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Modern Spraying Techniques For Grape Vineyards: A Review

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Abstract
During crop production, the most crucial techniques are being used for plant protection. Applying pesticides requires much more expertise and understanding than any other agricultural job, regardless of the crop being treated or the tools utilised. This is particularly applied to insect, disease, and mite control sprays in grapevines. The significant changes in canopy features (variety, height, and row to row spacing) create hindrance in spraying as it is difficult to reach top and bottom side of the grapevine. Because of this, the spraying of vineyards requires more managerial expertise and experience than spraying of the field crops. Evolution in spraying technology has been seen in recent years. Advancement of robotics and automated spraying technologies viz. the use of pneumatic sprayers, UAV sprayers, and variable rate sprayers, have attracted more interest. These cutting-edge spraying techniques effectively safeguard the environment lowering labor costs, spray losses and health hazards during pesticide application to the vineyards while extensive research is still awaited.

Keywords: Vineyard; Sprayer; UAV Sprayer; Pneumatic sprayer; Variable Rate Sprayers

Introduction

Nearly one in seven people, are expected to be hungry worldwide, out of an estimated 925 million people (Earth, 2011). The expected increase in global population to nine billion people by 2050 will make ensuring food security even more difficult (Anon, 2013). To boost production and output in horticultural and field crops, accurate use of agricultural inputs including seed, fertiliser, water, and pesticides is essential.

Grown in temperate climates across the globe, the grapevine (Vitis vinifera L; Family: Vitaceae) is one of the major commercial crops. Italy, France, Spain, USA, Turkey, China, and Argentina are the top grape-producing countries. With an annual production of 2,958 thousand metric tonnes and a productivity of 21.28 metric tonnes per hectare, grapes are produced on 139 thousand hectares in India (Devaraj, 2021). According to Jambhangi (2023), the primary grape-producing states in India include Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, North West Punjab area, Haryana, Western Uttar Pradesh, Rajasthan, and Madhya Pradesh. When it comes to production, Maharashtra is at the top, making up over 80% of the nation's output and having the highest productivity (Kumar and Devaraj, 2018).

Over 80% of the grapes produced in India are used as table grapes, and over 70% of the crop is picked in March and April. International markets, especially in Europe and Asia, are seeing an increase in demand for fresh Indian grapes (Handiganur and Haranesh, 1995). With the use of contemporary growing methods, improved infrastructure, and higher exports, the Indian grape sector has experienced tremendous expansion in recent years (Ketigadi, 2023). India's top export markets for grapes are Saudi Arabia, Bangladesh, the United Arab Emirates, the Netherlands, and the United Kingdom.

The two main factors restricting grape output in India are pests and illnesses. Pests of all kinds are often drawn to vineyards that cultivate grapes extensively and intensively. According to reports from several Indian states that grow grapes, up to 100 insect and mite pests might harm different areas of grapevines (Anon., 2021, TNAU Agritech Portal, Crop Protection). In India, pest infestations have been known to cause up to 80% of the grape crop's economic loss (Mani et al., 2008). It has been reported that in many grape-growing regions of Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu, the mealybugs, specifically the pink mealy bugs (Maconellicoccus Hirsutus) and the citrus mealy bugs (Planococcus citri), cause severe losses in grape production. The grape mealybug alone is said to have caused yield losses ranging from 50% to 100%.

The use of pesticides is regarded as important in plant protection procedures in contemporary agriculture. A higher agricultural output can be achieved by using pesticides efficiently to manage plant diseases and pests (Gil et al., 2014). According to Damalis et al. (2011), the use of pesticides accounts for a sizeable portion of production costs. Excessive pesticide use or ineffective spraying equipment can have a negative impact on both the environment and human health. To minimise off-target spray deposition, it is essential to apply pesticides effectively using well-designed, well-calibrated spraying equipment. As per Babul et al. (2020). To protect crops from pathogens, a variety of spraying techniques are available. Three different types of sprays exist based on the volume of application rate: high volume, low volume, and ultralow volume. As the

Three different types of sprays exist based on the volume of application rate: high volume, low volume, and ultralow volume. The low-volume sprayer significantly improves the bio-efficacy via better deposition, but it is more prone to spray drift. The high-volume sprayer causes spray loss due to greater droplet size and larger volume application rate. According to Pieche et al. (2000), the third approach exhibits superior deposition and bioefficacy when droplet size is optimised. However, drift cannot be controlled, resulting in pollution of the environment and chemical loss. Overuse of pesticides is a widespread issue in most nations, and its application causes a host of issues, including chemical waste and environmental degradation via spray drift. Numerous aspects, such as spraying technology, spray characteristics, operator skill and performance, and other microclimatic conditions including temperature, relative humidity, wind direction, and speed, can all contribute to spray drift (Rojo et al., 2019). Several strategies have been proposed to lower the pesticide content of agricultural sprays.

Using a backpack sprayer with a hydraulic nozzle, small- and medium-sized farmers often apply diluted pesticide solutions. Low field capacity, uneven spray dispersion, and high manpower costs are some of the method's shortcomings, despite its simplicity. A lot of chemical was wasted via drift with air-assisted sprayers, which farmers also employed despite producing smaller droplet sizes. A maximum of 50% of the chemical's mass transfer on the intended plant can be squandered to the ground (Graham Bryce, 1977) or 95% of the chemical can be wasted to the ground (Pimentel and Levitan, 1986). The latest idea in pesticides is to target the pest more effectively by choosing the right droplet size and density to maximise coverage and retention.

Using conventional sprayers in the fields requires a lot of manpower and large equipment. Farmers raise the application volume and total cost of spraying because of poor spraying practices, bad nozzle selection, inaccurate crop foliage detection, and inadequate weather parameter monitoring. From plant to plant and from crop to crop, the canopy and foliage differ. Spray homogeneity and spray loss were severely hampered by spray drift, which is not assessed by traditional sprayers like backpack sprayers and PTO-driven boom sprayers. Vineyards are being sprayed with tractor-operated large volume sprayers such as Rotary atomizer sprayers, hydraulic air blast sprayers, and vertical hydraulic boom sprayers, among others. These devices have a 1000 l/ha application rate for pesticides and insecticides.

These sprayers have an axial fan, which produces a lot of air volume and increases the chance of spray drift when the spray trajectory is greater than the canopy's height. Additionally, there is a noticeable increase in chemical loss and runoff with larger droplets (300-400 μm VMD) and a greater application rate (1000-1500 l / ha). A significant amount of these compounds are lost during the spraying process due to drift, evaporation, leaf runoff, and incorrect application. Pesticide waste and loss account for up to 90% of applied chemicals, which not only causes financial loss but also contaminates the air, water, and land (Gupta et al., 2004). It's also crucial to take the dynamic behaviour into account. The larger droplets have less adhesion due to surface tension and volume, which results in losses due to the large buildup of deposit pouring onto the ground. According to Nuyttens et al. (2010), the biggest element in minimising spray drift has been shown to be size. Less than 70 micron droplets are highly susceptible to wind, and the high temperature may cause them to evaporate, becoming increasingly smaller, or even dry out the solute chemical particle.

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As opposed to this, droplets of 100 or 200 microns have a better distribution, are carried by air spray into the spaces between vegetables, and produce a more even coating without leaking.

The geometric and structural features of plants and crops are traditionally measured manually, which is costly and time-consuming. However, with the advancement of spraying technologies, it is now reasonably easy to measure these parameters using sensors. The application of pesticides on variable rate sprayers, electrostatic sprayers, UAV sprayers, and other devices is changing due to advancements in spraying technology. With the use of internet of things (IoT) sensors for pest and weed detection, plant canopy and foliage measurement, leaf structure calculation, and weather parameter sensing, these technologies alter the scenario of pesticide application and apply the appropriate amount of pesticide to the necessary parts of plants and crops. This ultimately improves the framer's life through good crop production, less and effective pesticide use, and real-time pesticide application.

Spraying Techniques

The high number of spray applications that are applied annually throughout the growing season in mechanised commercial vineyards (Marucco et al., 2019) is an intense usage of Plant Protection Products (PPPs) that may have unfavourable impacts related to pesticide residues in grapes. Different types of sprayers are used to treat pests (weeds, insects, and diseases) in vineyards due to variations in:

- Canopy structure and characteristics (height, depth, density).
- Width between rows of the canopy.
- Land size

The important factors for selecting a vineyard sprayer are delivering the required application rate, spraying droplets of the appropriate size on the target uniformly, and minimising the loss of spray on the ground and in the air.

The sprayers used in vineyards are categorised as follows:-

Hydraulic sprayers

A hydraulic energy sprayer builds air pressure above the spray fluid in an airtight container by utilising an air pump or directly pressurising the fluid with a positive displacement pump. The spray lance, which regulates the amount and pattern, is then used to force the pressurised fluid through it.

Hand pumps, hand cans, backpacks and foot sprayers are examples of manually operated sprayers. As seen in Figure 1, manually operated backpack sprayers are mostly utilised for spot treatment and for smaller-scale vineyard and orchard spraying. Two general application rules, albeit minor ones, are as follows: i) Walk at a steady pace to keep the application rate relatively constant throughout the operation; ii) Spray at a constant pressure to maintain both the application rate and the droplet size uniform during the application. With a 16-liter tank capacity, the manually controlled sprayer uses a hand lever to maintain steady pressure. Spot spot treatment is the main application for this sprayer.

Lawns and field crops can both benefit from chemical applications with the hand compression sprayer. It is made up of a vertical air pump, pressure gauge, filling port, spray lance, nozzle, and flow control lever in addition to a tank with a 10-12 litre capacity to carry spray material. The operator carries the sprayer over his shoulder. The amount applied per hectare varies from 45 to 100 litres. The foot-operated/pedal-operated sprayer is commonly utilised for applying pesticides to tall plants and orchards. The foot lever-operated pump, delivery hose, strainer-equipped suction hose, spray lance with shut-off valve, and adjustable nozzles make up the sprayer.

Since the sprayer lacks an internal tank, it is necessary to use an external container or storage device to hold the spray liquid while keeping the suction hose strainer submerged. Its adaptability and field capacity are increased by the two discharge line provisions. Being a positive displacement pump, the plunger pump generates high pressure to propel spray liquid farther when paired with an appropriate boom. The vast area coverage and high spray volume of this sprayer are its advantages.

Figure 1. a. Knapsack Sprayer b. Hand compression sprayer c. Foot Sprayer

(Source: a)Agripro16L Knapsack Manual Sprayer, b) Khinda Hitech Industries, Indiamart, c) Neptune Rocker Sprayer,agriberi.com)

Hydraulic sprayers with vertical boom (no air assistance)

Field crop sprayers, such as those for maize, soybeans and wheat, and vertical boom hydraulic sprayers, share a lot of design similarities. The primary distinction is that field crop sprayers have a horizontal boom, whereas vineyard and orchard sprayers have a vertical boom. Higher spray pressure is another feature of hydraulic vineyard and orchard sprayers that aids in allowing droplets to pass through the dense grapevine canopy. However, even at higher pressures, the hydraulic sprayers' droplets are unable to efficiently reach the interior of the canopy.

Figure 2. Vertical Boom Hydraulic sprayer
(Source: Jacto Boom Sprayer, agriexpo. online, Cropland Trailed Sprayer, Agpoer.com.au)

Air-assisted sprayers

This is the category that includes the majority of sprayers used in vineyards. With these sprayers, liquid spray discharge is directed towards the canopy by a liquid spray discharge system that is powered by fan air. Pneumatic energy is used by this sprayer to help atomize, transfer, penetrate, and deposit spray droplets. Air is directed from nozzles towards the target canopy, creating droplets. The canopy leaves are separated by air blasted towards the canopy. Because of the increased open spaces created by the separation of the leaves, droplets can enter the canopy deeper and more thoroughly, improving the coverage of pesticides throughout the canopy. The dispersion of liquid spray from air-assisted sprayers is greatly impacted by the orchard's or vineyard's airflow pattern. Thus, canopy should be taken into consideration when choosing the appropriate kind of air-assisted sprayer.

Therefore, the right type of air-assisted sprayer should be selected based on canopy conditions in the vineyard or orchard. There is a wide range of air-assisted canopy sprayers.

Radial discharge airblast sprayers

These are the sprayers that are used in orchards and even vineyards the most frequently. The sprayer has a strong fan installed behind it, which can be either a tangential fan sprayer or an axial-flow, centrifugal, cross-flow, or axial-flow fan (Fig. 3). Air enters the side of an axial fan sprayer, rotates along its axis, and creates a broad air stream that aids in reaching the intended region. The revolving impeller in the centrifugal fan sprayer raises air velocity. Pressure is obtained by converting speed. It works well for forced draft and high-flow services in general. There are over 85% of these sprayers. Air enters the impeller at one point on the outside periphery, flows inward, and exits the sprayer at the cross-flow/tangential fan sprayer.

The qualities of this sprayer include high air rate and consistent discharge. It can function in the harshest conditions and can even withstand increased pressures and contaminated air (Thorat & associates, 2022). When using the radial discharge type, the fan draws air from behind the sprayer and lets it out in two directions: one direction, 90 degrees away from the fan, and the other, 180 degrees, spraying the canopies on each side of the sprayer. One drawback of conventional airblast sprayers is that they release air in a 180-degree radial pattern surrounding the fan outlet, including the area at the top without a canopy. Not only is there a substantial amount of air created trash, but it also contributes to loss of pesticide applied and results in excessive spray drift problems that are associated with airblast sprayers. (Ozkan, 2022).

(a) (b)

(c)

Figure 3. Air-assisted sprayers; a) Axial fan type, b) Centrifugal fan type, c) Crossflow/ tangential fan type

(Source:a) Dragone Trailed Sprayer,Indiamart.com b)Bora-Orcahard Sprayers, TUFASS Machinery, c)Orchard Sprayer, amegroup.com.au)

Tower-Type Airblast Sprayers

Sprayers with a vertically oriented shroud that discharges air from the fan in a horizontal orientation are designed to prevent the uneven vertical distribution of air flow that occurs when using standard airblast sprayers. As seen in figure 4, these sprayers are typically referred to as tower sprayers (Ozkan, 2022). Air enters the sprayer through the axial fan located inside the mesh housing ahead of the nozzle and exits the sprayer shroud in a horizontal manner. Some of these sprayers have a deflector nozzle (also known as a spray angle adjuster nozzle) in addition to horizontal or nearly horizontal air flows to enhance spray deposition even more, particularly in the upper sections of the canopy.

Sprayers with Adjustable spouts

Fans that create a high-speed, low-volume air stream through corrugated tubes are typically seen in adjustable spout sprayers. Nozzles can be positioned on the side of a narrow, elongated manifold that is connected to the corrugated tubes, or they can be found inside spouts where the air exits the tubes (Fig.ure 5). The ability to precisely and flexibly guide the spray towards the canopy or even a specific area of the canopy that has to be protected against specific insects or illnesses is the main benefit of these kinds of sprayers. It is possible to change the nozzle setup's angle and spout height (up, down, forward, and backward).

Figure 4. Tower sprayer

Source :Sprayers for effective application in Orchards & Vineyards, ohioonline.osu.edu

To spray only the conditions of the target canopy, some spouts have the option to turn off some or all of their nozzles. Adjustable sprayers have been more and more popular in recent years because accurate spray targeting may play the biggest part in the efficient management of insects and diseases. Compared to traditional airblast sprayers with radial air flow and spray discharge, they generally produce higher pesticide efficacy, use pesticides more effectively (using less pesticide per acre), and significantly reduce spray drift.

Figure 5. Sprayer with adjustable nozzles
Source: https://www.maschiogaspardo.com/c/document_library/get_file?uuid=3118926c-2d6f-7c2c-19a4-d8451ce40d1f&groupId=37909&version=1.0

Multi-Row Adjustable Sprayers

Applying, the majority of fruit and grape producers spray the two rows on either side of the sprayer in one pass, covering both sides. However, for large-acreage vineyards growing on relatively level ground (no steep slopes), sprayers that treat numerous rows of canopy in a single pass are also available. Two to eight rows of grapevines in multi-row units can be sprayed in a single pass, depending on canopy conditions (particularly row width), (Fig. 6). While multirow sprayers are significantly more expensive than traditional radial airblast sprayers, they save a significant amount of time when applying pesticides in large-scale vineyards and orchards by spraying numerous rows at once.

Figure 6. Sprayer with adjustable nozzles
Source: https://www.silvan.com.au/wp-content/uploads/2018/03/Vineyard-Spraying-Machinery-2018-16pp_LR.pdf

Air-Assisted sprayers with multi-head fans

Two rows can be sprayed simultaneously using the air-assisted sprayers with multi-head fans (Fig.7). Many small axial fans powered by hydraulic or electric motors are used by the majority of producers of these sprayers. These fans use hydraulic nozzles to direct a jet of air. Operators can change the size of the droplets by varying the system pressure or nozzle size. As seen in Figure 8, each fan typically has six to ten recessed nozzles. In order to decrease spray drift and ground deposits and increase uniformity of spray deposition and coverage, the fans can be changed based on the canopy's angle, height, and width. Instead of using all four fans during the early season, two fans that are diagonally opposed are used. Fan speed controllers that are separate from the tractor hydraulic system are installed in the cab of some manufacturers' tractors. Operators may compensate for being upwind or downwind and modify fan speeds for varying canopy conditions thanks to this separate control.]

Figure 7. Air-assisted sprayers with multi-head fans
Source: https://www.goodfruit.com/multi-row-sprayers/

Figure 8. Fan with 8 nozzles
Source: https://ohioline.osu.edu/factsheet/fabe-533

Pneumatic air-shear sprayers

The thin droplets produced by the sprayers are not produced by a high pressure nozzle, in contrast to conventional air-assisted hydraulic sprayers. The low-pressure liquid emitter of pneumatic air-shear sprayers (Fig. 9) is placed into the venturi tube's exit port. A rotary fan's air travels through a venturi tube before the liquid is released from the emitter, or nozzle, where it is sheared into minuscule droplets that are directed towards the target. Compared to airblast sprayers, the spray amount delivered per acre is much decreased since the liquid is converted to extremely tiny droplets. The number of droplets per square cm can be doubled, tripled, or quadrupled with a narrow droplet spectrum.

Additionally, by keeping the droplets on the vegetation rather than letting them fall to the ground, you enhance the effectiveness of the chemicals you spray. All that's needed to accomplish full coverage and good contact on the leaves is to replace the air in and around the plant with low volume sprayer air. Because the spray and air are homogenous, the chemical arrives where the air does. Because it can apply chemicals at a quicker ground speed, the "Low Volume" system greatly increases spraying time by minimising the need for tank refills and the wasted time commuting between fills. The time saved can be crucial in ensuring that pesticides are sprayed on the crop as effectively as possible.

Additionally, pneumatic sprayers use a lot less water to cover the same area of vegetation than high volume sprayers do, saving more water, chemicals, and improving the bioefficacy of the environment. The efficiency of the spray application process is greatly impacted by unfavourable weather conditions like low relative humidity, high temperatures, and windy days since pneumatic sprayers are made to offer low-volume application rates utilising very minute droplets. Consequently, in areas where certain environmental conditions are common, these sprayers are not recommended and should not be utilised.

One set of spouts on each side of the sprayer, which discharges droplets vertically, is typical of the basic three-point hitch variant of these sprayers. This configuration might offer sufficient coverage for the centre and bottom of small to medium-sized canopies.

Figure 9: Pneumatic air shear sprayer
Source: http://www.gearmore.com/gearmore/files/VenturiAirSprayerBook_2.pdf

Electrostatic sprayers

As is well known, the objective of pesticide application is to minimise spray drift while increasing the quantity and distribution of droplets on target surfaces. When sprayed on the topsides of leaves, large droplets have a limited drift potential and usually produce satisfactory deposition and coverage; however, they do not sufficiently treat the undersides of leaves. On the other hand, droplets of a smaller size tend to be blown away from the spraying area of their intended targets, despite the fact that smaller droplets offer better coverage on the topsides and undersides of leaves. It has been demonstrated that the deposition of small droplets on target leaves—particularly the undersides of the leaves—can be further enhanced by electrostatically charged droplets. This happens as a result of the attraction of items with opposing electrical charges. Large droplets have a restricted drift potential and often result in good deposition and coverage when sprayed on leaf topsides; however, they do not adequately treat leaf undersides. However, even though smaller droplets provide better coverage on the topsides and undersides of leaves, they also tend to be blown away from the spraying area of their intended targets. Due to their greater charge-to-mass ratios, tiny droplets are best suited for electrostatic loading. However, as charge-to-mass ratios drop, electrostatic charging loses some of its efficiency. When droplet size is greater, this happens. Using electrostatic spraying to apply insecticides efficiently in indoor environments like greenhouses has a lot of potential. Further research is necessary to validate its superiority in enhancing deposition and coverage, decreasing the spray volume rate, and minimising spray drift during pesticide application in outdoor orchard and vineyard spraying situations.

Drone spraying

Almost every component of a ground sprayer is present in a drone (Figure 11) that is used for spraying, including a tank and a pump that force pesticides via hoses to nozzles that disseminate the chemicals. Their spray tank holds between 5 and 20 litres, and their application rate usually varies between 15 and 40 litres per hectare. Depending on the application rate, the spray mixture in the tank may be sprayed for four to ten minutes. Drones have a maximum flight speed of 7-10 km/h, and depending on the type, size, and specs, batteries can last anywhere from five to fifteen minutes. Furthermore, some drones can be configured to return to their home base when their fuel runs low in order to refuel.

Figure 10. Electrostatic sprayer
Source: https://ohioline.osu.edu/factsheet/fabe-533

After being refuelled, the drone takes off again and resumes spraying. Usually, humans fly drones three to four metres over the target canopy. When spraying over uneven terrain, some drones have a terrain sensor as an optional feature. The drone can autonomously negotiate hills and slopes with the help of this capability. When using aerial spraying, one of the main problems is the effectiveness of the droplet deposition. Droplets from the UAV sprayer enter the crop canopy during the spraying process. But there is a lot of droplet drift, which wastes pesticides, lessens the control impact, and can potentially contaminate the environment and cause poisoning.

Drones are currently being promoted in India mainly as an automated spraying tool for crops, which may be used to spray pesticides and other materials to minimise health risks associated with hand spraying while also saving significant amounts of time, money, and manpower. The Indian government has offered many drone purchase subsidies in an effort to lower the cost of drones for farmers and other stakeholders and encourage drone adoption. According to estimates from the Indian Agriculture Ministry, the cost per acre for a drone with a 10 kilogramme payload capacity will be between Rs 350 and Rs 450.

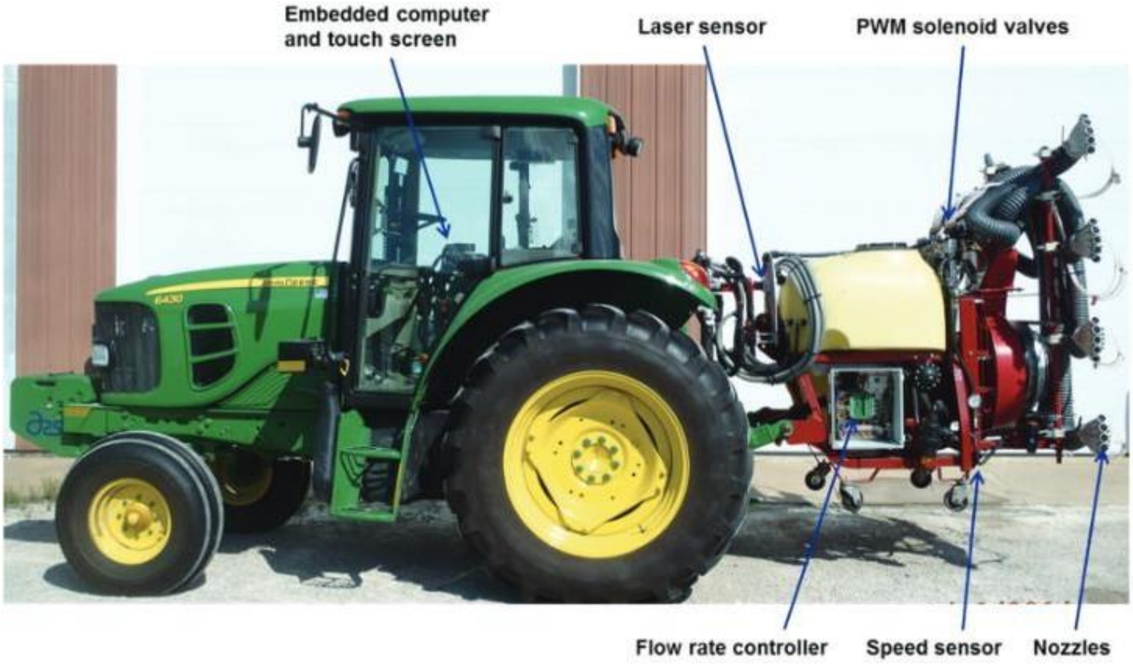
The computation is predicated on the notion that a drone outfitted with numerous batteries will be employed for a minimum of six hours daily, thereby traversing around thirty acres of agricultural land. The Indian Agriculture Ministry is giving SC-ST, small and marginal farmers, women, and farmers in northeastern states a 50%, or up to INR 0.5 million, subsidy to purchase drones in order to encourage the usage of Kisan Drones. Financial support up to 40% or a maximum of INR 0.4 million will be provided to additional farmers (Abhishek, 2022).

Figure 11. Drone Sprayer

Variable-rate application of pesticides

Vineyards differ greatly from field crops in terms of canopy structure and density. As the growing season goes on, even the amount of the canopy in a vineyard varies considerably. In orchards and vineyards, this growth rate may vary based on a variety of factors, including as topography and soil properties. Regretfully, applicators cannot manually shut off nozzles in between vines with today's typical sprayers. During the spray application process, applicators could also neglect to modify the sprayer's settings to correspond with the target vines' canopy characteristics (height, size, and form).

In these circumstances, a large portion of the material sprayed is wasted, particularly when spraying early in the season when the canopy cover is minimal. As a result, overuse of pesticides raises the possibility of environmental contamination and increases manufacturing expenses. An air-assisted, "intelligent sprayer" was created in Ohio to solve these issues and apply pesticides in orchards, vineyards, and nurseries at varying rates (Chen et al., 2012 and Shen et al. 2017). Using a high-speed laser scanning sensor, a specially made sensor-signal analyzer, and a variable-rate controller, this innovative spraying system allows you to adjust the duration of the variable-rate pulse width modulation (PWM) nozzles in a multi-channel delivery system. In order to match canopy volume and travel speed in real time, it first detects the presence of canopies, measures their size, shape, and density of foliage, and then independently adjusts the spray output of each nozzle. According to field testing, this sprayer technology may effectively manage insects and diseases while reducing airborne spray drift by up to 87%, spray loss onto the ground by 68-93%, and spray volume by 47-73%.



The technique has currently been commercialised in the United States by Smart Guided Systems. Smart Guided Systems offers parts to convert standard vineyard/orchard sprayers with constant rates into ones with variable rates so they can sprayed with pesticides. This enables producers to alter their current machinery and convert their constant-rate sprayer to a variable-rate sprayer for a significantly lower cost.
Figure 12. Phase II embedded-computer-controlled, variable-rate sprayer (Chen et al. 2012 and Shen et al. 2017)

Site-specific application of pesticides
In a vineyard or orchard, insects and diseases are rarely dispersed evenly. There might not be any infestation, a very low infestation, or a very high infestation in some places. Within the same orchard or vineyard, different locations may have different diseases or insects. Therefore, depending on the area of the orchard or vineyard that has to be treated, it can be required to apply different pesticides at varying rates.
There are currently technologies available and being developed for pesticide applications that are site-specific. The procedure is in two steps. First, a drone surveys the field from the air, collecting data (typically with cameras) to identify ground features like canopy characteristics and nutrient-stressed areas.
After the cameras' images are digitalized, a map with the previously given criteria is created. Using a drone fitted with spraying parts or a GPS-equipped tractor-driven sprayer, this data is then utilised to carry out site-specific spraying. The nozzles fire when the drone or traditional sprayer approaches an area that the digital map indicates needs to be sprayed. Spraying ceases in the areas designated on the digital map as no-spray zones. This process keeps going until the entire field has been sprayed in the manner shown by the digital map.

Way forward
Growers of grapes and fruit trees may now apply pesticides more effectively and efficiently thanks to technological advancements. When using pesticides in vineyards, we still need to consider the traditional and useful features of spraying. The application of pesticides, regardless of the crop being

treated or the equipment used, requires a considerably higher level of competence and understanding than any other agricultural operation. This is especially true, considering the shape of the target crop canopy, when spraying grapevines for disease and insect management. The target that needs to be treated for insects and diseases in vineyards is completely different from that of field crops, which are often uniform in size, short in dimension, and below a sprayer boom. When working with grapevines, the target is elevated and displays excellent. With grapevines, the target is above ground and exhibits great variation in height and depth which makes uniform treatment and coverage rather difficult.

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