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Dynamic Patterns of Varietal Diversification Across Major Apple Producing State of India: A Diversification and Perception Analysis

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DYNAMIC PATTERNS OF VARIETAL DIVERSIFICATION ACROSS MAJOR APPLE PRODUCING STATE OF INDIA: A DIVERSIFICATION AND PERCEPTION ANALYSIS.

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Abstract

Delicious cultivars have long been the predominant varieties of apple grown in Himachal Pradesh and the resultant production system of monoculture has become more susceptible to climatic changes and market volatility. The current research investigated the aspect of varietal diversification and the perception of farmers on new apple varieties in seven major districts of apples production by using primary data consisting of 420 growers selected using a multi-stage sampling method. The Simpson Diversity Index (SDI) and Herfindahl-Hirschman Index (HHI) were used to determine varietal diversification whereas the Response Priority Index (RPI) was used to determine perception of the farmers. The findings showed moderate diversification with HHI and SDI of 0.307 and 0.693 respectively. There was a gradual varietal change with Traditional Delicious Standard varieties dominating bearing orchards and non-bearing orchards with a higher proportion of improved varieties like Delicious Spur and Gala. The lower altitude areas like Kullu, Mandi and Sirmour had higher diversification whereas the higher altitude areas had more concentration under few varieties. The perceived analysis showed that the initial establishment cost was the major perceived attribute but the properties like increase in yield potential, consistency in quality of fruits and early fruiting were the greatest motivation for adoption. Environmental factors like low usage of pesticides were not significant consideration. The paper identified a structural transformation in the production of apples and the necessity to support policy intervention to encourage cost-efficient and climate-resistant varietal diversification.

Apple cultivation; Farmers' perception; Herfindahl–Hirschman Index; Simpson's Diversity Index; Varietal diversification

INTRODUCTION

Varietal diversity has long been recognized as an important aspect in attaining diverse set of goals in agricultural production systems. Gotor et al. (2021) demonstrated that higher varietal diversification enhances food security by improving productivity, raising adaptive capacity to climate vulnerability, and strengthening resilience in vulnerable agricultural systems. De Han et al. (2019) suggested that wide array of crop varieties help in enhancing food and nutritional security by improving the composition of diet through supplying essential nutrients. Gatto et al. (2021) in their study highlighted that maintaining varietal

diversity enhances resilience, builds resistance against pests and diseases, and contributes to sustainability of food systems. In Himachal Pradesh, a state located in the northern part on India, the production of Apple has long been dominated by cultivars of the traditional Delicious group, and therefore a monoculture production system has been established (Sharma 2026). Although these traditional varieties have continued to be popular because of their flexibility and preference in the market, these monocultures practices have been more prone to the environmental changes (Nautiyal et al. 2020). The strong dependency on traditional varieties has led to the concern of the sustainability and resilience of the apple production systems in the state. Over recent years, the temperate Himalayan region has undergone major climatic variations such as rise in temperature and reduction in snowfall (Sabin et al. 2020). Such changes have direct influence on the functionality of the old varieties of apples, as they need higher chilling hours for flower and fruit development. This has negatively affected the productivity of the low altitude apple growing regions. Priyanka and Bhardwaj (2020) in their study found that Kullu valley and some parts of Shimla district faced decline in chilling hours accumulation, thus leading to indications of reduced production of apples in these areas whereas, production was slowly moving towards areas of higher altitude where climatic conditions were more favorable (Rana et al. 2011). These changes in the apple growing belts is a clear indication of the growing impact of climate change to the horticultural systems in the state. To manage these new challenges, diversification towards better and improved varieties of apples that are more adapted to the changes in climatic conditions has been an effective strategy. New cultivars, such as Spur and Gala, are also gaining popularity among farmers due to their reduced chilling requirements and early bearing production (Rani et al. 2024). Sharma et al. (2017) found that various stains of Spur and Gala are potentially beneficial in terms of yield, quality of fruits and economic rewards in sub-temperate mid-hills, thus showing their lower chilling requirements, which makes them more suitable under the current circumstances. Along with adaptive benefits, new varieties in general improve the marketability of the fruit crops, fetching higher prices for their quality attributes (Bhat et al. 2022; Yue and Tone 2011). Yue and Tone (2011) carried out a consumer-based perception study and found that people were willing to pay higher for improved varieties with better quality and taste. Consequently, varietal diversification has become a significant tool to sustain apple farming and improve farm profitability. The diversification of the varieties also contributes significantly towards minimizing the production risks as well as enhancing the resilience of the orchard system (Tadesse and Blank 2003). Diversified varietal composition ensures that the risks of climatic variation, infestation of pests and market variations are shared among the diversified cultivars and hence generate stability in production and returns. The current situation of varietal composition and the degree of diversification in various districts, hence, is the key aspect in evaluating the current process of changing the apple cultivation. Farmers' perception is also a major factor that determines the adoption of new apple varieties in addition to agro-climatic and economic factors. Keleman et al. (2009) in their study emphasized that varietal diversity in agriculture was largely determined by management decisions, which are in turn influenced by policy frameworks, market dynamics, and livelihood strategies, thus, linking diversity with rural development. The choice of better cultivars is determined by several factors such as the potential yield, cost of cultivation, market and its prospects and availability of institutional support. Therefore, the perception of farmers to new varieties becomes important in finding out significant factors and constraints in their adoption. The current research was conducted to determine the status of varietal diversification of apple in various districts of Himachal Pradesh and to determine the perception that farmers have on the new apple varieties using the necessary quantitative parameters.

Varieties used for studying diversification

In the present study, five major groups of apple varieties cultivated in Himachal Pradesh were considered. The varietal groups are given as following:

a) Delicious Standard: This included traditional highly vigorous apple trees such as Royal delicious, Vance delicious, Top red, Early Red-I, Hepca, Standard Red delicious etc.
b) Delicious Spur: This group has lower vigour than standard varieties and yielded higher fruits per unit cross-sectional area of trunk (Dennis et al. 1996; Reig et al. 2020). The major varieties included under "Delicious Spur" were Jeromine, Red velox, Scarlet spur-II, Red chief, Super chief, Oregon spur II, Z-1, etc.
c) Gala: Gala was recommended for cultivation in sub-temperate zone (Sharma et al. 2017). This group included varieties such as Schnico gala, Dark Baron gala, Gale gala, Redlum gala etc.
d) Pollinizers: The pollinizers were included in another group as an appropriate proportion of pollinizers was required in apple orchards to have optimum fruit set (Jahed and Hirst 2017). This group included Golden delicious, Red golden, Granny smith, Golden spur, Summer queen etc
e) Fuji: This group is relatively new and grown in very small pockets of different districts.

MATERIAL AND METHODS

The study was conducted across major apple producing state of India viz., Himachal Pradesh. Further, Multi-stage sampling method was used for selecting the respondents. The purposive sampling in the first stage was done for selecting the state. At second stage, seven key commercial apple bearing districts of Himachal Pradesh namely Shimla, Kullu, Mandi, Kinnaur, Chamba, Sirmour and Lahaul & Spiti were selected as they have largest areas under apple. The third stage involved selection of blocks in each of the selected districts using the probability proportional to size (PPS) technique whereby more blocks were sampled in those districts where the area under apple cultivation was higher. In this regard, blocks chosen were Narkanda, Rohru, Jubbal-Kotkhai and Chaupal from Shimla district; Kullu and Naggar from Kullu district; Karsog and Janjehli from Mandi district; Kalpa from Kinnaur district, Bharmour from Chamba district, Rajgarh from Sirmour district and Lahaul block from Lahaul and Spiti district. At fourth stage, five villages were then chosen from each block. The last step involved random selection of seven apple growers per village forming a total sample size of 420 respondents for the study.

Analytical Tools

Varietal Diversification:

In present study, varietal diversification was quantified using commonly applied ecological and agricultural diversification measures based on proportional area shares of each apple variety. For each sample farm, the area under a particular variety (A_i) was recorded and converted into a relative proportion (p_i) by dividing it from the total apple area (A). These proportions were then used to compute indices representing richness, dominance, concentration and evenness. Simpson index was computed as a weighted index which assigns greater importance to the most abundant varieties, thus captures varietal concentration more effectively (Simpson 1949). Higher index means an even distribution across multiple varieties. Methodologically, the index is computed by first calculating the share of each variety in total cultivated area or production, squaring these shares, summing them across all crops, and subtracting the result from 1. The Simpson index is preferred in agricultural economics because it gives greater weight to dominant

variety and is sensitive to changes in varietal composition, thereby providing a robust measure of diversification patterns over time or across regions. The Simpson index was calculated using the formula:

$$SDI = 1 - \sum_{i=1}^{S} p_i^2$$

Where,

p_i : proportional share of ith variety
S : total number of apple varieties grown.

The Simpson's Diversity Index ranges from 0 to 1. Values near 1 indicate higher varietal diversification, meaning orchard area is distributed more evenly across different apple varieties. Values closer to 0 indicate lower diversification, implying that most of the orchard area is concentrated under few dominant varieties.

Varietal concentration in apple crop across different districts was examined using Herfindahl-Hirschman Index (HHI), which captures the extent to which total apple orchard area is concentrated under a few dominant varieties. The HHI increases when orchard area becomes concentrated with few varieties and decreases when area is distributed across a number of varieties. The squared shares used in the index assigns disproportionately higher weight to varieties with higher share in orchard area, thus, effectively identifies dominance and concentration patterns. The index is computed using proportional area shares of each variety (p_i) as:

$$HHI = \sum_{i=1}^{S} p_i^2$$

Where;

p_i : Share of total apple area under the i^{th}variety
S : Number of varieties cultivated.

The HHI gives proportionately greater weight to the higher shares of the larger firms, thus incorporates the relative size distribution of shares, making it more robust than the simple counts (Rhoades 1993). In the context of varietal diversification, a higher HHI indicates greater varietal specialization, while a lower HHI reflects greater varietal diversification. The index ranges from 0 to 1. The value of 1 implies complete dominance by a single variety, whereas values near to 0 indicate low concentration and higher diversification.

Perception Analysis

Past literature has found that new varieties are generally preferred due to their enhanced agronomic characteristics, marketability, and other socio-economic benefits (Adesina and Baidu-Forson 1995). However, farmers' preference for these new varieties are multifaceted, encompassing both monetary as

well as non-monetary plant characteristics that significantly influence adoption decisions (Baidu-Forson et al. 1997). For instance, key attributes such as environmental adaptability and yield stability are highly preferred by farmers and often favor successful incorporation of new varieties into existing agricultural systems (Asrat et al. 2010). To analyze the relative importance of different perception statements regarding new apple varieties, the Response Priority Index (RPI) was employed. Farmers often assign different levels of importance to various aspects while expressing their perception or preferences. Simply counting number of responses for each statement may not adequately capture these differences in priority, Perception analysis carried out using Likert Scale technique has an inherent limitation of generating only qualitative data (Chimi and Russell 2009). Therefore, the RPI method was used to assign appropriate weight to responses based on their level of importance. The apple growers were first asked to rank the perception on a 5-point Likert scale viz., Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. Then, using the frequency of responses assigned to different priority levels and the corresponding weights to those priorities. In this study levels were assigned weights of 5,4,3,2 and 1 for first, second, third, fourth and fifth priorities, respectively. A higher weight indicates greater importance to a particular statement. Response Priority Index (RPI) was constructed as a product of proportion of responses (PR) and Priority Estimate (PE), where PR for the i^{th} strategy gave the ratio of number of responses for a particular constraint to the total responses (Rao 2011) The index was then estimated using the formula:

$$\text{RPI} = \frac{\sum_{j=1}^{k} f_{ij} \times X_{(k+1-j)}}{\sum_{i=1}^{n} \sum_{j=1}^{k} f_{ij}}$$

Where,

f_{ij}	=	Number of respondents assigning the j^{th} priority to the i^{th} statement
k	=	Total number of priority levels considered
$X_{(k+1-j)}$	=	Weight assigned to the corresponding priority level
$\sum_{j=1}^{k} f_{ij}$	=	Total number of responses for the i^{th} statement
$\sum_{i=1}^{n} \sum_{j=1}^{k} f_{ij}$	=	Total number of responses for all statements.

Table 1: Likert Scale statements for studying the farmers' perception

Category	Statements for Likert Scale
Production Attributes	The new apple varieties have higher yield potential compared to traditional varieties.
	The fruits from new varieties are more uniform in size and quality.
	The improved varieties start bearing fruit earlier than traditional varieties.
	The new varieties are more resistant to pests and diseases.
	The new varieties require fewer pesticide applications.
	The new varieties are better adapted to changing climatic conditions.
Economic Constraints	The initial cost of establishing new apple varieties is high.
	The cost of inputs required for new varieties is high.
	Managing new varieties requires higher labour and increases cost.
Market Factor	The new apple varieties provide better price realization in the market.

Institutional & Social Factors	Extension services provide sufficient technical knowledge for managing new varieties.
	Planting material of new apple varieties is easily available.
	Success of other farmers influences the adoption of new varieties.

RESULTS AND DISCUSSIONS

In the past, most of the apple orchards in Himachal Pradesh were dominated by Delicious cultivars to establish a monoculture system (Sharma 2026). Nevertheless, the increased temperatures and reduced snowfall negatively impacted the traditional varieties in lower belts like Kullu valley and certain areas of Shimla and led to the decreased productivity, and movement towards higher altitudes (Rana et al. 2011). Growers were moving towards better varieties like Delicious Spur and Gala to adapt (Rani et al. 2024). The varietal composition presented in Table 1 showed that there were distinct regional differences. In Shimla, Kullu and Mandi, bearing orchards with a proportion of 46.79, 49.80 and 47.61 per cent had dominant shares of Delicious Standard which was negligible in non-bearing orchards signifying shift towards new plantations. Delicious Spur on the other hand recorded 47.75, 43.35 and 38.23 per cent in non-bearing orchards whereas Gala accounted 28.83, 31.76 to 37.88 per cent in non-bearing orchards of Shimla, Kullu and Mandi, respectively. Detailed comparison revealed that share of Delicious Standard varieties declined drastically in non-bearing orchards, with 0.90, 0.86 and 1.02 per cent in Shimla, Kullu and Mandi, respectively. This indicated that there was complete replacement of standard varieties. Similarly, the combined share of Delicious Spur and Gala varieties in non-bearing orchards was found to occupy 76.58, 75.11 and 76.11 per cent shares in Shimla, Kullu and Mandi, respectively, indicating a clear preference towards new varieties. In bearing orchards in the high-altitude districts, Delicious Standard had more than 50 per cent share whereas in non-bearing orchards, Delicious Spur was the predominant cultivar in the areas of Kinnaur (62.18%) and Lahaul and Spiti (76.64%). This indicated that even in higher altitudinal belts of apple, growers were increasingly shifting towards spur-type varieties for new plantations. However, the share of Standard varieties still remained higher in these districts, accounting for 42.95 and 46.13 per cent, in Kinnaur and Lahaul & Spiti, respectively. In Chamba district, Delicious Standard occupied 54.89 per cent in bearing orchards while in non-bearing orchards this proportion fell to 2.22 per cent. The proportion of Spur and Gala was higher in non-bearing orchards 40.00 and 37.78 per cent, respectively in non-bearing orchards. This declined proportion of Delicious Standard cultivars indicated shift in varietal composition. Sirmour was diversified (Delicious Standard with 17.49) and Spur (37.95) and Gala (32.18). In this regard, Sirmour presented a distinct pattern where even the bearing orchards showed lower proportions of standard cultivars. Further, the higher proportions of Gala and Spur showed reinforcement of shift towards new varieties. On aggregate level, Delicious Standard accounted for 46.25 per cent in bearing orchards and a sharp decline to 1.09 per cent in non-bearing orchards, whereas Spur and Gala had prominently higher shares of 47.83 and 30.98 per cent, respectively. On the whole, bearing orchards are still predominantly inhabited by traditional cultivars (Raj 2021; Verma and Thakur 2019), whereas non-bearing orchards are a positive indication of diversification as a method of adapting to climatic change (Veteto and Carlson 2014; Arundhati and Bhagat 2021).

The measured diversification indices (Table 2) based on the Simpson Diversity Index (SDI) and Herfindahl-Hirschman Index (HHI) was found to be 0.693, and HHI 0.307 showing an overall moderate level of diversification with a fairly low concentration. In bearing orchards (0.655) compared to non-bearing (0.611)

orchards, there was a greater level of diversification. This indicated that the established orchards were having relatively more diversified composition, while non-bearing orchards were comparatively concentrated around new varieties. However that pattern was not consistent among all districts. For instance, Kullu had higher diversification (0.680) in non-bearing orchards than the bearing orchards (0.661). Similarly in Mandi higher diversification (0.671) was observed in non-bearing orchards than the bearing orchards (0.664). Further, the inter-district analysis revealed that Kullu (0.736) and Mandi (0.730) had the highest levels of diversification, with lower concentration levels, indicating a more diversified composition. Shimla also exhibited a higher diversification (0.707). Kinnaur (SDI: 0.554; HHI: 0.446), and Lahaul and Spiti (SDI: 0.391; HHI: 0.609) on the other hand had comparatively lower diversification and a greater concentration than other districts. Among all districts, Lahaul & Spiti recorded lowest diversification (0.391) and highest concentration (0.609) which indicated a strong dominance of certain varieties and lower varietal spread. Kinnaur also showed slightly higher concentration compared to other districts. Sirmour (0.704; HHI: 0.296) appeared to have a highly diversified composition which demonstrated a well-balanced varietal composition which aligned with the varietal shares presented in Table 1. Chamba, with an SDI of 0.673 and HHI of 0.327, presented moderate diversification, indicating a transitional pattern between traditional dominance and improved varieties' adoption. An increase in diversification of lower belts is a sign of suitability to progress to better varieties (Arundhati and Bhagat 2021), and an increase in upper belt is an indication of traditional cultivars (Rana et al. 2011; Sahu et al. 2020; Devi and Prasher 2018). The contrast between bearing and non-bearing orchards was particularly evident in Kinnaur and Lahaul & Spiti. Overall, there was an evident inverse relationship between SDI and HHI across all the districts. The observed inter-district variations highlighted the fact that varietal diversification was influenced by factors such as altitude, climate, and farmer adoption behaviour (Fadre et al. 2014; Botero et al. 2021).

The perception of apple growers in Table 3 towards new varieties was analyzed using the Response Priority Index (RPI) based on a 5-point Likert scale. The results revealed that high initial establishment cost was the most important constraint across districts such as Shimla (4.29), Kullu (4.21), Mandi (4.24), Kinnaur (4.17), Chamba (4.26) and Lahaul & Spiti (4.23). In contrast, reduced requirement of pesticides was the least perceived attribute with RPI values of 3.21, 3.04, 2.87, 2.40, 2.74 and 2.66, respectively. In Sirmour, uniform fruit size and quality (4.14) was ranked highest, while reduced pesticide requirement (2.77) remained least important, indicating that cost-related factors dominated farmers' perception. The overall mean RPI scores further confirmed that higher initial establishment cost (RPI: 4.21) was ranked first among all the statements, highlighting its importance as the major adoption constraint. This dominance of higher establishment cost is consistent with earlier studies, which highlighted that higher capital investment and financial constraints were dominant factors in influencing farmers' adoption decisions particularly in perennials (Bocqueho 2017; Mwase et al. 2015). Domain-wise analysis showed that higher yield potential (3.98), uniform fruit quality (3.79) and early bearing (3.70) were the preferred attributes, followed by adaptability to climatic conditions (3.57). In case of production attributes, higher yield potential received consistently higher ranking across majority of the districts, with RPI scores reaching 4.21 in Mandi and 4.20 in Chamba, indicating farmers' strong preference for productivity-enhancing factor. In addition, quality attributes such as uniform, fruit size and quality also emerged as key attributes, particularly in district Sirmour (4.14), suggesting the dominance of market-related factors in varietal choices. This preference for higher yielding and early bearing traits reflected the economic perception of apple growers as suggested by previous studies that perceived productivity gain and quick returns ere the major drivers for varietal adoption (Ndeko et al. 2015, Mwebaze et al. 2024; Tsinigo et al. 2016). Among constraints,

high establishment cost (4.21), input cost (3.95) and labour requirement (3.38) were significant barriers. The higher scores of input cost (3.95) and labour requirement (3.38) further justified the economic constraint linked to adoption of new varieties. Similar findings were reported in various studies on agricultural innovation where factors such as cost of inputs, labour requirement and financial constraints were identified as major factors in adoption behaviour (Viloria et al. 2026; Hidayati et al. 2025; Vijaykumar et al. 2025). Market factors such as price realization (3.60) were moderately important, while institutional factors like extension support (3.26) ranked lowest. Better price realization recorded a moderate priority (3.60), which showed that although farmers considered market factors, the production- related traits remained the primary drivers of varietal perception. Institutional factors such as extension support (3.26) and planting material availability (3.46), were perceived relatively less important, suggesting that there were possible gaps in institutional access and resources. Overall, farmers prioritized productivity and economic returns, while environmental and institutional factors were less significant, highlighting the need to reduce costs and strengthen support systems for improved varietal adoption. One of the notable factor was that environmental consideration such as reduced pesticide requirement consistently received lowest score across all the districts, indicating that there was no reduction in pesticide usage in new apple variety, thus indicating lower importance in sustainability. **V**ariation in perception across the districts indicated that growers' behaviour was influenced by local socio-economic and agro-climatic conditions, which shaped their preferences, risk perceptions and adoption behaviour (Diyyala et al. 2025; Borra et al. 2026).

CONCLUSIONS

The study concluded showed that the development of apple cultivation in Himachal Pradesh was in a gradual process of replacement of traditional varietal dominance towards more diversified varietal system. Delicious Standard cultivars remain dominant in existing orchards but there was a definite shift which was evident in new plantation towards better varieties like Spur types and Gala. This change was the adaptive behaviour of apple growers towards the shifting climatic conditions especially in those areas where the old varieties were no longer productive enough. It was also found that there were differences in varietal diversification throughout the state. Diversification was observed to be relatively higher in lower altitude districts as compared to high altitude districts, where the composition was still dominated by traditional cultivars owing to agro-climatic appropriateness. This implied that location-specific factors and availability of resources played a significant role in determining the adoption of varieties. The transition was heavily determined by the perception of farmers. The reason for adoption of new varieties was the fact that these varieties were showing higher productivity, better fruits and faster economic returns. Nevertheless, major drawbacks still included higher initial costs and related expenses, which hampered their adoption particularly by small and marginal growers. Also, the comparatively lower priority assigned to environmental issues revealed that there was a lack of awareness regarding sustainable practices. In general, the paper highlighted the necessity of enhancing access to cost-effective technologies, enhancing extension services and making quality planting material available to aid in the process of carrying out sustainable varietal diversification in apple production.

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TABLES

Table 1: Varietal Composition of apple crop across different districts of Himachal Pradesh (ha).

District	Delicious Standard			Delicious Spur			Gala			Pollinizers			Fuji			Overall		
	B	NB	T	B	NB	T	B	NB	T	B	NB	T	B	NB	T	B	NB	T
Shimla	0.332 (46.79)	0.001 (0.90)	0.333 (41.68)	0.188 (26.49)	0.042 (47.75)	0.230 (28.86)	0.100 (14.09)	0.026 (28.83)	0.126 (15.73)	0.061 (8.57)	0.017 (18.92)	0.078 (9.72)	0.029 (4.06)	0.003 (3.60)	0.032 (4.01)	0.710 (100)	0.089 (100)	0.798 (100)
Kullu	0.195 (49.80)	0.002 (0.86)	0.197 (34.02)	0.100 (25.51)	0.081 (43.35)	0.181 (31.26)	0.050 (12.65)	0.059 (31.76)	0.109 (18.81)	0.037 (9.39)	0.029 (15.45)	0.066 (11.34)	0.010 (2.65)	0.016 (8.58)	0.026 (4.56)	0.392 (100)	0.186 (100)	0.578 (100)
Mandi	0.215 (47.61)	0.002 (1.02)	0.218 (31.70)	0.113 (24.96)	0.090 (38.23)	0.202 (29.49)	0.094 (20.88)	0.089 (37.88)	0.183 (26.69)	0.027 (6.02)	0.046 (19.45)	0.073 (10.61)	0.002 (0.53)	0.008 (3.41)	0.010 (1.52)	0.452 (100)	0.234 (100)	0.686 (100)
Kinnaur	0.426 (50.52)	0.002 (1.55)	0.429 (42.95)	0.268 (31.75)	0.096 (62.18)	0.364 (36.46)	0.046 (5.40)	0.033 (21.24)	0.078 (7.85)	0.071 (8.44)	0.017 (10.88)	0.088 (8.81)	0.033 (3.89)	0.006 (4.15)	0.039 (3.93)	0.844 (100)	0.154 (100)	0.998 (100)
Chamba	0.175 (54.89)	0.001 (2.22)	0.176 (49.55)	0.054 (17.04)	0.014 (40.00)	0.069 (19.37)	0.043 (13.53)	0.014 (37.78)	0.057 (15.99)	0.042 (13.03)	0.006 (15.56)	0.047 (13.29)	0.005 (1.50)	0.002 (4.44)	0.006 (1.80)	0.319 (100)	0.036 (100)	0.355 (100)
Lahaul & Spiti	0.294 (55.35)	0.002 (1.46)	0.295 (46.13)	0.158 (29.71)	0.084 (76.64)	0.242 (37.75)	0.029 (5.43)	0.012 (10.95)	0.041 (6.38)	0.038 (7.09)	0.010 (9.49)	0.048 (7.50)	0.013 (2.41)	0.002 (1.46)	0.014 (2.25)	0.530 (100)	0.110 (100)	0.640 (100)
Sirmour	0.085 (17.49)	0.000 (0.00)	0.085 (12.10)	0.184 (37.95)	0.083 (38.52)	0.267 (38.13)	0.156 (32.18)	0.086 (40.00)	0.242 (34.59)	0.049 (10.07)	0.038 (17.78)	0.087 (12.44)	0.011 (2.31)	0.008 (3.70)	0.019 (2.74)	0.485 (100)	0.216 (100)	0.701 (100)
Overall	0.246 (46.25)	0.002 (1.09)	0.247 (36.35)	0.152 (28.53)	0.070 (47.83)	0.222 (32.71)	0.074 (13.81)	0.046 (30.98)	0.119 (17.53)	0.046 (8.71)	0.023 (15.76)	0.070 (10.24)	0.014 (2.70)	0.006 (4.35)	0.021 (3.06)	0.533 (100)	0.147 (100)	0.680 (100)

Figures in parentheses shows percentages to total area under apple (bearing/ non-bearing/ overall).

Table 2: Varietal diversification and concentration indices across different districts.

District	Stage	Simpson's Diversity Index (SDI)	Herfindahl–Hirschman Index (HHI)
Shimla	Bearing	0.682	0.318
	Non-bearing	0.652	0.348
	Overall	0.707	0.293
Kullu	Bearing	0.661	0.339
	Non-bearing	0.680	0.320
	Overall	0.736	0.264
Mandi	Bearing	0.664	0.336
	Non-bearing	0.671	0.329
	Overall	0.730	0.270
Kinnaur	Bearing	0.632	0.368
	Non-bearing	0.554	0.446
	Overall	0.667	0.333
Chamba	Bearing	0.634	0.366
	Non-bearing	0.671	0.329
	Overall	0.673	0.327
Lahaul &Spiti	Bearing	0.597	0.403
	Non-bearing	0.391	0.609
	Overall	0.635	0.365
Sirmour	Bearing	0.711	0.289
	Non-bearing	0.659	0.341
	Overall	0.704	0.296
Overall	Bearing	0.655	0.345
	Non-bearing	0.611	0.389
	Overall	0.693	0.307

Table 3: Response priority index of apple growers on perception regarding new apple varieties

Statement	Shimla		Kullu		Mandi		Kinnaur		Chamba		Lahaul & Spiti		Sirmour		Overall Mean	
	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank	RPI	Rank
Production Attributes																
Higher yield potential	4.00	IV	4.11	II	4.21	II	4.17	II	4.20	II	3.06	VI	4.11	II	3.98	III
Uniform fruit size and quality	4.04	III	3.84	VI	4.09	III	3.77	VI	3.60	VI	3.03	VII	4.14	I	3.79	VI
Early bearing of fruit	4.07	II	3.79	VII	3.89	IV	4.11	IV	3.49	VIII	2.83	XI	3.71	III	3.70	VII
Resistance to pests and diseases	3.64	X	3.70	VIII	3.66	VIII	3.43	VII	3.26	IX	3.11	V	3.54	VI	3.48	IX
Reduced requirement of pesticides	3.21	XIII	3.04	XIII	2.87	XIII	2.40	XIII	2.74	XIII	2.66	XIII	2.77	XIII	2.81	XIII
Adaptability to changing climatic conditions	3.67	IX	3.63	IX	3.60	X	3.14	XI	4.20	III	3.23	X	3.49	VIII	3.57	VIII
Economic Constraints																
High initial establishment cost	4.29	I	4.21	I	4.24	I	4.17	I	4.26	I	4.23	I	4.09	IV	4.21	I
High cost of inputs	3.86	VII	3.71	VII	3.64	IX	3.94	V	3.97	IV	4.11	II	3.41	IX	3.95	II
High labour requirement	3.64	XI	3.50	XI	3.44	XII	3.20	XI	3.03	XI	3.46	III	3.37	X	3.38	X
Market Factor																
Better market price realization	3.90	VI	4.04	IV	3.91	V	3.54	IX	3.17	X	3.00	IX	3.66	V	3.60	VII
Institutional & Social Factors																
Availability of extension support	3.47	XII	3.27	XII	3.47	XI	3.06	XII	3.37	VII	2.89	X	3.31	XII	3.26	XI
Easy availability of planting material	3.99	V	4.06	III	3.86	VI	2.69	X	3.57	V	2.92	VIII	3.14	XI	3.46	IX
Influence of fellow farmers' success	3.79	VIII	3.57	X	3.60	X	3.31	X	3.03	XII	2.94	IX	3.34	VII	3.37	X

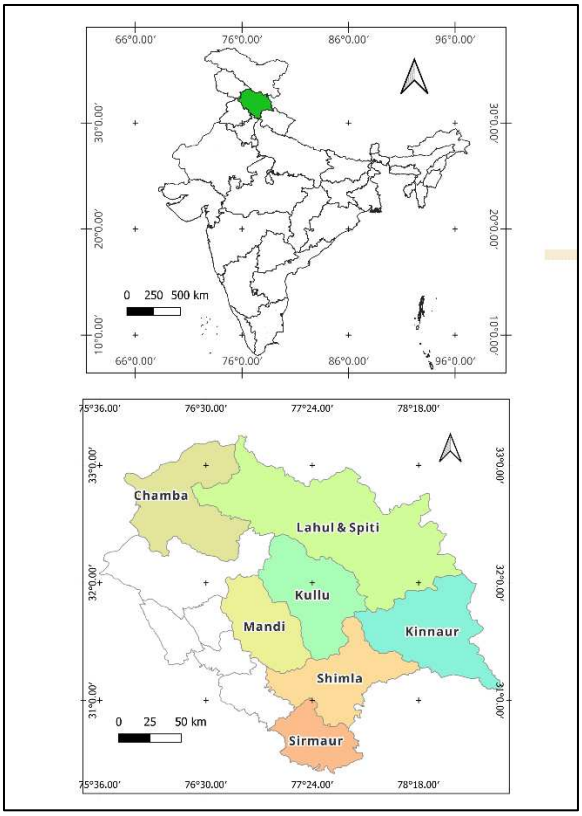


Figure 1: Location of the study area showing Himachal Pradesh in India and selected districts

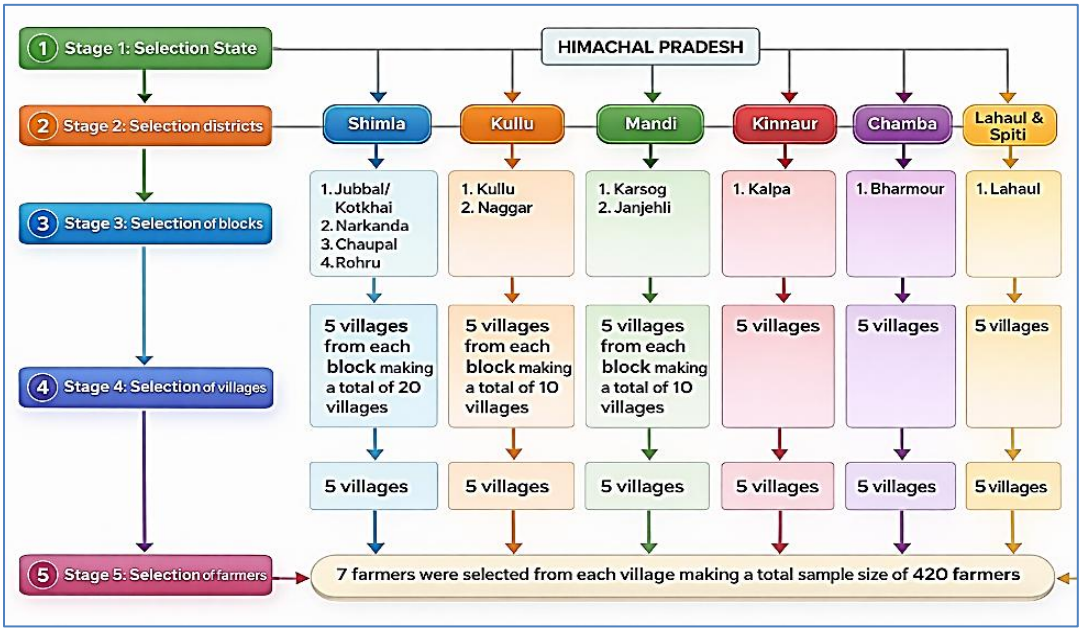


Figure 2 Sampling framework and selection of respondents across districts

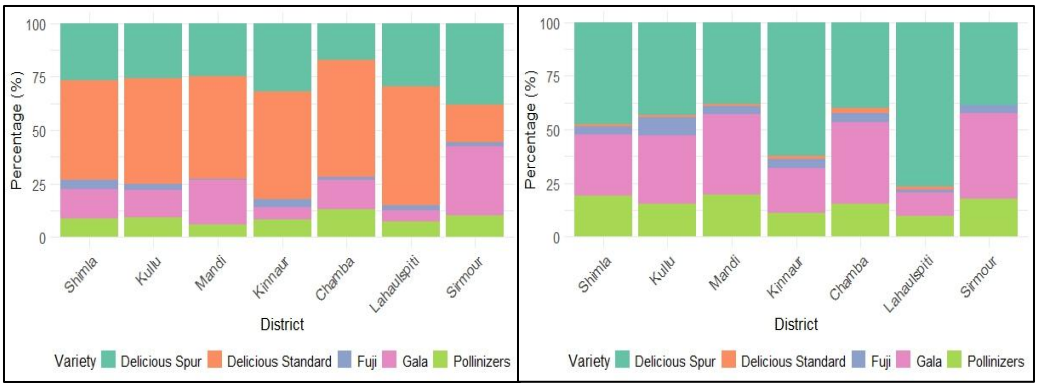


Figure 3a and 3b. Distribution of bearing and non-bearing apple varietal composition across selected districts of Himachal Pradesh.

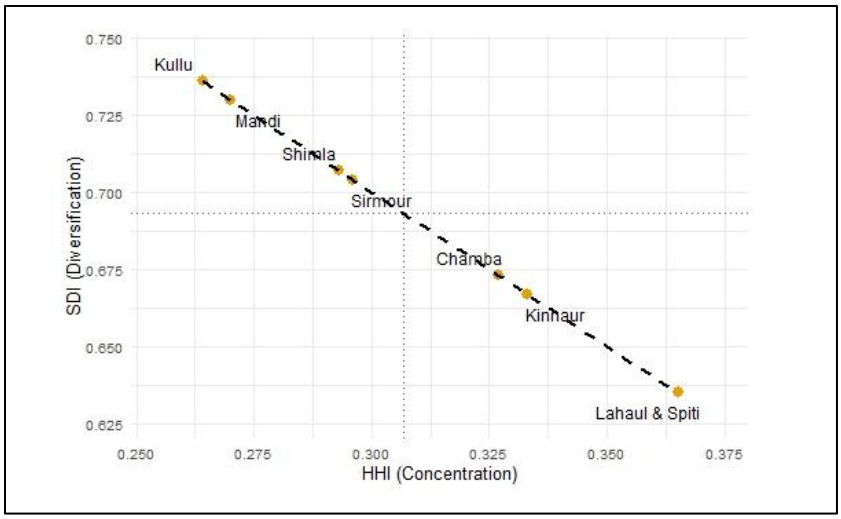


Figure 4: Relationship between Simpson Diversity Index (SDI) and Herfindahl–Hirschman Index (HHI) across selected districts of Himachal Pradesh

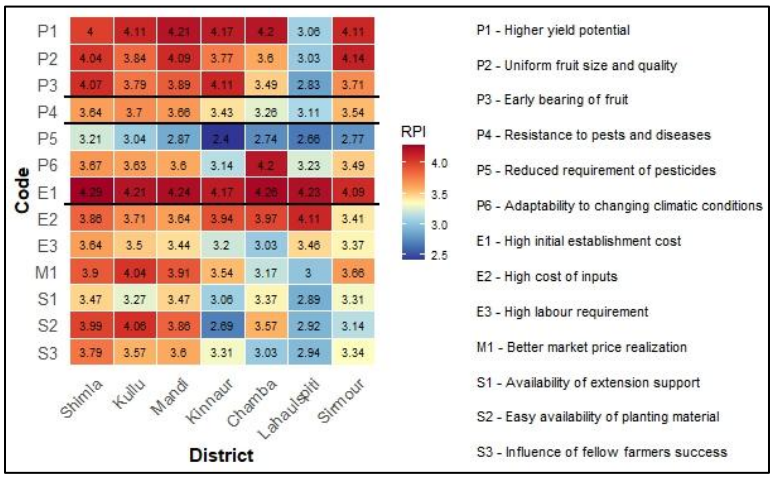


Figure 5: Heat map showing farmers' perceptions of new apple varieties based on Response Priority Index (RPI) across selected districts of Himachal Pradesh

STATEMENTS AND DECLARATIONS

There were no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

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