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Growth, Instability and Hazell's Decomposition Analysis of Apple: A District-wise Study of Himachal Pradesh

Shilpa Rani[1], Subhash Sharma[1], Anurita Kharayat[1]

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ABSTRACT

Background: The present study has made an attempt to estimate the sources of growth and instability of apple production in various districts of Himachal Pradesh using Hazell's decomposition model as our state has shown tremendous growth in area as well as production in last decades.

Methods: For analysis, secondary data on area, production and yield has been used and the study period for CAGR, instability indices and decomposition analysis had divided into two triennium periods *i.e.* Period-I (1974-77 to 1996-99) and Period-II (1999-02 to 2020-23).

Result: it was revealed that during the overall period, Sirmaur had the highest value of CAGR (27.70%) in apple production followed by Spiti (10.30%) and Mandi and main reason for this increasing trend was the increase of the apple area and climatically adaptable varieties as apple required chilling hours which were fulfilling in these districts. In Shimla, which had the highest area and production of apple in the state, there was a decline in the CAGR of apple production during the overall period (-3.70%).

Key words: Apple, Coppock, Growth rate, Hazell's decomposition.

INTRODUCTION

Himachal Pradesh is basically known as "The Apple State of India" because, in terms of quality, Himachal apples enjoy more consumer preference and are considered better for storage. The cultivation of apples was first done in Himachal Pradesh in 1870 and was first introduced by a British army captain, RC Scott, in the Kullu valley of Himachal Pradesh and spread across other areas of the state. This temperate fruit is primarily grown at an elevation of 1500-2700 m amsl with 1000-1500 hours of chilling (Powell *et al.* 1986). It also needs 100-120 cm of annual rainfall evenly distributed during the growing season for optimum growth and fruiting (Bera, 2015). The major apple growing belts are Shimla, Kullu, Sirmaur, Mandi, Chamba and Kinnaur. This unique location and climatic advantage enjoyed by the state have made it an ideal region for growing apples (Vishal, 2020; Barwal *et al.,* 2023; Rani and Prasher, 2021). The apple economy has also witnessed a tremendous growth (Dev *et al.,* 2024) as result of investment through the national horticulture mission (NHM) and several other programmes implemented by our government (Singh and Toppo, 2010). Apple occupied about 41 per cent of total area under fruits and 64.10 per cent of the area under temperate fruits. Apple is the principal fruit crop of Himachal Pradesh (Kumar, 2020) and contributed about 88 per cent of the total fruit production and 95 per cent of temperate fruit production in the state (Jindal *et al.,* 2001). The factors which affected the yield were non-uniformity in genetic potential of the cultivars planted, the effect of climatic and environmental conditions and management practices employed by growers (Singh *et al.,* 2004; Rani *et al.,* 2024; Rani *et al.,* 2019; Shivani *et al.,* 2023).

[1]Department of Social Sciences, College of Forestry, Dr Yashwant Singh Parmer University of Horticulture and Forestry, Nauni, Solan-173 230, Himachal Pradesh, India.

Corresponding Author: Shilpa Rani, Department of Social Sciences, College of Forestry, Dr Yashwant Singh Parmer University of Horticulture and Forestry, Nauni, Solan-173 230, Himachal Pradesh, India. Email: shilparani.rani535@gmail.com

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The variations in rainfall, prices, post-harvest losses and increased cost of production were some of the factors affecting growth and instability of apple in the state (Rani and Prasher, 2020). So, measures like growing of location favourable varieties, adoption of new technologies like shifting towards high density plantations of apple *etc.* can help in improving the growth and stabilizing the area, production and instability in state (Rani *et al.*, 2025). So, an attempt has been made in the present study to analyse the trends in area, production and productivity of area, instability and Hazell's decomposition analysis in the production of apple in Himachal Pradesh.

MATERIALS AND METHODS

The present study had been conducted in Dr Yashwant Singh Parmar University of Horticulture and Forestry, from year 2021-24 and it included secondary data on area, production and production from Directorate of Horticulture,

Himachal Pradesh and for analysis, study period for CAGR, instability indices and decomposition analysis had divided into two triennium periods *i.e.* Period-I (1974-77 to 1996-99) and Period-II (1999-02 to 2020-23). The sources of growth and instability of apple production in various districts of Himachal Pradesh was assessed by Hazell's decomposition model (Hazell, 1982). The area and yield data of apple were detrended and these detrended series were used as the basic data for decomposition of changes in average production and changes in variance of apple production.

Compound annual growth rate (CAGR)

The compound annual growth rates were computed by fitting the exponential function in area, production and productivity of apples in Himachal Pradesh for the period 1974-75 to 2022-23. The growth rate was estimated using exponential trend model (Rani, 2025) and was converted into log linear function with the help of logarithmic transformation as under:

$$Y = ae^{bt}$$

$$\ln^{f0}(Y) = \ln^{f0}(a) + bt$$

Compound annual growth rate (CGR) was calculated by using the following formula:

$$CAGR = b \times 100$$

Standard error (SE) of CAGR was calculated by using the following formula:

$$SE \text{ of } CAGR = 100 \times SE(b)$$

Where,
Y = Dependant variable (area, production and productivity).
t = Independent variable (time in year).
a = Intercept.
b = Regression co-efficient.
e = Euler's number.

Calculation of instability in area, production and productivity of apple

The agricultural instability can be measured by different methods, such as the coefficient of variation (CV), dispersion, cuddy della valle index (CDVI), Coppock's instability index, *etc.* The use of CV as a measure to show the instability in any time series data has some limitations. If the time series data exhibit any trend, the variation measured by CV can be overestimated, *i.e.* the region which has growing production are at constant rate will score high in instability of production if CV is applied for measuring instability. Thus, it is a better measure to capture instability in agricultural production using Coppock's instability index for measuring the instability.

Coppock's instability index (CII)

CII is a close approximation of the average year-to-year percentage variation adjusted for trend (Kaur and Singhal, 1988).

$$CII = \text{Anti log}\log V\text{-}1 \times 100$$

$$\text{Log } V = \log X_t + 1X_t - mN\text{-}1$$

Where,
X_t = Area/production/Yield in the year't'.
N = Number of years.
M = Arithmetic mean of the difference between the logs of X_{t+1}, X_t *etc.*
Log V = Logarithmic variance of the series.

The hazell's decomposition procedure produces the four components of change in average production that indicates the sources of growth of apple production (Hazell, 1982) (Table 1).

The first two terms, change in the mean yield and change in mean area are called as 'pure effects' which arise even if there were no other source of change. The third term is an interaction effect, which arise from the simultaneous occurrence of changes in mean yield and mean area. The fourth term in the equation represents interaction between area and yield covariance. The Hazell's decomposition procedure also produces the ten components of change in variances of the production that indicates the sources of instability of apple production (Hazell, 1984) (Table 2).

RESULTS AND DISCUSSION

Trends in area, production and productivity of apple in Himachal Pradesh

From Table 3, it was revealed that during the overall period, Sirmaur had the highest value of CAGR (27.70%) in apple production followed by Spiti (10.30%) and Mandi and main reason for this increasing trend was the increase of the apple area and climatically adaptable varieties as apple required chilling hours which were fulfilling in these districts. In Shimla, which had the highest area and production of apple in the state, there was a decline in the CAGR of apple production during the overall period (-3.70%) and the results were somewhat similar to those of Dev *et al.,* 2024. The main reason behind this might be climate change, which has reduced apple production in the last few years, as shown in its Period I and II values. Other reasons for decline might be delay in flowering and fruit set, disease incidence and insect-pest attack, poor post-harvest handling and storage. So, there is great need for use of technologically advanced techniques to protect the

Table 1: Components of change in average production.

Sources of change in average production	Symbol	Components of change
1. Change in mean yield of apple	$\Delta\bar{Y}$	$\bar{A}_1\Delta\bar{Y}$
2. Change in mean area of apple	$\Delta\bar{A}$	$\bar{Y}_1\Delta\bar{A}$
3. Interaction between changes in mean yield and mean area of apple	$\Delta\bar{A}\,\Delta\bar{Y}$	$\Delta\bar{Y}\Delta\bar{A}$
4. Change in area-yield covariance of apple	Δ cov (AY)	Δ cov (A,Y)

Note: $\bar{A}1$ and $\bar{Y}$ 1, are mean area and mean yield in first period.

apple fruit from the harmful impacts of climate change like HDP (High density planting) apple is one the best measures to deal with it as involves the use of proper production technologies to enhance the apple production in small area and it has been emerged as boon to marginal and small apple growers in the state. From Table 4, it was revealed that in the high category of CAGR of apple yield during the overall period, Mandi, Sirmour, Chamba and Lahaul-Spiti were the districts which were the districts with higher growth in yield. The main reason behind this inclining trend was the increase in the area under them in Period-II, better nutrient management and suitable climatic conditions for apple cultivation.

Instability analysis of apple in different districts of Himachal Pradesh

From Table 5, it was revealed that there was instability of more than 40 per cent in area, production and yield in all

Table 2: Components of change in the variance of production.

Sources of change in average production	Symbol	Components of change
1. Change in mean yield of apple	$\Delta \bar{Y}$	$2\bar{A}_1\Delta \bar{Y} cov(\bar{A}_1,Y_1) + \{2\bar{Y}_1\Delta\bar{Y}+(\Delta\bar{Y})^2\}V(A_1)$
2. Change in mean area of apple	$\Delta \bar{A}$	$2\bar{Y}_1 \Delta \bar{A} cov (A_1,Y_1) + \{2\bar{A}_1\Delta \bar{A}+(\Delta\bar{A})^2\}V(Y_1)$
3. Change in yield variance of apple	$\Delta V(Y)$	$\bar{A}_1^2\Delta V(Y)$
4. Change in area variance of apple	$\Delta V(A)$	$\bar{Y}_1^2\Delta V(A)$
5. Interaction between changes in mean yield and mean area of apple	$\Delta\bar{A}\,\Delta\bar{Y}$	$\{2\bar{A}_1\Delta\bar{Y}$-2 cov $(A_1,Y_1)\}\,\Delta$ cov (A,Y)-$\{\Delta$ cov $(A,Y)\}^2$
6. Change in area-yield covariance of apple	Δ cov (AY)	Δ cov (A,Y)
7. Interaction between changes in mean area and yield variance of apple	$\Delta\bar{A}\Delta V(Y)$	$\{2\bar{A}_1\Delta\bar{A}+(\Delta\bar{A})^2\}\Delta V(Y)$
8. Interaction between changes in yields and area variance of apple	$\Delta\bar{Y}\Delta V(A)$	$\{2\bar{Y}_1\Delta\bar{Y}+(\Delta\bar{Y})2\}\Delta V(A)$
9. Interaction between changes in mean area and yield and changes in area-yield covariance of apple	$\Delta\bar{A}\,\Delta\bar{Y}$ Δ cov (AY)	$(2\bar{A}_1\Delta\bar{Y}+2\bar{Y}_1\Delta\bar{A}+2\Delta\bar{A}\Delta\bar{Y})\Delta$ cov (A,Y)
10. Change in residual	ΔR	$\Delta V(A,Y)$-Sum of the other components

Table 3: District-wise CAGR (%) of area, production and yield of apple in Himachal Pradesh from Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23).

Particulars	Period-I			Period-II			Overall		
	A	P	Y	A	P	Y	A	P	Y
Mandi	3.90	-11.40	-14.70	0.80	8.70	7.30	0.60	9.00	8.40
	(0.003)*	(0.026)**	(0.024)**	(0.001)*	(0.012)*	(0.025)**	(0.001)*	(0.022)*	(0.022)*
Kullu	3.50	-7.20	-10.40	1.00	-1.90	-2.40	0.80	-0.50	-1.30
	(0.001)*	(0.056)**	(0.055)**	(0.001)*	(0.030)*	(0.031)**	(0.001)*	(0.030)**	0.031**
Shimla	4.00	-6.70	-10.30	1.50	-5.10	-6.00	1.30	-3.70	-4.90
	(0.002)*	(0.041)**	(0.040)**	(0.001)*	(0.037)**	(0.037)**	(0.001)*	(0.037)**	(0.037)**
Sirmour	1.30	-1.70	-2.90	-0.70	26.30	27.70	-0.90	27.70	28.80
	(0.001)*	0.089***	(0.088)***	(0.004)*	(0.054)**	(0.056)**	(0.004)*	(0.054)**	(0.056)**
Chamba	9.80	2.80	-6.30	-0.20	4.10	4.90	-0.40	5.50	6.00
	(0.005)**	(0.082)***	(0.076)***	(0.001)*	(0.050)**	(0.051)**	(0.001)*	(0.050)**	(0.051)**
Kinnaur	4.30	9.60	5.10	0.30	1.20	0.30	0.10	1.50	1.40
	(0.002)*	(0.031)*	(0.030)**	(0.002)*	(0.020)*	(0.020)**	(0.002)*	(0.020)*	(0.020)*
Lahaul-spiti	16.70	7.60	-7.80	1.50	10.00	7.80	1.30	10.30	8.90
	(0.011)**	(0.050)**	(0.050)**	(0.001)*	(0.028)*	(0.028)**	(0.001)*	(0.028)**	(0.028)**
Solan	0.70	-12.40	-13.00	5.00	4.50	-1.10	4.80	4.80	0.00
	(0.001)*	(0.059)**	(0.059)**	(0.026)**	(0.024)*	(0.015)*	(0.026)*	(0.024)**	(0.015)*
Kangra	0.60	-4.10	-4.70	4.80	-8.47	-5.90	4.60	-0.40	-4.80
	(0.002)*	(0.048)**	(0.049)**	(0.003)*	(0.010)*	(0.011)*	(0.003)*	(0.010)*	(0.011)*
HP	4.00	3.50	0.70	1.50	4.20	2.70	2.70	3.50	0.70
	(0.001)*	(0.005)*	(0.005)*	(0.001)*	(0.015)*	(0.011)*	(0.001)*	(0.005)*	(0.005)*

(Source: Directorate of Horticulture, Himachal Pradesh, 2024).

Note: The figures in parentheses are standard errors of estimates; ***, ** and * denote significance level at 1%, 5% and 10%.

periods and Lahaul-Spiti had the highest instability variations in the overall period, followed by Solan and Chamba, which meant that apple growers had increased or decreased the area under apple cultivation in the last few years.

From Table 6, it was revealed that in the high instability category in the overall period, Sirmour and Kangra have the highest instability in yield and the reason behind this might be an increase in area under apple cultivation in the last few years and proper orchard management.

Decomposition analysis of production in Himachal Pradesh using Hazel decomposition model

From Table 7, it was revealed that in the overall period, Chamba district had the highest percent contribution of change in mean area, yield and their interaction, which led

Table 4: Classification of districts according to CAGR (%) of apple in Himachal Pradesh from Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23).

Particulars	A			P			Y		
	<2% (Low)	2-5% (Moderate)	<5% (High)	<2% (Low)	2-5% (Moderate)	<5% (High)	<2% (Low)	2-5% (Moderate)	<5% (High)
Period-I	Kangra Solan Sirmour	Kinnaur Mandi Kullu Shimla	Lahaul-Spiti	Mandi Kullu Shimla Sirmour Solan Kangra	Chamba	Kinnaur Lahaul-Spiti	Mandi Kullu Shimla Sirmour Chamba Solan Kangra		Kinnaur Lahaul-Spiti
Period-II	Mandi Kullu Shimla Sirmour Chamba Kinnaur Lahaul-Spiti	Solan Kangra		Kullu Shimla Kinnaur Kangra	Chamba Solan	Mandi Sirmour Lahaul-Spiti	Kullu Shimla Kinnaur Solan Kangra	Chamba	Mandi Sirmour Lahaul-Spiti
Overall	Mandi Kullu Shimla Sirmour Chamba Kinnaur Lahaul-Spiti	Solan Kangra		Kullu Shimla Kangra	Solan	Mandi Sirmour Chamba Kinnaur Lahaul-Spiti	Kullu Shimla Kinnaur Solan Kangra		Mandi Sirmour Chamba Lahaul-Spiti

(Source: Directorate of Horticulture, Himachal Pradesh, 2024).

Table 5: District-wise instability indices (%) of apple in Himachal Pradesh from Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23) using Coppock's instability index.

Particulars	Period-I			Period-II			Overall		
	A	P	Y	A	P	Y	A	P	Y
Mandi	42.09	48.20	49.57	38.04	51.67	50.64	43.71	54.26	50.75
Kullu	41.27	46.42	45.22	38.91	49.42	48.53	43.61	49.27	46.88
Shimla	40.73	47.34	45.19	39.01	48.95	48.88	42.03	50.38	47.39
Sirmour	39.52	56.61	59.23	39.52	62.25	66.12	39.50	59.24	62.43
Chamba	49.54	49.32	48.84	39.00	51.36	50.15	54.22	55.66	49.57
Kinnaur	47.43	53.44	45.16	40.42	45.12	41.47	50.89	59.59	45.05
Lahaul-spiti	51.50	49.90	42.92	47.27	50.14	46.24	67.30	62.83	45.55
Solan	43.59	53.99	58.64	51.68	51.57	46.91	55.02	60.60	53.31
Kangra	40.14	62.47	66.35	39.28	43.24	44.83	39.72	54.31	57.00
HP	41.72	45.92	43.76	38.72	47.50	46.69	38.72	47.50	46.69

(Source: Directorate of Horticulture, Himachal Pradesh, 2024).

Note: A= Area; P= Production and Y= Yield.

us to the conclusion that the area under cultivation, as well as productivity and their combined effect, had impacted the average production of apple followed by Lahaul-Spiti and Shimla. Similarly, while considering the factors causing changes in variance of apple production in various districts from Table 8, it was revealed that in terms of yield, in overall period, Shimla, Chamba and Kinnaur had negative impact on change in variance of apple production whereas Kullu had positive impact and main reasons behind these negative impacts might be the climatic variations in these

Table 6: Classification of districts according to instability indices (%) of Apple in Himachal Pradesh from period Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23).

Particulars	A			P			Y		
	>45% (Less moderate)	45-55% (Moderately high)	>55% (High)	>45% (Less moderate)	45-55% (Moderately high)	>55% (High)	>45% (Less moderate)	45-55% (Moderately high)	>55% (High)
Period-I	Mandi Kullu Shimla Sirmour Solan Kangra	Chamba Kinnaur Lahaul-Spiti			Mandi Kullu Shimla Chamba Kinnaur Lahaul-Spiti Solan	Sirmour Kangra	Lahaul-Spiti	Mandi Kullu Shimla Chamba Kinnaur	Sirmour Solan Kangra
Period-II	Mandi Kullu Shimla Sirmour Chamba Kinnaur Kangra	Solan Lahaul-Spiti		Kangra	Mandi Kullu Shimla Chamba Kinnaur Lahaul-Spiti Solan	Sirmour Kangra	Kinnaur Solan Lahaul-Spiti	Mandi Kullu Shimla Chamba Sirmour	Sirmour
Overall	Mandi Kullu Shimla Sirmour Kangra	Chamba Kinnaur	Solan Lahaul-Spiti		Mandi Kullu Shimla Kangra	Sirmour Chamba Kinnaur Solan Lahaul-Spiti		Mandi Kullu Shimla Chamba Kinnaur Solan Lahaul-Spiti	Sirmour Kangra

(Source: Directorate of Horticulture, Himachal Pradesh, 2024).

Table 7: District-wise percent contribution of change in average production of apple in Himachal Pradesh from Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23) using Hazel's decomposition model.

Districts	Period-I			Period-II			Overall period		
	Change in mean area	Change in mean yield	Interaction between change in mean area and mean yield	Change in mean area	Change in mean yield	Interaction between change in mean area and mean yield	Change in mean area	Change in mean yield	Interaction between change in mean area and mean yield
Mandi	2.18	-0.74	-0.92	0.33	4.95	6.91	2.67	0.15	1.78
Kullu	1.59	0.55	-0.40	0.52	0.02	0.55	2.62	0.14	3.80
Shimla	1.29	2.32	0.45	0.32	-0.07	0.22	1.72	0.10	5.94
Sirmour	0.91	-0.94	-0.97	-0.33	19.44	12.62	0.13	0.02	0.01
Chamba	7.92	1.01	-0.78	0.82	2.17	4.78	14.04	0.40	15.80
Kinnaur	6.27	4.82	-0.20	0.98	1.07	3.10	11.81	0.38	26.91
Lahaul-Spiti	0.76	1.21	1.20	8.20	7.89	9.97	10.86	7.11	12.02
Solan	1.59	-0.89	-0.96	-0.87	1.70	-0.64	-0.46	-0.12	-0.97
Kangra	0.94	-0.84	-0.92	-0.12	0.33	0.16	0.67	0.09	-0.73
HP	1.77	1.21	-0.20	0.43	0.17	0.67	1.34	0.99	0.45

Table 8: District-wise per cent contribution of change in variance of apple production in Himachal Pradesh from Period-I (1974-77 to 1996-99) to Period-II (1999-02 to 2020-23) using Hazel's decomposition model.

Time period	Districts	Change in area variance	Change in yield variance	Interaction between change in area and yield co-variance	Interaction between mean yield and area variance	Interaction between mean area and yield variance	Interaction between change in mean area and yield and area and change in area-yield co-variance
Period-I	Mandi	0.43	3.68	2.28	-4.76	1.25	9.38
	Kullu	0.94	1.02	1.31	-0.50	1.63	-1.61
	Shimla	0.97	1.29	8.61	8.15	2.49	12.27
	Sirmour	-0.34	1.01	1.01	-1.07	0.38	2.97
	Chamba	0.36	0.92	0.87	-0.50	22.24	-46.04
	Kinnaur	0.88	0.54	-6.39	12.24	34.42	-30.80
	Lahaul-Spiti	-27.86	0.02	-1.11	0.06	-82.94	-196.70
	Solan	-0.06	0.50	0.06	-0.56	-0.04	3.86
	Kangra	0.37	1.60	1.60	-1.81	-0.35	5.41
	HP	0.93	1.56	6.52	1.67	2.54	-2.54
Period-II	Mandi	1.61	1.38	0.38	41.82	9.52	107.78
	Kullu	1.03	1.03	0.03	1.14	1.41	2.83
	Shimla	0.54	0.15	0.15	0.07	0.30	0.15
	Sirmour	7.03	1.86	0.86	50.08	51.60	124.84
	Chamba	2.02	1.51	0.51	21.47	20.68	4119.65
	Kinnaur	1.04	1.04	0.04	7.64	7.45	99.93
	Lahaul-Spiti	1.78	1.44	0.44	3.93	6.03	21.40
	Solan	49.82	1.98	0.98	3.17	-26.40	31.65
	Kangra	14.75	1.93	0.93	0.83	5.02	1.89
	HP	0.73	0.63	-0.37	0.86	1.11	2.73
Overall period	Mandi	-1.61	2.62	1.62	9.37	-17.20	-26.37
	Kullu	1.07	1.06	0.06	8.11	15.43	181.91
	Shimla	-2.69	2.37	1.37	28.21	-39.91	-136.89
	Sirmour	2.40	1.58	0.58	0.04	0.10	0.003
	Chamba	-1.74	2.57	1.57	40.56	-71.47	-150.30
	Kinnaur	0.13	-5.42	-6.42	-54.02	3.28	-184.47
	L/Spiti	-0.35	4.90	3.90	16.02	-0.96	32.67
	Solan	9.81	1.90	0.90	-3.64	-16.90	39.65
	Kangra	6.04	1.83	0.83	-2.65	-6.04	12.53
	HP	0.77	0.70	-0.30	1.32	2.08	4.25

districts in last decades which had also negatively impacted their production and hence, in overall Himachal Pradesh had a fluctuating pattern in apple production in last few years as discussed earlier and as an adaptive measure to this issue of climate change apple growers had started shifting from traditional apple cultivation to HDP apple as it was a technologically efficient technique to deal with climate change.

CONCLUSION

The above discussion has led us to the conclusion that although the area under apple has increased over the years in Himachal Pradesh, the production under it has been declining from last few years and main reason for this declining is changing climate which causes delayed flowering and fruit set and fluctuations in precipitation causes poor vegetative growth and development and causes poor development of apple fruit and ultimately reduced apple production. The decomposing apple production with area and yield, it was also revealed that variation in apple yield is the major factor causing changes in apple production in various districts of Himachal Pradesh. So, to deal with these issues, some farmers are preferring altitude shift to find more favourable conditions for apple and some have already shifted to HDP apple, which has 4-5 times more potential yield than conventional apple. Apart from this, some farmers are also diversifying their crops to earn more profits and research has also

been going on to develop those cultivars which can deal with changing climatic conditions. State government is also playing a crucial role in making farmers attain better prices in the market and also providing them with subsidies on some inputs. But still there is a need for improvement, like introducing those policy measures like weather-based crop insurance, timely market information, development of new cultivars, *etc*., which can help farmers in generating higher yield and returns. Further, improvement in infrastructure and use of more sustainable methods like the introduction of natural farming methods in apple orchards will not only reduce input cost but also help in attaining more nutritional and eco-friendly produce. Although these sustainable measures are still in initial steps in our state, with the help of the state government, this will be a breakthrough in higher apple production in the future.

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Conflict of interest

The authors have no conflict of interest.

REFERENCES

Barwal, P., Sharma, S., Diksha, Rani, S. and Laishram, C. (2023). Market participation of smallholder vegetable growers: concepts and evidences from different agro-climatic zones of Himachal Pradesh. *Agricultural Mechanization in Asia.* **54:** 12603-12617.

Bera, G. (2015). An assessment of apple cultivation in kalpa, Kinnaur District, Himachal Pradesh. *IOSR Journal of Humanities and Social Science*. **20:** 20-23.

Hazell, PBR. (1982). Instability in Indian Foodgrain Production. International Food Policy Research Institute. pp: 30.

Hazell, PBR. (1984). Sources of increased instability in Indian and US cereal production. *American Journal of Agricultural Economics.* **66:** 302-311.

Jindal, K.K., Chauhan, P.S. and Mankotia, M.S. (2001). Apple productivity in relation to environmental components. Eds. Jindal KK and Gautam DR. In "Productivity of temperate fruits" Dr YS Parmar UHF, Nauni, Solan, HP. pp: 12-20.

Kaur, N. and Singhal, K.C. (1988). India's Export Instability. *Margin.* **21:** 54-61.

Kumar, A. (2020). Effect of nitrobenzene on flowering, fruiting and quality parameters of apple cv. royal delicious under cold dry temperate region of Himachal Pradesh. *Agricultural Science Digest*. **40:** 171-174. doi: 10.18805/ag.D-5040.

Powell, L. (1986). The chilling requirement in apple and its role in regulating time of flowering in spring in cold-winter climates. *Acta Horticulturae.* **179:** 129-140.

Raj, D., Raina, A., Dev, K. and Shubham (2024). Analysis of growth trends, regional variations and productivity metrics of apple cultivation in Himachal Pradesh, India. *Journal of Scientific Research and Reports*. **30:** 8-19.

Rani, S. (2019). Impact Assessment of Climate Change on Agricultural Economy in Low Hills of Himachal Pradesh. MSc Thesis. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). pp: 91.

Rani, S. (2025). Economic Evaluation of Production and Marketing of High Density Apple Plantation in Himachal Pradesh. PhD Thesis. Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). pp: 267.

Rani, S. and Prasher, R.S. (2020). Analysis of vulnerability indices in Hamirpur District of Himachal Pradesh. *International Journal of Farm Sciences.* **10:** 33-44.

Rani, S. and Prasher, R.S. (2021). Farmers' perceptions towards climate change and its adaptation strategies in Hamirpur District of Himachal Pradesh. *Indian Journal of Economics and Development.* **17:** 77-85.

Rani, S., Prasher, R.S., Mandial, A. and Shivani (2025). Impact of climate change on livestock production in Himachal Pradesh: A case study of Hamirpur District of Himachal Pradesh. *Bhartiya Krishi Anushandhan Patrika.* **40:** 242-246. doi: 10.18805/BKAP740.

Rani, S., Sharma, S. and Shivani (2024). Perceptions of apple growers on impact of climate change on apple production in mid and high hills of Himachal Pradesh, India. *International Journal of Environment and Climate Change.* **14:** 685-696. https://doi.org/10.9734/ijecc/2024/v14i124654.

Shivani, Tamanna and Rani, S. (2023). Wood biomass and bioenergy: Utilization and technological innovation. *Advances in Forestry and Agroforestry.* **1:** 1-19.

Singh, A.K., Vasisht, B.R., Atteri and Singh, D. (2004). Assessment of market infrastructure and integration: A case study of Orissa. *Indian Journal of Agricultural Marketing.* **18:** 243-261.

Singh, R.P. and Toppo, A. (2010). Economics of production and marketing of tomato in Kanke block of Ranchi district. *Indian Journal of Agricultural Marketing.* **24:** 3-16.

Vishal C. (2020). Economics of apple production in Himachal Pradesh: A comparative study of different blocks of district Shimla. *Agricultural Science Digest*. **40:** 1-9. doi: 10.18805/ag.D-5005.