Agrochemical Spray Technology Adoption and Safety Awareness Assessment in Crop Protection in Vineyard Cultivation

Dattatray G. Bhalekar[1], Roaf Ahmad Parray*[2], Indra Mani[2], Tapan Kumar Khura[2], Susheel Kumar Sarkar[3], N V Kumbhare[2]

[1]*Department of Biological Systems Engineering, Washington State University, Prosser, Washington (USA) -99164-1035*
[2*]*Division of Agricultural Engineering, ICAR-IARI, New Delhi*
[3]*Indian Agricultural Statistics Research Institute, New Delhi.*

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**Corresponding Author Email: rouf.engg@gmail.com*

Abstract: A study was conducted in the Jalna district of Maharashtra to assess the adoption pattern of spray technology, and safety awareness among grape growers. The respondents were selected through random sampling and data was collected through a structured interview. The study revealed that among marginal landholders (< 1 ha) back-pack type sprayer was mostly in operation with an adoption level of 75%. In small landholders (1-2 ha), horizontal triplex pump (HTP) sprayers with an adoption level of 51.85% followed by tractor-operated air-blast sprayers (40.75%) were prevalent pesticide spraying technologies. More than 2/3rd (76.00%) of medium landholders (2-4 ha) had adopted tractor-operated air blast sprayers. For the application of plant growth regulators, 62.5% of small farmers, 81.8% of medium, and 100% of farmers had adopted electrostatic sprayers. The number of chemical sprays per season varied from 25 to 100, making grapes one of the major pesticide-consuming crops. Capacity, efficiency, cost, and availability of sprayers on a custom hiring basis were the four major factors affecting the adoption of spraying technologies.

KEYWORDS: *Air-blast sprayer, Custom hiring, Electrostatic sprayer, Plant growth regulator.*

1. Introduction: Agriculture is the mainstay of the Indian economy and contributes about 18.8% of the Gross Value Added (GVA) of the country (Economic Survey of India, 2021-22). Since Independence, India has witnessed tremendous growth in agriculture- 5 times increase in grain production, 9 times in horticultural production, 12 times in fish production, and 9.5 times in milk production [1] Horticulture has become a key driver for economic development in many of the states in the country and it contributes 30.4% to the gross domestic product (GDP) of agriculture [2]. Among horticultural crops, India has emerged as one of the major grapes growing countries in the world. India ranks first with average grape productivity of 22.32 tonnes ha^{-1} against the global average productivity of 9.32 tonnes ha^{-1}. Grape production has increased by about 195% from 1057 thousand tonnes in 2000-01 to 3125 thousand tonnes in 2019-20 [3]. In India, about 0.14 million hectares of grape cultivation produces 3.12 million tonnes of grapes annually. India is the only country in the world, where table grapes are available during April-May [4] Grapes occupy the prominent position in exports with 188.2 thousand tonnes valued at ₹1,89,99 million [5]. In India, Maharashtra State (MS) is the largest producer of grapes, accounting for up to 78.3% of the country's total grape production followed by Karnataka and Tamil Nadu. Maharashtra has an estimated grapes cultivation area of 0.09 million hectares with an annual production of 774000 tonnes in 2015 [6]. For the production of quality grapes with sustainable yields especially in tropical climates, farmers often use pesticides to control diseases like downy mildew, powdery mildew, and insect pests such as thrips, jassids, and mealybugs therefore, pesticide consumption in grape farms is on the higher side. Due to the widespread use of pesticides, their toxic residue has been reported in various environmental matrices [7].

The precision chemical and growth regulator application in vineyard cultivation demands mechanization in crop protection operations. Specialty crop spray application methods have advanced significantly in recent years in terms of better control and lower costs with improved spray performance and reduced off-target drift. Recently, the use of sensor-based control volume [8] and electrostatic spray technology [9] has shown improved spray deposition compared to conventional sprayers. To develop and disseminate different technologies for vineyard cultivation, it is essential to analyse the existing technology adoption pattern among different farmers and develop scale neutral technologies for widespread adaptability. A survey was conducted in the grape-growing Jalna district (Marathwada region) of Maharashtra (India) to understand spraying technology adoption patterns and worker health safety awareness among grape-growing farmers of India. The primary aim of the study was to investigate the adoption pattern of spray technology and safety practices across diverse land holdings within the study area. The overarching goal was to pinpoint potential interventions that could enhance the mechanization of spraying operations specifically within vineyards in the Marathwada region.

2. Experimental Procedure

A study was conducted in major grape-cultivating villages of the Jalna district (MS, India). Five villages namely, Kadwanchi (19.9199°N,75.9986°E), Dharkalyan (19.8868° N, 76.0218° E), Nandapur (19.9064° N, 75.9754° E), Gondegaon (19.9376°N, 75.9289°E), and Thar (19.9139° N, 75.9608° E) were selected randomly from this region (fig.1) for this study.

Fig.1 Satellite image of the study area

Further, from each village 14 farmers were selected randomly, thus making a total sample size of 70 farmers. The basic information about cropping patterns, cultivation practices, major grape cultivation regions, etc. of Jalna district was taken from District Agriculture Offices and *Krishi Vigyan Kendra* (KVK), Jalna, MS. The data were collected by the researcher by interviewing the respondents with the help of a pre-tested standard interview questionnaire. The collected data were compiled, tabulated, and analysed using statistical tools.

In order to validate the effect of spraying technology on growth of grape clusters, a pilot study was conducted at ICAR-Indian Agricultural Research Institute, New Delhi. The study employed three distinct treatment methods for the application of the plant growth hormone Gibberellic acid (GA3) at a concentration of 40 ppm. The three methods utilized were:

Sensor-Based Control Volume Sprayer (SB)

This treatment involved the use of a sensor-based control volume sprayer, which likely leveraged advanced technology for precise and controlled spraying of the Gibberellic acid on the berry clusters.

Conventional Hand Dipping (DP)

The conventional hand dipping method implied manually immersing berry clusters in a solution containing Gibberellic acid. This traditional method may involve direct contact with the solution and manual labor.

Manual Compressed Air Sprayer

This treatment utilized manual compressed air sprayer (Model No: B0BKTCQG5H, 5 L, compressed air sprayer, Saiagro Ltd., India) to facilitate the spraying of the Gibberellic acid solution onto the berry clusters.

Statistical Analysis

In order to assess the effectiveness of the Plant Growth Regulator (PGR) application method on the growth of clusters, a statistical analysis of variance (ANOVA) was conducted at a significance level of $\alpha = 0.05$. The cluster and berry growth datasets were normalized using cube- root transformation. All the statistical analysis was performed in RStudio programming software (version: 2022.12.0+353, public-benefit corporation, USA).

3. Results and Discussion

The major observations inferred from the survey data are presented below,

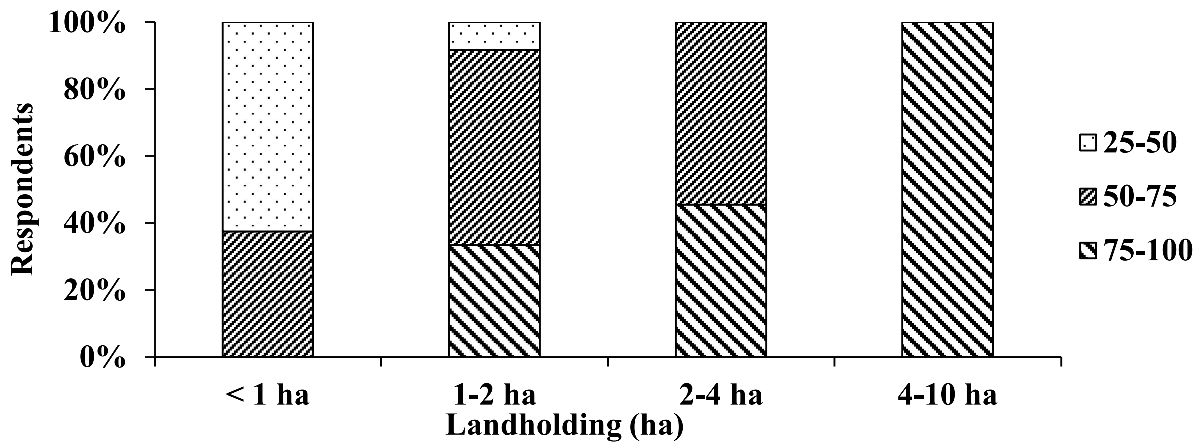
I. Educational status of respondents

The educational status of the respondents shows that the majority of farmers (41.43%) had completed their secondary education whereas farmers without any formal education were 2.85%. The respondents who had completed their primary and higher secondary levels were 20 and 25.72% respectively. Farmers who had received education up to graduation level were around 10%. Based on the information provided by the farmers it was observed that all the respondents belonged to the age group of 25 years to 60 years [10][11] . The inclusion of educational status and age-related data is essential because psychological factors play a crucial role in understanding how individuals perceive and adopt new technologies. Those with higher education levels may be more open to embracing new technologies due to a better understanding of their benefits. The age of farmers aligns with the Innovation Diffusion Theory, which suggests that the adoption of innovations follows a pattern, with younger individuals often adopting new technologies earlier than older individuals. Understanding this pattern is crucial for designing interventions that consider the varying needs of different age groups.

II. Technology adaptation pattern among different landholding categories

Grapes are highly vulnerable to various diseases throughout the season from fruit setting to harvesting and hence require frequent chemical applications. Fig. 2 shows the frequency of chemical application including the growth regulator sprays per season varied from 25 to 100, making grapes one of the major pesticide-consuming crop. However, the frequency of sprays varied with landholding. It was observed that sometimes 2-3 sprays were done during a single day depending upon the disease incidence and weather conditions. Spray frequency for marginal farmers ranged from 25-50 sprays per season. The spray frequency was 50-75 sprays per season for 40% of small and 51.5% of medium landholding farmers. All the respondents from the large landholding category reported a higher spray frequency of 75-100 per season. A major factor affecting the frequency of spraying among the different categories was the type of technology and man-hours requirement for spray applications. Mostly, marginal and small farmers were using the small capacity sprayers hence, more man-hours were required which resulted in reduced spray frequency. However, large landholding farmers had adopted high-capacity tractor-operated sprayers with fewer man-hour requirements, hence, the increased frequency was observed.

Fig. 2. Frequency of chemical applications among the different landholding category



Based on the details provided by respondents, it was observed that three different types of sprayers were adopted by the farmers of the surveyed region. These were backpack-type sprayers, engine-driven stationary type (horizontal triplex pump [HTP]), and tractor PTO-driven airblast sprayers (fig 3a) (also known as blowers locally). Farmers with landholding less than one hectare were using backpack sprayers (fig 3b) such as battery-operated knapsack sprayers and backpack-type power sprayers; with few being HTP. Farmers of the small landholding category (1-2 ha) were mainly using HTP with a tank capacity of 200

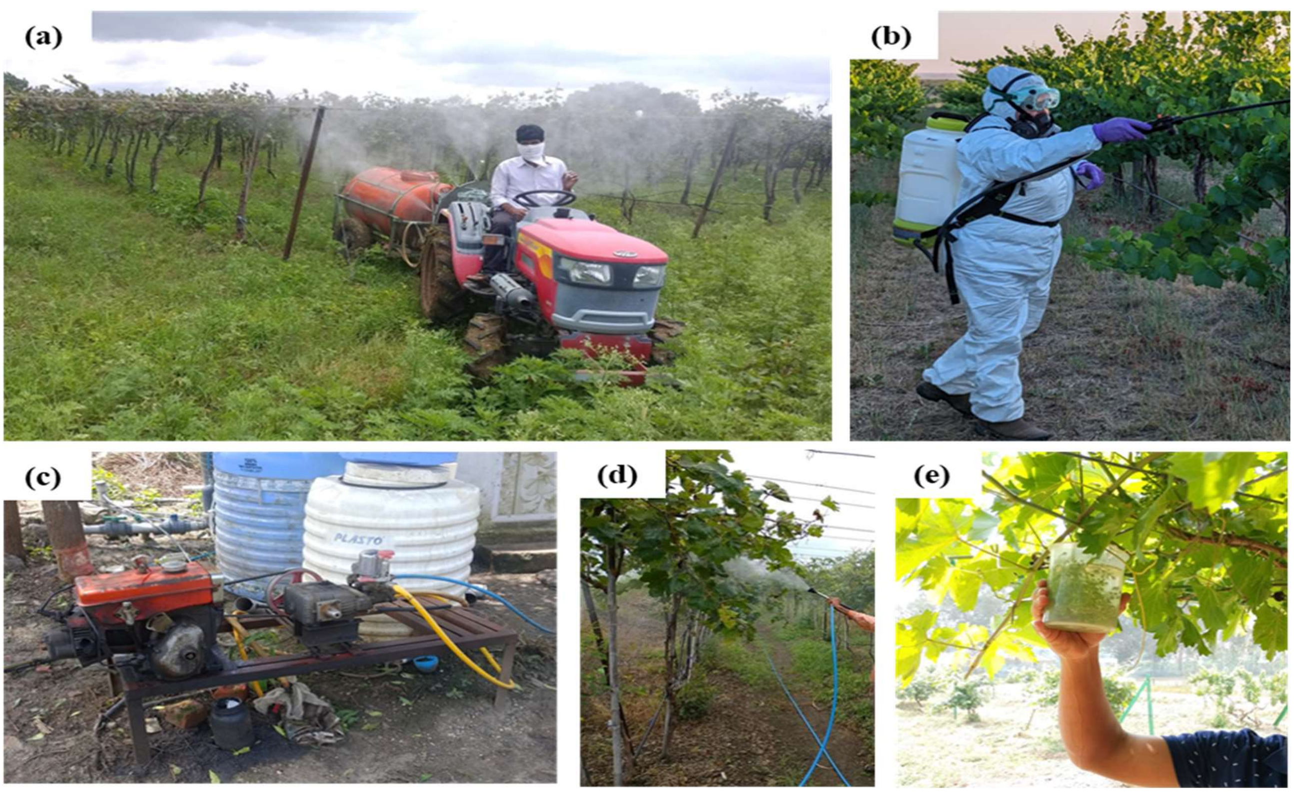


Fig. 3 Spray application technologies adopted in vineyard cultivation a) airblast sprayer, b) backpack sprayer, c, d) Horizontal triplex pump with hand spray gun, e) hand dipping

liters (fig. 3c,d). A fraction of them had adopted tractor-operated air-blast type sprayers, whereas very few were using backpack sprayers. Growers of medium and large landholding categories (2-4 ha) preferred high-volume tractor-operated airblast sprayers.

Plant growth regulators (PGR) are essential for the uniform growth of grape berries. Better productivity can be obtained by precise plant growth regulator applications. Respondents reported that grapes usually require about four to six PGR sprays per season.

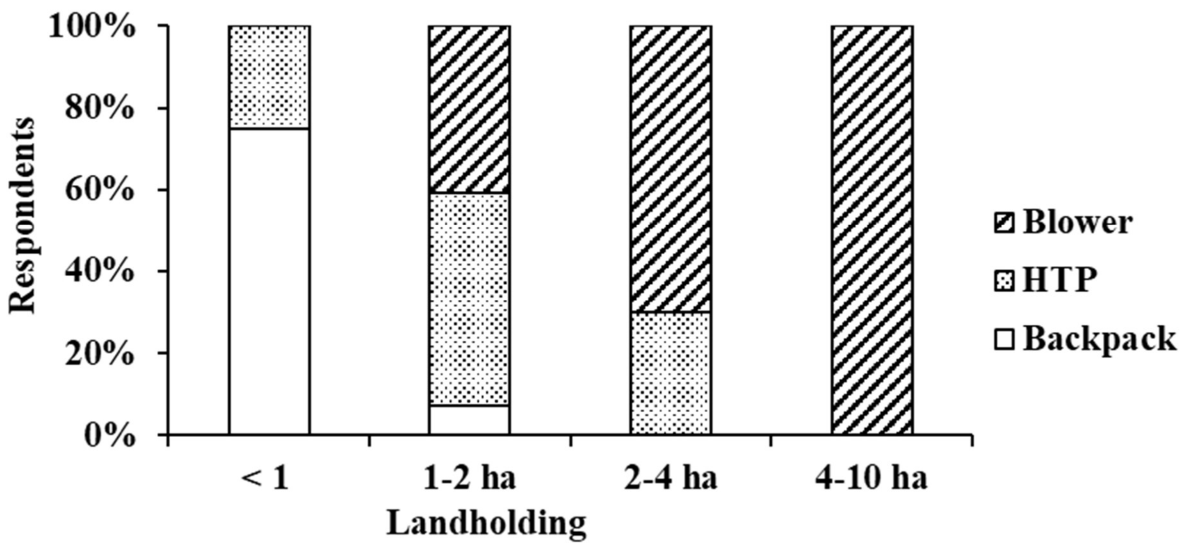


Fig. 4 Variations in number of sprays per season among different landholdings

Graphical representation of adopted spraying technology by the respondents of different landholding categories (Fig.3) indicates that about 75% of marginal landholding grape growers were using back-pack type sprayers and 25% had adopted HTP type sprayers. In case of small landholding category, the adoption of different spraying technology was like HTP sprayers (51.85%), tractor-operated airblast sprayers (40.75%) and 7.5% using backpack sprayers. In medium landholding grape growers, 76% had adopted airblast sprayers. It was observed that as the landholding increased, the adoption of tractor-operated sprayers also increased. It could potentially be due to the affordability of tractor-operated sprayers among large land-holding farmers. 12] highlighted that age, annual income, education, social involvement, usage of information sources, land ownership, knowledge, and socio-economic level were shown to be correlated with the adoption of improved technologies.

Significant variation in the adoption of plant growth regulator spraying technology was also observed among the different categories of landholding farmers. Farmers of marginal landholdings majorly were using the traditional hand-dipping method of PGR application in which every grape cluster was dipped manually into a conical pot full of chemicals (fig. 3e).

In small land-holding farmers, four different modes of PGR application i.e. hand dipping, horizontal triplex pump, blower, and electrostatic sprayer were prevalent with adoption levels of 8.55%, 16.45%, 12.5%, and 62.5%, respectively (Fig.4).

In case of medium landholding category, 81.8% grape growers were using electrostatic sprayers and remaining (18.2%) were using a blower. All large landholding farmers had adopted electrostatic sprayers for the precise application of plant growth regulators. One major observation was the farmers' perception of the need for the application of an optimum concentration plant growth regulator. Less concentration was reported to be ineffective in grape cluster development, while overdose caused adverse effects on the quality of the grape cluster. Although 67.15% of farmers were using electrostatic sprayers, however, only 7.15% of farmers owned electrostatic sprayers while the majority of farmers were using electrostatic sprayers on a custom-hire basis. Therefore, custom hiring services had a great role to play in technology adoption due to the affordability of high-cost sprayers by most farmers.

III. Factors affecting the adoption of spraying technology in vineyards

The major focus of the study was to elicit information on different factors affecting the selection of spray equipment for pesticide management in grape orchards. [13] reported 80% of variation in agricultural mechanization could be attributed to four major factors-land holding, family income, custom hiring service availability, and education. The adoption or non-adoption of spraying technologies was mainly related to three major factors- cost, efficiency, and availability of sprayers.

(i) **Efficiency and capacity of spraying:** A majority (57%) of farmers responded that the efficiency and capacity of a sprayer for grape cultivation was a major factor in the selection of a sprayer. However, most of such farmers were of medium and large land holding categories, therefore adoption of high-cost air-blast type sprayers and the electrostatic sprayer was economically feasible for them.

(ii) **Cost of sprayer**: Cost is one of the major factors affecting the adoption of machinery among resource-poor farmers. Among the total surveyed grape growers, 31% reported that cost of operation was a major concern for the adoption of efficient and high-capacity sprayers like air-blast type sprayers and electrostatic sprayers. Most of the farmers in this category were marginal, small, and medium landholding category. For such farmers, the purchase of machinery like air-blast type sprayers and electrostatic sprayers was against economics of scale due to fewer annual use hours. Many farmers in this category were availing of custom hiring services for the use of high-cost machinery for spraying in their orchards. Farmers of the marginal and small categories were adopting manual backpack sprayers.

(iii) **Ease of availability:** Custom hiring of agricultural machinery plays an important role in machinery dissemination [14] . Out of the total surveyed farmers, 11 percent reported the non-availability of machinery on a custom hiring basis as a major constraint in the adoption of sprayers for pesticide and growth regulator application in grapes. Most of the farmers reported non-availability of sprayers a major concern were medium land holders. [15]while studying farm power-machinery status and custom-hiring opportunities reported the need for facilitation of high-cost machines through custom hiring centers, *Krishi Vigyan Kendra,* and through private-public partnerships to improve the mechanization status of the country.

IV. Safety awareness and health issues associated with pesticide application in the vineyard

Variations in the level of safety precaution during pesticide application were observed in selected respondents. During the survey, farmers were asked for the type of protective measure they follow while pesticide spraying in grape orchards. All three types of respondents i.e., those not following any safety precaution during spraying of hazardous pesticides, farmers with partial precaution (covering the nose and mouth with proper clothing), and farmers with full precautions (safety goggles, shoes, and personal protective kit) were observed (Table 1).

The data relating to protective measures followed by grape growers while spraying indicates that about 87.5% of farmers of marginal landholding were not following any protective measure, whereas, as a fraction of them were using partial precaution while spraying. In the case of small and medium farmers about 62.5% and 48.5%, respectively were not following any safety precautions while spraying in a vineyard. The safety awareness was found quite satisfactory in large landholding farmers with 60% taking partial precaution and 40% following full precaution in pesticide application. This was because of the reason that most of the large land-holding farmers had higher education and were voluntarily involved in training related to agriculture. [16] revealed education level and lack of training related to pesticide use among major factors certain factors affecting the safety awareness of farmers in pesticide application practices in India.

Table 1 Safety measures pattern observed in selected respondents

Level of precautions	% Respondents among different landholdings			
	< 1 ha	1-2 ha	2-4 ha	4-10 ha
No Precautions	10.00	21.43	22.86	0.00
Partial Precautions	1.43	10.00	20.00	4.29
Full Precautions	0.00	2.86	4.29	2.86

V. Health issues related to pesticide application reported by the farmers

Pesticides act as plant-protection agents to control most dreadful diseases in agriculture. However, exposure to pesticides continuously for a bit longer period causes a range of human health-associated issues. From the surveyed area, headache was the most common problem reported by about 41.42% of the grape growers. Most of these farmers were observed to apply pesticides without any protective measures. The next major health issue faced by about 25.71% of farmers was breathing problems after pesticide spraying. Other 12.85% and 5.71% farmers had experienced eye problems and nausea, respectively during pesticide spraying in grape orchards. It was found that farmers of all age groups were equally susceptible to the health effects due to unsafe pesticide application practices. However, 14.28% cent of farmers who were following either complete or partial protective measures while spraying did not report any major health issues. The major reason behind health issues was improper information about the chemical composition of sprayed pesticides due to lack of awareness. Given that farmers were observed applying pesticides without protective measures, the risk of dermal issues becomes a significant concern. The use of appropriate personal protective equipment (PPE) like gloves, long-sleeved clothing, and other protective gear is crucial to minimize direct skin contact and mitigate the potential health risks associated with pesticide exposure. It is recommended to raise awareness among farmers about the importance of using PPE and providing them with proper training on safe pesticide handling practices to reduce the occurrence of dermal issues and other health-related problems. [17] reported that middle-aged group farmers mostly being illiterate are dependent on others for reading information given on pesticide bottles or instructions provided by agriculture extension departments. Thus, the availability of information in the local language may sensitize the people to better follow up on necessary protocols during pesticide application to avoid health hazards.

Effect of spraying technology on growth characteristics of grape cluster

The analysis of variance (ANOVA) revealed a significant difference in cluster length ($F_{2,99}$ = 4.84, p = 9.84 $\times 10^{-3}$) based on the application method. However, no significant differences were observed in cluster width ($F_{2,99}$ = 1.39, p = 0.25) when considering the application method as the main effect. The change in cluster length (Mean ± Std. Error) observed in the selected plant growth application methods were as: Sensor-Based (SB) Sprayer: 16.89 ± 1.72 mm; Hand Dipping (DP): 16.66 ± 1.55 mm; Conventional Manual Sprayer (CS): 7.63 ± 0.94 mm. On the other hand, the maximum growth in cluster width was observed in the SB method (16.23 ± 1.84 mm), followed by DP (11.12 ± 1.28 mm) and CS (8.55 ± 1.77 mm), respectively. The cluster growth was comparable between the SB and DP methods, while the least growth was observed in the CS method (Figure 5). This change in cluster growth may be attributed to potential influence of higher atomization and increased spray deposition on clusters under control volume conditions, particularly in the SB method (Dattatray *et al.,* 2023)

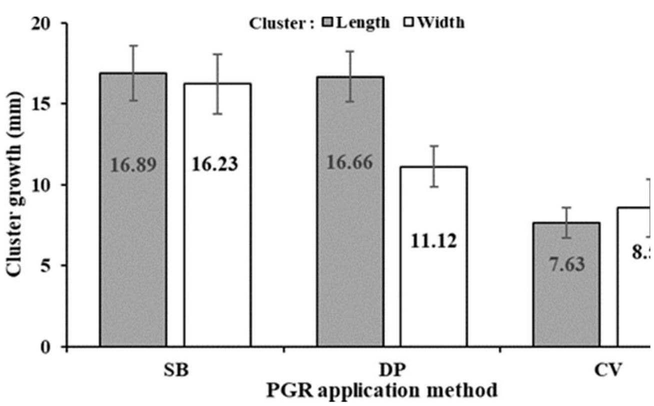


Figure 5 Effect of PGR application methods on cluster growth

4. Conclusions: The study's key findings highlight that the adoption of farm machinery for pesticide and plant growth regulator application in grape cultivation is significantly influenced by the size of land holdings. Large land-holding farmers tend to embrace advanced technologies like tractor-operated air-blast sprayers and electrostatic sprayers, whereas such technologies see limited use among small land-holding farmers. To bridge this gap and promote the widespread adoption of advanced and precise equipment, there is a proposed strategy of making such machinery available on a custom hiring basis. This approach aims to increase accessibility to innovative technologies, ultimately reducing input costs and minimizing environmental impact. The study underscores the necessity for developing affordable spraying technologies customized to the needs of small and marginal farmers. This is critical to make farmers with limited land holdings reap the benefits associated with advanced and efficient spraying technologies. Moreover, the low adoption pattern of precautionary measures among farmers requires specialized training programs to educate farmers about the importance of implementing proper protection measures during pesticide application. This proactive approach will enhance awareness and promote safer practices, addressing health concerns associated with pesticide exposure. Overall, , the study suggests a multifaceted approach to improve the adoption of advanced agricultural machinery and enhance safety measures during pesticide application, catering to the diverse needs of farmers with varying land holdings. The findings on the specific effects of different PGR application methods on grape cluster dimensions, highlighted the potential advantages of sensor-based spraying technology in promoting cluster elongation.

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