TARGETING KEY CONSTRAINTS: EMPIRICAL ANALYSIS OF SIX MAJOR FACTORS INFLUENCING HORTICULTURE PRODUCTIVITY IN KUMAON

Tara Chandra[1*], Ravi Sanwal[2]

[1]Research Scholar, S.V. Govt. P.G. College, Lohaghat, Uttarakhand, India
[2]Assistant Professor, S.V. Govt. P.G. College Lohaghat, Uttarakhand, India

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Abstract: Horticulture contributes significantly to agricultural production and rural economic growth in hilly areas, where traditional crop production potential is low. But, because of the geographic complexities, there are many challenges in the way of the industry's commercialization and production in areas, such as Kumaon region of Uttarakhand. The objective of this study is to assess the intensity of the six most significant constraints perceived by horticulture producers, which considerably impact horticultural production in the Kumaon region. The study identifies six major constraints that are listed as wildlife interference, lack of horticulture storage infrastructure, high transportation cost, unavailability of regional horticulture-based enterprises, unavailability of structured procurement mechanisms, and small size of agricultural landholding. Based on the producers' assessments, their collective impact is measured against the dependent variable, 'the level of horticulture productivity'. The five-point Likert scale has been employed in this study as a primary method of collecting data from horticulturists to structure and quantify these challenges. Furthermore, multiple regression analysis is employed to assess the relative impact of each constraint on horticulture productivity. This study will provide clear insights into the constraints that need to be addressed through various steps and measures by different stakeholders. The research thus contributes to the wider debate on the development of sustainable horticulture in mountain areas, identifying the key issues. It even suggests practical policy measures for effective productivity, improved market access, and long-term profitability of horticulture in Kumaon.

Keywords: Horticultural constraints, Horticultural productivity, Kumaon, Multiple regression analysis, Wildlife interference.

Introduction

Horticultural production is an important part of the agricultural economy across the world and is especially important in mountainous areas, providing livelihood and employment. The Kumaon region of the state of Uttarakhand holds significant opportunities for horticulture-based livelihood generation owing to diverse agro-climatic conditions supporting a variety of high-value crop cultivation[1]; notwithstanding this potential, horticulture productivity in the region is restricted by multiple infrastructural, operational, and economic challenges leading to limited commercialization and sustained growth. Finding solutions to these limitations is the key to increase farmers' income, strengthening regional economies and ensuring food security in hilly regions.

One of the immediate challenges is the insufficient post-harvest framework and logistical inefficiency. This results in high post-harvest losses, low profit margins, and acts as a discouragement for farmers to invest in horticulture without the development of cold storage and efficient transportation networks[2]. Farmers lack proper storage mechanisms and are then forced to sell their produce at low prices, which leads to further income instability. Moreover, expensive transportation due to unfavorable topographies and insufficient road conditions restricts market access and stabilization of profits, which embattles horticulturists to outcompete in the market[3]. Absence of structured procurement mechanisms and organized market linkages is another significant constraint in horticulture commercialization. Fragmented supply chains and inadequate institutional support have relegated many farmers to low-end markets[4]. In the horticultural sector, informal intermediaries are the norm, and the price that farmers get is

often a mere fraction of the price in the final market. However, improving structured procurement systems and direct farmer-market linkages can improve price realization and reduce market volatility[5].

There are a number of regional horticulture based enterprises that contribute significantly to the growth of the horticultural economy in Maharashtra; however, they remain undeveloped[6]. Through the establishment of processing units, value addition, and cooperatives, it can provide richer economic avenues by diversifying farmers' revenues. Nonetheless, investment in these types of enterprises remains scarce, and access to financial support in general is limited. Government subsidies and initiatives, as well as providing private-sector involvement, will help in promoting entrepreneurship in horticulture—this would help unlock the potential of the sector[7]. Another major threat in the region comes from wildlife and its interference, which often results in crop damage and monetary loss to farmers. The proximity of agricultural lands to forests has significantly contributed to the problem of wildlife visiting agricultural fields[8]. Farmers face a lack of effective wildlife management strategies, which discourages them from protecting their horticulture ventures, which leads to a further limitation in productivity. Community-driven controlling strategies, compensation policies, and sustainable land-use planning can help offset this growing concern[9].

Another factor that influences horticulture productivity is the landholding size. While the general assumption is that larger agricultural landholdings yield higher output, research shows that landholding size does not always correlate with productivity in the hilly terrains of Kumaon[10]. Rather, the critical determinants of success in horticulture are access to technology, quality inputs, and financial aids. As land in India is still fragmented, so cooperative land consolidation and farming models are vital to the maximization of production[11]. In larger conceptual terms, horticulture has greatly benefitted due to government interventions and the development of rural infrastructure[12]. In some of those agricultural regions, policies that subsidized inputs, strengthened extension services, and developed connectivity to rural areas had positive effects. But such policies are not sufficiently implemented in mountainous terrains, which make them incapable to address the core limitations of farmers. There is the need of effective action, such as strengthening institutional support and access to credit, to make horticulture sustainable and profitable[13].

Regional migration trends further show a departure from agriculture as a principal livelihood opportunity, citing one of the contributing factors as a lack of economic opportunities coupled with the high risk of agrarian-based livelihood activities[14]. The exit of farmers, especially younger generations, to urban areas for more stable work reflects this trend. Efforts towards employment generation via horticultural value chains, agribusiness opportunities, skill development programs, etc. can help retain the rural workforce and develop long-term agricultural sustainability[15]. Back in the context of worldwide agricultural improvement, marketplace integration and structural transformation have been cited as key solutions to the issue of sustainable agricultural development. Horticulture productivity and efficiency could be improved by the use of technological advancements, smart irrigation systems, and precision agriculture[16]. Kumaon region, which has lesser adoption of these practices, there is little awareness and accessibility to such innovations. This gap can be filled by encouraging tech-enabled interventions and farmer education programs to accelerate modern horticultural practices[4].

This paper attempts to contribute towards that end with an empirical analysis of six major constraints affecting horticulture production in Kumaon, which is missing in the literature to date. With its focus on these critical issues, the research aims to advance the understanding of how to build a sustainable horticulture industry in mountainous areas. The insights derived from this analysis will provide recommendations for pathways forward to assist policymakers in determining when and where to intervene at the most impactful scale, with the goal of achieving meaningful and timely progress towards meeting the broader target. The horticulture sector in Kumaon can be developed into a sustainable and economically viable sector through evidence-based policy making, infrastructural interventions, and effective farmer support systems.

Key horticultural constraints

This study focuses on six major constraints that significantly affect Kumaon's horticultural productivity. The producers' perception of the current state of constraint gravity, measured on a five-point Likert scale, is used to deal with these constraints, and the quantitative level of "Horticulture productivity," which is also measured on a five-

point Likert scale, is used as the dependent variable to evaluate the relative impact of these constraints, which are treated as independent variables:

(I) Addressing Wildlife Interference
(II) Adequacy of Horticulture Storage Infrastructure
(III) Affordability of Transportation Costs
(IV) Availability of Regional Horticulture Based Enterprises
(V) Availability of Structured Procurement Mechanisms
(VI) Size of Agricultural Landholding

Research Objectives

(I) To examine whether any of the six identified constraints have a significant impact on horticulture productivity in the Kumaon region.
(II) To determine the relative influence of each constraint on horticulture productivity through multiple regression analysis and rank the constraints based on their impact.
(III) To provide policy recommendations and strategic interventions for addressing the most significant constraints, thereby enhancing horticulture productivity in the region.

Research Question and Hypotheses

"Do any of the six identified constraints have a significant impact on horticulture productivity in the Kumaon region?" is the study's subject of investigation. The hypotheses for the research question are as follows:

(I) Null Hypothesis (H0): None of the six identified constraints have a significant impact on horticulture productivity in the Kumaon region.
(II) Alternative Hypothesis (H1): At least one of the six identified constraints has a significant impact on horticulture productivity in the Kumaon region.

Materials and Methodology

Research Design

As horticulture is typically associated with the agrarian class of people; hence the study adopts descriptive and explanatory research design under quantitative research approach to understand the impact of any of the six identified constraints on horticulture productivity of the Kumaon region. Using primary data collection and statistical analysis, the study is able to quantify the relative effect of those constraints on horticulture productivity. The study is based on primary data collected from horticulturists of all six districts of Kumaon region by a structured survey questionnaire. A five-point Likert scale is employed in the questionnaire to evaluate horticulturists' perception of horticulture productivity and the influence of six major constraints. Horticulturists without any classification in landholding sizes are chosen using a multistage sampling process. This study includes 368 horticulturists so that regression analysis is statistically valid.

Data Analysis Techniques

The data on the six constraining factors in the productivity of horticulture is analyzed using a range of statistic processes using SPSS 30.0, in addition to descriptive and frequency distribution statistics, Model summary, ANOVA and Regression coefficients analysis has been studied under multiple linear regression analysis (MLR) to see whether any of the six identified constraints influences the productivity of horticulture significantly or not and rank them on the basis of statistical significance and relative influence. The internal consistency of the Likert scale variables was examined by Cronbach's Alpha. Also, to strengthen the validity and reliability of research, the questionnaire was tested on a small scale before the data was collected on a larger scale. All ethical principles related to the research process were followed to protect respondents' identities. This study was conducted in accordance with the code of ethics in research, and the data collected were used solely for academic research.

Results and Discussion

Descriptive Statistics

Table 1 presents the descriptive statistics of the six identified constraints and the dependent variable, horticulture productivity, measured on a five-point Likert scale. Statistical significance is observed with a sample size of n=368 respondents. Across all factors, the mean varies between 2.02 (with 1 being not at all constrained, and 5 being highly constrained), indicating that respondents perceive moderate constraints when averaged across all factors. Among the independent variables, horticulture storage infrastructures showed a minimum mean (2.02), meaning there is no adequate horticulture storage facility available; thus, horticulturists consider this issue as a very common issue. Similarly, constraints such as affordability of transportation cost (2.03), Availability of regional horticulture-based enterprises (2.05), and Availability of structured procurement mechanism (2.06) show comparatively lower mean values, indicating general issues in this regard. The standard deviation numeric values that indicate variability in responses show the differing views. It could be because of differences in landholding sizes, access to internal markets, or availability of resources. Maximum standard deviation observed with procurement mechanisms (1.167) and regional horticulture-based enterprises (1.109), while horticulture storage infrastructures have the least standard deviation, which shows that jointly farmers feel storage infrastructures, are inadequate.

Table 1: Descriptive Statistics

	N	Min.	Max.	Mean	Std. Deviation
Addressing wildlife interference	368	1	5	2.08	1.070
Adequacy of horticulture storage infrastructure	368	1	5	2.02	.983
Affordability of transportation cost	368	1	5	2.03	1.105
Availability of regional horticulture based enterprises	368	1	5	2.05	1.109
Availability of structured procurement mechanism	368	1	5	2.06	1.167
Size of agricultural land holding	368	1	5	2.08	1.052
Horticulture productivity	368	1	5	2.08	1.190
Valid N (list wise)	368				

(Source: Compiled from SPSS 30 output)

It can be understood from the descriptive statistics, that the perception of contribution towards horticulture productivity is relatively poor (in low numbers). Infrastructures and market-related constraints in this aspect are the major contributing factors towards low productivity. The mean values for all the constraints show relatively low values, indicating that all respondents regarded this factor as a constraint to productivity. The differences in standard deviations convey differences in experience, particularly at the market access and procurement level. These results provide a foundation for statistical analysis 'Multiple Linear Regression' to analyze the degree to which these constraints are significantly impacting the horticulture productivity of Kumaon region.

Reliability Statistics

Commonly used metrics of internal consistency assess the extent to which survey items measuring the same constructs are correlated. Seven items were included in this study. 'Cronbach's alpha' value is the number that shows reliability and level of internal consistency of the Likert scale items measured in this construct of horticulture constraints and productivity. Table 2 shows Cronbach's Alpha value of 0.967 for this construct.

Table 2: Reliability Statistics

Cronbach's Alpha	N of Items
.967	7

(Source: Compiled from SPSS 30 output)

As it is above the commonly accepted threshold of 0.7 for good reliability and 0.9 for excellent reliability, hence it is considered excellent. This indicates that the responses to the seven variables (horticulture productivity and six identified constraints) are highly consistent across the sample of 368 respondents

Model Summary

Model Summary in Table 3 provides the statistics for the regression model that help evaluate the strength and the appropriateness of the regression model for horticulture productivity analysis in the Kumaon region.

Table 3: Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.948[a]	.898	.896	.383	2.027

(Source: Compiled from SPSS 30 output)

a. Independent variables
b. Dependent Variable: Horticulture productivity

Also, R-value (0.948) affirms strong positive correlation between independent variables and dependent variable i.e. the selected constraints are very much influential to horticulture productivity. A high value of R indicates that variations in horticulture productivity would be sufficiently explained by the six independent variables included in this study. The R-Square (0.898) shows that the regression model explains 89.8% of the variance in horticulture productivity. This indicates that the six constraints included in the analysis largely explain a significant share of the variation in horticulture productivity. This means that still 10.2% of the variance is unexplored by the variables included in the model. The Adjusted R Square (.896) is slightly lower than the R squared (0.896) as it corrects for the number of independent variables. A less degree of difference shows well-fitted model and non over fitted, which ensures its reliability in approximating horticulture productivity trends. The Standard Error of the Estimate (0.383) is the standard deviation of the prediction errors, which indicates how far the predicted values are from the actual horticulture productivity values on average. A lower standard error is confirming that we have a valid model for the data. The autoc

orrelation within the residuals in the regression model is being measured by the Durbin-Watson statistic (2.027).

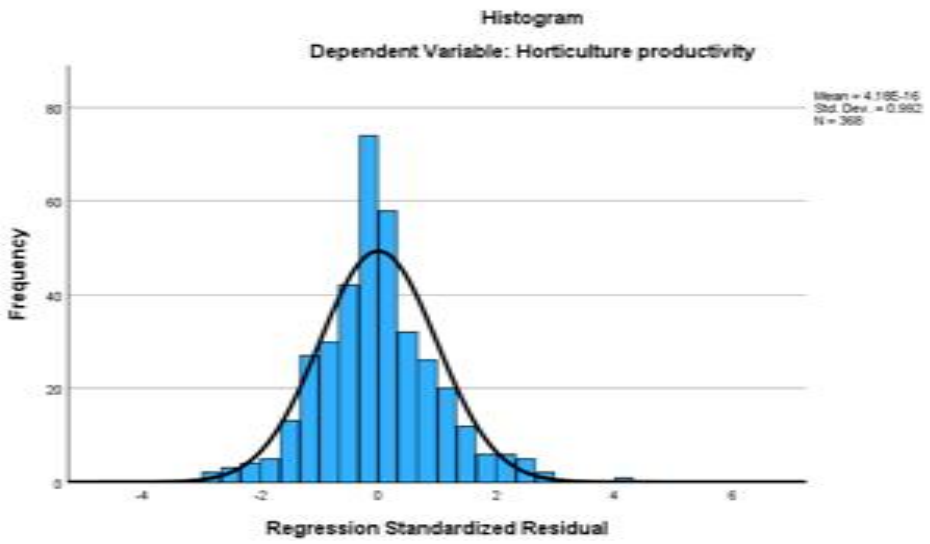

Fig.1: Evaluating the Normality of Residuals

A value near 2.0 indicates residual independence, i.e., there are no major autocorrelation problems. It is one of the essential assumptions in regression analysis. The model summary results suggest that the independent variables selected are strongly influencing horticulture productivity, and thus, this regression model is statistically robust and reliable for further analysis.

ANOVA

To see if the independent variables collectively significantly contribute to the productivity of horticulture, Table 4 represents ANOVA (Analysis of Variance). It tests the overall significance of the regression model. The variation that is attributable to the effects of the six independent variables in the model is the Regression Sum of Squares (466.563). A high value implies that the independent variables (predictors) explain a large amount of the variation in the dependent variable. The left unaccounted amount of variance in horticulture productivity is measured by specified Residual Sum of Squares (52.991). A lower residual sum of squares than the regression sum of squares indicates that the model captures the key factors affecting horticulture productivity.

Table 4: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	466.563	6	77.761	529.738	<.001[b]
	Residual	52.991	361	.147		
	Total	519.554	367			

(Source: Compiled from SPSS 30 output)

a. Dependent Variable: Horticulture productivity
b. Six Independent variables

In this model, the Total Sum of Squares (519.554) can be represented as the sum of the regression and the residual sums of squares that indicate the total variability in the data set. The mean square values are obtained by dividing the sum of squares by the respective degrees of freedom (df). The Mean Square for Regression (77.761) is significantly higher than the Mean Square for Residuals (0.147); it confirms the substantial contribution of independent variables in explaining variations in horticulture productivity. The F-statistic (529.738) measures how well the independent variables explain variation in the dependent variable. The higher F-value indicates that the regression model explains variations strongly. The associated significance value ($p < 0.001$) indicates that the regression model is highly significant, and at least one of the independent variables has a significant impact on horticulture productivity. As the p-value is well below the conventional 0.05 threshold, we can confidently reject the null hypothesis, i.e., 'none of the six identified constraints have a significant impact on horticulture productivity.' Therefore, by the ANOVA results, it is confirmed that the regression model is statistically significant and effectively explains the variation in horticulture productivity.

Multiple Linear Regression Coefficients Analysis

The regression coefficients shown in Table 5 summarize the impact of six independent variables which affects the productivity of horticulture in the Kumaon region. All coefficients enable us to assess the degree of impact and the importance of each constraint on horticulture productivity for their respective ranking. Unstandardized coefficients (B-values), standardized coefficients (Beta), t-values, significance (p-values), and collinearity statistics (Tolerance and VIF values) are examined in this analysis for evaluation of reliability and predictive power of the regression model.

Table 5: Multiple Linear Regression Coefficients

Model	Unstandardized Coefficients		Std. Coff.	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-.268	.048		-5.578	<.001		
Addressing wildlife interference	.178	.036	.160	4.951	<.001	.270	3.703
Adequacy of horticulture storage	.305	.039	.252	7.741	<.001		

	infrastructure						.267	3.748
1	Affordability of transportation cost	.329	.039	.306	8.408	<.001	.214	4.676
	Availability of regional horticulture based enterprises	.128	.036	.120	3.537	<.001	.247	4.048
	Availability of structured procurement mechanism	.145	.039	.142	3.753	<.001	.196	5.097
	Size of agricultural land holding	.065	.037	.058	1.749	.081	.260	3.845
(Source: Compiled from SPSS 30 output)								

The constant (-0.268) is the predicted level of horticulture productivity when all independent variables are equal to zero.

Because this constant is negative and significant ($t = -5.578$, $p < 0.001$), it instructs that if there is no change in any of the six constraints, horticulture productivity itself would be low or even negative. This highlights the fundamental importance of infrastructure and operational enhancements in productivity progress. Certainly, within constraints, wildlife interference is one of the most detrimental constraints affecting horticulture productivity, ($p < 0.001$). The B-value of 0.178 indicates that wildlife management strategies could accelerate horticulture productivity by 0.178 units for every unit increment. Wildlife interference is classified as a moderately significant constraint, as indicated by the Beta value (0.160). As wildlife intrusion is a recurrent problem in mountainous areas, farmers lose a lot of crops and money resulting in low productivity. Such a constraint highlights the necessity for effective wildlife management approaches including fencing, mitigation initiatives driven by communities and compensation policies to enhance horticulture yield in Kumaon.

'Adequacy of horticulture storage infrastructure' is the constraint in the study affecting horticulture productivity. The 'B' value of 0.305 means that one-unit improvement in horticulture storage infrastructure will increase horticulture productivity by 0.305 units. The beta value (0.252) indicates that storage deficiencies are the second most critical factor (among the six factors studied). This indicates the urgent need for post-harvest management solutions, especially in agriculture-dominated rural areas having limited access to cold storage and preservation facilities. The establishment of better storage infrastructure may reduce post-harvest losses, which ultimately improves the product quality and market competitiveness.

Of all the constraints assessed, transportation cost affordability appears to be the best predictor for horticulture productivity. The obtained B (0.329) indicates a direct impact, which specifies that as transportation affordability increases by one unit, horticulture productivity increases by 0.329 units. Transportation costs have the highest Beta value (0.306) out of any predictive factor, indicating it is the strongest factor affecting productivity. Farmers face high transportation costs that limit access to markets, increase input costs, and lower profitability. Thus, efforts that reduce transportation expanses and collaborative logistics can have a high impact on increasing horticulture productivity.

The distribution of regional horticulture-based enterprises is another element that influences horticulture productivity, although it has a lesser impact than the other factors. For the B-value (0.128), improving regional enterprises by one unit would increase productivity by 0.128 units. Its (0.120) Beta value suggests that it is one of the least significant factors in the study. It finds that despite their lower impact, regional companies contribute significantly to the horticulture value chain through market access, agro-processing, and alternative income for farmers.

The 'Availability of structured procurement mechanisms' is another statistically significant predictor of horticulture productivity. The B-values (0.145) mean that for a one-unit improvement of structured procurement, productivity will increase by 0.145 units. The low Beta value (0.142) indicates that procurement mechanisms represent an essential but less significant factor than transportation and storage infrastructure. Procurement mechanisms, when designed well, can minimize volatility while ensuring price realization for farmers. Direct procurement channels, integrated farm gates, contract farming models, and cooperative supply chain systems need to be strengthened for effective and cost-efficient distribution of food products.

Only the size of agricultural landholding is not significant at the 5% level (p = 0.081). Landholding size occupies the least significant impact on horticulture productivity, as indicated by the B-value (0.065) and the Beta value (0.058), the lowest of all factors. Therefore, the finding suggests that of all the constraints, only land size is not a key determinant of horticulture productivity in Kumaon, whereas improved storage, transport, and market linkages become more important. This result is in line with earlier studies showing that while all forms of productive engagement are important, the amount of landholding may be less of a determinant of productivity levels compared to support relating to technology, finance, and infrastructural dimensions.

Looking at the collinearity statistics (Tolerance & VIF values), all VIF (Variance Inflation Factor) values lie between 3.703 and 5.097, which indicates that there is no serious multicollinearity problem among the independent variables. All the tolerance values are above 0.196, which indicates that each variable provides distinct additional information in the regression model. This confirms that the results are statistically sound and the predictors do not overlap unduly in explaining horticultural productivity.

The analysis of a regression reveals that the affordability of transportation cost, storage infrastructure, and wildlife interference are the dominant factors that influence horticulture productivity in Kumaon region. The size of agricultural landholding is not statistically significant, which means that productivity is more influenced by infrastructure, logistics and institutional mechanisms than by the size of the farm. Therefore, these results show the necessity for targeted interventions with respect to transportation networks, storage structures and formal market access, which can enhance the commercialization of horticulture, as well as improve the financial feasibility of farmers. This would be an important step towards making horticulture productivity a potential source of sustainable income for the farmers in the Kumaon region through evidence-based policymaking and strategic investment.

Conclusion and Implications

According to the findings of this study, producers consider 'transportation cost' and 'inadequate horticulture storage facilities' as the two most significant constraints affecting horticulture productivity in the region respectively. 'Wildlife interference,' 'non-availability of structured procurement mechanism,' and 'non-availability of regional horticulture-based enterprises' rank third, fourth, and fifth, respectively. Horticulturists perceived 'size of agricultural landholding' to be the least significant constraint out of the six tested under this construct. As a result, five of the six constraints have a significant effect on horticulture productivity, and the study's findings support the rejection of the 'Null Hypothesis' in favor of the alternate hypothesis, i.e., 'At least one of the constraints has a significant effect on horticulture productivity.'

To increase horticulture productivity and commercialization, stakeholders, particularly the state government, must work together to plan and create horticulture infrastructure that is helpful for the producers living in the region's most distant places. Transportation costs and insufficient horticulture storage infrastructure are the two most significant constraints respectively, requiring huge investment that is difficult to implement immediately even for the state government. 'Wildlife interference,' which is considered the third most significant constraint in the region, can be effectively addressed by producers through the application of technological innovations, but scattered landholding remains an obstacle in this regard. The fourth and fifth most important obstacles, 'non-availability of 'structured procurement mechanism' and 'regional horticulture-based enterprises,' both require significant public participation in this sector, which is challenging in the current situation. Given the scope of the obstacles, the state government's active involvement in regulating the production and sale of locally produced horticulture products is expected to bring positive outcomes. The village panchayat' well-established networking can be used in the production and procurement method, motivating producers for assured sale of their output. This approach may also make it easier for entrepreneurs to establish regional horticulture firms. These steps can effectively address the issues associated with constraints.

Overall, this study shows that targeted infrastructure upgrades and government involvement are needed to increase horticultural production in the Kumaon region. The guidelines below can assist in determining policies and initiatives for promoting sustainability in the horticulture sector.

(I) Development of horticulture infrastructure in the region that meets the requirements of the people, even in remote areas.
(II) Providing producers with cost-effective technical solutions for managing wildlife interference.
(III) Considering land consolidation to decrease fragmented landholdings and promote cooperative agriculture to control wild life interference.
(IV) Interference by the state government through village panchayat in regulating the production, procurement, grading, packing, and selling of local horticultural output for a specific period of time.

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Conflict of Interest: The study followed all ethical guidelines in data collection and reporting, hence, there are no conflicts of interest. The study followed the ethical principles suggested in the academic rules.

Data Availability Statement: The data used in this study includes participants' personal information, which cannot be shared publicly due to privacy and legal restrictions. However, the remaining dataset supporting this study is available from the corresponding author on reasonable request.

Authors' Contribution: TC contributed to the data collection, data analysis, and writing of the original draft of this study. RS contributed to the conceptualization, supervision, theoretical guidance, review, and editing, ensuring the academic integrity of the research. Both authors have read and approved the final manuscript.

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