues such as a high level of pesticide residues which harm the soil, water sources, and beneficial organisms and lower the quality of grapes, this increases health risk to the consumers (Bhardwaj & Sharma, 2013; Yadav & Devi, 2017).

3.1. Pesticides residues

The production of grapes involves frequent application of a wide range of pesticides namely insecticides and fungicides. Notwithstanding, when pesticides are applied in the vineyard and inappropriate agricultural methods are used, trace levels of these chemicals, known

Table 2. Registered fungicides commonly used to control grape powdery mildew in the world

S/NO	Active ingredient	Group name (Chemical group)
1	Chlorothalonil	Organochloride
2	Mancozeb	Dithiocarbamates and relatives
3	Metiram	
4	Propineb	
5	Folpet	Phthalimides
6	Cyprodinil	Anilinopyrimidines
7	Metrafenone	Benzophenone
8	Pyriofenone	
9	Carbendazim	Methyl-Benzimidazole Carbamates (MBC fungicides)
10	Thiophanate-methyl	
11	Azoxystrobin	Methoxyacrylates
12	Fluoxastrobin	Dihydro-dioxazines
13	Pyraclostrobin	Methoxycarbamates
14	Trifloxystrobin	Oximino acetates
15	Fenpropidin	Amines ("morpholines")
16	Fenpropimorph	
17	Spiroxamine	Spiroketalamines
18	Cyproconazole	Triazoles
19	Difenoconazole	
20	Epoxiconazole	
21	Flutriafol	
22	Hexaconazole	
23	Tebuconazole	
24	Tetraconazole	
25	Triadimefon	
26	Triadimenol	
27	Sulphur	Inorganic

Source: (Essling et al., 2021; FRAC, 2023b; Lewis et al., 2016; Vielba-Fernández et al., 2020).

Table 3. Chemical classes of fungicides currently registered to control downy mildew

S/NO	Active ingredient	Group name
1	Mancozeb	Dithiocarbamates and relatives
2	Thiram	
3	Metalaxyl	Phenylamide (Acylalanines)
4	Copper	Copper-based
5	Captan	Phthalimide
6	Folpet	
7	Flutriafol	Triazoles
8	Tebuconazole	
9	Propiconazole	
10	Myclobutanil	
11	Dithianon	Quinones
12	Pyrimethanil	Anilino- Pyrimidines
13	Cyprodinil	
14	Propamocarb	Carbamates

Source: (Agrios, 2005; FRAC, 2023b; Romanazzi et al., 2022).

as residues, may stay on or in the grapes (Golge & Kabak, 2018). Because of this, the amount of pesticide residues in or on grapes at the time of harvest is higher than the standard (Grimalt & Dehouck, 2016). Numerous international organizations, including the European Union and the Codex Alimentarius Commission and other nations have declared their own pesticide maximum residual limits (MRLs) in food items (Bouagga et al., 2019; Lima et al., 2017). Table 4 below shows the pesticide used in grape production and its MRLs

3.1.1. Residues in grapes and their products

Pesticides residues can be detected in the whole grape as in the grape skin (Teixeira et al., 2004). These residues from certain pesticides may leave a chemical which affect the aroma, flavor, texture, or appearance changes, reducing levels of nutritional values of grapes, and quality of the juice and wine (Song et al., 2022; Urkude et al., 2019; Zhao et al., 2022). A study by Angioni and Dedola (2013) in monitoring survey of pesticide residues in Sardinia wines revealed that only 38% of pesticide applied has been found in atleast one cultivar, whereas metalaxyl, myclobutanil, and penconazole were the most frequently found pesticides with metalaxyl being the pesticide with the highest recorded amounts (54.5% of the samples). A study by González et al. (2022), revealed 21.4% of tested wine samples were free of pesticide residues. A high level of pesticide residues can affect the quality of the grapes and its processed products and it may ultimately reach the consumer and cause health hazards (Grimalt & Dehouck, 2016).

Table 4. Vineyard pesticides and their MRLs by codex alimentarius commission

S/no	Pesticide	MRL	Year of adoption
1	Abamectin	0.03 mg/Kg	2009
2	Acetamiprid	0.5 mg/Kg	2012
3	Azoxystrobin	2 mg/Kg	2009
4	Captan	25 mg/Kg	2008
5	Carbendazim	3 mg/Kg	2008
6	Chlormequat	0.04 mg/Kg	2018
7	Chlorothalonil	3 mg/Kg	2011
8	Chlorpyrifos-Methyl	1 mg/Kg	2010
9	Clyclaniliprole	0.6 mg/Kg	2021
10	Cypermethrins (including alpha- and zeta- cypermethrin)	0.2 mg/Kg	2009
11	Cyprodinil	3 mg/Kg	2005
12	Deltamethrin	0.2 mg/Kg	2004
13	Difenoconazole	3 mg/Kg	2014
14	Emamectin benzoate	0.03 mg/Kg	2012
15	Fluazifop-p-butyl	0.01 mg/Kg	2017
16	Fosetyl Al	60 mg/Kg	2018
17	Imidacloprid	1 mg/Kg	2004
18	Indoxacarb	2 mg/Kg	2006
19	Manderstrobin	5 mg/Kg	2021
20	Metaflumizone	5 mg/Kg	2021
21	Metalaxyl	1.5 mg/Kg	2022
22	Pendimethalin	0.05 mg/Kg	2022
23	Pyraziflumid	3 mg/Kg	2022
24	Tebuconazole	6 mg/Kg	2012
25	Triadimefon	0.3 mg/Kg	2015
26	Triadimenol	0.3 mg/Kg	2015

Source(FAO, 2023).

3.1.2. Human health

Pesticides pose risks to human health not only to farmers who come into direct contact with active molecules but also to consumers because of pesticide residues in agricultural goods (Pathak et al., 2022; Saladin & Clément, 2005). A study conducted by Chamgenzi (2020) in Tanzania, revealed that most of the tested wine samples contained pesticide residues that exceeded MRLs set by European standards for grape wine, indicating that grape wine was not safe for human consumption and could lead to negative health effects to consumers. On the other hand, a study by Čuš et al. (2010) in Slovania, indicated that the studied wine samples had nine pesticide residues. The category of wines having only one or two pesticide residues included more than half of the wines. Boscalid was found in wines the most often (76% of samples), followed by fenhexamid (44%). These pesticides come from several chemical classes, which means that their physicochemical characteristics and, as a result, their behavior (transport, mobility, and fate) in the environment might range significantly. Because of this, there are a variety of possible risks associated with their use. Currently, the public is concerned about the extensive use of pesticides in vineyards because of the toxic consequences that can be discovered in wine products intended for human consumption (Rabiet et al., 2010). According to Damalas and Eleftherohorinos (2011), inhaling, and orally ingesting these poisonous substances can expose one to major acute and chronic health problems such as allergic problems, eye and skin irritation, nausea, headache, immune suppression, hormonal imbalances, reproductive abnormalities, and cancers (Bouagga et al., 2019; Kumari & John, 2019). Eventually, the available evidence suggests that consuming grapes with pesticide residues above established MRLs is likely to pose significant immediate health risks for most individuals. Thus, when appropriate agricultural practices are followed and MRLs has been met, acute poisoning from consuming pesticide-contaminated grapes is uncommon.

3.1.3. Pesticides residues in the natural environment

About 80% of sprayed pesticides are thought to directly harm the environment, and 98% of sprayed pesticides directly or indirectly harm non-target organisms, which is a serious hazard (S. Ali et al., 2021). Pesticide use may cause long-term residual effects while otherwise acute fatal effects. For instance, most organochlorine pesticides are long-lasting in the environment and contaminate groundwater, surface water, food products, air, and soil (Yadav & Devi, 2017). Depending on the environmental conditions and the pesticide's chemical characteristics, the degradation of pesticides can be by microbes, chemical reactions or light and it may take hours, days or years (Abian et al., 1993; Tcaciuc et al., 2018; Wu et al., 2018). Pesticide degradation procedures provides the concept of a half-life of the pesticides in the environment, and regulate the persistence of pesticides in soils and produce various metabolites (Tudi et al., 2021). Furthermore, some grape-growing regions have reported the availability of pesticide components persists in natural water sources, soils, and air of the surrounding environments (Dorosh et al., 2021; Herrero-Hernández et al., 2020). Additionally, factors connected to climate change have an impact on how pesticides are applied, leading to greater pesticide use and contamination (Tudi et al., 2021). It is now time to identify some alternatives that prioritize environmental conservation and, ultimately, human health.

3.1.3.1. Pesticide residues in the atmosphere. Air pollution is caused by the ground and aerial application of persistent organic pesticides (POP). Adsorbed aerosol particles are pesticides that are semi-volatile in nature. The half-lives of these particles can range from a few days to more than a month, depending on gas-phase reactivity (Socorro et al., 2016). POP transform from their natural form to a very harmful one through oxidation and photochemical reactions. POP travel differently depending on the solubility in water, weather, temperature, and humidity (Woodrow et al., 2019). Current Use Pesticides (CUPs) are more biodegradable, less toxic, and less persistent than previously used organochlorine pesticides (Chen et al., 2020). The presence of pesticide residues in the air resulting from the use of pesticides in grape farming has been reported as among the sources of atmospheric pollutants (Coscollà et al., 2010; Raherison et al., 2019). Moreover, encouraging the adoption of integrated pest management (IPM), adopting targeted application techniques, the proper handling, storage, and disposal of pesticides can help minimize their impact on the atmosphere and surrounding ecosystems.

3.1.3.2. Pesticide residues in soil. The amount of pesticide residues remaining in the soil depends on several variables, including chemical characteristics and concentrations of the sprayed compounds, the characteristics of the soils, the presence of organic amendments added, the frequency and rate of treatments and the form of application (Vryzas, 2018). Uniform application may lessen pesticide losses by volatilization and runoff; nevertheless, repeated applications of pesticides affect the half-life of pesticides in soils (Farlin et al., 2013). The processes of adsorption, degradation, or movement and the factors governing them will determine how long these compounds remain in the soil. Water-soluble pesticides can infiltrate into groundwater, while other chemicals improve their persistence by forming residues that link to soil particles or organic matter (OM) which can then be entrained in surface waters (Gevao et al., 2000). There are few studies on the dispersion of pesticide residues in soils in the literature; instead, most studies concentrate on the distribution of persistent organic pesticides (Aichner et al., 2013). Organochlorine pesticides are one of the groups that have been the subject of the most research, in soils from India, Pakistan, China, and Mexico (U. Ali et al., 2014; Jiang et al., 2009; Li et al., 2014; Mishra et al., 2012; Wong et al., 2010). According to Geissen et al. (2021) and Silva et al. (2019), conventional agricultural soils primarily contained mixes of pesticide residues with the maximum number of residues per sample compared to organic agricultural soils which contained noticeably less residue. Herbicide residues, specifically pendimethalin (S-V), glyphosate, and its primary metabolite AMPA (p-G, N-P, S-O), were the most frequently found and highest concentrations in soil (da Graça Silva, 2022). A study by Wightwick et al. (2008) reported the presence of elevated copper (Cu) concentrations in Australian vineyard soils, to notice, the excessive Cu concentrations were reported to have sublethal effects on the invertebrates. The microbial communities found in vineyard soils are negatively impacted by elevated Cu concentrations, both in terms of quantity and diversity (Díaz-Raviña et al., 2007; Lejon et al., 2008). Lower mineralization rates of organic xenobiotics, such as organic pesticides, can result from reductions in microorganism activity and/or modifications in microbial populations (Komárek et al., 2010).

3.1.3.3. Residues in underground water sources. Spraying pesticides affect water quality due to leaching into the groundwater and transfer to surface water through runoff, drift, and erosion (Laini et al., 2012; Nario et al., 2018). Pesticides' physicochemical properties such as water solubility, groundwater ubiquity score (GUS) index, ability to bind to soil components, and rate of degradation influence pollution in the groundwater (Herrero-Hernández et al., 2013). In addition, the features of the soil, the slope of the soil, and the frequency and severity of rainfall have the impacts on the contamination of the groundwater following pesticides application (Marsala et al., 2020). A study by Hildebrandt et al. (2008) found that only 12% of the studied pesticides in vineyards exceeded the 0.1 μg/L limit of MRLs. Nevertheless, large quantities were occasionally found up to 2.46 μg/L in groundwater and 0.63 μg/L in surface water. This indicates that ground water was highly contaminated than that of surface water for the studied pesticides. Other findings from a study by Herrero-Hernández et al. (2017) indicated that more than half of the studied compounds had the total amount of chemicals (mostly herbicides) greater than 0.5 μg/L in ground water sources of the vineyard areas. Therefore, improper use of pesticides for grapevine cultivation can result in groundwater contamination. This suggests the need for a deeper examination of hydrology studies, farmer behavior and the urgent introduction of best management practices, and mitigation measures to encourage the sustainable use of pesticides in viticulture (Marsala et al., 2020; Suciu et al., 2020).

4. Current trends of pesticide

Less pesticide use and the adoption of more ecologically friendly and sustainable farming methods are the trends in grape production (Perria et al., 2022). This trend is based on the pressure from regulatory bodies and a growing awareness of the consumer demand for the effects of pesticides on health and the environments. Consumers are increasingly concerned about pesticide residues in their food and beverages. As a result, there is a growing demand for organic and sustainably produced grapes and wines that drive farmers to organic and sustainable farming practices (Baiano, 2021).

4.1. Pesticide resistance

Pesticide resistance occurs when a pest population decreases susceptibility to a chemical that was previously successful at controlling the pest (Hoy, 2008). Although resistance affects fungicides more frequently in viticulture, insecticide, and acaricide resistance is a serious concern (Pertot et al., 2017). An acquired heritable decrease in a fungus' susceptibility to a particular anti-fungal chemical is referred to as 'fungicide resistance' (FRAC, 2023a). *P. viticola* is considered among the high-risk pathogens which affect grapevines and its life cycle is complicated, which includes polycyclic activities and both sexual and asexual reproduction (Gobbin et al., 2005). Every reproductive cycle may result in genetic modifications, but these changes are either negative or unimportant, nevertheless, they occasionally offer a fitness advantage. When genetic changes cause a stable and heritable decrease in sensitivity to a particular fungicide, fungicide resistance increases (Massi et al., 2021). The number of sensitive individuals may drop in favour of resistant mutants after numerous applications of the same active substance, which applies selection pressure to the fungal population (Ma & Michailides, 2005). The disease can no longer be successfully managed by the fungicide once resistant mutations become dominant in the population (Hewitt, 1998). Given that they inhibit the same target and have the same mode of action, fungicides that share this property should be regarded as cross-resistant and should not be used without consulting a professional to prevent the selection of resistant populations (Rossi et al., 2021). One of the most difficult problems in disease prevention is the evolution of resistance, for several years, fungicides are frequently applied to vineyards, often several times every season as a result, the agronomic risk of fungicide resistance is significant (Toffolatti et al., 2018). In-depth research focusing on molecular mechanisms underlying resistance is frequently overlooked despite the prevalence of pesticide resistance issues, particularly in obligate biotrophs like *U. necator*, the cause of powdery mildew on grapevines. As a result, it is more difficult to create the quick, precise, and sensitive methods for resistance identification that are necessary to support the proper application of anti-resistance tactics (Kunova et al., 2021; Toffolatti et al., 2018). Although the formation of pesticide resistance is a common occurrence, recent advances in science and technology have reignited interest in this problem leading to the creation of resistance risk assessments for several species using different assay techniques (Durmuşoğlu et al., 2015). The evaluation of resistance risk can help in resistance management. The regulatory authorities need risk evaluations for each fungicide product, and they are used to determine the scope of risk 'modifiers' (i.e. anti-resistance techniques) that may be necessary to attain an acceptable level of risk (Grimmer et al., 2014).

In some cases, weed species such as horseweed have developed resistance against glyphosate and cannot be controlled by the use of glyphosate alone thus require a tank mix with a combination of different herbicides with different modes of action (Doğan et al., 2022; Tahmasebi et al., 2018). In addition to helping to increase the control of resistant weeds, herbicide combinations with various modes of action may prevent or postpone the evolution of resistance (Ghanizadeh & Harrington, 2021; Peachey et al., 2013; Tahmasebi et al., 2018). There is a need to incorporate other weed management methods such as mechanical planting, crop covering, or mulching to minimize the risks of weed resistance to herbicide and reduce chances of pesticides residues in soil. Eventually, it is essential to approach pesticide use in grapevines as part of a comprehensive pest management strategy by alternating different classes or modes of actions to prevent the development of pesticide resistance.

4.2. Awareness of pesticides residues

Consumers in European nations are concerned about pesticide residues in their food and wish to minimize to prevent health risk (Kariathi et al., 2017). The overuse of pesticides, however, has developed into a significant issue in agricultural output as the result of lack of awareness to farmers (Hou & Wu, 2010). Small-scale farmers in developing nations frequently lack access to expertise which limits the ability to manage various products, obtain necessities, and explore opportunities for safe use (Rahman et al., 2020). Therefore, it is essential for consumers to be aware of the potential risks associated with pesticide residues and make informed choices when consuming grapes and grape products. Also enhancing awareness among grape farmers about pesticide residues is crucial for the long-term sustainability of grape cultivation.

5. Alternatives to pesticides in viticulture

To mitigate the effects of pesticides on the environment and their risks to customers' health, it is crucial to encourage farmers to seek alternate methods, including, physical/mechanical practices, cultural practices, and biological control for managing pests and diseases in grapevines. Alternatives to insecticide and fungicide use are still a serious challenge in viticulture, although alternatives to herbicide use are more common (Pertot et al., 2017). The use of bio-control agents or resistant cultivars, as alternatives to chemical treatments for grapevine diseases, currently contributes slightly to disease management (Gessler et al., 2011; Vielba-Fernández et al., 2020). However, the use of other beneficial microorganisms such as bacteria has shown positive effects for controlling some of the grapevine diseases (Compant et al., 2013; Zang et al., 2020). Furthermore, biological control methods for insect pest management including, introducing beneficial insects and using pheromones to disrupt pest mating patterns can effectively reduce pest populations while minimizing the need for synthetic pesticides (Daane et al., 2012; Ibouh et al., 2019). On the other hand, weed control by alternative methods is practiced widely, with cover crops and tillage being the most popular strategies for controlling weeds in vineyards. To keep the soil surface under the rows either bare or covered, appropriate machinery should be utilized

(Pertot et al., 2017). Tillage increases weed control, soil aeration, and water infiltration which increase the amount of water and nitrogen available to grapevines (Ferrero et al., 2005). Tillage encourages soil erosion in vineyards on steep slopes and during rainy weather and decreases trafficability during wet weather (Pertot et al., 2017). Cover crops prevent contaminants which enter surface water and causing soil erosion and runoff (Battany & Grismer, 2000). It promotes water infiltration and legumes are used as a supply of nitrogen (Gaudin et al., 2010). According to Morlat and Jacquet (2003), cover crops improve soil structure and enhance the amount of organic matter and soil biological activity. It lessens the grapevine's vegetative vigor and its susceptibility to powdery mildew and grey mold (Valdés-Gómez et al., 2008, 2011). Furthermore, cover crops result in yield and/or quality losses because of competition with grapevines for soil resources especially in dry climates and/or shallow soils (Celette et al., 2008, 2009).

6. Conclusion

To reduce or eliminate yield losses and maintain a high level of product quality, chemical pesticides are used in grape production to manage a variety of pests, including weeds, insect pests, and diseases. It is revealed that, use of chemical pesticides in grapevines may cause problems with the toxicity levels of the pesticide residues left in the grapes and the surrounding environments. Governments and other grape stakeholders around the world should play a vital role in providing education to farmers about the pesticide handling techniques, potential risks and promoting alternative farming practices to protect human health, and preserve the environment to meet the consumer demands. Grape growers are advised to adopt the recommended alternate effective methods that are currently practiced worldwide, such as integrated pest management (IPM) which optimizes the preventive measures to maintain pest pressure below the economic damage threshold while minimizing the use of chemical pesticides when control is required. The regulatory bodies should implement stricter regulations on pesticide usage in grape farming to protect public health and the environment. Nevertheless, further scientific research should be conducted focusing on advancements in technology, such as drones and sensor-based monitoring systems, to enable farmers to precisely target pest infestations and apply pesticides only when and where necessary.

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No potential conflict of interest was reported by the author(s).

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Public Interest Statement

This study aimed to examine the effects of pesticide use on grape production, a review of previous researches was done to observe the facts about this topic. Findings reveal that using pesticides is the most effective way to control pests and diseases in grapevines yard. However, both positive and negative effects of pesticides on grapes and environment were observed. Pesticide use can cause environmental and health hazards regardless of its potential high yield with improved grape quality. To mitigate the negative effects of pesticides in grape production, it is recommended to use minimal amounts of pesticides and incorporate other effective methods in pest and disease control including physical/mechanical practices, cultural practices, and biological control.

Author's contribution

OM developed the idea, drafted the review paper, AM reviewed and added more inputs for the final version of the paper to be submitted for publication, WN and ER critically revised the paper and ZM participated on constructing title and inputs in the paper.

Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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