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Sanitary and phytosanitary compliance and market access in viticulture: Evidence from grape farmers in Nashik district, Maharashtra

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ABSTRACT

Sanitary and phytosanitary (SPS) requirements are increasingly important for grape farmers seeking access to premium domestic and international markets. This study focuses on the key challenges farmers face in complying with SPS standards, differences in compliance costs across purchasing arrangements, and the role of compliance-related factors in market access. Primary data were collected from 50 grape farmers and analyzed using Garrett Ranking Technique, one-way ANOVA, frequency and percentage analysis, and multiple regression. The findings show that limited technical knowledge of SPS regulations was the most significant perceived challenge, followed by difficulties in producing market-compliant quality grapes, maintaining documentation and MRL records, accessing training and facilities, and managing compliance costs. Compliance costs also differed significantly among FPO, Trader and Individual purchasing models ($F = 210.65, p = 3.37 \times 10^{-17}$). The regression model explained 72.8% of the variation in the dependent variable ($R^2 = 0.728$), with cost emerging as the only statistically significant individual predictor ($\beta = 0.379, p = 0.002$). These findings highlight the need for practical technical training, accessible compliance facilities, improved farm-record systems and stronger coordination across the grape supply chain.

Keywords: SPS compliance, Grape farmers, Market access, Garrett ranking, ANOVA, Compliance cost, Maharashtra

1. Introduction

Agriculture is increasingly integrated with national and international food supply chains, where compliance with food safety and plant health requirements has become an important consideration for agricultural producers and exporters. Sanitary and phytosanitary (SPS) measures are established under the World Trade Organization (WTO) framework to protect human, animal and plant health. At the same time, compliance with these measures can create technical and institutional challenges for producers in developing countries, particularly when they lack access to appropriate testing facilities, information and support systems (WTO, 1995; Unnevehr, 2000) [2, 1]. Fresh agricultural products, including table grapes, require careful management throughout production, harvesting, post-harvest handling and distribution. Unnevehr (2000) [1] highlighted the food-safety risks associated with fresh food exports and emphasised the importance of farm-to-table approaches, HACCP and public-sector capacity in supporting food-safety assurance. These observations demonstrate why SPS compliance should be considered a coordinated supply-chain activity rather than solely an individual farmer responsibility.

In the Indian context, table grape production and exports are economically relevant to the horticultural sector. According to the Agricultural and Processed Food Products Export Development Authority (APEDA), Maharashtra accounted for more than 69.24 per cent of India's grape production in 2024–25, while Karnataka accounted for 24.63 per cent. APEDA reports that India exported 224,401.27 metric tonnes of grapes, valued at US\$367.99 million, during 2025–26. The major export destinations listed by APEDA included the Netherlands, Russia, the United Kingdom, the United Arab Emirates and Bangladesh. (APEDA, 2026) [3]

India's grape export system also involves formal monitoring and traceability mechanisms. APEDA's GrapeNet platform supports farm registration, laboratory testing, residue analysis, Agmark inspection, phytosanitary certification and traceability-related processes. These institutional arrangements demonstrate the operational significance of compliance systems in the export-oriented grape value chain. (APEDA, 2026) [4] However, the ability of farmers to comply with SPS requirements may be influenced by their technical knowledge, access to testing facilities, record-keeping capabilities, training and financial resources. Henson and Jaffee (2004) examined standards and agro-food exports from developing countries and discussed the importance of institutional capacity and the relationship between standards and international market partici

pation. Similarly, Larcher (2005), as identified in the supplied literature, focused on the costs associated with agri-food safety and SPS compliance, highlighting the relevance of infrastructure and compliance-related expenditure. These perspectives provide a basis for examining compliance as both a technical and an economic activity.

The organization of the purchasing relationship may also influence how farmers manage compliance-related activities. Farmers operating through FPOs, traders or individual marketing arrangements may experience differences in access to buyers, technical guidance, documentation support and compliance services. Bijman (2008) [5] discussed the role of contractual and organizational arrangements in coordinating farmers' access to markets, information and production resources. Consequently, the present study examines whether reported compliance costs differ across the selected purchasing models.

From an agri-business perspective, SPS compliance is connected to the ability of farmers to maintain product quality, satisfy buyer requirements and participate in high-value markets. The supplied literature, including the work of Jaffee and Henson (2004), Henson *et al.* (2008) [6], and Graffham *et al.* (2009) [7], provides a foundation for examining how technical and institutional capacity influences compliance and market participation. These studies also support the importance of considering the costs and organizational requirements associated with standards.

Despite the importance of SPS compliance in the grape value chain, there is a need to examine farmer-level challenges alongside purchasing arrangements and compliance-related market access factors within the local context. Therefore, the present study focuses on grape farmers in Nashik district, Maharashtra, to identify and rank their major SPS compliance challenges, analyses differences in compliance costs across FPO, Trader and Individual purchasing models, and examine the relationship between selected compliance-related factors and market access.

2. Objectives and hypothesis of study

The specific objective of the study was adopted for the study are as follows:

To identify and rank the major SPS compliance challenges faced by grape farmers.

To examine differences in compliance costs across FPO, Trader and Individual purchasing models.

To analyse the relationship between farmers' compliance-related factors and market access.

The Hypothesis from objectives are formed as:

H₀: There is no significant difference in mean compliance costs across the purchasing models.

H₁: There is a significant difference in mean compliance costs across the purchasing models.

H₀: SPS compliance-related factors have no significant joint association with farmers' market-access-related outcome.

H₁: SPS compliance-related factors have a significant joint association with farmers' market-access-related outcome.

3. Material and Methods

3.1 Research design and study area

The study adopted a descriptive and analytical research design to examine SPS compliance challenges, compliance costs and market-access-related factors among grape farmers. The study was conducted in Nashik district, Maharashtra, an important grape-producing region in India. The empirical analysis was based on primary data collected from 50 grape farmers. For the purchasing-model cost comparison, the reported observations comprised 30 farmers distributed equally among FPO, Trader and Individual purchasing models, with 10 farmers in each group.

3.2 Sampling procedure

For the present study, a total sample of 50 farmers was selected. Farmers were selected from Nashik district to represent export-oriented agricultural producers, while the exporters were included to obtain information regarding SPS compliance requirements, purchasing models, and market access practices. The selected sample provides the necessary primary data for achieving the objectives of the study and conducting the proposed statistical analysis.

3.3 Analytical tools and techniques

The study employed Garrett Ranking Technique, one-way ANOVA and multiple regression analysis.

3.3.1 Garrett's ranking technique

Garrett's Ranking Technique will be used to prioritize the SPS compliance challenges faced by farmers.

The percentage position will be calculated as:

$$\text{Percentage Position} = \frac{100(R_{ij} - 0.5)}{N_j}$$

Where:

R_{ij} = Rank given to the i^{th} factor by the j^{th} respondent

N_j = Total number of factors ranked by the j^{th} respondent

The percentage position will then be converted into Garrett scores using the standard Garrett conversion table.

The mean Garrett score will be calculated as:

$$\text{Mean Garrett Score} = \frac{\sum \text{Garrett Scores}}{N}$$

The factors will be ranked in descending order of their mean Garrett scores. The factor having the highest mean score will be considered the most important constraint.

3.3.2 One-way analysis of variance (ANOVA)

One-way ANOVA will be used to determine whether the mean SPS compliance cost differs significantly among FPO, Trader and Individual purchasing models.

The F -statistic will be calculated as:

$$F = \frac{MS_B}{MS_W}$$

Where:

$$MS_B = \frac{SS_B}{k - 1}$$

$$MS_W = \frac{SS_W}{N - k}$$

Therefore,

$$F = \frac{SS_B/(k - 1)}{SS_W/(N - k)}$$

Where:

SS_B = Sum of Squares Between Groups

SS_W = Sum of Squares Within Groups

k = Number of groups

N = Total number of observations

MS_B = Mean Square Between Groups

MS_W = Mean Square Within Groups

The resulting F -value and p -value will be used to determine whether the differences in compliance costs among purchasing models are statistically significant at the 5 per cent level.

3.3.3 Multiple regression analysis

Multiple regression analysis will be employed to determine the influence of SPS compliance factors on farmers' access to high-value markets.

The regression model will be specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_k X_k + \varepsilon$$

Where:

Y = Farmers' access to high-value markets

β_0 = Intercept/constant

$X_1, X_2, \dots, X_k$ = SPS compliance factors

$\beta_1, \beta_2, \dots, \beta_k$ = Regression coefficients

ε = Error term

The coefficient of determination will be calculated as:

$$R^2 = 1 - \frac{SS_{Residual}}{SS_{Total}}$$

The adjusted coefficient of determination will be calculated as:

$$Adjusted R^2 = 1 - \left(1 - R^2\right) \frac{N - 1}{N - k - 1}$$

The significance of individual independent variables will be assessed using the t -statistic:

$$t = \frac{\widehat{\beta}_i}{SE(\widehat{\beta}_i)}$$

The overall significance of the regression model will be assessed using the F -test. The results will be interpreted at the 5 per cent level of significance.

4. Results

4.1 SPS compliance challenges faced by farmers

The adoption of SPS compliance practices requires farmers to manage technical, operational and market-related requirements. In the present study, five major challenges were assessed using the Garrett Ranking Technique: technical knowledge about SPS regulations, meeting high-value market access through quality production, documentation and record keeping for MRL management, availability of training and facilities, and the cost of meeting SPS standards.

Technical knowledge about SPS regulations received the highest Garrett score of 3,750 and was ranked first. This finding indicates that respondents perceived knowledge-related constraints as the most im-

portant challenge among those examined. SPS compliance requires an understanding of pesticide application practices, residue requirements, pre-harvest intervals, traceability and associated documentation. The second-ranked challenge was meeting high-value market access through quality production, with a Garrett score of 3,000. This finding reflects the importance of maintaining quality and compliance requirements in accessing higher-value markets. Documentation and record keeping for MRL management ranked third, with a score of 2,500. Accurate records of pesticide applications, dosages, application dates and relevant production activities support traceability and compliance monitoring. Availability of training and facilities ranked fourth, with a score of 2,000. The cost of meeting SPS standards received the lowest ranking, with a score of 1,200. The finding should therefore be interpreted as a relative ranking of perceived challenges, not as evidence that compliance costs have no economic effect.

Table 1. Garrett Ranking of SPS Compliance Challenges

Sr. No.	Challenge	Garrett Score	Rank
1	Technical knowledge about SPS regulations	3,750	I
2	Meeting high-value market access through quality production	3,000	II
3	Documentation and record keeping for MRL management	2,500	III
4	Availability of training and facilities	2,000	IV
5	Cost of meeting SPS standards	1,200	V

Source: Field survey data.

4.2 Compliance cost across purchasing models

The purchasing-model analysis examined differences in the reported mean compliance costs of farmers operating through FPO, Trader and Individual arrangements.

The Individual purchasing model recorded the highest mean compliance cost at ₹21,750, followed by the Trader model at ₹15,355 and the FPO model at ₹15,100. The difference between the Individual and FPO mean costs was ₹6,650 based on the reported values.

The Individual model also recorded the highest standard deviation, indicating greater dispersion in reported compliance costs within this sample. The relatively lower standard deviations of the FPO and Trader groups indicate less variation in their reported costs.

Table 2. Compliance Cost by Purchasing Model

Purchasing Model	Farmers	Mean Cost (₹)	SD (₹)
FPO	10	15,100	349.60
Trader	10	15,355	311.31
Individual	10	21,750	1,342.68

Source: Field survey data.

These results showed differences in the observed purchasing-model groups. They do not independently establish that FPO participation causes lower compliance costs, because other factors such as farm size, exporter arrangements, service access and production characteristics may also influence expenditure.

4.3 One-way ANOVA of compliance costs

Table 3. One-Way ANOVA of Compliance Costs

Source	SS	df	MS	F-value	p-value
Between Groups	28,39,45,166.67	2	14,19,72,583.33	210.65	3.37×10^{-17}
Within Groups	1,81,97,250.00	27	6,73,972.22	—	—
Total	30,21,42,416.67	29	—	—	—

(continued on next page)

Source: Computed from field survey data.

The one-way ANOVA reported an F -value of 210.65 and a p -value of 3.37×10^{-17} . At the 5 per cent significance level, the null hypothesis of equal mean compliance costs across the three purchasing models is rejected. Here, H_0 is rejected based on the reported ANOVA result. The observed cost differences provide a basis for examining whether institutional arrangements, shared services and coordination mechanisms are associated with compliance expenditure. A stronger causal

interpretation would require controlling for relevant farmer and farm-level characteristics.

4.4 Multiple regression analysis of compliance factors and market access

The multiple regression analysis examined the reported relationship between cost, facilities and training, documentation, technical ability, and the market-access-related dependent variable.

Table 4. Multiple Regression Analysis

Factor	β	t -value	p -value	Significance
Constant	-0.447	-0.528	0.600	Not significant
Cost (X1)	0.379	3.222	0.002	Significant
Facilities and Training (X2)	0.051	0.786	0.436	Not significant
Documentation (X3)	0.165	1.232	0.224	Not significant
Technical (X4)	0.217	1.606	0.115	Not significant

Source: Computed from field survey data.

The cost variable recorded a positive regression coefficient of 0.379 and was statistically significant at the 5 per cent level ($p = 0.002$). This result indicates a positive statistical association between the cost variable and the dependent variable, conditional on the other variables included in the model. The direction of the relationship should be interpreted in accordance with the exact coding of the cost construct and the dependent variable.

Facilities and training, documentation, and technical ability were not statistically significant individually at the 5 per cent level. Their lack of individual statistical significance does not establish that these factors are irrelevant to SPS compliance. It indicates that the study did not identify sufficient evidence of an independent association at the specified significance level, given the model and sample.

Table 5. Summary of Regression Model

Test	Result
R^2	0.728
Adjusted R^2	0.703
F -value	30.09
Significance F	3.326×10^{-12}

The reported R^2 of 0.728 indicates that approximately 72.8 per cent of the variation in the dependent variable is explained by the included predictors within the estimated sample model. The adjusted R^2 of 0.703 accounts for the number of predictors in the model.

The overall regression model was reported as statistically significant ($F = 30.09$, $p = 3.326 \times 10^{-12}$). Thus, the model provides evidence of a statistically significant joint association between the explanatory variables and the dependent variable. The result should not be interpreted as proof that the predictors causally improve market access. Based on the reported regression model, the overall F -test was statistically significant ($F = 30.09$, $p = 3.326 \times 10^{-12}$). Therefore, H_0 is rejected for the joint model test.

5. Discussion

The findings demonstrate that SPS compliance among grape farmers involves multiple interconnected technical, institutional and economic dimensions. Technical knowledge was the highest-ranked perceived challenge, suggesting that farmers' understanding of regulatory requirements is an important component of compliance management. This finding is relevant to the broader functioning of agricultural value chains, where producers must coordinate production practices with quality standards, testing procedures and market requirements.

The significant variation in compliance costs across purchasing models indicates that the organization of market participation may be associated with farmers' compliance expenditure. The higher reported cost in the Individual model warrants further investigation into differences in service access, testing arrangements, farm characteristics and buyer requirements. However, the present findings cannot independently establish that one purchasing model is more cost-effective after controlling for these factors.

The regression results provide evidence of a statistically significant joint relationship between the selected explanatory variables and the reported market-access-related outcome. The positive and significant coefficient for cost requires careful interpretation because the direction of the association depends on how the variable was measured. Future research could improve the analysis by defining the constructs clearly, testing for multicollinearity and including relevant control variables.

SPS compliance can be understood as a value-chain management function involving farmers, exporters, laboratories, packhouses, regulatory institutions and buyers. Strengthening coordination among these stakeholders may help farmers access technical information, compliance facilities and market requirements more efficiently.

6. Conclusion

The study examined SPS compliance challenges, differences in compliance costs across purchasing models and the relationship between compliance-related factors and market access among grape farmers.

The Garrett ranking results identified technical knowledge about SPS regulations as the highest-ranked perceived challenge. Meeting high-value market requirements through quality production and documentation and record keeping were ranked second and third, respectively. The findings highlight the importance of farmer-level technical knowledge and operational compliance capabilities.

The ANOVA results indicated statistically significant differences in reported mean compliance costs across FPO, Trader and Individual purchasing models. The regression analysis also reported a statistically significant overall model, with cost being the only individually significant predictor.

The findings suggest that strengthening SPS compliance requires co-ordinated interventions involving technical training, accessible testing infrastructure, documentation support and market-oriented production management. However, the study's cross-sectional data and reported model structure limit causal interpretation. Further research should incorporate control variables, post-hoc comparisons and validated measures of market access to establish more robust evidence for policy and business decisions.

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8. Competing interests

Authors have declared that no competing interests exist.

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